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MICRO/MINI HYDROELECTRIC PROJECT EVALUATION

USAID/Thailand

FINAL REPORT

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List of Acronyms and Abbreviations

RTG	Royal Thai Government
NEA	National Energy Administration
PEA	Provincial Electricity Authority
EGAT	Electricity Generating Authority of Thailand
POU	Project Operations Unit
NESDB	National Economic and Social Development Board
FARA	Fixed Amount Reimbursement Agreement
TEAM-KEC-SCI	Association of TEAM Consulting Engineers, Co. Ltd., K Engineering Consultants, Co. Ltd., Stanley Consultants, Inc.
CAD	Computer Aided Design
TA	Technical Assistance
TAG	Technical Assistance Group
NSO	National Statistical Office
NRECA	National Rural Electric Cooperative Association
E-M	Electromechanical Equipment
kW	Kilowatts
MW	Megawatts
kWh	Kilowatt Hours
MWh	Megawatt Hours

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$ 1 U.S. = BAHT 25

EXECUTIVE SUMMARY

At the request of the USAID Mission in Thailand, Hagler, Bailly & Company carried out an evaluation of the Micro/Mini Hydroelectric Project (No. 493-0324) over a five week period during May-June 1987. This project was designed to complement a broad strategy to reduce Thailand's dependence on imported fossil fuels used for electricity generation. The specific goal of this project is to provide the Royal Thai Government (RTG) with the capability to identify economically attractive sites for micro and mini run-of-the-river hydroelectric power development. This was to be done through the design and construction of up to twelve plants which would provide electricity to local villages or to the national grid. The project, being implemented by the National Energy Administration (NEA) began in 1982 and fell behind schedule due to a variety of delays experienced in its first two years. However, six sites are currently well along in construction and scheduled for completion over the next year and a half. The remaining two sites are under design. It is anticipated that they will be operational by the early part of 1989.

This evaluation is a broad review to determine if and how the project should be extended beyond its current completion date of September 1987, to allow for construction of all eight mini-hydro sites. The evaluation team consisting of two foreign consultants, an engineer and an economist, and one Thai social scientist, spent two weeks visiting the six sites under construction, reviewing the quality of design and construction, and interviewing the residents in the proposed service area. An additional two weeks were spent interviewing NEA and private sector personnel directly involved in the project, government officials working in the energy sector and local manufacturers of small-scale hydroelectric equipment. An extensive review was also made of the site selection model developed for the project and of the financial and economic constraints which existed at the time of the project's conception, as well as today.

Findings and Conclusions

The principal achievements of this project, so far, have been;

1. It has provided a broad institutional setting for the development of mini-hydro within Thailand, both at NEA and within the private sector.

2. It has encouraged the NEA and the Thai private sector to refine their abilities in the selection and assessment of mini-hydro sites based on economic, financial and social variables.

3. It has allowed both the NEA and the private sector to develop capabilities for the engineering design of hydropower facilities in the 0.5 to 1.5 MW range, including the design of civil works, construction supervision and the specification of electromechanical equipment.

4. It has provided the Thai fabrication and manufacturing sector with a limited market for the provision of electromechanical equipment for minihydro plants.

5. It has resulted in the construction of six mini-hydro facilities in the rural areas of Thailand, with planning underway for an additional two sites.

The six sites visited showed an evolution in the quality of design, construction techniques and management indicating that the NEA and Thai consultants have continued to refine their capabilities as the project evolved. The replicability of this effort is clearly established and demonstrated by parallel efforts to develop mini-hydro facilities with funding from other donors. This project and the Renewable Non-Conventional Energy Project which preceded it, have demonstrated the ability of the NEA working together with the Thai private sector to develop energy systems with sustainable benefits for the country.

Despite its successes, this project has not been without delays and high costs. Most of these problems have been overcome through the efforts of the Thai participants. For example, the rather lengthy delay in the project was due to bureaucratic issues caused by requirements in the procurement and contracting process. The financial mechanism used by AID required special arrangements by the RTG to fund the project until plants began to produce electricity. The per diem rates established for project personnel required considerable time to negotiate. The procurement of electromechanical equipment became a complex problem because the design of specifications, the lack of enough firms to bid and with the changing rules of the proposal evaluation processes. Once these problems were resolved and construction began, the project was able to move along rapidly.

The project objectives have evolved since the time of the drafting of the Project Paper when a range of hydropower options were considered, including isolated microhydro, isolated mini-hydro and grid-connected mini-hydro. The evolution has been to sites which are mini-hydro and grid-connected. This was a reasonable progression, given that the NEA already had considerable experience in the construction of micro-hydro facilities and that the national electrical grid was being rapidly expanded to reach the more remote areas of the country. The project participants therefore took on the more challenging task of designing mini-hydro units for which there were only two precedents, a 6 MW facility constructed by NEA in 1964 in Sakon Nakhon and a 1 MW facility constructed in the early 1970's in Mae Hong Sorn. Unfortunately, the PP's site selection model was developed for isolated micro-hydro and did not undergo a similar evolution, although the scope of work called for its refinement.

The economic environment in which the project was originally designed is radically different from the current situation. Not only have fuel prices and exchange rates undergone rapid fluctuations over the last few years, but Thailand's energy sector has been radically altered. The exploitation of domestic supplies of natural gas, lignite and

petroleum has proceeded rapidly. At the same time, the mix of energy sources used for electricity generation have moved away from a significant dependence on imported fuels to the extensive use of domestic energy sources including large-scale hydro. In addition, Thailand has had a surplus of large scale generating capacity over the last few years.

The foreign technical assistance provided under this project was focused on developing a site selection model and assessing local manufacturing capabilities. Most of this assistance went towards implementing the model as originally proposed, rather than developing a more appropriate model. The assessment of local capabilities for manufacturing electromechanical equipment appears to have provided relatively little new information while assistance was badly needed in preparing technical specifications for contracting purposes. More time should have been given to providing technical support related to design and contracting.

The site assessment procedures were constrained in their attempts to identify and develop mini-hydro sites. These procedures excluded consideration of generation alternative other than large scale diesels and they did not examine different scales and phasing of these investments. Specifically, no determination was made of the marginal costs and benefits of different capacities of the hydropower and diesel alternatives.

The sustainability of the mini-hydro development in Thailand is currently unclear because of existing government priorities in the energy sector, the preference for large scale central plants and because no regular source of funding for further construction of mini-hydro facilities has been established. In addition, the role of NEA is currently under review. Much of its responsibility for energy planning will be shifted to the Office of the Prime Minister. Meanwhile, NEA's role in the future development of mini-hydro will depend in part on the willingness of The Electricity Generating Authority of Thailand (EGAT) to assume responsibility for the operation of these facilities once they are brought on-line.

Recommendations

The general recommendations of this report are:

1. USAID should continue its involvement in this project through the completion of at least the first six mini-hydro sites. Since the benefits far outweigh the marginal cost necessary for completion. The two remaining sites currently being planned should be reviewed by the Thai government. While it is unlikely that their financial or economic rates of return are acceptable, they are marginally financially viable given the conditions of the USAID loans and they may meet social and political objectives which are important to the Thai government.

2. The present system used by USAID to fund this project, the FARA system, should be reviewed. While it offers incentives to rapid project implementation by limiting the monitoring requirements of USAID and provides some form of financial performance incentive by limiting the total funds made available, these benefits do not outweigh its negative features. This system requires the RTG to provide funding during the construction period from funds which would otherwise be allocated to other economic development activities.

3. The current effort to resolve the bid evaluation procedure for electrical and mechanical equipment should set as its primary objective choosing the bid which represents the least economic cost to Thailand. The current efforts to discount taxes and duties paid to the government is a necessary step to meet this goal. It also takes into account the competitiveness of local and foreign suppliers.

4. Future efforts by AID to form a POU should benefit from the experience in this project and should utilize existing organizational structures to the maximum extent possible so as to insure a sustainable activity within the institution.

5. In addition, NEA should focus its efforts more on project management and less on design and construction supervision. This would resolve what the evaluation team perceives as a shortage of experienced technical staff to undertake the range of projects which NEA should consider. In this regard, the collaborations between NEA and both the public and private sector participants in the mini-hydro project and the renewable energy project represent good models to be followed.

6. Priority should be given to producing an agreement between NEA and EGAT on the terms under which the latter will assume responsibility for the mini-hydro facilities once they are operational. This agreement should set the basis for NEA's further work in the development of grid-connected mini-hydro and should contain the basis for establishing a revolving fund or other financial mechanism to fund an on-going program of mini-hydro construction.

7. The size of the market does not justify the development of a domestic capability for fabrication of complete mini-hydro scale turbines. The current emphasis on a mix of domestic and imported components should be encouraged.

Several activities should receive special attention during the final phase of this project. These include:

1. Geotechnical and brief environmental surveys beyond simple checklists, should be made of the first six micro-hydro sites to determine any potential problems which might arise from the operation of these sites. Also environmental surveys should be made of the last two sites under consideration and their findings should be incorporated into the design process. Thai consultants can be used for both of these efforts.

2. Foreign technical assistance should be provided to perform an engineering review of plant design and operation after two mini-hydro sites have been operational for a few months. Potential problems which would warrant such a review are problems with deteriorating concrete, penstock joint integrity, erosion along the headrace and access roads, equipment vibration, water hammer and cavitation.

3. The design of an appropriate site selection model should be completed. This model would include separate components for micro-hydro, isolated mini-hydro, grid-connected mini-hydro and grid extension. The latter should incorporate the methodology being used by the consultants in the development of the National Mini-hydro Plan. The first two would require revisions in the economic and financial evaluation techniques proposed in the Project Paper.

Lessons Learned

The principal lessons learned from this project and the implications for future project design are:

1. Project design must take into account existing government regulations and procedures. An individual familiar with these regulations and procedures should be retained to identify potential conflicts and to estimate the length of the delays which will result.

2. The basic economics of micro-hydro, isolated mini-hydro and grid-connected mini-hydro as applied to rural electrification should be established and methods for quantifying their benefits should be agreed upon. This issue continues to plague the development community.

3. Project evaluation of energy projects should allow for a closer examination of the viability of a project as a function of changes in energy costs, capital costs and discount rates. The project design should consider the marginal benefits and costs for different levels of capacity and for different sets of capacity expansion over time. The analytical capabilities of existing micro-computer software have greatly reduced the labor required for such analysis.

4. Project design should include a more careful assessment of institutional capability so that the specification of technical assistance will complement existing institutional capabilities and be coordinated with the activities of other donors.

5. USAID needs to develop a more effective approach to contracting and monitoring of technical assistance to insure that the personnel provided and their scope of work will provide useful inputs given that these requirements may change over the life of a project.

6. In the design of energy projects, a certain flexibility must be built in. As economic, financial and natural resource constraints change, project implementors should have some flexibility to change project goals. Negative criticism of a project because its original goals were not met is not an appropriate response in situations where the underlying economic conditions and the resulting rationale for a project have been altered during the life of the project.

CHAPTER 1: INTRODUCTION

The Micro/Mini Hydroelectric Project was conceived by the Royal Thai Government (RTG) and the United States Agency for International Development (USAID) with the aim to reduce Thailand's dependency on imported fossil fuels for electricity generation. The approach was to provide for rural electrical energy needs through the application of mini and micro hydropower technology.

USAID agreed to provide a five year, $8 million loan and a $100,000 grant to Thailand for the development of up to twelve micro/mini hydropower plants with an amount of $4.7 million equivalent, as the RTG contribution. The implementing agency is the National Energy Administration (NEA). The present project completion date was September 1, 1987 but because of delays, that date was not met. An extension was requested by the RTG to continue for another two years.

This report is a mid-point evaluation to provide guidance on how the project should be administered and managed from this point foreward.

Purpose of the Evaluation

The purpose for this evaluation is to provide the RTG and USAID with implementable recommendations on effectively completing this project in accordance with the original objectives or modifications of these objectives. The broad areas that are addressed in this report will include:

a) An assessment of the progress of the physical work and trends at each of the six sites under construction through document review and field visits.

b) An assessment of the relationship of this project to other power projects in the country.

c) A review of the appropriateness of the site selection model and its effectiveness as a tool for analysis.

d) An assessment of the environmental impacts of the physical work at each site as constructed and during operation.

e) An assessment of NEA institutional capacity to perform and sustain mini-hydropower planning and project implementation.

Methodology

The evaluation team consisted of an engineer Dr. Jack Fritz, an economist, Mr. John Arnold, and a social scientist, Dr. Sangkom Suwannarat. The team was assisted by USAID/Thailand's Office of Engineering. The assignment was carried out through

interviews, a review of project-related documents and field visits to the six sites currently under construction. The team began its work in Bangkok by meeting with officials of USAID, NEA and other government organizations and by visiting several private sector firms involved in planning, design and equipment procurement.

The interviews at NEA were with members of the Project Operations Unit (POU), which was created to implement this project. Other government organizations which the team visited included the Electricity Generating Authority of Thailand (EGAT), the Provincial Electricity Authority (PEA) and the National Economic and Social Development Board (NESDB). The evaluation team also visited TEAM Consultants, the project's principal design firm and Layne & Bowler, the manufacturer of the turbine-generator which will be installed at the first site.

Among the documents reviewed were the Project Paper, the site selection model, reports prepared by consultants, site drawings and various files in the USAID offices. A complete list of contacts and references is given in Appendix L.

Project Creation and Government Objectives

This project was created during 1981-1982, a period of great uncertainty in world oil markets with petroleum prices above the $30 per barrel level. With considerable fear about the future of fossil fuel prices, and a consensus that they would surely continue to rise, utilities the world over were searching for energy sources based on indigenous resources. Small hydropower was known as an old and mature technology which had fallen into disfavor because of high unit costs compared to fossil fuel generated electricity. However, with fossil fuel prices on the rise, small hydropower was once again of interest to economic planners.

Under Thailand's 5th National Plan, renewable energy resources were to be given special emphasis and NEA was formally made responsible for all micro and mini hydropower planning and implementation in Thailand. The NEA mandate had the following principal elements,

a) to replace existing diesel generation plants in rural areas with micro or minihydro plants

b) to provide additional power to the national grid in order to reduce oil consumption at large thermal power plants,

c) to supply electric power to newly developed or rural areas.

USAID development policy during this period was consistent with Thai energy goals, namely those of accelerating rural development, increasing the involvement of the private sector and promoting rural electrification. Because these goals matched, the Micro/MiniHydroelectric Project came into being.

Project History

The Micro/Mini Hydroelectric Project (493-0324) was formally initiated on September 16, 1982 when the loan agreement was signed between AID and the Royal Thai Government. The stated objective of the project was to develop the institutional capacity of the implementing agency, the National Energy Administration, and to plan and construct 12 micro/mini hydropower plants over a five year period. Funding of $ 12.8 million for the project was to be provided jointly by USAID and the RTG. USAID's share was to be a loan of $8.0 million and a $100,000 grant for evaluation purposes and the RTG was to provide the remaining $4.7 million. USAID funding was to be made using the Fixed Amount Reimbursement Agreement (FARA) approach. Under this method, the funding would only be forthcoming when the hydropower plants began operation. The funds for construction would have to be borne through NEA sources until the first plant produced power.

Under this project, USAID would only provide for 50% of the cost of civil works, transmission and distribution and 100% of the cost of the electromechanical equipment. This approach, it was thought, would encourage efficient and rapid implementation by NEA. However, for a variety of reasons to be discussed later, this has not happened.

The minihydro plants were to be built in remote areas to service rural energy consumers. Some plants would be grid-connected while others would serve remote villages. Also, NEA would build the plants, operate them for one year and then turn them over to the Provincial Electricity Authority if the plants were isolated, or to the Electricity Generating Authority of Thailand if they were connected to the nationl grid.

Twelve plants were to be constructed in two phases. The initial six would be used to develop the site selection methodology with the assistance of foreign consultants. Of the six selected at the time of PP preparation, only three are currently under construction. The other three were dropped when more detailed feasibility work revealed unfavorable economics.

To assist NEA in implementing this project, professional services were solicited. The winner of the competition was the Association of TEAM Consulting Engineering Co. Ltd., K. Engineering Consultants Co., Ltd. and Stanley Consultants, Inc. (TEAM-KEC-SCI). TEAM was to design the plants, K. Engineering was to carry out the survey work and Stanley was to assist NEA in site selection. and training of the POU.

The Project Paper proposed that the POU be made up of 5 to 6 people. These were professionals drawn mainly from construction ranks but also included specialists in hydrology, geology, etc. However, during the evaluation team's visit, the POU was inactive, its members having returned to their previous jobs.

The period of involvement of Stanley Consultants was 22 months during which several volumes documenting the site selection procedure were produced for NEA. It was through the application of this procedure that three of the original sites were dropped

and new sites added. Currently, there are six active sites, all in various phases of construction and two additional sites for which detailed designs are being prepared by TEAM.

The assistance provided by Stanley was clearly helpful but not crucial. Their approach tended to be academic, with emphasis on studies and computer modelling rather than project management. However, this was partly a result of the type of contractual services solicited.[1] In addition, there was a change in the staffing by Stanley after 6 or 7 months.

Reasons for slow implementation of this project tended to be bureaucratic. Early problems centered around contractual problems between NEA and the Ministry of Finance over such issues as contractor overhead. There was also some weakness in the initial project design and a clear lack of built-in flexibility on technical issues such as the number and scale of plants to be constructed.

The project turned out to be more a process than a series of discrete accomplishments. It was to be a process of analysis followed by field implementation. The PP was not clear on this point. As a process, changes in objective or scope should be expected since the heart of the activity was the site selection and evaluation procedure. When these tasks are properly carried out, some sites may be dropped, others added and the actual field implementation would be delayed.

Currently six sites are under construction with two more to be added shortly. They are geographically distributed, two in the North and three in the South, and one in the Northeast. They range in size from 500 kW to 1,182 kW and are at various stages of completion (see Exhibit 2.1). They are scheduled to be operating by April 1989 (Appendix N). Over the last six months, there has been a flurry of activity as various bureaucratic impediments have been removed.

Currently, Stanley Consultants has completed its contract. TEAM is designing the plants without assistance; and NEA is supervising construction and continually monitoring field contractors. PEA is extending its transmission lines into the service areas of the plants so that they can be connected to the national grid. Although an early objective was to construct isolated plants the grid-connected projects are more financially viable because they can sell their power to the grid and therefore have a 100% capacity factor.

Remaining concerns center around slow implementation, what are percieved to be arbitrary changes in sites, the temporary inactivity of the POU and the issue of long-term economic and financial viability of mini-hydro in Thailand, given PEA's vigorous expansion program. These concerns are all addressed further on in this report.

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1 The scope of work included in Annex K called for a range of services including management, assistance in contracting for construction and development and implementation of the Site Selection Model.

Thai Energy Policy: The Role of Minihydro

Thailand's energy policy with regards to electricity over the last five years has emphasized three activities: 1. the substitution of technologies using fuel oil with technologies using domestic sources of energy, 2. the exploration for and exploitation of domestic reserves of energy, especially petroleum, natural gas, lignite and hydropower, 3. the extension of the electricity distribution system to the more remote areas of Thailand.

These three approaches were the basis under which the current project was undertaken. Since that time, the implementation of these policies has been relatively successful with the result that the development of domestic energy resources and the extension of the national grid is expected to proceed with more attention to economic viability. With the drop in the price of petroleum fuels and the increasing amount of recoverable reserves of oil and gas within Thailand, it is expected that the priority given to the development of hydropower will diminish. While this may not effect the large hydropower facilities currently planned for construction by EGAT, it will have an impact on the development of smaller scale mini and micro-hydro. As yet there has not emerged a clear policy with regards to development of these technologies. There is however, a national minihydro plan being developed by NEA. It is therefore likely that the development of micro-hydro as a source of energy in areas which are too remote for extension of the grid will continue. However, the development of mini-hydro facilities to serve a cluster of remote villages has yet to be proven economically viable. The development of grid connected mini-hydro will also be problematic because of the reluctance of EGAT to take on responsibility for the management and staffing of facilities which add very little capacity to the national electricity system.

Organization of the Report

This report is organized along the following lines. Chapter 2 describes the current status of all six sites, their execution and the various organizational and procedural processes used. Chapter 3 gives details of the site selection procedure. Chapter 4 examines the economic and financial considerations inherent in this project as well as social issues. Chapter 5 considers the institutional issues. Chapter 6 describes the environmental impact of the six sites currently under construction and Chapter 7 gives the findings, conclusions and recommendations.

Several Appendices are included to support the text and Executive Summary.

CHAPTER 2. CURRENT PROJECT STATUS

Site Characteristics

All six project sites currently under construction were visited by the evaluation team and project components from weir to tailrace were inspected. Each plant visit was followed by a tour to one or more of the communities which will be electrified. The six plant locations that were visited were (see Exhibit 2.1):

1. Lam Pra Plerng
2. Nam Kha Mun
3. Nam Mae Hat
4. Khlong Duson
5. Khlong Lam Plok
6. Huai Lam Sin

All these plants are in the minihydro category varying in capacity from approximately 500 kW to 1200 kW. The construction details for each site are very similar with exception of Lam Pra Plerng which is built into an existing irrigation outlet works. In order to give the reader an appreciation of the scale, complexity and construction aspects, the characteristics of a typical minihydro plant are as follows (see Exhibit 2.2):

Each plant is generally located in a hilly, well forested area, or foothill area near a group of villages which may or may not have electric power. The critical physical element is to have a stream that has sufficient flow and head throughout the year. The determination of this information forms part of the site selection process.

A location on the stream must chosen where a weir or intake can be constructed on bedrock or other solid foundation. This structure diverts a portion of the flow into the headrace by controlling a large gate valve. Provisions are made to be able to sluice sediment out of this intake structure. This may be done within the structure or at a separate flow control structure located a short distance from the intake. The weir is designed so that even during periods of low flow, all the flow can be diverted to the intake in order to remove the sediment. Any excess stream flow can be discharged via another gate valve located on the downstream side of the weir.

The weir is usually made of reinforced concrete and generally has an access road going to it so it can be serviced. Only the Huai Lam Sin site does not have an access road because of the difficulty of the terrain. All the weirs were well built with provisions for flood mitigation, sediment removal and easy gate operation.

The intake guides the flow into the headrace which brings it along a slight grade to the forebay near the plant. Headraces are commonly designed with an open

Exhibit 2.1

MICRO/MINI HYDROELECTRIC PROJECT

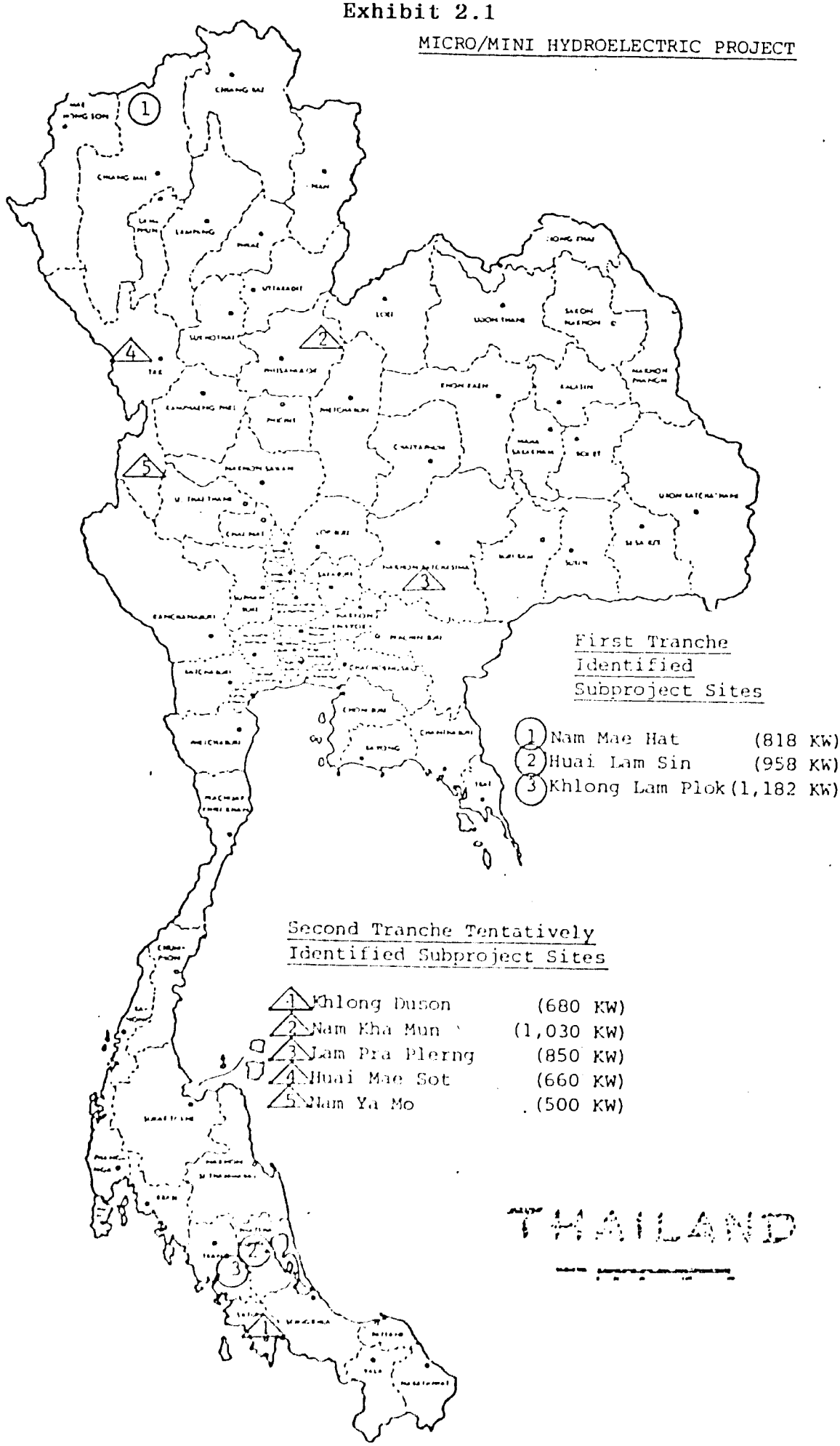
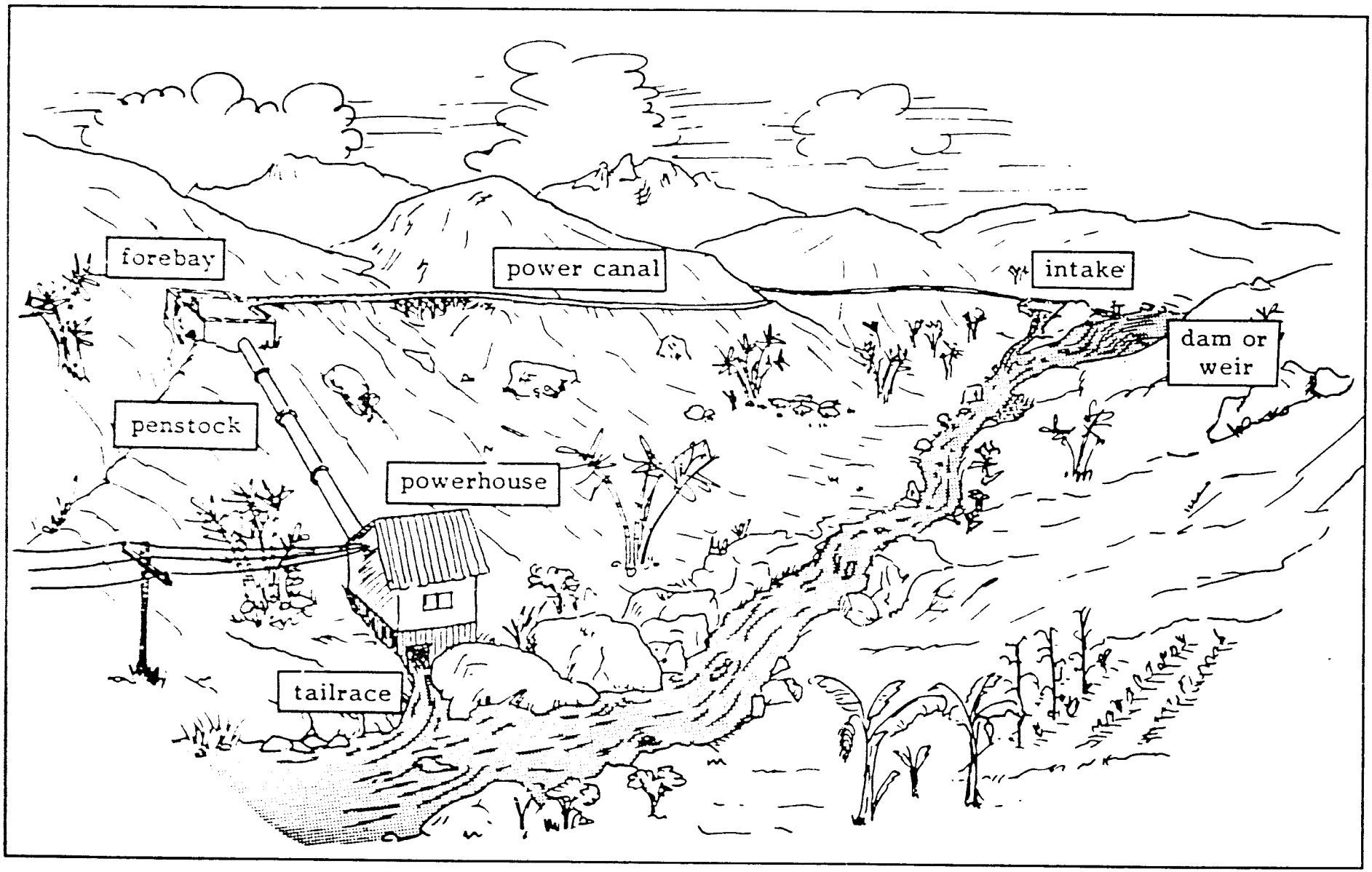


EXHIBIT 2.2: TYPICAL MINIHYDRO PLANT



channel, similar to an irrigation canal. However, the Thais have used steel pipe suspended on concrete anchors to conduct the flow at most sites. The higher costs can be justified by the lower maintenance required. Because of the terrain and alluvial nature of the soils, as well as the types of cuts that had to be made, erosion would have quickly filled an open channel with sediment.

The headrace at the six sites is from one to three km in length and usually follows the existing topography. The road to the weir generally follows the headrace for service and construction convenience. In most cases, the headrace construction was sound. At one site, however, Huai Lam Sin, we found the concrete anchors to be supported by large boulders which were cracked. This may be a problem, and it is recommended that a geotechnical engineer inspect the site.

At Nam Mae Hat, buried concrete pipe of the type used in sewers was utilized. This may become a problem if leaks develop since the pipe is buried in a cut and fill manner, in unconsolidated alluvial soils. The project personnel at the site informed us that the site had been through two rainy seasons so far, and no serious erosion problems had developed. However, the headrace has not had to sustain a continuous flow since the plant is not yet in operation.

The headrace ends at the forebay which stabilizes the flow and is the last point where water can be discharged before going to the turbines. It is the point where surges are dampened and where sediment can be sluiced. The forebay is similar in design to the intake structure. The water level in the forebay is essentially the head available to the turbine (minus small friction losses in the penstock).

The penstock design is critical because of high pressures. It connects the forebay with the powerhouse and conveys the water to the turbine. The penstock is made of steel pipe which must be well anchored to bedrock. Stresses increase near the bottom where it withstands the full pressure provided by the head.

Most of the penstock work was complete at the six sites. In some cases the pipe was buried but the tendency was to keep it above ground for servicing. Down near the powerhouse, the penstock becomes a "Y" and the flow is split between two turbines.

The powerhouse generally contains two turbines and all control equipment. Since these are high head sites, above 50m or so, they have either Pelton or Francis turbines. After the water has imparted its energy to the turbines, it exits via a sump under the powerhouse to the tailrace.

The tailrace is usually located to one side of the powerhouse and directs the flow back into the stream. It is designed so that most of the energy left in the flow will be dissipated before reaching the stream.

The electricity that is produced by the generator is usually stepped up to 22kV in the switchyard located adjacent to the powerhouse. This voltage is considered optimal

because it is high enough to minimize losses but low enough so that reduction to 220v is not very costly.

All areas of these sites must be accessible for maintenance. Access road construction is therefore the first field activity undertaken. The cost associated with roads is usually significant because heavy equipment is used and continued maintenance is required. The team found the roads to be in good condition, however, several of them had been only recently constructed. At one site, Huai Lam Sin, the terrain was too steep to construct a road up to the weir, but all other sites were equipped with such a road.

In general, the team found the sites to be well under way and the construction methods up to date and safe. The one exception being Nam Kha Mun where careless handling of explosives caused the death of one worker.
Each site has an NEA Resident Advisor who reports directly to the Project Manager. There appears to be a reluctance to make decisions in the field without checking with NEA in Bangkok first. This in part slowed construction and tended to keep the Project Manager heavily involved. Some procedure to streamline field decision making should be considered.

Construction Progress to Date

Lam Pra Plerng:
This site, located in an existing irrigation system near the city of Khorat, is in the early stages of construction (7% completed). Its capacity will be about 870 kW and cost is approximately $ 1550 /kW installed. The plant should come on line late 1988. The area it will serve is not remote, but has had PEA supplied power for several years.

Nam Kha Mun:
This site is located in a highland, forested area the city of Phitsanulok. This was a region of great political turmoil during the 1970's and has now been made into a recreational area. The 1.0 MW plant will cost about $1700 per installed kW. The plant will be grid connected and serve an area which is already electrified. The plant is about 30% complete and should come on line in late 1988.

Nam Mae Hat:
This site has been under construction since 1985 and was the first of the six sites to came on-line in October 1987. Construction is 95% complete with electromechanical equipment installed in June-August 1987. The plant is located in a remote area of Chiang Mai Province near the Burmese border. The PEA grid has been extended to within six km of the plant. Plant costs are $ 2650/kW installed.

Khlong Lam Plok:
This site is located near the city of Trang, in Southern Thailand. It is a 1.2 MW facility. The site is approximately 80% complete and should came on-line by mid -

1988. The missing element is the powerhouse, electromechanical equipment and tailrace. PEA lines are also within 2 km of the plant and the grid has been extended to most of the villages in the service area. Plant costs are $ 1900/kW installed.

Khlong Duson:
This site is near Satun, also is Southern Thailand, close to the Malaysian border. Most of the villages in the area have been recently electrified and the grid extended to within 1 km of the site. Construction on the 700 kW plant is just getting under way (10-15% complete) and should be finished late 1988. Capital costs should be approximately $ 2300/kW installed.

Huai Lam Sin:
This site is located near the city of Phathalung, in Southern Thailand in a hilly, forested area. The PEA grid extends to within 2 km of the plant and most of the villages in the area have had electricity for several years. The 1.2 MW facility is 90% complete, lacking only the powerhouse and installation of electromechanical equipment. This plant was to come on line in late 1987 and will cost approximately $ 1600/kW.

Thai Private Sector Capabilities in Minihydropower

In order to implement a major small or minihydro program in Thailand, a strong private sector capability must exist to carry out project design, construction and equipment manufacturing. To some extent, these capabilities currently exist in Thailand.

The PP stressed the need to develop indigenous manufacturing capability and joint business ventures with U.S. manufacturers. Therefore, under the technical assistance program carried out by the consulting group (TEAM-KEC-SCI), an assessment was undertaken to determine private sector capabilities to implement small hydro. The assessment sought to determine the capability for equipment manufacturing rather than for project management or for civil engineering. Several months were devoted to the study and selected manufacturing facilities were visited. The general conclusions indicated that there is a wide range of manufacturing capability in Thailand made up of companies ranging from small "cottage scale" machine shops to several large multi-company organizations which can design and manufacture minihydro components. Capabilities exist for casting, machining and fabrication. However, much of the work is done on a custom basis rather than for mass production. There is also little quality control during fabrication, but each component is usually thoroughly checked after production. There is an emphasis on quality but this is balanced against cost savings through use of existing resources.

There are few automatic or tape controlled machine tools. Again much is left to the skill of the operators who pride themselves on being able to do a good job that would usually requires more up-to-date or automatic machine tools in other countries. There is a great deal of creativity and innovation at the shop floor level.

The TEAM-KEC-SCI study indicated that Thai manufacturers were not yet ready to build turbines in the mini range, above 100 kW, or generators above 500 kW. It appears that this situation will continue unless a major market for this equipment develops in the region.

The PP also suggests that this project be designed to both encourage the "nascent" Thai industry in the smaller range of equipment (less than 1 MW) and provide a market for U.S. manufacturers in the larger size units (above 1 MW). In fact, this distinction will turn out to be rather artificial if a real market was to develop.

The evaluation team visited the manufacturing facilities of Layne & Bowler, the fabricators of the electromechanical equipment for the Nam Mae Hat site. Thai turbine manufacturing is still limited to the micro range, primarily cross-flow and Pelton units. For larger plants, the turbine runner has to be imported. Layne & Bowler use French Bouvier runners, but the balance of the system which includes the governor, valving, casing and balancing is manufactured at their Bangkok plant. The generators for this site, both in the 500 kW range, are also being manufactured locally.

While at Layne & Bowler, the evaluation team saw turbines in the one to three MW range being assembled for other NEA minihydro projects. These units were of the Francis type also with imported Bouvier runners. However, the casings, wicket gates and other turbine components were manufactured in Thailand. Balancing and installation is also being done by Thai firms.

Clearly, the most important issue for Thai equipment manufacturers is the dimensions of the market. There are basically two segments of the market that Thai industry could handle. The first is the micro range, less than 100 kW. This is already is being well taken care of by a variety of local manufacturers. The only exception being modern governors or load control technology based on microprocessors.

The second market segment is between 100 kW and perhaps 5 MW. The dimensions of this larger market will depend on NEA's plans for building more minihydro plants. If NEA builds one to two dozen plants year, then there is a small but sufficient market to encourage development of local manufacturing capability. However if only three or four are built, then the market is insufficient to justify such a local capability. In either case, the current approach of importing the turbine runner should be continued. To tool up for runner machining in the one MW range would require a significant capital investment which could only be justified on a regional basis.

Another reason to move cautiously is that EGAT has tended to favor large plants, whether hydro or thermal, and may not support a program to build dozens of minihydro plants which they would have to operate. Although these large plants have a high foreign exchange component, on a per kW basis, their total costs compare favorably with an 80% locally manufactured turbine generator unit.

One of the goals of the PP was to assist in the development of an indigenous manufacturing base in Thailand, not only for the national market but also for neighboring Malaysia and Indonesia. The skills base, management talent and enthusiasm certainly exist today in Thailand, but there are a number of issues that need to be resolved first.

The first issue, as mentioned is the market, how big is it, what scale of equipment and what are the opportunities in the neighboring countries? The second issue which needs to be resolved is the role of U.S.-based firms in supplying equipment to the Thai market. Efforts to encourage Thai industry to manufacture its own equipment while simultaneously developing opportunities for U.S. manufacturers appears inconsistent. Artificial bounds can be set, on the basis of size for example, but generally they do not work. A national policy should be established regarding U.S. commercial interests so as not to send mixed signals to the Thais.

The design task was advertised locally and won by the Association of TEAM Consulting Engineers Co., Ltd., K. Engineering Consultants Co., Ltd., and Stanley Consultants, Inc. (TEAM-KEC-SCI). KEC had the responsibility of surveying the sites, TEAM had the responsibility of design and engineering and SCI for training, Technical Assistance and implementation of the site selection methodology.

The evaluation team visited TEAM Consulting Engineering Co., Ltd. to review design work on the six plants. The firm is made up of approximately 70 engineers, designers and draftsmen and has a reputation for infrastructure design, primarily in the irrigation and water resources field. Design methods are very up-to-date using Computer Aided Design (CAD) techniques. They also have a modern and well stocked library. They were, therefore familiar with hydraulic design prior to the start of the contract. However, they had only a minimal capability in the small hydro field.

It is our understanding that there are other engineering design firms with this level of capability in Thailand which are presently involved in other NEA mini-hydro projects. The evaluation team therefore feels that there is no limitation in terms of existing available design services in Thailand.

The construction of the six sites has been moving along rather briskly. There are sufficient construction contractors with appropriate skill and management resources to carry out the implementation phase of this project. The methods that have been proposed tend to be labor intensive so as to maximize local participation. Thai contractors are familiar with these methods. Construction capability is not a limitation to the implementation of this project.

Procurement History

The key provision regarding procurement is that the use of host country procedures were recommended in the PP with the source being U.S., Thai or Code 941.

However, each procurement initiative had to be approved by AID, although no funds were to be forthcoming until power was generated. The PP also recommended that AID direct contracting procedures be considered to save time and cost. Although there were delays and problems with procurement, this option was never seriously considered. Four broad categories of procurement tasks can be considered, Design, Construction, Electromechanical and Technical Assistance. Each is discussed separately:

Design:

Contracting of the design process has been relatively smooth. Throughout the project, the designs used in the civil works have been developed by TEAM. For this reason, all plant design features tend to be similar. The issue becomes one of determining if the design is appropriate. If a particular design feature is bad, then all six plants will have it. However, there has been some evolution in the design process, for example, changing from the concrete pipe headrace to steel pipe. Currently, TEAM is in the design phase of the last two projects.

Construction:

The civil works and transmission line contracting were carried out according to PP requirements. NEA prepared the bid documents and invitations to bid were published both locally and in the U.S. In most cases, there were between three and six bidders for the construction work, all Thai. Upon winning, through negotiation, a new, lower price was generally agreed upon. Each step of the construction procurement process was monitored by AID technical offices and all documents (specifications, drawings, bid documents) were sent to AID for approval prior to formal action by NEA.

The evaluation team found all procedures specified in the PP adhered to, if not in fact, then in spirit. However, work at the sites fell seriously behind schedule because of difficult terrain, rain and slow decision making in the field. Although somewhat slow to get under way, construction progress at all six plants is progressing well at this time.

Electromechanical Equipment:

The contracting of the equipment turned out to be a very competitive process. There were few bidders, in some cases only one, so that the bidding process sometimes had to be repeated. However, the competition between the few firms turned out to be rather fierce.

Several thorny issues surfaced. A leading problem was the way that NEA included import duties and taxes in the bid evaluation. If a manufacturer imports a larger

fraction of the overall package, then the costs will not be competitive if the duties are considered in the evaluation process. A truly competitive bidding process agreeable to both NEA and AID has never been agreed to and this debate continues. The PP gives little or no guidance in this matter.

In terms of policy, there seems to be a fine line between encouraging U.S. manufacturers to participate in these ventures and trying to build up local industry. Although artificial limits or particular market niches can be established, at some point in the future, conflicts will surely arise. A more coherent policy must be established within USAID and communicated to Thai and U.S. manufacturers. When the PP was written, this was not as serious an issue as it is currently.

Technical issues also surfaced during the team's examination. Some firms feel they have new technology, particularly in the control area, and are aggressively marketing it. For the equipment procurement for the Nam Mae Hat plant, NEA wrote very specific requirements for all components. This made it difficult for any new or different technology to be introduced.

This was done because NEA was not familiar with performance specifications and was unsure of the methods of evaluation of low bids by performance specifications. Also, the local Thai bidders requested absolute and detailed specifications so they would know how to build the E-M equipment. Since the local builders had not built equipment of this size and complexity before, and did not have the design expertise to do so, they had to rely upon very detailed specifications to be able to bid.

Technical Assistance:

The PP proposed that NEA retain several long term specialists on private contract. This approach was not strictly followed and TEAM-KEC-SCI was given the responsibility for most technical assistance. Their task consisted primarily of developing a site selection model for NEA and training POU staff in its use. TEAM also participated in developing the computer and design models. Several volumes of studies were produced in conjunction with Stanley through which the six plants currently under construction, were analyzed for their engineering, economic, financial and social viability. TEAM also performed the least cost analysis on the last two plants, Huai Mae Sot and Nam Ya Mo as well.

Also, the TA Group performed the socio-economic and consumer promotion case studies and the feasibility studies (economics, financial and least-cost) for Lam Pra Plerng, Nam Kha Mun and Khlong Duson (Final Report, Volume III, Summary of Technical Assistance Group Activities). The principal benefit of the Stanley assistance was to get NEA to think in broader terms than had been previous practice.

In summary, the question to ask regarding the procurement process is to determine how it contributed to the overall goals of the project. It allowed TEAM to develop

a capacity for minihydro planning and implementation. It encouraged several private sector manufacturing firms to venture into the small hydro machinery field. It will also save foreign exchange by obviating the need for imported fuel and by using a great deal of local labor and materials. However, before the last two sites of the project are built some further effort to streamline the procurement process should be made. Among the actions to be taken are:

1. An analysis comparing NEA and AID procurement procedures to determine which would be more efficient should be considered.

2. Clarification of AID's policy regarding the encouragement of local industry while promoting the use of U.S. equipment should be put forward.

3. The National Minihydro Plan being prepared by TEAM to determine what role the private sector can play in implementing it should be circulated and reviewed.

4. Better methods to settle the disputes and bidding issues which have arisen between equipment competitors and NEA should be developed.

Conclusions

Construction:

Although the program is far behind schedule, there has been significant progress over the past year. Nam Mae Hat is farthest along. It had the electromechanical equipment installed in June with plant start scheduled for October 1987. The other sites are scheduled for start up at intervals over the next two years. The delays in the project were caused by a combination of bureaucratic delays (regarding approval of relatively minor budget items) and weather, which limited access to these sites during the rainy season.

NEA management and monitoring of field work has been good considering the limited number of staff available for this project. Each site has a resident field engineer, but major changes from the final drawings or specifications must be approved by the project manager. This approval procedure has been a recurring source of delay since site visits were often necessary. Streamlined field supervision must be implemented rapidly so that all six plants currently under construction will be operating by the end of 1988.

Equipment Manufacturing:

The manufacturing capability within Thailand to build the electromechanical components for hydropower facilities is excellent for micro-hydro but limited for mini-hydro. Above the 100 kW range, the turbine runner and some of the control components have to be imported. Local manufacturers can fabricate all of the other turbine components up to the 2-3 MW range. At present, the largest generator which is locally manufactured is 500 kW, but it should be possible to produce larger units.

The principal constraint on the local manufacturing capability is not the complexity of the technology but the size of the market. The current level of demand is too small to justify investments in manufacturing capability for larger units.

Design:

The design of these facilities has been carried out by TEAM, a local engineering design firm and monitored by NEA. Similar designs were used for the different sites, however, the quality of execution appears to have improved in the later sites.

Procurement:

The project paper originally proposed that the RTG procurement procedures be used to solicit services from the private sector. Both Thai and US firms were encouraged to participate. Procurement of the civil engineering services and transmission line construction were relatively routine. For electromechanical equipment, the procurement was more difficult since on many occasions there were only one or two bidders.

CHAPTER 3: SITE SELECTION PROCESS

The site selection procedure presented in the PP involved a multiple step screening process as shown in Exhibit 3.1. This approach was followed rather closely in the initial two rounds of site selection during which the six sites discussed in this report were selected. Many elements of this procedure were familiar to NEA from previous efforts to develop mini-hydro facilities.

Site Selection

The information used in the first step of this process was obtained primarily from earlier mini-hydro studies performed for NEA. The second step used procedures similar to those applied in these earlier studies. The third step involved making physical measurements which NEA had used in previous hydropower projects. The socio-economic studies made in the third step were similar to, but more simple than, those used by NEA in performing its rural energy demand surveys and in planning for some of its micro-hydro projects.

The only elements in the site selection procedure which had not been employed by NEA in the past, were the demand forecasts and the specific methods of financial and economic analysis proposed in the PP. These elements had significant methodological problems which will be discussed in the next chapter. This chapter focuses on how well this procedure worked.

The criteria applied in preliminary site selection included not only the availability of adequate year-around flow for power production but also the selection of sites with special attention to:

1. Geographical distribution; so that sites would be located throughout the country;

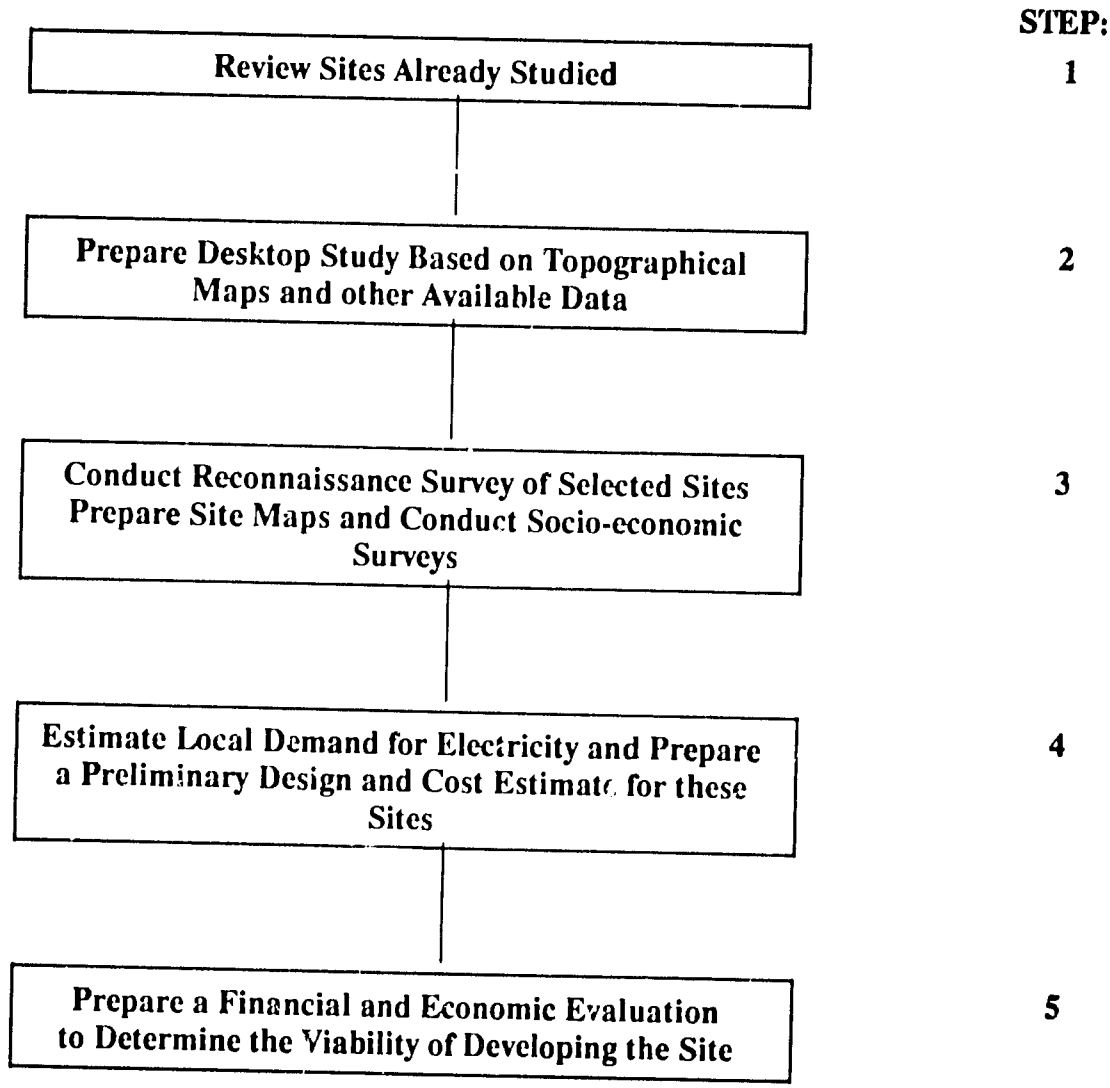
2. Isolation; the original intent being to provide power to areas remote from the grid;

3. Potential for diesel replacement; so as to reduce the demand for imported fuels.

As the project progressed, it became apparent that the options for constructing isolated sites were limited not only by economic viability but also by the rapid expansion of the national grid, the willingness of PEA to extend its lines to areas which were uneconomic, and the interest of PEA in following in the footsteps of NEA. As a result, grid connected sites were included in the site selection procedure with the additional criteria that these sites should be located close to the grid.

Exhibit 3.1

Schematic for Site Selection Procedure



The evolution in emphasis from micro-hydro to mini-hydro and from isolated to grid-connected reduced the usefulness of the site selection procedure as well as the relevance of other components of the project such as load promotion. The differences between alternative hydropower systems are summarized in Exhibit 3.2. The social analysis, local demand forecasting and comparative analysis are very important for micro-hydro but largely irrelevant for grid-connected mini-hydro. Although the site selection procedure was maintained intact throughout the selection of the first six sites,[1] much of the less relevant data was collected and tabulated but not analyzed.

With regard to the least cost analysis of alternatives, the comparison between connection to the grid and development of an isolated system provided the most meaningful justification for the project. However, in all but three of the twelve sites evaluated, the distance to the grid did not exceed 3 kilometers. For three of the sites located near the grid, Khlong Lam Plok, Huai Lam Sin, and Nam Kha Mun, the savings in additional capacity and fuel costs for not providing electricity through the national grid were estimated to be significantly greater than the cost of providing power from the mini-hydro site (see Exhibit E.2).

In the end, the sites that were selected were chosen not only on the basis of perceived economic and financial viability but on additional merits such as proximity to border areas. The original analysis for Nam Mae Hat showed that an isolated system would not be financially viable, but presumably the subsequent review of a grid-connected site at Nam Mae Hat provided a different conclusion. In any case, the site is in an areas recently secured by the army from intrusion by Burmese guerrillas. The site at Lam Pra Plerng was not considered economically viable but was financially viable and is part of an existing irrigation project.

The principal lesson derived from the use of the site selection model was the need for greater flexibility. While the project scope called for the improvement of the model, it appears that most of the project's effort was directed at trying to apply the model described in the PP. A more careful effort would have distinguished between the different types of hydropower facilities and would have developed separate approaches to their analysis.

The simplest type of facility to analyze, is the grid-connected mini-hydro because it represents an expansion of the national generation system. The techniques for performing this analysis have already been developed by the TEAM consultants and are being applied in the preparation of the National Mini-Hydro Plan for NEA. The most difficult type of facility to evaluate is the micro-hydro facility because its impacts are largely in the form of social benefits to the user. The cost for these facilities cannot

1 The extent to which these procedures were followed in the selection of the final two sites could not be determined at the time of the evaluation.

Exhibit 3.2

Differences Between Hydropower Alternatives

Characteristic	Micro-hydro	Isolated Mini-hydro	Grid-Connected Mini-hydro
local participation in construction	important	less important because of scale	not important
local participation in operation	essential	less important because of scale	not done
local demand for electricity	essential for viability	essential for viability	not important
seasonal variation in output	determines design capacity and output	determines design capacity and output	determines output for a given capacity
location of the grid	important to be isolated	important to be isolated	important to be close
cost of extending the grid	not important if isolated	important to economic viability	important when site is far from the grid
current cost for generation of power used in the grid	not important	not important	important to economic viability
setting of tariffs	essential for viability	essential for viability	not applicable

easily be measured. A simplified survey approach is required. Some of the elements of this survey are discussed further on.

Another lesson to be drawn from the use of the site selection model is the importance of incorporating the development of mini-hydro into a national plan for developing electricity generating capacity. The method for selecting alternative systems appears to rely on the availability of donor funds and the relative political weight of the implementing agencies These include, in decreasing level of importance, EGAT, NEA and PEA.

The failure to develop a meaningful Energy Master Plan has left Thailand without a method for screening alternative electricity generation schemes. A basis for comparison between alternatives is presented in very simplified form in Appendix A. This analysis emphasizes the importance of the load factor on the average cost per kilowatt-hour. This consideration is normally limited to the selection of different sources of generation for peak power and for baseload power, however, in Thailand the utilization of the system as a whole is relatively low and the utilization of hydropower is constrained by irrigation and by flood control requirements.[2]

Other factors which must be considered in the selection among alternative generation systems are the uncertainties associated with the future costs and availability of different fuels. Also included should be the relative costs of labor and capital in the future, the use of local resources in construction and operation and future changes in technologies which will affect energy conversion efficiencies.

Social Impact Surveys

The project as originally conceived was to have direct impacts on the villages within the service areas of the mini-hydro sites. Now, however, the grid has been extended to all of the six sites and most of the villages in these service areas are already electrified. The socio-economic survey conducted as part of the site selection process was to have provided data for two purposes; forecasting demand and evaluating the impact of the project on the villagers in the service area.

The format of the survey instrument was based on previously used rural energy survey questionnaires, but the design was not well conceived. The emphasis on collecting income data for use as input to the residential forecasting models caused the greatest problems. Not only were the forecasting models poorly designed (see Appendix F), but any attempt to collect income data is difficult. It generally produces biased results which need to be cross-checked through more subtle questions. Also, it causes the respondent to question the motives of the interviewer. To these problems, must be

2 In 1985, NEA reported that 41% of system capacity was classified as peak generation capacity and that the system load factor was about 40%

added the difficulties of using recall to estimate annual income and expenditures,[3] the necessity of determining income in-kind,[4] and the need to account for year-to-year fluctuations in income. The household survey also used a relatively large sample size to increase the accuracy of the results (in a statistical sense). In the future, a simpler procedure using a smaller sample needs to be developed.

The evaluation team's brief visits to villages in the service areas of the six mini-hydro sites provided important insights regarding the residential use of electricity and the means for simplifying the survey procedures. The first is that the initial rate of hookup will depend on the total cost to the villagers including the costs for bringing the line to the village (if a payment must be made to PEA for this service), of connecting the house to the line and of the cost for wiring the house.

The second is that the wealth of a village and its inhabitants, as measured by their physical possessions, is a more important measure than income for predicting the rate of hookups and the average consumption per hookup. Wealth represents a floating average of the income of the rural household which provides more insight into ability to invest in both the hookup and the consumer durables associated with use of electricity.

The third point is that the demonstration effect of having villages nearby which are electrified and the provision of training concerning the use of electricity and the wiring of houses will have a major impact on the rate of acceptance of electricity in the village. The fourth insight is that the demand pattern for electricity is relatively similar in different parts of Thailand. The basic appliances and their order of procurement are household lighting, rice cookers,[5] color televisions, and fans. A poor household will consume on the order of 12- 14 kWh per month (30 days, 4-5 hours per day, 80-100 watts) primarily for lighting, a median income household will consume 35-40 kWh per month (200 watts) for lighting, a television and a fan with longer hours of operation, and a wealthy household will consume 70-100 kWh per month (500 watts) for a refrigerator, more lighting and larger fans.

Future efforts at predicting the demand for electricity in rural areas should build upon the National Statistical Office (NSO) expenditure survey data regarding appliance ownership (see Exhibit F.3) and on the consumption data from PEA for recently connected villages which separate out the effects of rate of hookup and average consumption per hookup. To this information should be added a brief survey on household wealth and village awareness of the uses electricity and electrical appliances.

The other purpose of performing the socio-economic surveys was to measure the benefits obtained from the introduction of electricity in rural areas. The post-project

3 The survey compounded these errors by estimating cash surplus based on the inaccurate estimates of annual income and expenditures

4 Very often those villagers with the larger cash income are the poorer people who have no land and must work as hired labor

5 Except in areas where glutinous rice is eaten

survey and evaluation is to be performed by NEA. This effort will be used to measure both the benefits of electrification and the degree of participation of the villagers in the project. However, neither is relevant since most of the villages in the service area are already electrified.

While much has been made of the secondary and intangible benefits associated with access to electricity, the basis for these claims is tenuous at best. The strong correlation between the introduction of electricity and other developments which promote economic growth make it difficult to verify any causal relationship. Furthermore, the correlation between wealth and the level of consumption of electricity tends to obscure any specific impacts of electricity on the quality of life other than those achieved through fuel substitution. Towards this end, the efforts by the World Bank, in its evaluation of the ARE.2 program, to measure the savings in energy costs due to the introduction of electricity are in the right direction. If the socio-economic survey is to be effective as a measure of benefits from introduction of isolated mini and micro hydro then it should perform measurements of current fuel and energy consumption pattern to serve as a baseline for measuring the change in energy use as a result of electrification.

The baseline survey should also have considered the impacts on women as a result of the introduction of electricity into the villages. Fortunately these benefits are relatively well defined. The principle appliances acquired once a household is electrified include fluorescent lighting, rice cookers, and televisions and less frequently fans and electric irons. The improvement in lighting allows for the pursuit of handicrafts or other income generating activities during the evening hours. The rice cooker reduces the cooking effort and the fuel collection effort which is traditionally shared by men and women. The television provides a source of information on current events and fashion which provide the villagers with a greater awareness of and sense of participation in the development of the country. Since most of the villages are already electrified, these benefits need not be measured for purposes of evaluating the project.

Conclusions

This report deals at some length with the problems associated with the financial analysis, the economic evaluation, the demand forecasting and the design of the socio-economic survey. It is important to note that as the project evolved, parts of the socio-economic survey and evaluation were eliminated because they were not relevant for the type of systems being designed.

The site selection procedure developed for this project contained two elements; a physical survey and design procedure which has already been used by NEA on earlier projects and a socio-economic survey and evaluation procedure, which differed from the approaches previously used. Unfortunately, this methodology was not well thought out. It attempted to develop a single simple procedure to evaluate micro-hydro and

both isolated and grid-connected mini-hydro sites and resulted in a methodology which is neither simple not correct.

The site selection procedure actually used, applied the procedures outlined in the PP. However, the initial screening was done with four specific objectives in mind. The first was that the sites should be isolated, but in the end only the eighth site was selected to be isolated. The first is now scheduled to be connected and it is not clear if the second site will be economically or financially viable. The second criteria was that the hydro-power facility should replace existing diesel capacity, but again this was rarely achieved. The third objective was that, if the facility was not to be isolated then it should be close to the existing grid. The fourth objective was that the sites should be regionally distributed and this objective appears to have been achieved.

The site selection procedure recommended in the PP included a socio- economic survey. This survey was meant to provide information for load forecasting and for preparation of the baseline data against which an evaluation survey could be conducted. The importance of this survey was diminished by the fact that nearly all of the sites are to be grid connected and that PEA is in the process of extending their lines to most of the villages in the proposed service areas. The survey instrument was derived from earlier efforts by NEA, USAID and the Thai Universities. Unfortunately, the questionnaire does not appear to be well designed for the collection of baseline data. The most relevant information for such an evaluation would be energy use and fuel consumption patterns against which cost savings and qualitative benefits could be measured.

The social benefits associated with rural electrification are in no way exclusive to the mini-hydro project and in fact are superfluous since the villages in the service area will be grid-connected. However, efforts to evaluate the impact of the project should be undertaken by NEA if for no other reason than to provide hard data on the benefits of rural electrification in remote areas.

CHAPTER 4: FINANCIAL, ECONOMIC AND SOCIAL ISSUES

The selection of the most appropriate technology for expanding a nation's electricity generation and distribution requires that a range of factors be considered. This chapter will focus on the economic, financial and social factors, but before proceeding, it is important to consider some other factors.

One such factor is the source of funds for investment. The purpose of economic analysis is to allocate these investments efficiently, but it is a less than perfect world. Both development banks and multi-national commercial banks prefer to make large loans to public utilities. Bilateral donors tend to favor projects in which there is a large component of inputs from their own country. Private sector investments focus on those parts of the power sector which are accessible to private investment and offer substantial profit. Direct government investments are allocated through a largely political process which responds to the size and location of that constituency which benefits from development of the sector. One need not agree with these rationales in order to accept their significance for project selection. This project allocated funds exclusively for the development of micro/mini-hydro systems.

Another factor is the sensitivity to risk. The energy sector has experienced an unprecedented level of change in the last 15 years and considerable uncertainties remain regarding the future of energy supplies, prices and conversion efficiencies. The RTG has made a conscious effort to diversify its source of supplies for electricity generation in the last decade as discussed in Appendix A. At the same time, it has invested heavily in exploration for and exploitation of domestic sources of lignite, natural gas and petroleum. As a result, the known reserves of these fuels have increased dramatically. The investments have not always been economically justifiable at the time of their implementation, but they have been effective in reducing the uncertainties associated with reliance on external sources of fuel and in minimizing the possible impacts resulting from shortages of a specific source of energy. Hydropower is one area in which the government has invested heavily in order to reduce the use of fuel oil.

A third factor is the issue of increasing investments in the poorer areas of the country, especially those areas close to the national border. The extension of the national electrical grid to areas where the costs far outweigh the potential revenue will continue as long as Thailand has a clear policy of developing those areas.

The economic and financial factors must be balanced against these other concerns in the selection of investments. However, the basic criteria of economic and financial viability should be respected when selecting projects.

Methodological Issues

The procedures for economic analysis of projects that involve extending electricity to rural areas have not been standardized because of the difficulties in estimating the benefits from these projects. The World Bank in its evaluation of the ARE.2 project used an estimate of the cost savings from fuel substitution as a basis for calculating benefits. The Inter-American Bank prefers to use a calculation of consumer surplus to estimate the benefits. USAID, in this and other projects, has made use of a least-cost approach in an attempt to avoid calculating the benefits. While the evaluation team prefers the World Bank approach and includes some examples of their calculations in Appendix I, the method actually selected should be tailored to the specific project conditions and the availability of information regarding these conditions.

In the project as originally proposed, the mini-hydro sites were to include mostly isolated sites which would not be connected to the grid. The method of economic analysis proposed in the PP compared the costs of this alternative with costs of connection to the grid and of a diesel power plant with local distribution network. The objective was to select the alternative with the lowest NPV for the life cycle costs. This approach had five problems.

1. The three alternatives would not provide identical benefits,
2. The isolated hydropower plant cannot supply more than the "dependable capacity" unless there are large consumers that can use additional power during the season of peak capacity,
3. The proposed diesel systems were designed to match the mini-hydro peak capacity and to have a 100% backup,
4. The comparison did not allow for a buildup in capacity over time in response to the buildup in local demand,
5. The shadow prices conversion factors clearly favored the mini-hydro and did not correspond to the factors used in other studies.

These problems are discussed in detail in Appendix G.

A more significant issue, was not to distinguish between the methodologies which should be used for grid-connected and for isolated mini-hydro. The methodology in the project paper, while far from perfect, is clearly directed towards the evaluation of isolated systems. In the project as finally evolved, all but one of the sites will be connected to the grid. This situation was known at the time of site screening for all but one of the sites. Ironically,the project paper proposed the use of a least-cost analysis which is not really appropriate for isolated sites can be used for grid-connected sites since the benefits from alternative investments are identical.

The financial analysis as presented in the project paper and as applied in the project was more carefully designed. Pro forma reports for sources and allocation of funds and for cash flow were prepared to determine the funding requirements of the project. However, the evaluation of financial viability was based on the project's internal rate of return and this figure was incorrectly computed from the cash flow schedule rather than from the schedule of income and expense. Fortunately, the distortions which resulted did not result in the selection of sites which were not financially viable.

Sensitivity Analysis

The economic and financial analysis as presented in the PP and as applied in the project failed to allow for the uncertainties with regards to the construction costs, relative energy prices and the discount factor more importantly no tests were made of the sensitivity of project viability to changes in the real prices of the capital cost estimates includes contingencies and an allowance for inflation during the construction period, but no tests were performed to determine the sensitivity of the project to variations in the relative costs of civil works, and equipment electricity and imported fuels. It is unlikely, that the results of such tests would have altered the decisions made, while it would have been easier to accept the change in economic or financial viability for the remaining two sites as discussed below. An effort was made in the second round of site investigations to take into account the sensitivity of project viability to changes in the discount rate, but other parameters were not tested.

Results of the Re-evaluation

A recalculation of the financial and economic viability of the first six sites was performed as part of this evaluation. The economic evaluation compared the mini-hydro facility with the least cost generation alternative which is a thermal plant fired with residual oil (see Appendix G for details). The financial analysis used the current buyback rate for electricity of 1.03 Baht/kWh as recently enacted by the RTG. The currently forecast costs for the six sites were used (see Appendix D for details) but revised shadow price conversion factors were applied. The Mekong Committee estimates of a Standard Conversion Factor of 0.75 (Exhibit G.3) seems low given that almost half of the costs are for civil works and other inputs with a high proportion of local resources and given that the markets for labor and materials are very competitive. The World Bank has suggested a SCF of 0.85 which seems more reasonable. In lieu of better information, we have compromised on 0.82. The discount rates were left at 12% for the economic analysis but reduced to 8% for the financial analysis. A sample input for this analysis is shown in Exhibit 4.1. The results of this analysis are shown in Exhibit 4.2. It is important to note that these results do not measure the economic or financial viability of continuing these projects, but are merely results which would be obtained if a proper evaluation were made today for construction of these sites over the next two

Exhibit 4.1

Basic Assumptions in Revised Analysis

Name of Site: Nam Kha Mun

Financial discount rate	12.0%
Economic discount rate	8.0%
Shadow price (SCF)	0.82
Design capacity	1,030 kW
Dependable capacity	184 kW
Buyback rate	1.03 Baht/kWh
Economic cost of capacity	15.45 000's Baht/MW
% O&M rate for this capacity	1.25%
Economic cost fuel replaced	0.804 Baht/kWh
Marginal line losses	15%

Exhibit 4.2

Results of Revised Economic and Financial Analysis

	Financial Analysis			Economic Analysis		
	IRR %	NPV Million Baht	B/C	IRR %	NPV Million Baht	B/C
Nam Mae Hat	7.1	(3.6)	0.94	11.8	(.5)	0.99
Huai Lam Sin	8.4	1.8	1.05	11.1	(2.5)	0.94
Khlong Lam Plok	10.4	7.6	1.19	14.9	5.0	1.16
Khlong Duson	9.1	3.5	1.08	11.6	(0.7)	0.98
Nam Kha Mun	5.3	(8.8)	0.81	7.5	(8.5)	0.75
Lam Pra Plerng	2.7	(12.0)	0.66	11.8	(0.2)	0.99
Huai Mae Sot	1.2	(18.4)	0.59	3.1	(14.8)	0.56
Nam Ya Mo	1.1	(27.2)	0.56	3.0	(21.9)	0.53

years. As such these results are representative if the outcome to be expected for the financial and economic analysis of the remaining sites.

Before reviewing these results, it is necessary to consider what changes have occurred since these projects were first evaluated. The most dramatic change has been the drop in the cost of petroleum fuels by about 50%. The current evaluation uses an economic delivered cost of fuel oil of 3.4 Baht per liter (CIF price 3.0 Baht).

The second change is the drop in the price charged for electricity. The buyback price of electricity dropped by approximated 25% during the period of the evaluation and had fallen in terms of constant costs by about 1.2% in the four years prior to that.

The third change is the drop in the discount rate as the fears of worldwide inflation declined. The financial discount rate is currently closer to 6-8% than to the 12% rate used at the time of analysis. The extension of the grid, while having had an important impact on the selection and design of the mini-hydro sites, has had little impact on their economic and financial viability since the grid was near to the service areas of all six sites at the time of evaluation.

The performance measures in Exhibit 4.2 indicate that only Huai Lam Sin would be economically feasible under current conditions. For Huai Lam Sin the financial IRR is 10.4% and the economic IRR is 14.9%. Four other sites are close to being economically viable with IRRs ranging from 11.1% to 11.8%. Two of these Khlong Duson and Khlong Lam Plok are financially viable, but the other two, Nam Mae Hat and Lam Pra Plerng are not. The least desirable project appears to be Nam Kha Mun.

These results were also subjected to sensitivity analysis. Since the costs were in most cases taken from bids, no sensitivity on capital costs was performed. The sensitivity test on the price of electricity indicated that four of the projects would be financially viable if the buyback price for electricity were to rise to 1.2 Baht per kilowatt-hour and all of the projects would be viable if the price were 1.6 Baht per kilowatt-hour. The sensitivity test on the price of fuel oil indicates that five of the six would be economically viable if the price of petroleum and natural gas were to rise by 10% and the other would be viable if the price rose by 40%. The sensitivity test on discount rate indicated that for the net present value of a majority of the projects to be positive, the financial discount rate would have to be on the order of 7% and the economic discount rate would have to be on the order of 11%. The results of these sensitivity tests are shown in graphical form in Appendix I.

Tariffs

The terms of reference for the project and for the evaluation required a review of tariffs as they effect project viability. Such a review is not needed since the price of the electricity generated will be set equal to the rate which PEA pays EGAT for electricity.

This rate is only 1.03 Baht/kWh and appears low, but the RTG feels that this rate is adequate to allow EGAT a rate of return on investment of 7%.

If mini-hydro sites are to be constructed at isolated sites, then the question of rates should be carefully considered. NEA's present policy for electricity supplied by microhydro is to charge the same rate as PEA in order to be "competitive", however, such a rate in no way covers the costs for these installations. For isolated mini-hydro a similar situation would apply. Although the economies of scale reduce the price per kW of installed capacity, isolated systems have extremely low utilization for three reasons:

1. Most of the load is concentrated in a four hour period in the evening,
2. The output of the facility must be limited to the "dependable capacity" since there is no way to sell surplus capacity,
3. The growth in load will occur over a number of years as households connect to the system and the electricity-consuming appliances are purchased.

Whereas a grid-connected system can have a utilization approaching 100% of the energy available, the isolated system has a utilization of less than 15% of the energy available. This would imply a charge per kWh on the order of 12 Baht in order to achieve financial viability.

Social Analysis

Many of the social issues which were thought to be important in the design of isolated micro and mini-hydro sites may not be as relevant for grid-connected mini-hydro. The contribution of local resources to the construction and operation of mini-hydro facilities may be minimal. The civil works are built by private contractors who employ mix of local and outside labor. The main transmission system to the area is constructed by PEA. But the local distribution lines are constructed by private contractors. The facility will be operated by NEA personnel for the first year and then presumably by EGAT personnel. Meter reading and bill collection will be performed by PEA. The only local input of note is the use of local labor for house wiring.

The social benefits of electrification are not attributable to the project since most of the villages within the service areas are already electrified. The impacts of electrification on the villagers will be primarily in the form of improved lighting and increased potential for productive night time activities. Rural industries and commercial establishments will benefit from access to electricity but these activities are limited. Also it is unlikely that electricity by itself will not create additional economic activity. None of the villages which were visited had significant productive uses of electricity other than the use of power tools for house construction and, in one case, an electric motor which replaced a diesel engine in a rice mill.

The ability to use rice cookers will reduce the time spent for cooking and the time required for gathering cooking fuels, both tasks in which women are involved. Work on handicrafts can be undertaken at night by both men and women who work in the fields during the day. Although electric water pumps were observed in some villages, these were usually purchased to provide irrigation for small plots and were only used during the rainy season to pump water to the house. However, the water generally came from open wells located near the house and thus the labor savings were relatively small.

One of the principal benefits of electricity in the perception of the villagers is the ability to watch color television. The access to news and other programs not only provides the villager with new information but also imparts a greater sense of being part of the nation.

Conclusions

The economic environment affecting the selection among energy options has changed dramatically since the project was begun. The energy sector infrastructure has been increased through extension of the grid, diversification of power generation systems and exploitation of domestic supplies of gas, oil and lignite. These changes have had a major impact on the economic and financial viability of mini-hydro facilities.

The effects of the changes in the energy sector have produced a situation in which the projects currently underway would not be feasible to undertake because other energy sources would be more attractive. However, given the large proportion of sunk costs associated with the work in progress, the team believes that the six sites presently under construction will produce benefits well in excess of the marginal costs to complete and operate these facilities. In contrast, the two sites not yet under construction are not justifiable either economically or financially, except if an allowance is made for the favorable terms of the USAID loan (see table 4.2). As pointed out earlier, other factors may justify the continuation of these projects in spite of their low economic and financial IRR's.

In addition to these changes, the economic and financial analysis performed for each site had some methodological problems. These problems were not fatal for the projects selected because of significant benefits from each site with the exception of Nam Mae Hat. However, in subsequent site selection efforts with more marginal sites, these problems could cause the selection of projects which are not viable.

The social benefits from this project are not clear since the contribution of local resources in the construction and operation of the sites is small and since most of the villages in the service areas of the mini-hydro sites are already connected to the grid. However, it would be quite useful to quantify these benefits for future minihydro projects.

CHAPTER 5: INSTITUTIONAL ISSUES

Project Organization, Procedures and Monitoring

The procedures developed for design and construction of the mini-hydro sites appears to have been relatively complex. This complexity was in response to three issues:

1. the number of participating organizations,
2. the fact that very few of participants were familiar with mini-hydro civil works and none were familiar with the electromechanical equipment, and
3. the need for interaction with the Technical Assistance Group (TAG) and both NEA and TEAM.

The resulting organizational structure (see Exhibit B.1) lacked clear lines of authority, however, in the process of implementing the project, NEA was gradually able to establish effective control over the project.

The procedures for site selection, design, contracting and construction were also complex. The site selection procedure required the participation of different divisions of the NEA, and all of the members of the Technical Assistance Group. The design activity was undertaken largely by TEAM consultants, but a complex set of review procedures, as described in Annex B, was developed to permit NEA to closely monitor this design project. This multiple review process slowed the progress of the project but was useful in insuring good design work.

The contracting activity suffered from the mix of conflicting objectives, procedures and regulations of the RTG and USAID. The FARA method of financing and the process of bid evaluation caused significant delays. Now that the project has reached the construction stage, the rate of implementation has accelerated as NEA applies its considerable experience with hydropower construction and as contractors push to meet their contractual deadlines.

The Project Operations Unit

At the start of this project, a Project Operations Unit (POU) was established at NEA. This unit was exclusively responsible for implementing the mini-hydro project. The POU provided a focus for project activities during the first 22 months of the project but lacked either leadership from the project coordinator or line responsibility within NEA. The staff was relatively junior and most of the design review responsibilities were maintained in the NEA's Design Division.

The level of staffing of the POU has now been reduced as the project enters the construction phase. The scaling down of this unit appears to have had little impact on

the construction of the project to the credit of the project manager. It appears that the NEA and its consultants have developed the skills necessary to sustain this project and have prevented these skills from being limited to the participants in the POU.

Institution Building

Technical Assistance:

One of the questionable objectives of the project was that of strengthening NEA's capabilities in implementing mini-hydro development. At the time the project began, NEA had already constructed two mini-hydro facilities. During the last four years it has constructed an additional three units and has three more under construction in addition to these being developed under this project. NEA's experience in this area allowed it to provide much of the technical support for the design, engineering and supervision for this project. The foreign technical assistance provided under this project served as a focus for project activities, but the scope of work provided for relatively little technology transfer.

NEA working with the Thai consultants appear to have been technically self-sufficient with only two exceptions, the preparation of specifications for the electromechanical equipment for a 0.5 to 1.5 MW hydro-power plant and the design of civil works so as to minimize negative environmental impacts. Neither area was the subject of technical assistance. Difficulties in producing equipment specifications caused serious delays in the procurement of the equipment so that the power houses at several sites will be completed before the equipment is available. The significance of the problem of developing these specifications was not identified until it represented the critical path. An NRECA consultant was brought out under another source of funds to assist the POU with preparation of the equipment specifications, but in the end TEAM Consultants used Thai electrical engineers from outside NEA were eventually employed to prepare the specifications. The need for technical assistance in the area of effective environmental design was not identified in the PP. Until recently no effort has been made to look at the environmental effects of the construction activity and the potential effects from operating these facilities.

The need for technical assistance from abroad for the balance of this project should be minimal. NEA and the Thai private sector can plan, construct and operate these systems. Specific areas in which assistance would be helpful are in a review of geo-technical and environmental conditions of the site and an engineering review of the facilities once they are operational. The first two tasks are within the capabilities of the Thai consulting community, but the third task might benefit from the experience of a foreign expert familiar with the design of mini-hydro facilities in different countries.

The recommended method of financing, the FARA method, encouraged a hands-off approach to the project because NEA already had considerable experience in the

design and construction of mini-hydro plants. Nevertheless, the considerable delays at the beginning of the project, the rather protracted problems with the specifications for the electromechanical equipment and the current lack of knowledge regarding the status of the remaining two sites, should have been a signal that this method of financing may not have been appropriate. However, many of these early institutional problems have been overcome.

The quality of the physical construction does not appear to have been a problem nor does the role of the Thai participants. The problems arose in the provision of technical assistance and in the design and application of the site selection model. These are areas which USAID should have been monitoring.

Training:

The training provided under this project was limited to two activities. The first was the on-the-job training provided to the staff of the POU the second was the formal training provided by the project consultants on site selection methods. The former was relatively limited because the project coordinators leadership of the POU was relatively ineffectual. On the other hand, the two-week training course on site selection procedures, which was attended by about 30 NEA staff, was considered effective.

NEA's Changing Requirements:

One of the issues which should now be addressed as part of the institution building process concerns the future role of NEA and its ability to fund its future activities. Despite a large number of highly qualified staff, NEA is facing a growing manpower shortage. Senior staff are retiring or leaving for higher paying jobs with parastatal or private organizations. Junior staff are obtaining hands-on experience with NEA and then leaving for "more interesting" jobs. This turnover has been occurring for a number of years and has reduced the number of projects which NEA can design and construct. The NEA has been able to maintain its project load through the use of local consultants and foreign assistance.

The transition of the organization's function from engineering and construction to project management and administration has been gradual but inevitable. Its success in earlier projects was based on its ability to work in technical areas together with private sector consultants and contractors and to provide effective technical review of the private sector activities. This ability continues to be the underlying strength of the organization, but now a greater emphasis on effective project management and efficient use of technical personnel is necessary. The rather heavy time commitments placed on the project manager for this project point out the need for a better allocation of support staff as well as a need to develop management techniques which will increase the efficiency of NEA's top technical staff.

Replicability and Sustainability

The replicability of this project has never been in doubt. The NEA has considerable experience in the design and construction of micro and mini-hydro facilities as shown in Annex N. Nearly 50 microhydro plants have been constructed in the last eight years and five mini-hydro plants have been constructed, mostly over in the last few years. The microhydro program is currently aiming to build about six units a year. The mini-hydro program is less clear although there are three other sites under construction in addition to those being built under this project. The uncertainty regarding mini-hydro has more to do with the changes in the economics of the energy sector than with any question of NEA's ability or interest in undertaking these projects.

The NEA is currently preparing a National Mini-hydro Master Plan to guide development in this area over the next 20 years. This plan is based on an analysis of generating costs for some 800 sites which would be connected to the grid. The method of analysis is based on a comparison with the least-cost source of electricity generation. A draft of this plan was recently submitted to NEA but was not available at the time of this evaluation. However, only a relatively small proportion of the sites appear to be viable in the current environment of low oil prices. While the government policy towards this type investment has yet to be finalized, there appears to be a certain lack of enthusiasm on the part of EGAT to operate small hydro power facilities.

A major factor affecting the sustainability of the mini-hydro program activity is the source of funding. All sites currently under construction are being financed with donor assistance (see Appendix O). The NEA's annual budget is set by the Bureau of the Budget based on previous levels of expenditure rather than on a defined set of projects. Since the mini-hydro projects have mostly been off-budget items, the NEA does not currently obtain sufficient government funding to maintain this level of effort. Also the units currently under construction will be attached to the grid and, as pointed out in the previous chapter, will not generate sufficient revenues under the current electricity tariff to pay for both their operating and capital costs.

In principle, it would be useful to establish a revolving fund in which the income from previous projects, or the value of the assets constructed, could be rolled over to fund new projects, however, this option is unlikely to occur because

1. The NEA has failed to reach an agreement with EGAT on the terms under which the latter will assume responsibility for the mini-hydro sites being constructed

2. The revenues from the operation of these facilities would normally be treated as general revenue while new funds would have to come from the budget.

3. There are few examples of such funds being used within the government. The current attempt to set up a relatively simple equipment fund in the Highway Department appears to be experiencing considerable difficulty.

4. As the better sites are developed, the marginal cost per installed kilowatt will increase and the amount generated per installed kilowatt will decrease thus reducing the number of projects which can be undertaken without constantly adding to this revolving fund.

Faced with these difficult financial constraints, NEA cannot continue its mini-hydro program without both an increasing commitment of funds by donors and the supporting commitment from the government.

National Energy Planning

Recently, the RTG recognized the need for a more coordinated approach to energy planning was required. The National Energy Policy Committee was formed under the chairmanship of the Prime Minister. It includes among its members the Minister of Science, Technology and Energy, and the Secretary Generals of NEA. A National Energy Policy Office has also been established in the Prime Minister's Office which will eventually assume responsibility for preparing the energy component of the Five-Year Plan.

Previously, NEA had attempted to undertake energy planning as well as the development of energy production systems, but, so far, it has failed to produce a National Energy Plan. Given the departure of the head of its Planning Division, the reorganization of his Division and the efforts of the Prime Minister's office to redefine NEA's function towards implementation, it is unlikely that NEA will have a significant role in macro energy planning in the future. Instead, it will be involved in energy planning in a much more defined role.

One of NEA's current tasks is to prepare plans for the development of lignite in existing mining concessions and to conduct research to promote the use of lignite. Another task is the preparation of a national plan for the development of mini-hydropower.

Within its role as an implementing agency, NEA will continue to concentrate on:

1. the development of micro and mini hydro facilities,

2. the promotion of renewable energy systems,

3. energy conservation, and

4. the installation of electric-power pump irrigation systems.

The relationship between NEA and other agencies involved in energy related activities is mixed. The experience of NEA in the Non-Conventional Renewable Energy Project was relatively positive in its relationships with the Royal Forestry Department. On the other hand, it seems to have assumed a competitive role vis-a-vis the PEA. PEA has encouraged this competition by extending its grid into remote areas which have little attraction other than the presence of NEA hydropower projects.

There is also the question of the role of PEA once the national grid has been extended to cover 95% of the country. If it were to become active in the electricity generation area, then small-scale hydro would be a logical sector for it to be involved in. NEA has clearly responded to this pressure in its microhydro projects by setting the cost at a level which is competitive with PEA rates but in no way adequate to cover capital and operating costs.

The relationship between EGAT and NEA appears to be better because there is no area of direct competition. However, the failure of NEA to reach an agreement with EGAT on the terms under which the latter will assume responsibility for the mini-hydro facilities points to a lack of coordination between the organizations. The situation could become acute in the future due to NEA's interest in developing more grid-connected mini-hydro sites and EGAT's lack of interest in managing small generating facilities.

The role of mini-hydro in providing electricity in isolated areas remains unresolved. The current goal of the government is to increase the percentage of villages electrified from an estimated 76% in 1986 to 95% by 1991. This will involve considerable expenditure and will significantly increase PEA's operating ratio. Therefore, it is expected that over the next five years a mixed strategy of grid extension and isolated power systems will have to be developed and that NEA and PEA will participate in implementation of this strategy.

For the NEA, the strategy should be based on the following five generating options:

1. Village-operated diesel generators of 1 to 10 kW with low voltage distribution (220 volt).

2. Village-operated micro-hydro of 5 to 20 kW with low or high voltage distribution (22 kv) to serve a village.

3. PEA-operated diesel generators 10 to 200 kW with high voltage distribution to serve a group of contiguous villages.

4. Village-operated micro-hydro of 40 to 100 kW with high voltage distribution to serve one large village or up to three contiguous villages.

5. Isolated mini-hydro of 0.5 to 1.5 MW with high voltage distribution to serve several villages within a 20 kilometer radius.

This strategy should consider the differences in quality of the service provided by these alternatives and compare the benefits of improved service with the costs. The implementation of this strategy would be separate from the development of the grid-connected mini-hydro facility as addressed in the national mini-hydro plan.

Conclusions

The organization of the Mini/Micro Hydroelectric Project was relatively complex and the procedures for planning, design and procurement were relatively cumbersome. After an appropriate level of delay, the NEA has been able to simplify the lines of authority and the procedures, with the exception of procurement of electromechanical equipment.

The POU, while not performing its anticipated role, did provide a focus for project activities. The gradual scaling down of its activities will in no way reduce NEA's ability to undertake similar projects.

This project was successful in supporting the government's effort to develop mini-hydro facilities. It was less successful in providing technical assistance for this activity. In the future, more attention must be given to monitoring the quality and appropriateness of the foreign technical assistance provided. Given the overall sophistication of Thailand's private sector, the skills of Thai professionals in engineering and science and the contributions of other donors, this will become an increasingly difficult task.

The ability of NEA to replicate this project was never in doubt, since most of the technical capabilities existed prior to the project and other donor agencies were involved in similar projects. The sustainability of this project presents a more difficult problem because of national funding priorities. The success of the country in weaning itself from imported fuels has reduced the incentives for further construction of hydropower facilities. Also the economics of alternative electricity sources currently favors traditional forms of generation.

The role of NEA in the planning and development of the national energy sector is in a state of flux. The macro-planning responsibilities are being shifted into the political arena. The competition between PEA and NEA is expected to increase and become increasingly detrimental to the nation. NEA's technical staffing problems are expected to increase as long as there are significant pay differentials with the parastatals and management is unable to develop sufficient projects to keep its staff busy. The need for an active, well-defined role for the NEA in the national energy sector needs to be addressed. NEA, in turn, needs to develop better management procedures to accommodate an increasing range of projects to qualified project managers.

CHAPTER 6: ENVIRONMENTAL IMPACT OF MINIHYDRO PLANTS IN THAILAND

The negative environmental and social impacts of large hydropower projects is well documented and remains a controversial topic among development planners. Poor countries have need for irrigation water, flood control and electricity, but the large hydropower plants permanently altered, large sections of river valley ecosystems by flooding, increased sedimentation problems and the displacement of rural families.

The negative consequences associated with such large schemes should not be confused with the environmental impacts of mini or microhydropower plants. There is the tendency among environmental groups to condemn all hydropower construction on the basis of popular perceptions associated with the large projects. The environmental impacts which will be described here are those associated with minihydropower plants of the type currently being built in Thailand and visited by the team. These plants are between 700 and 1200 kW and located in forested, hilly areas, with a low population density and scattered villages.

Construction Impacts

The most significant environmental impacts occur during the construction phase. To build the weir, headrace, penstock, powerhouse and access roads, wide swaths of land have to be cleared. This is generally done with large earthmoving equipment and little manual labor. Prior to land clearing, a limited environmental survey should have been undertaken at each site. Such pre- and post- surveys would have given NEA planners a better idea of how the environment is affected and how to avoid any serious impacts in the future through improved construction techniques. However, USAID did stress its concern over the erosion that will take place on roadways, headrace and powerhouse areas, and in particular the penstock trench. As a result of this concern, NEA was given a paper that highlighted measures that should be taken to mitigate the effects of erosion. NEA accepted the paper and added an additional recommendation on the need for riprap to be constructed along the penstock trench.

NEA has awarded small subcontracts to construct concrete channels in the penstock trenches to divert runoff to natural watercourses, and to install concrete blocks to break the rapid flow until it can be diverted. The subprojects are Nam Kha Mun, Khlong Lam Plok, Huai Lam Gin and eventually Khlong Duson. Each subproject cost NEA between Baht 100,000 to Baht 200,000. Some action, therefore, has already been taken, and more will be done after the construction has been completed.

All the sites are located in somewhat remote areas having little direct impact on villagers, but some on the wildlife in the immediate vicinity. The evaluation team noted

that wildlife did not appear to be plentiful although some of the sites are located in national parks, forest reserves and wildlife sanctuaries.

As mentioned, the most significant impact is the possibility of soil erosion occurring during the rainy season. Two rainy seasons will pass during the construction of each plant. The soils in these areas are alluvial, thin and of low bulk density. They tend to wash away if not held in place by vegetation. When visiting the sites, the team did not notice any significant erosion, but many of the sites are relatively new and have not endured a rainy season. The Nam Mae Hat site has gone through two rainy seasons but no serious erosion problems had occurred.

At other sites, there were fallen trees across the access roads and collapsed roadway sections. We do not consider this serious since the access roads will always be subject to the vagaries of the weather. However, these roads must be well maintained so as not to contribute to the sediment load. Replanting in adjacent areas should be considered in areas that do not recover on their own. After two or three years, stability should return to the ecosystem.

Operational Impacts

The environmental impacts of minihydro plants after construction is completed, are minimal. In some cases, increased land clearing for development may result in the watershed because of the existence of the power plant. This will add to the sediment load and endanger the area's stability. The watershed must not be altered since it could lead to an increase in sediment load and a decrease in flow due to decreased runoff or increased upstream consumptive water use. Therefore, careful and thoughtful management of the catchment area must be practiced.

Often, the biggest problem with minihydro plants is the temporary withdrawal of water from the reach of the stream between the weir and the powerhouse. None of the six plants will divert more than 40% of the stream flow during periods of normal flow and power generation. The greatest danger will occur during the dry season, when 100% of the flow may have to diverted. This reach of the stream is usually not more than one or two km in length but the ecological chain will be broken. This impact is described in more detail in Appendix H.

Major negative impact of plants which have water storage, such as the flooding of good farmland, thermal stratification and anoxic conditions in the benthos do not occur in run-of-the-river plants such as the Thai minihydro plants.

Conclusions

The environmental impact of the minihydro facilities is minimal. There is little agricultural development in the upstream catchment areas therefore few problems with

sedimentation are anticipated except during extreme hydrological events. The major disruption to the ecosystem occurs during construction. There was significant disruption during construction as large swaths need to be cleared. However, these areas should stabilize in two to three years after completion of construction. Some erosion problems may arise along the access roads and at the overflow spillways.

Long-term environmental impacts are expected to be minimal during the operational life of the plant. Sediment poses the only real problem, but its impact will be on the equipment rather than on the environment. On occasion, during the dry season, most of the flow in the stream will be diverted for electricity generation. This condition will last for relatively brief periods and is not expected to be harmful to flora or fauna.

Although the environmental impacts of these projects are expected to be minor, the project has not given sufficient attention to this issue during the design phase. However, in 1986, a paper on ways to mitigate against negative environmental impacts was passed on to the NEA. It would seem that the recommendations are being seriously considered and implemented. In addition, an environmental specialist familiar with conditions in Thailand should be engaged to review the sites for potential impacts and to develop a simple procedure for incorporating this type of analysis in future site selection surveys.

The evaluation team recommends that brief environmental analyses be undertaken of the last two sites currently being designed (Huai Mae Sot and Nam Ya Mo). This would involve placing a biologist at the site for one or two days to catalogue the ecosystem and provide some guidelines for mitigating negative impacts during construction. This short report would be submitted to the Royal Forestry Department and the National Environmental Council by the NEA staff in order to obtain permission to develop the site. After the plants have been in operation for a year or two, a follow up environmental survey should be carried out to determine how the area has changed as a result of the plant's existence. Only a long look through time will answer the question of environmental impact of these sites.

One member of the POU should have clear responsibility on environmental matters through interaction with the civil designers and construction contractors. This individual would travel to the site and provide guidance on cost-effective techniques for avoiding environmentally harmful construction approaches.

If funds are available, a brief guide for civil contractors should be prepared which will sensitize them to environmental concerns. This guide should point out the economic impact of bad natural resource management. Any major minihydro effort in Thailand must have an environmental component. As natural resource constraints became more important to Thailand's development, environmental consideration must become part of all project design.

CHAPTER 7: FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the major findings, conclusions and recommendations are given.

Findings

The principal findings of this project, are;

1. The project has provided a broad institutional setting for the development of mini-hydro within Thailand, both at NEA and the private sector.

2. It has encouraged the NEA and the Thai private sector to refine their abilities in the selection an assessment of mini-hydro sites based on economic, financial and social variables.

3. It has allowed both the NEA and the private sector to develop capabilities for the engineering design of hydropower facilities in the 0.5 to 1.5 MW range, including the design of civil works, construction supervision and the specification of electromechanical equipment.

4. It has provided the Thai fabrication and manufacturing sector with a limited market for the provision of electromechanical equipment for mini-hydro plants.

5. It has resulted in the construction of six mini-hydro facilities in the rural areas of Thailand, with p[illegible]ng underway for an additional two sites.

Conclusions

1. The revised economic and financial analysis indicate that the viability of the minihydro projects is questionable given current fuel prices. However, taking into account the marginal costs to complete the projects versus the marginal benefits, it is clear that the six sites currently under construction should be completed. The remaining two sites which are being designed should be reviewed for economic and financial viability. While it is likely that both the financial and economic internal rate of return from these projects will be below the hurdle rate of 12%, this does not mean that they would not be financially justified given the terms of the loan for USAID financing.

2. The foreign technical assistance provided under this project was in general appropriate but not crucial to meet the requirements of the project or the NEA. This is partly due to the scope of work which was defined in the Project Paper. Monitoring was encumbered by having to deal with administrative matters instead of technical substance. Also, the difficulties

of the USAID Mission in Thailand in providing good technical assistance is in part due to the high quality of technical input required as well as the difficulties of replacing experts who do not perform well.

3. The site selection model as presented in the project paper and as executed by the TAG is insufficient because it does not distinguish between mini and micro hydro and between isolated and grid connected systems. The grid connected mini-hydro model would compare the hydro facility with other grid connected methods of power generation. The isolated micro-hydro model should examine the hydropower operation with other local generation systems including diesel generators. The isolated mini-hydro model should take into account the limitation on output equal to the dependable capacity and should compare this system with other multiple-village generation and distribution systems and with the extension of the grid. Since the project placed special emphasis on this development and implementation of this model, it seems appropriate that some effort be made to finalize the model.

4. The NEA is currently limited in its approach to the development of isolated power systems. A more general strategy is needed in which the NEA can respond to the needs of isolated enclaves with several alternative isolated power systems depending on which is more financially viable.

5. NEA's institutional role has shifted from being primarily an engineering organization to being a project management organization. The different managerial skills implied by that transition need to be addressed through development of the managerial capabilities of and the supporting staff for the project managers.

6. The sustainability of the mini-hydro program in NEA faces a serious problem. While there is no question that NEA has the technical capability to manage these projects and to deliver working systems, there is a serious financial question as to the source of funds for continuing this program. At present most of the funding for this project comes from off-budget funds and in particular from foreign aid and central government funds. The cash flow analysis in Appendix I indicates that the sites will produce sufficient revenues to meet the debt service and provide a small surplus. However, a similar analysis assuming no USAID loans but rather commercial loans indicates that the projects would not generate a surplus until 15 years into the project. No operational budget exists to support similar projects in the future. The only apparent option for NEA given the declining interest of donors in hydropower is to develop a revolving fund which would receive the value of the asset at the time it is transferred to the operating agency, presumably EGAT, and make those funds available for further investments.

7. The RTG is currently in the process of revising its procedures for energy planning. This revision is most obvious in the transfer of responsibility for preparing the energy component of the five year plan from the NESDB to the Office of National Energy Policy. However, the government needs to develop a more rational approach to the selection among alternatives for electricity generation which takes into account the uncertainties related to the relative costs of fuel and labor over time and the real costs of exploiting domestic energy resources.

8. Little environmental analysis was carried out at the six sites. There is some negative environmental impact which can be noticed during the construction phase. Permission from the Royal Thai Forestry Department to proceed with construction has also been slow in coming, in part due to an initial lack of concern for environmental issues. More recently however, both USAID and the NEA have given new attention to this issue and it is expected that some sort of environmental analysis will be done at the remaining two sites.

Recommendations

1. The first six sites currently under construction should be completed. The remaining two sites should be reviewed by the RTG to determine whether factors other than the simple economic and financial analyses justify construction of these facilities.

2. USAID should review its procedures for monitoring foreign technical assistance to insure that the quality of the consultants and the scope of their assistance is appropriate to the requirements of Thailand.

3. The site selection model should be revised beginning with adoption of the model developed by TEAM, for analysis of grid connected minihydro and adding to this more standard procedures for evaluating isolated mini-hydro and microhydro.

4. NEA should develop a mixed strategy for developing isolated power systems and should request authority from the government to assist those villages which are too remote to be connected to the gird by installing the most cost effective power systems.

5. NEA's training activities should focus on the development of the management capabilities of its project managers. The focus of this training should emphasize skills in project scheduling and monitoring, preparation and enforcement of contractual agreements, staff reporting systems, etc. If requested, USAID might consider providing support in these training efforts.

6. A permanent funding mechanism needs to be developed to allow NEA to continue the development of mini-hydro projects where they are economically and financially justified. Part of this financing might be a revolving fund into which the net operating income from existing facilities is placed for use in future capital investment. Alternatively, if EGAT is willing to assume responsibility for the facilities and to pay NEA for them, then the receipts from transfer of the assets can be used to fund additional investments.

7. The arrangement with EGAT for assumption of operating responsibility for the mini-hydro facilities, after the period of initial operation, needs to be resolved. Discussions with EGAT indicated that if a large number of plants were built, a major staff increase and training effort would be required. With current control technology, such staff increases may not be necessary. An examination of this issue might be considered since labor is the largest component of O&M costs.

8. The RTG should develop a general screening model for selection among alternatives for generating electricity for the grid and for choosing the method of delivering power to remote villages. This model should focus on the least cost alternative while taking into account any differences in the quality of the power provided.

9. The last two sites, Huai Mae Sot and Nam Ya Mo, should have environmental impact studies prepared. These need not be major studies, but an inventory of the natural resources and the conditions at the site. This could be done using local university and private sector professionals.

APPENDIX A: THAILAND'S ENERGY SITUATION

The Electrical Power Sector

Electrical power generation experienced strong growth over the last decade as shown in Exhibit A.1. Average growth was 9.5% in the period 1977 to 1985. Most of the growth in capacity to meet this demand has been through public sector expansion, almost all of it developed by EGAT. Because of the increasing cost of petroleum fuels during the 1970's and in response to the discovery of major supplies of gas and lignite in Thailand, there has been a dramatic shift away from the use of fuel-oil fired plants as shown in Exhibit A.2. Fuel oil currently accounts for less than 1/7 of the electricity generated in Thailand while natural gas provides nearly 1/2 and lignite almost 1/4. In all cases, these fuels are used in thermal plants or more recently in combined cycle plants. Gas turbines are used to generate of about 2-1/2% of the electricity generated and diesel generators provide less than 1% of the power.

The expansion plan for EGAT calls for an increase in capacity of 1.32 GW by the end of 1991 as shown in Exhibit A.3. This increase will be derived 1/3 from large hydro facilities, 1/2 from lignite and the remainder from natural gas. The domestic supplies of natural gas and lignite are such that the role of these fuels will continue to be significant for the next several decades.

Hydropower

Hydropower contributes slightly less than one of sixth of the total electricity consumed in Thailand. Although the hydro capacity has increased dramatically over the last decade, it has not kept pace with the rate of growth in overall demand for electricity as shown in Exhibit A.4. A number of additional sites for large hydro facilities have already been identified. Currently EGAT has about 420 MW of hydropower facilities under construction with an additional 840 MW planned for development by 1995.

Many of the existing facilities have been constructed in conjunction with irrigation and flood control projects, and therefore the generation of electricity is treated as a by-product. Other facilities are constructed without storage capacity. As a result the annual load factor for the hydropower system is relatively low, averaging below 30% over the last decade and hitting a low of 12% during the severe drought of 1980. The limited availability of power due to the mixed use of these facilities has caused the RTG to treat hydropower as a source of energy to meet peak demands.

Currently there are a number of small scale hydropower facilities in the country. NEA has been in charge of the development of many of these sites but upon completion, most have been turned over to EGAT for operation. Altogether 5 mini-hydro sites and 46 micro-hydro sites have been constructed by NEA (see Exhibit A.5). If these are added to the estimated capacity of the eight mini-hydro sites included in this project

Exhibit A.1

Total Electricity Generation
Public and Private

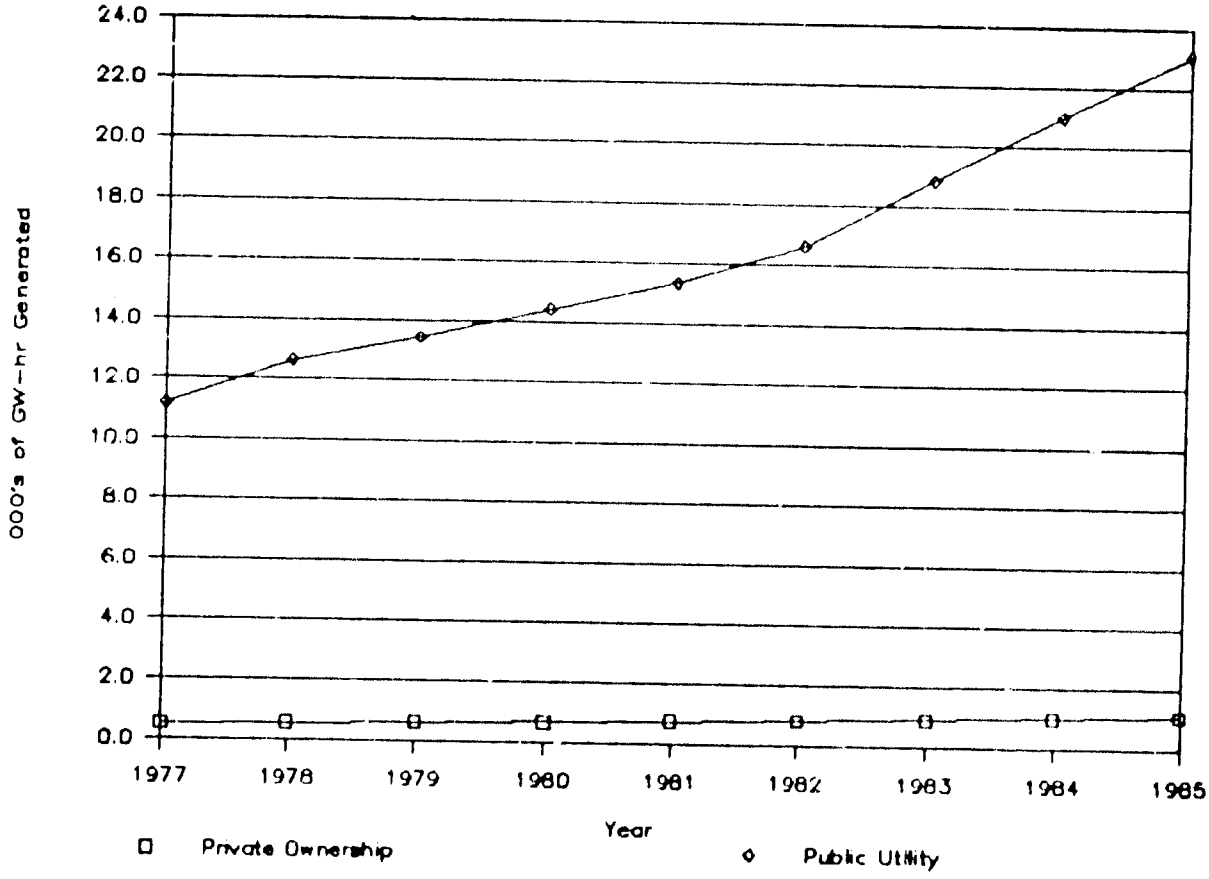
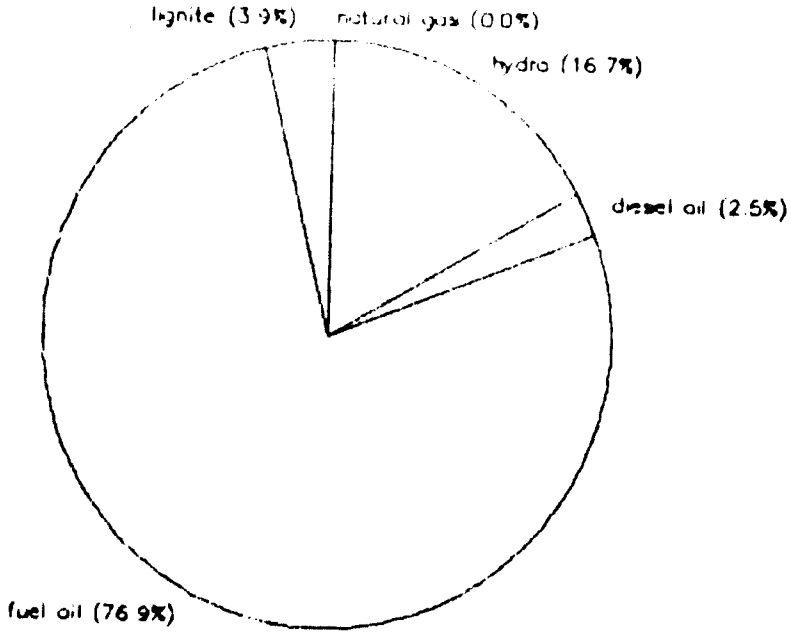


Exhibit A.2

Electricity Generation by
Source of Energy in 1978



Electricity Generation by
Source of Energy in 1985

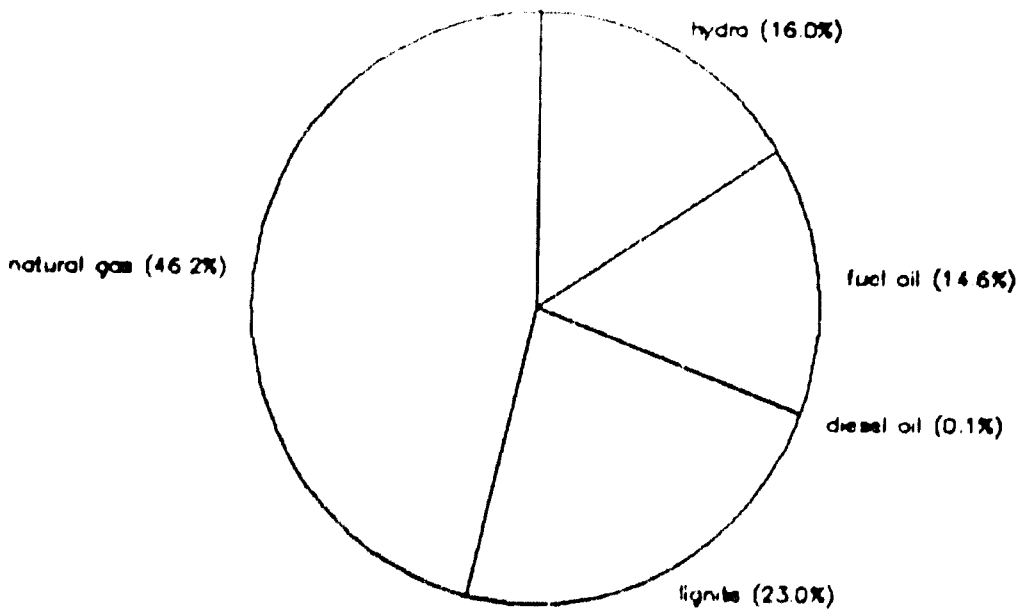


Exhibit A.3

Planned EGAT Expansion

Project	Capacity (MW)	Availability	Fuel Source
Chiew Larn	240	mid 1987	hydro
Barge #2	75	mid 1988	natural gas
Mae Moh #8	300	mid 1989	lignite
Mae Moh #9	300	mid 1990	lignite
Srinagarind #5	180	late 1991	hydro
Khanmo* #1	150	late 1991	nat gas
New R^3 #1	75	late 1991	lignite

* Combined Cycle

Source: "Annual Report: 1985", Electric Generating Authority of Thailand

Exhibit A.4

National Hydro-Power Energy Profile

	1977	1978	1979	1980	1981	1982	1983	1984	1985
National Consumpt (GWh)	9962	11366	12434	13149	13837	15033	16832	18572	20032
Generation (GWh)	11691	13204	14067	15112	16125	17450	19770	22029	24180
Hydro									
Generating Capacity (MW)	910	910	910	1270	1361	1519	1501	1714	1824
Annual Output (GWh)	3265	2110	3263	1273	2974	3837	3660	4081	3692
Average Load Factor	41.0%	26.5%	40.9%	11.4%	24.9%	28.8%	27.8%	27.2%	23.1%
% Capacity from Hydro	29.5%	28.4%	27.4%	33.0%	30.5%	29.7%	24.9%	25.4%	25.3%
% Generation from Hydro	32.8%	18.6%	26.2%	9.7%	21.5%	25.5%	21.7%	22.0%	18.4%

Source: "Electric Power in Thailand 1985", NEA

and the other three sites currently under construction then the total accounts for about 1-1/2% of the hydropower capacity planned for 1989. The NEA is currently in the process of developing a National Mini-hydro Development Plan which examines 800 potential sites, evaluates their economic feasibility and attempts to schedule their development according to anticipated budget limits.

Rural Electrification

The Provincial Electrical Authority (PEA) provides electricity to all areas of the country with the exception of the Bangkok Metropolitan area. It generates very little of its own electricity and instead buys power from EGAT for distribution through its own transmission network. The number of customers and the sales of electricity have increased rapidly for all sectors over the last 15 years as shown in Exhibit A.6. However, as the network has expanded there has been a decrease in the level of consumption of the marginal customer leading to a drop in the average consumption figures for all sectors except government. This drop was also a result of the increase in the real price of electricity during the 1979-1981 period. The average consumption per hookup is expected to be relatively stable over the next five years assuming that tariffs areadjusted in line with inflation and the lower level of use by new customers is balanced by the growth in average consumption for users in the provincial capitals and the amphoe towns.

During the last two decades, there has been an accelerated effort in rural electrification. As a result the number of electrified villages has increased from 2% of the total villages in 1961 to 76% at the end of 1986. This percentage is scheduled to increase steadily through 1991 as shown in Exhibit A.7. The goal of the Sixth Economic and Social Development Plan (1987-1991) is to electrify 95% of all villages in Thailand by 1991. However, this goal is unlikely to be reached because of the increasing marginal cost of electrifying remote areas and the increasingly difficult financial situation of PEA. The rate of return on PEA's rural electrification projects was only 5% in 1985 and is thought to have decreased to 4% in 1986.

Despite these difficulties, PEA continues to maintain an active schedule of projects not only for rural electrification but also diesel replacement and upgrading of the system as shown in Exhibit A.8. These projects are being funded from a variety of sources but primarily from the government budget (see Exhibit A.9).

National Energy Policy

The formulation of Thailand's energy policy as presented in the annual five year plans has traditionally been prepared by NESDB from inputs supplied by the relevant government authorities including, EGAT, PEA, MEA, PTT, and NEA. In general, the plans and policies are developed as a composite of these submissions without much

Exhibit A.5

Existing NEA Micro and Mini Hydro Facilities

Size (kW)	Number	Total Capacity (MW)
5-20	24	0.38
21-50	15	0.56
51-100	3	0.26
101-500	4	0.70
501-1000	2	1.86
1001-1500	2	2.56
1501-2500	0	--
2501-6000	4	18.60

Source: NEA

Exhibit A.6

PEA Power Sales, 1970 - 1985

Category	Total Consumption (GWh/yr)				
	1970	1975	1978	1981	1985
Residential	240.9	547.2	981.3	1582.1	2912.0
Small Business		311.7	677.1	528.6	684.9
Industry & Commercial	501.9	1194.4	1889.6	2990.3	4760.5
Agricultural	0.6	4.5	9.9	18.4	55.6
Government	8.1	14.1	19.1	19.8	30.7
Other	17.9	48.1	72.6	70.5	113.4
Total	**769.4**	**2120.0**	**3649.6**	**5209.7**	**8557.1**

	Total Number of Customers (000's)				
	1970	1975	1978	1981	1985
Residential	470.6	768.2	1324.2	2230.2	3990.5
Small Business		8.5	18.5	28.1	45.3
Industry & Commercial	5.5	0.7	1.0	3.7	7.8
Agricultural	0.1	0.0	0.1	0.3	0.7
Government	1.6	1.8	2.2	2.6	3.2
Other	1.2	2.3	3.3	5.6	6.1
Total	**479.0**	**781.5**	**1349.3**	**2270.4**	**4053.6**

(1) includes government hospitals and schools

Source: NEA

Exhibit A.7

PEA Village Electrification Forecast

Year	No. of Village Electrified	Accumulated No. of Villages	Percentage* Electrified
1980	3,966	18,600	34
1981	4,000	22,600	41
1982	3,800	26,400	48
1983	3,986	30,386	56
1984	2,598	32,984	61
1985	4,110	37,094	68
1986	4,096	41,190	76
1987	4,543	54,733	83
1988	2,431	48,164	87
1989	1,564	49,728	90
1990	1,564	51,292	93
1991	1,464	52,756	95

* There are 54,492 villages in 70 provinces in PEA service area.

Sources: PEA

Exhibit A.8

PEA Rural Electriciation Under the Sixth Economic and Social Development Plan

(No. of Villages Electrified)

Project	1987	1988	1989	1990	1991	Total
Continued Projects from 5th Plan						
- Normal Rural Electrification Project: Phase I	1,000					1,000
- Village Electrification Project: Phase I & II	1,276	1,000				2,276
- Accelerated Electrification Project: Phase II	2,160	754				2,914
- Replacing Existing Diesel Generator	63					63
- Mini-Hydroelectric Project	13					13
Subtotal	4,499	1,767				6,266
New Projects for 6th Plan						
- Normal Rural Electrification Project: Phase II	-	600	500	500	400	2,000
- Village Electrification Project: Phase III	-	-	1,000	1,000	1,000	3,000
- Kula Rong Hai Village Electrifcation	44	64	64	64	64	300
Total	4,543	2,431	1,564	1,564	1,464	11,566

Sources: PEA

Exhibit A.9

Summary of PEA Projects and Sources of Funds

Project	Year Completed	Number of Villages	Households Served	Foreign Aid and Grant	Total Cost
Rural Electrification	1983	5,076	514,000	741.60	2,200.50
	1985	4,567	480,000	880.63	2,207.08
	1987	3,000	350,000	1,361.80	2,343.21
	1988	11,878	900,000	4,091.21	8,193.93
	1991	5,300	370,000	2,126.00	3,834.00
Improve and Upgrade System	1982		21,700	96.39	159.37
	1986		2,200,000	1,607.00	2,699.00
	1988		480,000	836.00	1,353.00
	1990		670,000	969.00	1,539.00
	1992		2,400,000	2,735.00	4,500.00
Replacing Diesel Generators	1982		137,000	239.25	429.00
	1984		20,000	81.52	148.92
	1987		3,500	187.00	247.00
Mini Hydroelectric	1985			80.00	187.00
	1991			200.00	472.00
Solar Generating	1986			52.65	60.53
Electricity (Experiment Project)					
Wind Charger	1988		700	5.00	10.00

Source: NEA

critical review. Those government policies which have had the greatest impact on the energy sector of the country are:

1. the decision to emphasize the use of domestic commercial energy sources for electricity generation,

2. the policy of rapid exploration for and exploitation of domestic energy sources including natural gas, petroleum and lignite and,

3. the plan to extend electrification to nearly all of the villages of Thailand.

More recently, the government has begun to encourage the development of dual-fueled plants in order to balance the risks between increases in the real price of imported fuels and the limits on future discoveries of usable natural gas and lignite. Also the government has begun to develop incentives for energy conservation including the promotion of energy efficient appliances and equipment and an adjustment in energy prices to reflect the actual costs of providing this energy.

While the government has developed broad policy guidelines for the energy sector, it has yet to develop a national plan aimed at minimizing the future cost of energy to the nation. NEA undertook to develop such an Energy Master Plan in 1981, using a standard macro-economic energy planning model, however, the plan resulting from this analysis has never been formally approved.

Recently, the RTG recognized that a more coordinated approach to energy planning was required in order to provide a more coherent energy policy. The National Energy Policy Committee was formed under the chairmanship of the Prime Minister. It includes the Ministers of Finance, Commerce, Industry, and Science, Technology and Energy, and the Secretary Generals of NEA and NESDB. In addition, a National Energy Policy Office was established in the Prime Minister's Office and the head of this Office is also Secretary to the Committee. At present this office is in the process of staffing up and its activities have been limited to resolving conflicts between the development plans proposed by EGAT, PEA, PTT and NEA. Eventually it will assume responsibility for preparing the energy component of the Five-Year Plan, a role currently performed by NESDB.

The Role of NEA in Thailand Energy Policy

The future role of NEA in the development of energy policy is expected to be limited. Previously, NEA has attempted to fill two functions, energy planning as well as the development of energy production systems, however, it has so far failed to produce a National Energy Plan. With the departure of the head of its Planning Division, the reorganization and reduction of this Division and the efforts of the Prime Minister's office to redefine NEA's function towards implementation, it is unlikely that NEA will have a significant role in energy planning in the future. Within its role as an

implementing agency, NEA is expected to continue concentrating on the development of micro and mini-hydro facilities, on the promotion of renewable energy systems and energy conservation, and on the installation of electric-power pump irrigation systems. In addition, the NEA is expected to prepare plans for the development of lignite in existing mining concessions and to conduct research to promote the use of lignite

The Role of Mini-hydro in Thailand Energy Policy

The role of mini-hydro in the national electricity generation system has not been clearly defined. So far the NEA has been responsible for construction of most of the mini-hydro facilities in the country, but most of the electricity will be sold to PEA. NEA plans to operate the mini-hydro facilities constructed under this project for a break-in period of one year and then to turn the facilities over to EGAT for operation as part of the national system. However, the terms for this turnover in responsibility have not been resolved and discussions with EGAT indicate a certain reluctance to manage small-scale power plants while the demands for additional capacity are rising at an annual rate of approximately 250 MW per year.

The NEA is currently preparing a National Mini-hydro Master Plan which will identify the sites to be developed and propose a schedule for construction of these facilities. Most of these sites are planned for connection to the grid. The capacity of NEA to develop these sites is well established but a national commitment to their development appears to be lacking in the current environment of local oil prices and adequate domestic fuel supplies.

The role of mini-hydro in providing electricity in isolated areas remains unresolved. The current goal of the government is to extend the national grid to 95% of Thailand's villages by 1991 will involve considerable expense. As the more remote areas are connected, the operating ratio of PEA will increase significantly and its overall return on investment will decline below 4%.

Considering the increasing cost of the grid extension, it is important that a mixed strategy be developed over the next five years. This strategy should include several options in addition to connecting villages to the national grid. The isolated power generating systems which should be included in this strategy are:

1. Village-operated diesel generators 1 to 10 kW with low voltage distribution,

2. PEA-operated diesel generators 10 to 200 kW with high voltage (22 kV) distribution to serve a group of contiguous villages,

3. Village-operated micro-hydro of 40 to 100 kW with high voltage (22 kV) distribution to serve one to three contiguous villages,

4. Isolated mini-hydro of 0.5 to 1.5 MW with high voltage (22 kV) distribution to serve several villages within a 20 kilometer radius.

The selection among alternatives could then be based on the costs and benefits of these alternative relative to the extension of the grid.

Alternative Generating Costs

The decision on the mix of electricity generation technologies which should be used in Thailand must take into account not only the issue of least cost but also the risks associated with the variation in relative prices and availability of alternative fuels and the adjustment in the relative costs of labor and capital over time. The identification of the least cost alternative for electricity generation should begin with a comparison of the economic costs for different generation systems. Some estimates of the costs for eight different generating systems are presented in Exhibit A.10. In order to compare the average cost per unit of electricity produced by each of these systems, it is necessary to amortize the capital costs over the life of the system and to estimate the average load factor.

A comparison of the costs using a 12% interest rate over a 25 year amortization is shown in Exhibit A.11 for load factors between 30% and 60% and in Exhibit A.12 for load factors between 60% and 100%. These results clearly indicate that the Combined Cycle Natural Gas currently represents the least cost alternative up to a utilization rate of about 90%. Thermal plants using fuel oil are the second lowest in cost in the range of 50% to 70% utilization. Hydropower (assuming an average capital cost of US $1750 per installed kW and a three year construction period) is competitive at levels of utilization above 80% but is the most costly alternative next to lignite for load factors up to 60%.

Exhibit A.10

ALTERNATIVE POWER PLANT ECONOMIC COST FOR

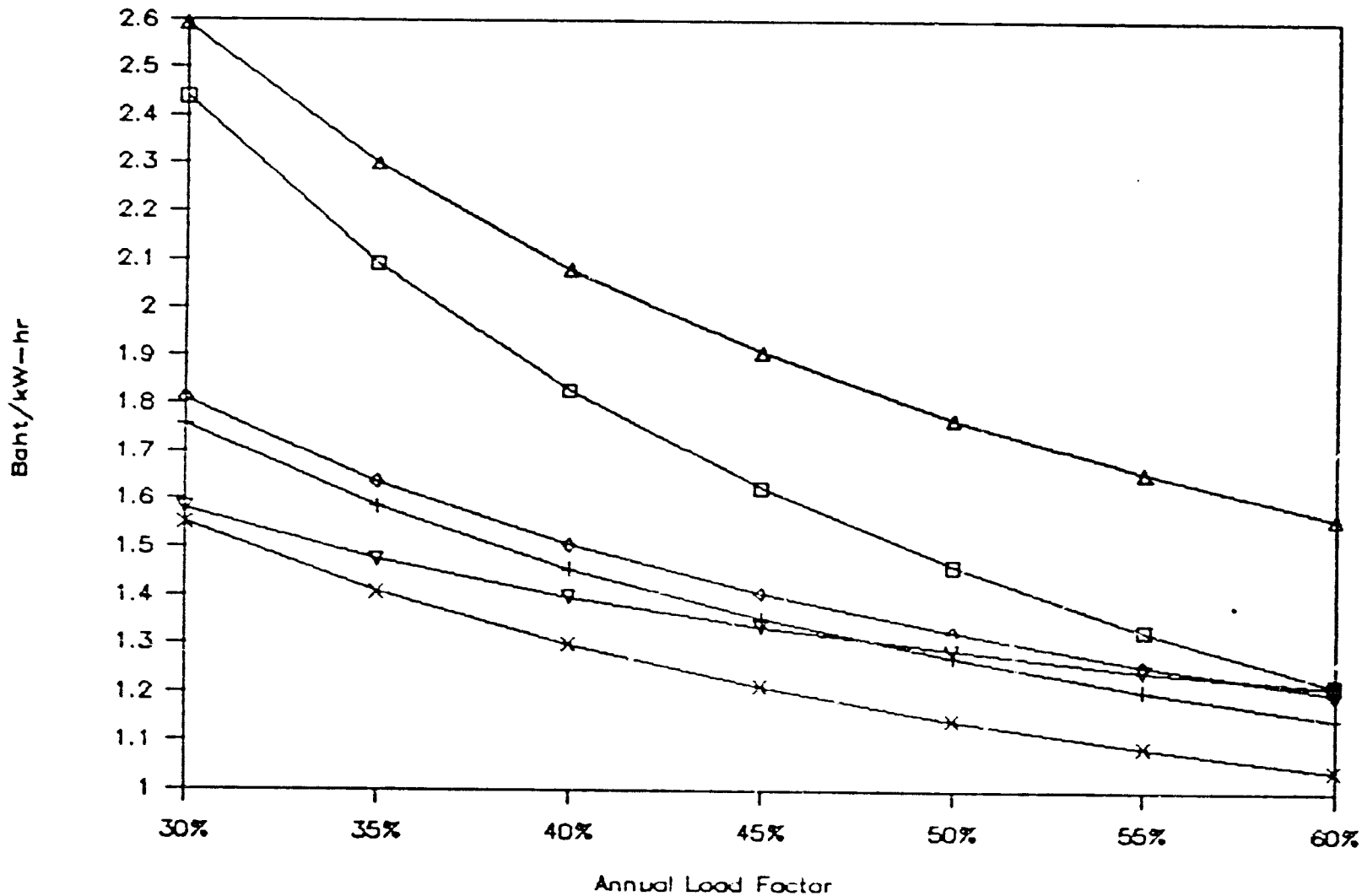
Description		Thermal Plant			Combined Cycle			Gas Turbine	
		Import. Coal	Heavy	Nat.Gas F.	Lignite F.	Diesel Oil	Nat. Gas	Disel Oil	Nat.Gas
1. Installed Capacity	MW	600	550	550	150	120	120	60	60
2. Dependable Capacity	%	95	95	95	95	95	95	90	80
3. Annual Plant Factor	%	40-75	40-80	40-80	40-75	60	60	5-50	5-50
4. Station Consumption	%	5	5	5	5	5	5	1	1
5. Capital Cost	US$/kW	796	583	583	962	509	509	386	386
(B26.5 = US$1)	MB/MW	21.09	15.45	15.45	25.49	13.49	13.49	10.25	10.23
6. Annual Expenditure									
- Year 1	%	10	10	10	15	0	0	0	0
- Year 2	%	35	30	30	25	15	15	0	0
- Year 3	%	35	35	35	25	45	45	20	20
- Year 4	%	10	15	15	25	30	30	70	70
- Year 5	%	10	10	10	10	10	10	10	10
7. Annual O & M Cost	%	3.0	2.5	2.5	3.0	2.8	2.8	3.0	3.0
8. Service Life	year	25	25	25	25	20	20	20	20
9. Unit	litre, ton, cu.ft.	kg	litre	cu.ft.	leg	litre	cu.ft.	litre	cu.ft.
10. Fuel Consumption	unit/kWh	.391	0.233	9.00	.972	0.288	8.11	0.361	12.83
11. Fuel Cost	Baht/unit	1,2115.0	2,219*	0.0628	528.59	3.2270*	0.0628	3.2270*	0.0628
	Baht/kWh	0.475	0.516	0.565	0.514	0.736	0.509	1.164	0.805

Note: * Fuel at Ban Pakong Site

Source: Team Consultants

Exhibit A.11

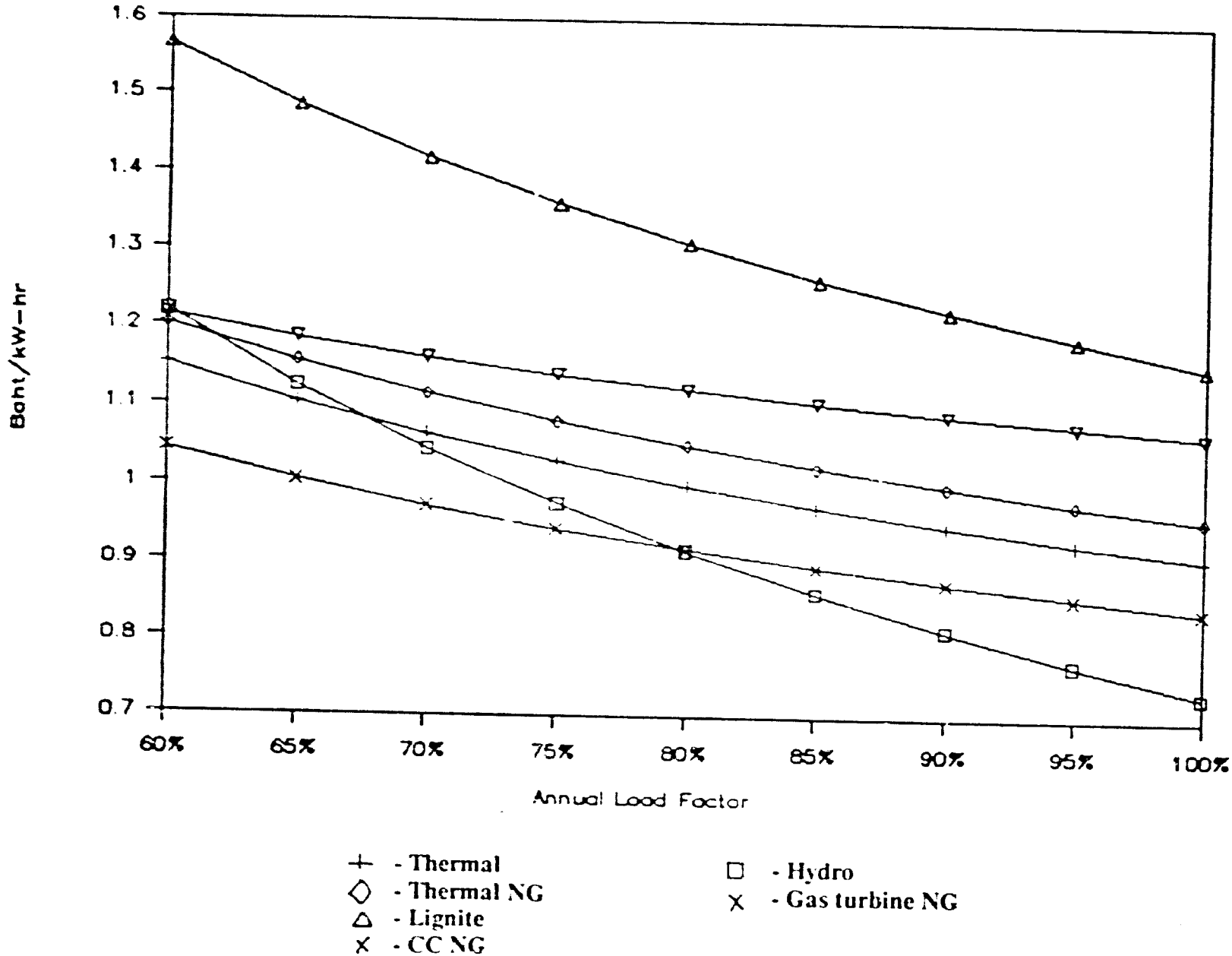
Comparison of Generating Costs for 35% to 60% Load Factors



+ - Thermal
◇ - Thermal NG
△ - Lignite
× - CC NG
□ - Hydro
▽ - Gas turbine NG

Exhibit A.12

Comparison of Generating Costs for 65% to 95% Load Factors



APPENDIX B: PROJECT ORGANIZATION, PROCEDURES AND PERSONNEL

Project Organization

The organization of the project is shown in Exhibit B.1. Despite the parallel lines of authority, the project resulted in an effective working relationship between the NEA and the technical consultants. The principal activities have been the development of the site selection model, the selection of appropriate sites, the development of workable designs, the preparation of bid documents, the selection of contractors and suppliers and the supervision of construction activities.

Project Procedure

The procedure developed for project implementation was not very efficient due to the large number of participants, however, it did work. A step-by-step outline of this procedure is presented below. This procedure followed the initial development of the Design Criteria which were submitted in May 1984.

1. NEA selects sites to be analyzed based on information from previous studies and desktop study of available data.

2. Field reconnaissance survey is performed by representatives of NEA and TEAM.

3. TEAM reviews the desktop studies and submits the results to NEA for approval.

4. K Engineering Consultants (KEC) conducts topographical survey and NEA enumerators under direction of NEA and TEAM Consulting Engineers supervisors perform socio-economic survey.

5. NEA reviews findings of physical survey and process data from socio-economic survey.

6. Preliminary design prepared by TEAM and submitted to Technical Assistance Group (TAG) for review by POU.

7. Preliminary Cost estimates are prepared.

8. Economic and financial analysis are performed on sites selected.

9. Detailed design begins.

Exhibit B.1

Organization of Micro/Mini Hydroelectric Project

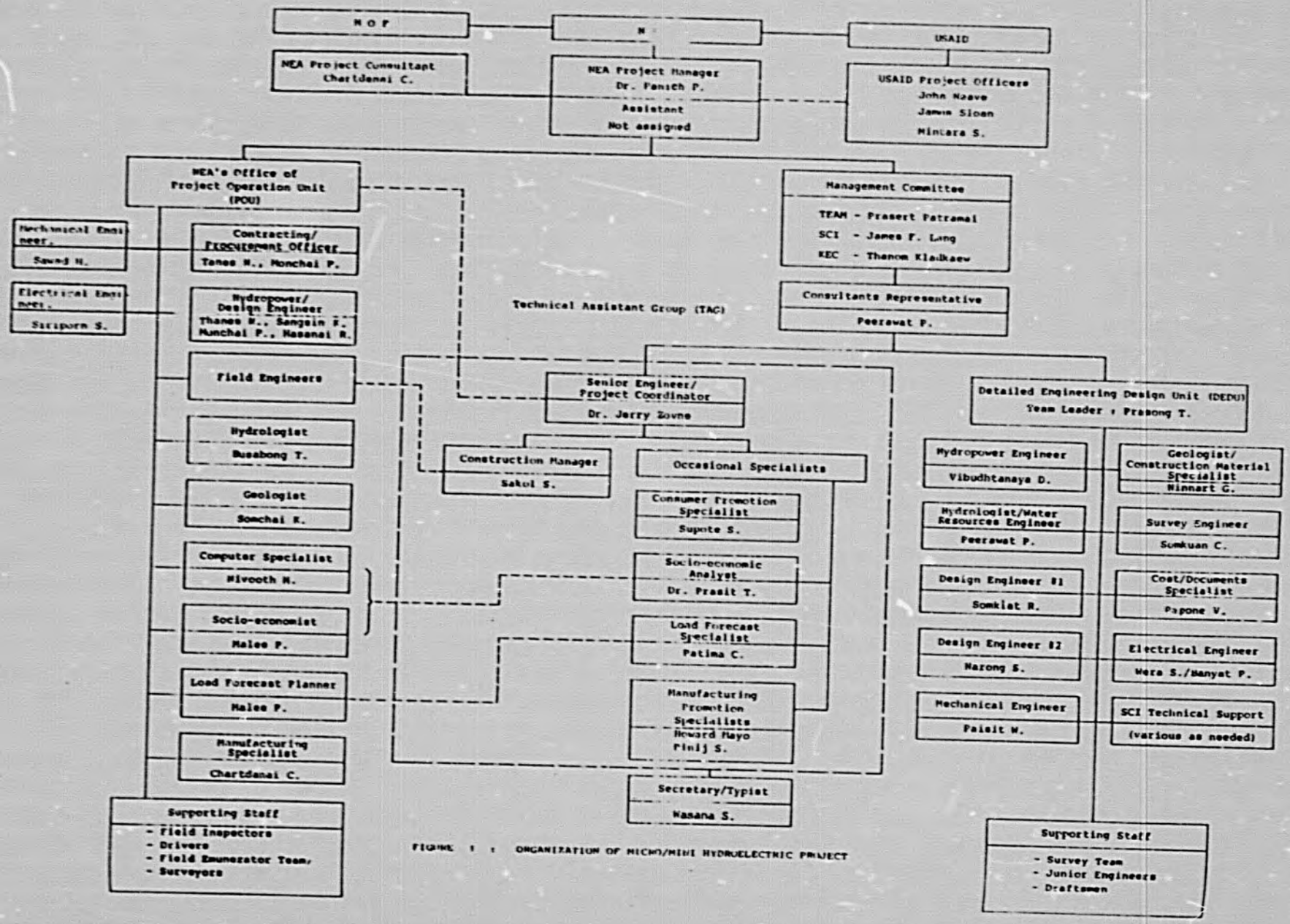


FIGURE 1 : ORGANIZATION OF MICRO/MINI HYDROELECTRIC PROJECT

10. After drawings are 15% complete they are submitted to TAG for review by POU and NEA's Design Department

11. A meeting is held with TEAM, POU, Stanley Consultants' Proj. Coordinator (PC) and NEA Project Manager to finalize drawings.

12. Final drawings are prepared along with contract documents, design manual and geology report submitted to TAG for review by NEA staff and PC.

13. A meeting is held with TEAM, POU, Stanley Consultants and NEA Project Manager to discuss final revisions.

14. Final contract documents drawings and detailed cost estimates are submitted to NEA for final review and approval.

15. Bid documents are reviewed by NEA Design Department (for Civil Works) and TAG and POU (for Electrical and Mechanical Equipment).

16. TEAM prepares 50 copies of bid documents.

17. NEA requests USAID approval.

18. Bid Announcement is made.

19. Bid review is performed by three committees, the Bid Receiving Committee (NEA Procurement Depart), Bid Opening Committee (POU, NEA Design Department, Energy Development and Promotion Division), and the Bid Acceptance Committee.

20. Contractor is selected based on cost and promised efficiency.

21. NEA requests USAID approval for the selection contractor before signing.

22. Construction supervision is performed by NEA site engineer under supervision of Project Manager and TEAM's Construction Manager (CM).

23. Changes in design or specifications is reviewed by Project Manager and CM.

24. Final approval given by NEA.

25. NEA personnel operate plant for one year.

26. NEA turns over operation of plant to EGAT.

Three difficulties which slowed this process in the early stages of this project were:

1. The lack of experience in the preparation and review of the technical specifications for the electrical and mechanical equipment.

2. The requirement for NEA Design Department to approve the drawings as well as the POU and the Project Manager.

3. The problem of communications with the site and the lack of experience of the site engineers.

Item 2 was subsequently resolved when the NEA Design Department agreed to review the drawings within 10 days. However, Item 3 caused delays during construction because approval for significant changes in design or work orders needed to be approved by the Project Manager or the Construction Manager who were both stationed in Bangkok.

Performance of Personnel

The position of Senior Engineer/Project Coordinator was filled by Stanley Consultants. According to the contract, this individual had a range of duties including:

1. Assisting and advising NEA and the Project Manager in various matters including contracting the construction services which conform with NEA and AID guidelines,

2. Coordinating the activities of the Technical Assistance Group with those of TEAM and NEA,

3. Directly managing the POU group,

4. Further refining of the site model,

5. Reviewing final engineering designs, contract documents and specifications,

6. Preparing the plans for impact evaluation and project monitoring, and,

7. Producing quarterly and final reports.

The first individual assigned to this project was familiar with the construction of mini-hydro facilities, however, his tenure was relatively brief and he stayed only long enough to complete a draft set of design criteria. The second individual was not familiar with construction or with the review of technical drawings. Since the contract documents and specifications were prepared in Thai, the NEA Design Department assumed responsibility for reviewing these documents. Also, this individual did not undertake day-to-day supervision of the POU staff. His primary effort was coordinating the development of the site selection model including the inputs of the social scientist and

load forecasting experts to the design of the model, the efforts of the NEA and TEAM in conducting and processing the socio-economic surveys and the efforts of TEAM in developing the necessary software and performing the actual evaluation. He was also responsible for supervising the production of the multiple volume final report which provides excellent documentation of the information used in the site selection and evaluation process. Finally, at the request of NEA, he organized together with TEAM a two week training course for NEA personnel in the use of the site selection model.

The Construction Manager was provided by TEAM on a full-time basis to assist;

1. NEA and the field engineers in preparation of construction work sites,

2. the Project Manager and the Project Coordinator in contracting of civil works construction,

3. the Project Manager in procurement of the power plant equipment and to share responsibility with the Project Manager in the supervision of the civil works construction and the changing of drawings to suit the changing site condition. The NEA felt that the time spent by this individual on assisting in contracting and on direct site supervision was not adequate. However, there were considerable logistic problems in visiting six, dispersed remote sites more than once a month and the Construction Manager's contract ended fairly early in the construction cycle.

The Manufacturing Promotion Specialists included both a local and foreign specialist. The latter was in Thailand for approximately one month. During this period most of his efforts were spent meeting with representatives of firms involved in the manufacture of equipment which could be used in the hydro-electric facilities. Very little time was given to assisting the NEA and TEAM in the design of specifications for the electrical and mechanical equipment, an activity not in the scope of work, but in retrospect the most important contribution that this specialist could have made. The contribution of the two specialists appears to have been in identifying a number of manufacturers within Thailand. Their contribution to the final report was limited to a series of photocopies of business cards, photographs of manufacturing sites, table of contents from publicly available reports and the unprocessed results of a manufacturer questionnaire.

The NEA Design Department was responsible for engineering design, cost estimating, and preparation of all specifications, drawings and contract documents. These services were provided by TEAM consultants. Although TEAM had no previous experience with design and construction of hydro electric facilities, they were able to fulfill their responsibilities reasonably well by working in collaboration with NEA which had the technical expertise but not sufficient manpower. The area in which TEAM's performance should have been somewhat better are the preparation of the electrical and mechanical equipment specifications.

The POU suffered from a lack of senior staff. The unit had a staff of four civil engineers and various support personnel. Once the Project Coordinator left, the unit was effectively disbanded although two of the engineers continue to work on the project as site engineers.

The unit performed reasonably well, considering the normal experience with such entities. It provided a focus for training of the civil engineers. It integrated its activities with the established role of the Design Department in the review of project design. And finally, its disbanding in no way reduced the ability of NEA to undertake similar projects.

APPENDIX C: FIELD VISITS

LAM PRA PLERNG

Site Characteristics:

The Lam Pra Plerng site is located within an existing irrigation project in Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima which has been in operation since 1969. The nearest large community is Khorat, some 63 km. away. The plant is situated at the outlet works of a large rock and earth dam and reservoir which is operated year round to irrigate some 89,720 rai. The irrigation project has some 75 km. of main canal and 38 km. of distribution canals. It serves a prosperous area where 85 percent of the population is engaged in agriculture (rice, corn, cassava) with an average annual family income of approximately 37,000 Baht.

Construction Progress to Date:

The Lam Pra Plerng site is in the early stages of construction (7% complete) with an expected completion date of October 1988 (see Exhibit C.1). When the team visited the site, a geotechnical problem was just being unearthed. Core samples revealed the occurrence of several large boulders some 3 to 7 m below the powerhouse site making it difficult to provide a proper foundation. Plans are now being made to remove these boulders and backfill the area.

Construction is being carried out by Summit Grade Partners Ltd. All civil work should be complete by April 1988 and the electro-mechanical equipment is scheduled to be installed in August 1988. Plant operation should begin October 1988.

The following are some detailed comments on major project components:

(a) Penstock

No construction activity has been started.

(b) River Outlet and Stilling Basin (see Exhibit C.2)

Demolition of the existing river outlet is just getting under way. A complete new outlet will be constructed.

Exhibit C.1
Lam Pra
Plerng Site

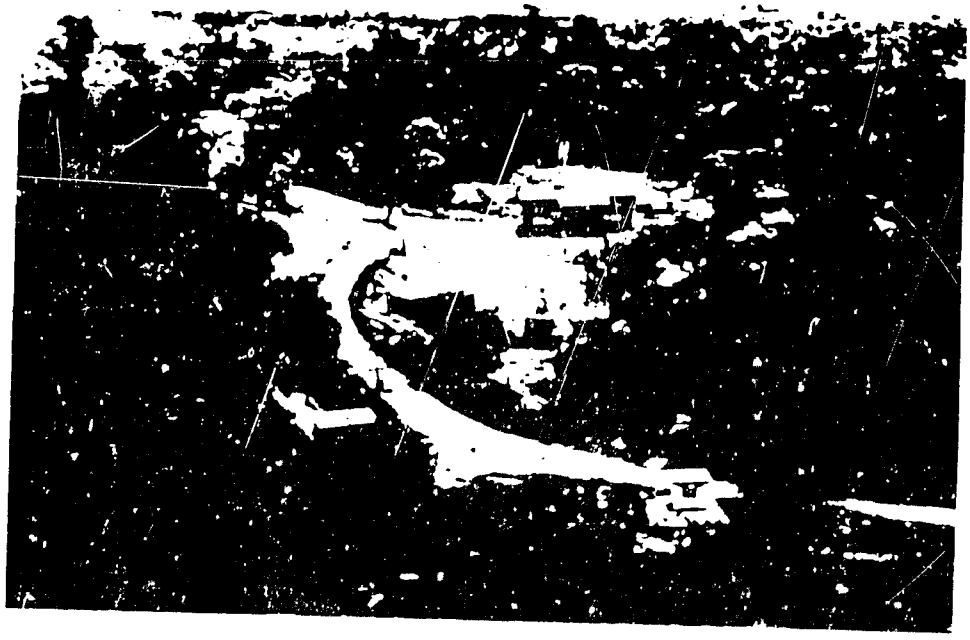


Exhibit C.2
Lam Pra Plerng Site
Outlet and Stilling Basin

(c) Powerhouse

Some excavation has been done but no construction as of yet until the geotechnical problems are solved.

(d) Tailrace

No construction on the tailrace has been started.

(e) Bypass Chute

Some excavation activity has been started.

(f) Office

The office building is complete.

(g) General Site Housekeeping

The site is neat and clean despite the fact that it is in a very confined area.

Environmental Impact:

Little or no negative environmental impacts should occur at this site since most of the civil works are already in place. The principal impact was created when the original dam and canal were built by removing most of the water (95%) from the natural stream bed. The existence of the hydroplant will therefore have no additional negative impact other than that which is already occurring.

Fish ingestion is also not a problem because of the screens located on the water inlet at the dam as well as the trashtrack at the plant. There is little upstream fishing and no downstream fishing.

There is no occurrence of any water borne disease typically associated with reservoirs. Since the flow originates from an existing reservoir, sediment transport into the turbine will not be a problem. However, there is some minor sedimentation of the existing stream from construction site runoff. In summary, the environmental impact of this project is minimal, the only exception being the dust, noise and excavation associated with construction. Once complete, there should be no long term negative environmental impacts.

Procurement:

As mentioned, construction on this project started very recently in February 1987. Civil works bids were submitted in September of 1986 and Summit Grade was selected as the winner to begin work in early 1987.

Socio-Economic Analysis:

Most of the villages in this site are connected to the grid. While the original plan also included connecting up the isolated remaining villages, PEA is now in the process of extending lines to most of these villages. The hydro power which is to be derived from an irrigation dam will be sold to PEA but the arrangement which has not yet been agreed between the parties is for NEA to operate the facility for a year during which it will sell the power to PEA and to the turn over the facility to EGAT which will use it as part of their national generating system.

Two villages were visited at the site. The first, Bu Hua Chang, has had electricity for the last 24 years. It started with a diesel unit and then connected to the grid in about 1975. The distribution system is provided by PEA using concrete poles, meters and wiring up to the house. The villagers are responsible for wiring within the house, but the PEA checks this wiring prior to hookup. Among the local industries which use the electricity are a rice mill, an ice factory and a repair shop which uses an electric arc welding unit. For commercial establishment, the electric appliances include refrigerator and coolers. For the households, the principle appliances are televisions and rice cookers. The latter have increased in popularity in recent years as the price has decreased. In addition, about 5 of the 130 households in the Muban use electric pumps for drinking water (although without pressure storage tanks). These pumps and the electrical appliances must be repaired in the city of Korat as no local people have this ability.

Village development activities are generally organized by the village headman working through the village council. The sources of credit are limited with most villagers relying of their own savings or loans from friends. The only formal sources of credit are supplier credits from the appliance stores and the Agricultural Bank. For the latter, the farmers must apply as a group and co-sign the loan if they cannot offer farmland as collateral.

The second village, Wang Tak Kien, has had electricity for the last three years. About 30 of the 80 households in the village are connected. These household pay between 50 and 80 Baht per month for light and operating rice cookers and televisions. Most of the lighting is with 40 watt fluorescent bulbs. About 11 of the 30 households have televisions. Five or six households use electric irons. Rice cookers have increased in popularity since they were brought into the village last year by a merchant. The commercial establishments use refrigerators and coolers.

The electricity was originally brought to the village through the efforts of the local headmaster who felt that the electricity could be used for pumping irrigation water from the canal to the upland areas. At present the village uses a diesel pump from the irrigation department an pays the fuel and maintenance costs of 20 Baht per rai. Each participating villager contributed 100 Baht per rai of land plus between 500 and 1000 Baht per household to finance the cost of bringing the line into the village. It took about a year to collect the money which was then paid to PEA for extension of the line to the village. Once the line came to the village, then each household had to pay between 2500 and 3000 Baht for a hookup, depending on their distance from the PEA line. In addition, the household had to pay for wiring of the house, a track performed by someone from the nearby town at a cost of 30 Baht per outlet. As a result of the additional costs, many of the households which had contributed for bringing the line to the village have been unable to raise the money to connect their homes. In addition, the village continues to use the diesel pump since they were unable to obtain a electric pump from NEA (and cannot afford to purchase one).

About 40 households are currently connected. Together they form a user's group and if other households wish to connect to the lines but have not previously contributed to bringing the line into the village,then the group decides on what they should be charged according to how much they can pay. Some of the households have borrowed money from the agricultural cooperative in a nearby Amphoe Pak Thong Chai to pay for connection of their house. The villagers did not contribute any materials or labor to the electrification of the activity and no opportunity was offered by PEA. When making other improvements to the village, labor is generally contributed by the villagers and organized by the village headman.

SITE SUMMARY

LAM PRA PLERNG

Physical Data:

1. Location	A. Pak Thong Chai C. Nakhon Rat Chasima
2. Status	Grid connected
3. Catchment Area, km2	reservoir
4. Net Head, m	18.5
5. Design Discharge, m3/s	5.51
6. Installed Capacity, kW	850
7. Dependable Capacity, kW	850
8. Annual Energy, GWh/y	3.044 [3.187]
9. Transmission Line, km	0
10. Access Road, km	0

Socio-Economic Data:

1. No. of villages Served	23
2. No. of Households Served	1,349
3. No. of People Served	7,111
4. Population Growth Rate, %	3.5
5. Annual Household Income, B/y	36,856
6. Principal Economic Activity	Agriculture, 85%

Financial Economic Data: $ U.S. (1000's)

1. Civil Works and Powerhouse Costs	311 [331]
2. Transmission Line Costs	[0]
3. Electromechanical Costs	863 [1,034]
4. Admin. & Design	136
5. Total System	1,310 [1,481]
6. Cost per kW Installed	$1,541 [1,743]

Note: Numbers in brackets were given in May 1987. Numbers to their left were revised in November 1987.

NAM KHA MUN

Site Characteristics:

This site is located in a highland forested area in Tambon Neon Phoem of Amphoe Nakon Thai, Changwat Phitsanulok. The nearest major town is Phitsanulok. This was an area of great political turmoil during the 1970's and has been made into a national park. Waterways in the area are few and the site is located on the only major stream, the Nam Kha Mun, which has a catchment area of 75 sq. km. The project area has been served by PEA since 1982. This project will make it possible to connect those villages which have not been connected to the grid.

Construction Progress to Date:

The site is approximately 30% complete and work continues to progress at a brisk pace despite the fact that permission from the Royal Forestry Department to proceed with the project is still pending. NEA will continue work so that there will be less chance of opposition once the plant begins to operate.

Construction Progress to Date:

The site is approximately 30% complete and work continues to progress at a brisk pace despite the fact that permission from the Royal Forestry Department to proceed with the project is still pending. NEA will continue work so that there will be less chance of opposition once the plant begins to operate.

All civil work is scheduled for completion by approximately July 1988 with electro-mechanical equipment being installed October 1988 and operation to begin in November. Specific comments on major project components are given below:

(a) Weir (see Exhibit C.3)

The weir or intake is at an early stage of construction with some framing for concrete work in place. Work is slated to be halted during the rainy season which is about to start because diversion around the area would be too costly and the flows are unpredictable during this period. Work on the weir will continue in November of this year.

(b) Access Roads (see Exhibit C.4)

All the roads have been constructed but their condition remains variable. Maintenance will be a continuous requirement.

Exhibit C.3 Nam Kha Mun Weir Site

Exhibit C.4 Nam Kha Mun Access Road to Weir

(c) Powerhouse

Some excavation has been done but no construction as of yet until the geotechnical problems are solved.

(d) Tailrace

No construction on the tailrace has been started.

(e) Bypass Chute

Some excavation activity has been started.

(f) Office

The office building is complete.

(g) General Site Housekeeping

The site is neat and clean despite the fact that it is in a very confined area.

Environmental Impact:

Little or no negative environmental impacts should occur at this site since most of the civil works are already in place. The principal impact was created when the original dam and canal were built by removing most of the water (95%) from the natural stream bed. The existence of the hydroplant will therefore have no additional negative impact other than that which is already occurring.

Fish ingestion is also not a problem because of the screens located on the water inlet at the dam as well as the trashtrack at the plant. There is little upstream fishing and no downstream fishing.

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Procurement:

As mentioned, construction on this project started very recently in February 1987. Civil works bids were submitted in September of 1986 and Summit Grade was selected as the winner to begin work in early 1987.

Socio-Economic Analysis:

Most of the villages in this site are connected to the grid. While the original plan also included connecting up the isolated remaining villages, PEA is now in the process of extending lines to most of these villages. The hydro power which is to be derived from an irrigation dam will be sold to PEA but the arrangement which has not yet been agreed between the parties is for NEA to operate the facility for a year during which it will sell the power to PEA and to the turn over the facility to EGAT which will use it as part of their national generating system.

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LAM PRA PLERNG

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9. Transmission Line, km	0
10. Access Road, km	0

Socio-Economic Data:

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Note: Numbers in brackets were given in May 1987. Numbers to their left were revised in November 1987.

NAM KHA MUN

Site Characteristics:

This site is located in a highland forested area in Tambon Neon Phoem of Amphoe Nakon Thai, Changwat Phitsanulok. The nearest major town is Phitsanulok. This was an area of great political turmoil during the 1970's and has been made into a national park. Waterways in the area are few and the site is located on the only major stream, the Nam Kha Mun, which has a catchment area of 75 sq. km. The project area has been served by PEA since 1982. This project will make it possible to connect those villages which have not been connected to the grid.

Construction Progress to Date:

The site is approximately 30% complete and work continues to progress at a brisk pace despite the fact that permission from the Royal Forestry Department to proceed with the project is still pending. NEA will continue work so that there will be less chance of opposition once the plant begins to operate.

Construction Progress to Date:

The site is approximately 30% complete and work continues to progress at a brisk pace despite the fact that permission from the Royal Forestry Department to proceed with the project is still pending. NEA will continue work so that there will be less chance of opposition once the plant begins to operate.

All civil work is scheduled for completion by approximately July 1988 with electro-mechanical equipment being installed October 1988 and operation to begin in November. Specific comments on major project components are given below:

(a) Weir (see Exhibit C.3)

The weir or intake is at an early stage of construction with some framing for concrete work in place. Work is slated to be halted during the rainy season which is about to start because diversion around the area would be too costly and the flows are unpredictable during this period. Work on the weir will continue in November of this year.

(b) Access Roads (see Exhibit C.4)

All the roads have been constructed but their condition remains variable. Maintenance will be a continuous requirement.

Exhibit C.3 Nam Kha Mun Weir Site

Exhibit C.4 Nam Kha Mun Access Road to Weir

(c) Intake Pipe and Road

The area around the intake pipe and sand trap is ready for construction. No excavation has been done for the intake, sand trap and tailrace but the area has been prepared with heavy equipment. This work can start immediately despite the imminent rains.

(d) Headrace

No work on the headrace has been done, but the excavation is complete. NEA is waiting for Royal Forestry Department permission before continuing on this section.

(e) Surge Tank (see Exhibit C.5)

The area for the surge tank has been excavated and the reinforcing rods are in place. Concrete work on tank will begin shortly.

(f) Penstock (see Exhibit C.6)

All excavation for the penstock is complete. About 1/2 of the penstock is in place and the piers are being set along it entire length. All penstock pipe is at the site.

(g) Powerhouse (see Exhibit C.7)

Structural work on the powerhouse is complete. Floors, roof, walls and the electro-mechanical work remain to be installed.

(h) Tailrace

Only excavation work on the tailrace has been done.

(i) Office

All office and personnel housing units are complete.

(j) Powerline

The powerline is complete.

(k) General Site Housekeeping (see Exhibit C.8)

The housekeeping around the site is fair. The terrain is very difficult, especially along the penstock. Some improvement could be made around the powerhouse and offices. There also should be more emphasis on safety. On February 16, 1987, there was an explosion at the construction contractor's camp/ office/store due to careless handling of dynamite. As a result, the administrative and store office was blown apart and

Exhibit C.5
Nam Kha Mun
Surge Tank

Exhibit C.6
Nam Kha Mun
Penstock

Exhibit C.7 Nam Kha Mun Powerhouse

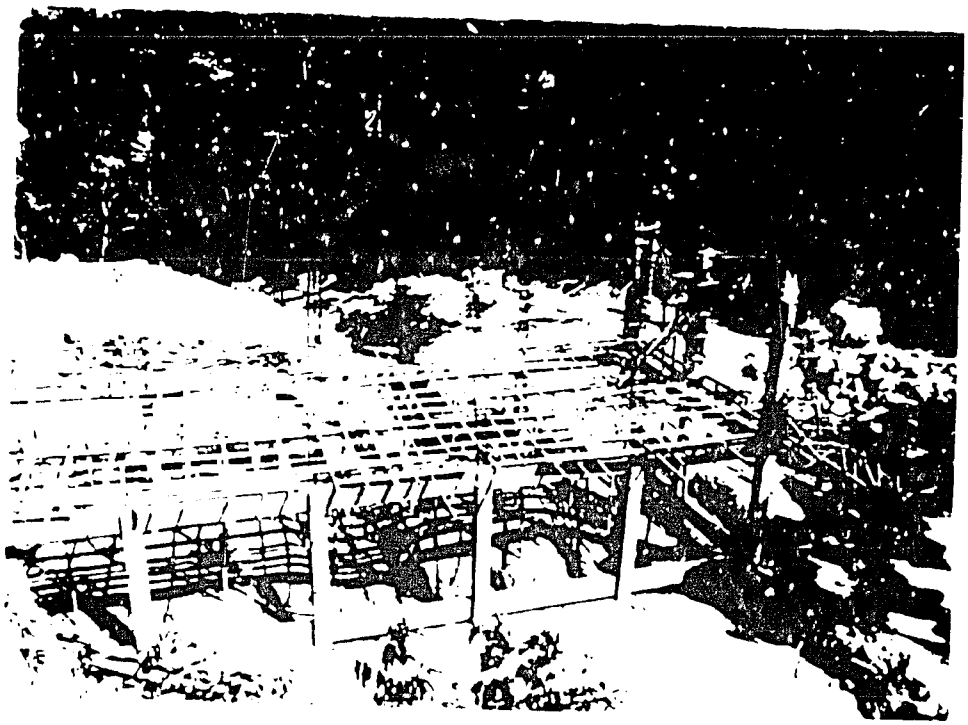


Exhibit C.8 Nam Kha Mun General Site Conditions

burned. The construction contractor's Project Manager (an engineer) and store keeper were killed instantly, and four laborers were seriously injured. The dynamite between 15 to 20 kilos used for rock blasting, had been stored on the inside roofline rafter where the roof structure joined the wall line. The explosion rattled walls in the town of Nakhon Thai, 20 kilometers distant. The accident, however, has not been an obstacle to the progress of the work.Environmental Impact:

The environmental impact of this project will be relatively minor after construction is complete. However, a number of negative impacts caused during the construction phase can be noted. The area near the weir and intake required a major cut and fill operation of approximately 300 m in length. How this area will regenerate is not known. Some replanting may be required.

The water to be withdrawn from the stream (0.90 m3/s), constitutes approximately 20% of its average flow. However, this flow tends to be highly variable and during periods of low flow (0.12 m3/s), the entire flow will be withdrawn. This may cause a downstream problem to aquatic and terrestrial life if the condition persists. However, this will only affect the reach of the stream between intake and powerhouse, a distance of approximately one km.

Sedimentation should not present a major problem since the area is forested and well vegetated. There is a low bedload during normal periods but this tends to increase during the rainy season. There is a sand trap in the flow control structure. However, a combination of sedimentation and erosion may occur in the penstock trench and adjacent roadway. The penstock is built on a steep incline. Since the penstock is to be left uncovered, the walls may need to be stabilized.

In general, the site looks rather rough at this time because of major excavation work required by the difficult terrain. Once construction is complete, vegetation will again take over the lacerated areas and the long term negative environmental impacts should be minor.

Procurement:

Drawing and bid packages were submitted to AID by NEA in August of 1986, and immediately approved. The bid process began shortly thereafter and three firms submitted proposals. By September 30, 1986 a contract had been signed with Permpol Construction Partnership Ltd., the winner of the competition. The construction period was 330 days and was to begin immediately. Based on what the team saw during its visit and the imminent rain, an extension will be required.

As with the other contracts, NEA would pay Permpol on a monthly basis and there would be a one year warranty on all work when completed.

Socio-Economic Analysis:

This site is located in a hilly area much of which has been converted to a national park, Phu Hin Rong Khla. All except for two of the villages in the site have been connected to the PEA grid which was extended to this area in 1982. Two villages were visited in this site, one electrified and the other not.

The village teacher in the electrified village, Huey Tin Tang, was interviewed. Electricity was brought to this village about three years ago. The extension of the PEA lines to the village was originally requested by the Tambon council. Since several of the surrounding villages already had electricity there was considerable interest at the time and now all of the 140 households are connected. There was no charge to bring the line to the village, but each house was charged between 2000 and 2500 Baht for a hookup depending on its location relative to the PEA power lines. This amount includes the payment to the electrical appliance store in Phisanulok for the house wiring. The villagers were able to prepare for electrification by saving for the hookup costs because representatives from this store also came to the villager beforehand to explain what the costs for hookup would be and what would be required.

The villagers use 20 or 40 watt fluorescent bulbs for lighting and average about 2 bulbs per household. The selection is based on what the leader of their group purchase. Many households have fans, 5 have refrigerators and 7 have televisions. The refrigerators were introduced by Singer. None of the households use rice cookers since the villagers eat glutinous rice. The only electric iron is owned by the school teachers. Their are no industrial uses of electricity. All the rice mills are diesel powered. There is no water pumping because gravity flow from the stream is used. The public buildings including the school and weaving center are not electrified but the watt is.

The monthly charge per household averages about 10 Baht/month if the electricity is used for lighting. For households with televisions the monthly cost is on the order of 70 to 80 Baht. For commercial establishments which use a refrigerator or cooler the cost increases to 100-200 Baht per month.

There is no local capability for repairing appliances but some of the local people know a about house wiring. Formerly repair services were provided by the shop in Phisanulok but now there is a shop only 20 kilometers away in Nakhon Thai which can fix televisions and refrigerators. Short-term credit for the purchase of appliances and for hookups was provided by the electrical supply store. Other local sources of credit include the the Bank of Agriculture and Cooperatives in Nakhon Thai which is widely used by the villagers.

Development activities are generally undertaken with the direction of the village headman and the development council. The labor is provided by the different groups (defense zones) in the village under the direction of their local leaders. This

mechanism has been used to construct fences along the road, maintain the village water supply system and, in past times, to manage the communal animal pen.

The second village, Hauy Nam Sai, is a resettlement village for Hmong (Meo) tribesman. The local teacher and the assistant headman were both interviewed. The village was established only 5 years ago and still very much in transition. The village contains about 180 households, but is not yet officially designated as a muban village. The village is divided into defense zones and the leaders of each zone are included in the village committee which organize the village labor for local improvements. The principal activity is the cultivation of maize. The village has a deficit in rice production. There are no local industries other than a rice mill and very little non-farm employment. The only non-farm skills are metalworking. The village does not have electricity, however, the villagers are familiar with the use of electricity from the adjoining villages or from the villages in which they previously resided.

There are difficulties with the quality of the land provided to the villagers. The villagers previously planted in the forest land but the area has been declared a national park and access to the area has been restricted. This constraint combined with a drop in the price for maize, the villager's primary crop, has significantly reduced the income of the villagers. Despite this drop in income, the villagers have considerable wealth (savings from previous years), as indicated by ownership of 13 trucks and 6 motorcycles. It is expected that 40%-60% of the villagers will be able to afford the hookup charges.

At present there are no sources of electricity in the village, but the soldiers occasionally bring a battery-powered television for the entertainment of the villagers. The initial purchases by the villagers are likely to be fluorescent lights and possibly televisions and fans (since it is hotter in the resettlement village than in their former homes). The availability of credit for the purchase of the hookup and the appliances is limited. The villagers have savings but cannot use the Agricultural Bank because they do not own their land and many do not have identity cards.

SITE SUMMARY

NAM KHA MUN

Physical Data:

1. Location	A.Nakhon Thai C. Phitsanulok
2. Status	Grid connected
3. Catchment Area, km2	40.0
4. Net Head, m	150
5. Design Discharge, m3/s	0.90
6. Installed Capacity, kW	2 x 515
7. Dependable Capacity, kW	184
8. Annual Energy, GWh/y	4.81 [5.25]
9. Transmission Line, km	8.3
10. Access road, km	2.2

Socio-Economic Data:

1. No. of Villages Served	12
2. No. of Households Served	461
3. No. of People Served	2,246
4. Population Growth Rate, %	2.0
5. Annual Household Income, B/y	22,048
6. Principal Economic Activity	Agriculture, 90%

Financial Economic Data: $ U.S. (1000's)

1. Civil Works and Powerhouse Costs	839
2. Transmission Line Costs	39 [38]
3. Electromechanical Costs	718 [863]
4. Admin. & Design	145
5. Total System	1,741 [1,885]
6. Cost per kW Installed	$1,690 [1,830]

Note: Costs in brackets were those given May 1987 numbers to their left were revised November 1987.

NAM MAE HAT

Site Characteristics:

The Nam Mae Hat site is located in Tambon Maung Haeng of King Amphoe Wiang Haeng, an area about 185 km north of Chiang Mai and eight km from the Burmese border. It is the most remote of the six sites and was until recently, at some considerable distance from the national grid.

It was the first site developed under this project, with construction started in September 1985. It therefore provided a learning experience for NEA, TEAM and others. This project contains a number of design issues which might cause problems during its early operational phase.

The economic sustenance of the area is agriculture and a variety of trading activities with neighboring Burma. This area was very isolated and has been of political interest to the Thai government for some time and is therefore the focus of development efforts.

This project, as originally conceived, was to be isolated from the national grid, however for unknown reasons, PEA has extended its power lines to within 8 km from Nam Mae Hat. The proposed interconnection will make the project more attractive economically since it should operate around the clock and able to sell power to the grid.

Construction Progress to Date:

The plant is located on a small stream, the Nam Mae Hat, which drains some 75 sq. km of mountainous terrain. It is 90% complete, the hydraulic works in their entirety. Still missing is the powerhouse floor and installation of electro-mechanical components. Some of this equipment was to be shipped to the site in June.

Permission by the Royal Forestry Department has not been officially granted but some sort of informal verbal approval does seem to exist. The site will become operational in October of 1987.

All construction has been done by local contractors from Chiang Mai. The powerhouse is being built by Phoopakdee Civil Engineering Ltd. and the civil works by Chiang Mai Construction. There is a significant local labor content in this project.

Specific details of system components are given below:

(a) Weir and Intake (see Exhibit C.9)

All work on this component is complete.

Exhibit C.9 Nam Mae Hat Weir and Intake

(b) Flow Control Structure

All work on this component is complete.

(c) Headrace (see Exhibit C.10)

Constructed of round concrete pipe, this element is already in place and covered by the access road There is some concern about cracks and leakage at the joints and soil stability. Should leakage occur, it could undermine the access road which consists largely of unconsolidated soil and sand. This would lead to pipe failure as the supporting soil is washed away. This must be carefully monitored when the plant is put into operation.

(d) Flume (see Exhibit C.11)

In several locations there is a transition to a covered elevated flume in order to cross a gully or small stream. Structural integrity must be determined when a water load is imposed. Also the flume covers are occasionally stolen for their metal handles.

(e) Forebay (see Exhibit C.12)

The forebay, where the headrace ends and the penstock begins, is complete but lacking a proper cover. The evaluation team was told that a mesh cover will be provided.

(f) Penstock

The penstock is complete and buried. The team was not able to inspect any of its design details.

(g) Powerhouse (see Exhibit C.13)

The powerhouse is 80% complete, lacking only a floor and the electro-mechanical components. Before the floor can be finished, the turbine must be set in place since its casing will be placed in the concrete. Currently, the reinforcing rods are in place.

(h) Electro-mechanical Equipment (see Exhibit C.14)

The locally manufactured turbines, generators and governors, was to be shipped to the site in June 1987 from Layne & Bowler located near Bangkok. The switchgear has been ordered and will arrive at the site also within two months.

Exhibit C.10 Nam Mae Hat Headrace and Access Road

Exhibit C.11
Nam Mae Hat
Flume

Exhibit C.12
Nam Mae Hat
Forebay

Exhibit C.13
Nam Mae Hat
Powerhouse

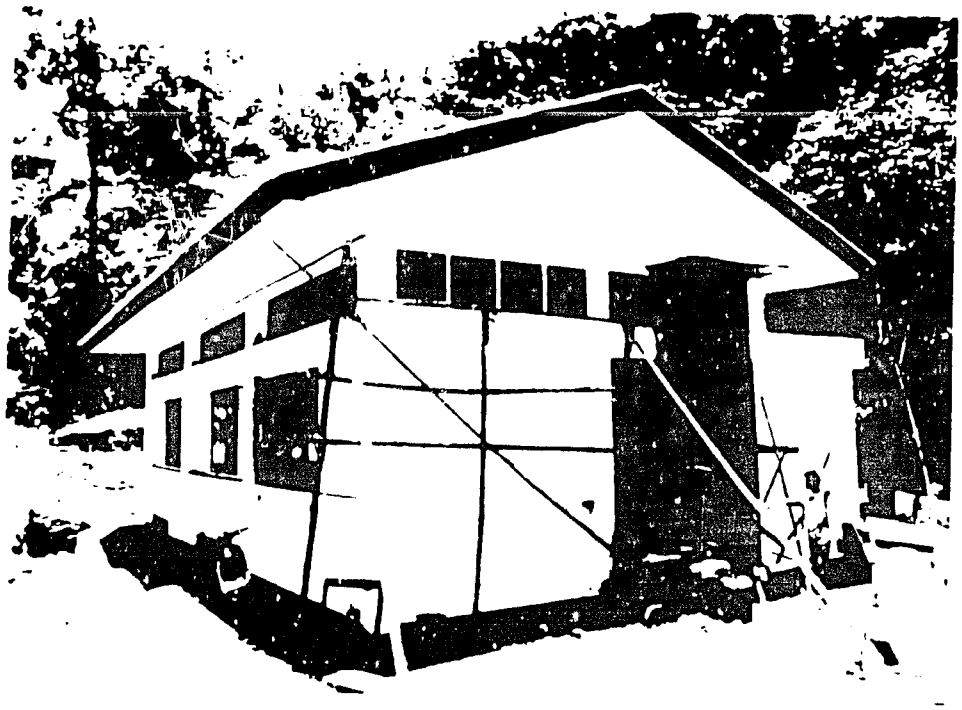


Exhibit C.14
Nam Mae Hat
Pelton Turbine

(i) Access Roads

All access roads are complete. The road along the headrace will need to be constantly maintained although its condition during the team's visit was good and it had already been through two rainy seasons.

(j) Tailrace

The tailrace construction is complete.

(k) General Site Housekeeping

The site was generally neat and tidy. No unsafe conditions were observed.

Environmental Impact:

In addition to permission from the Royal Forestry Department, the newly created National Environmental Board also needs to approve the project even though the board did not exist at the time this project was started.

The only major environmental problem that requires monitoring is the stability of the access road to the weir and intake. As mentioned, if there are leaks in the headrace, this could cause major erosion and stability problems. Sedimentation should not be a major problem since all hydraulic structures have been designed for easy sediment removal. In addition, since the area in general, is well forested, there should be minimal suspended sediment in the stream.

Procurement:

Bid documents for the civil works produced by NEA were submitted to AID in August 1984 followed shortly thereafter by documents for the 22 kV transmission lines, both of which were quickly approved. Construction on Nam Mae Hat began late 1984 when a contract was signed between Chiang Mai Construction Co. Ltd. and NEA (September 28, 1984). The contract was for all civil works at 16.7 billion Baht to cover a 275 day period. Work was to be completed by the end of June 1985. The contract for 34 km of 22 kV transmission lines was also signed in September of 1984 with Siam Civil Engineering Co. Ltd. for 10.2 million Baht.

During a site inspection in February 1985, when civil works were well under way, several problems were identified. Much of the pipe used as headrace was damaged during delivery. Apparently, many of the joints were damaged during unloading of the pipe at the site. This could lead to leaks under the roadway. The impact is not known until the system is put into operation.

The contract for the E-M equipment was signed July 1986, with Layne & Bowler Co. Ltd. for 16.75 million Baht. Prequalification for suppliers was put together in mid 1985 and only one firm submitted a bid, therefore the process had to be repeated. Two firms then submitted bids, Layne & Bowler Co. Ltd. and another firm. However, only Layne & Bowler met the required qualifications. The other firm sought to resubmit their bid on March 1986. However this was rejected and Layne & Bowler was finally awarded the contract. The reason Layne & Bowler won the contract was that they were the only one to submit a bid for the first procurement, then they were the only firm which was responsive to specifications during the rebid and therefore according to Thai procurement regulations, they automatically won the contract. The re-bid process was carried out again (3rd bid) and the same two firms responded and again only Layne & Bowler was found to be responsive.

In January 1987, construction of the powerhouse as part of Chiang Mai's contract was canceled because of delay in acquisition of the turbine-generator. A separate contract was given to Phoopakdee Civil Engineering Ltd. for 0.657 million Baht to construct the power house which is now complete.

Socio-Economic Analysis

The Nam Mae Hat mini-hydro site is expected to connect to the grid but the project also includes extending lines to seven unelectrified villages in the tambon of Muang Haeng and Piang Luang. The only village visited at the site was the village of Piang Luang were there is a 20 kW diesel generator which provides electricity to most of the household.

This village is relatively prosperous because of the cross-border trade with Burma. The tambon includes about 750 households of which about 200 are Thai Yai, 250 are local Thai and the remainder are ethnic Chinese. The tambon is organized around the three ethnic groups, and village improvements are organized by the local leaders of these three groups under the overall coordination of the kamnan.

Much of the activity in the village is commercial and serves the cross-border trade. In addition there are 4 rice mills and 2 grinding mills for corn. Local artisans have experience in working with brick and concrete and also have experience with house wiring and motorcycle and appliance repair. Because of the relative wealth of the villagers and the extensive use of electricity at present, it is likely that most households will connect to the NEA lines. Because the NEA system will provide power throughout the day at relatively low cost, it is likely that the villagers will purchase additional televisions and rice cookers and that the commercial shops will purchase refrigerators.

The diesel generator has been in operation for several years. It was brought into the village by a private entrepreneur. It is operated from 7 to 10 pm each day by an operator who had previous experience with generators in Burma. A total of 260 households are connected. The tariff is 40 Baht per month for a 15 watt fluorescent

bulb, 80 Baht per month for a 40 watt bulb, and 30 Baht per month for a television. Wiring of the village was done by the generator operator and his assistant. House wiring is performed by seven villagers who were trained by PEA under a program organized by the district officer. This program involved a 7 day course given to about 35 villagers from different villages. The system is relatively reliable, although outages occur a few times each month and can last up to 7 days in the case of a major breakdown. In addition to the large generator, there are several smaller Honda generators used by households. One of these was observed in use at a house construction site to power a hand-held planar.

SITE SUMMARY

NAM MAE HAT

Physical Data:

1. Location	K.A. Wiang Haeng C. Chiang Mai
2. Status	Isolated (grid connected)
3. Catchment Area, km2	75
4. Net Head, m	160
5. Design Discharge, m3/s	0.68
6. Installed Capacity, kW	2 x 409
7. Dependable Capacity, kW	636 [407]
8. Annual Energy, GWh/y	67.95 [2.84]
9. Transmission Line, km	27.0
10. Access Road, km	2.0

Socio-Economic Data:

1. No. of Villages Served	7
2. No. of Households Served	1,122
3. No. of People Served	5,670
4. Population Growth Rate, %	3.7
5. Annual Household Income, B/y	47,737
6. Principal Economic Activity	Agriculture, 80%

Financial Economic Data: $ U.S. (1000's)

1. Civil Works and Powerhouse Costs	682 [655]
2. Transmission Line Costs	400 [319]
3. Electromechanical Costs	657 [730]
4. Admin. & Design	424
5. Total System	2,163 [2,128]
6. Cost per kW Installed	$2,644 [2,602]

Note: Numbers in brackets were provided May 1987. Numbers to their left were revised November 1987.

KHLONG LAM PLOK

Site Characteristics:

This site is located near Trang, in Southern Thailand in a hilly, forested region which produces mainly rubber and rice. A PEA powerline extends to within two kilometers of the site but is missing the conductor. Therefore, there is no electric power in the area yet. The project is also located in both a wildlife and forest preserve.

Construction Progress to Date:

This site was one of the most challenging from a construction standpoint requiring significant excavation. The civil works is approximately 80% complete. The missing elements are powerhouse, tailrace and small sections of the headrace. Although the contract for construction was signed in September 1985, actual construction did not start until 10 months ago, but progress has been significant since then.

The Royal Forestry Department has already given its permission to carry out the project. All civil works should be complete within three months and the request for electro-mechanical equipment is currently in the approval process at the Ministry of Science, Technology and Energy.

Specific comments on the major project components are given below:

(a) Weir (see Exhibit C.15)

All construction around the weir and intake has been completed. We noted some sediment buildup behind it but were told that this is a periodic occurrence and will be flushed out with the next rain. It is constructed in one of the few narrow sections in the stream at approximately 2 km from the powerhouse.

(b) Headrace (see Exhibit C.16)

The headrace is 80% complete with a missing section near the intake. This area is currently being prepared. Anchoring the headrace requires blasting, excavation and fill. The headrace is above ground and made of 80 cm diameter steel pipe. Although more costly than concrete pipe used at Nam Mae Hat it is by far easier to maintain and not subject to cracks.

(c) Forebay (see Exhibit C.17 and C.18)

The forebay is almost complete with the penstock connection being made while the team was there. The forebay has a sand sluice and upon close

Exhibit C.15 Khlong Lam Plok Weir and Intake

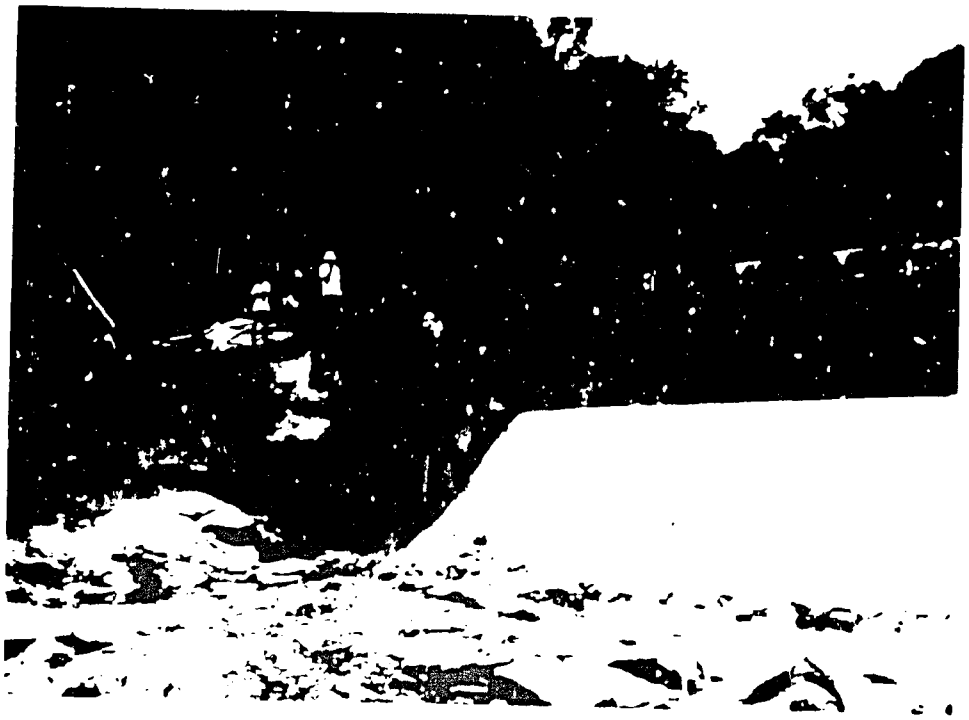


Exhibit C.16 Khlong Lam Plok Headrace

Exhibit C.17
Khlong Lam
Plok Forebay

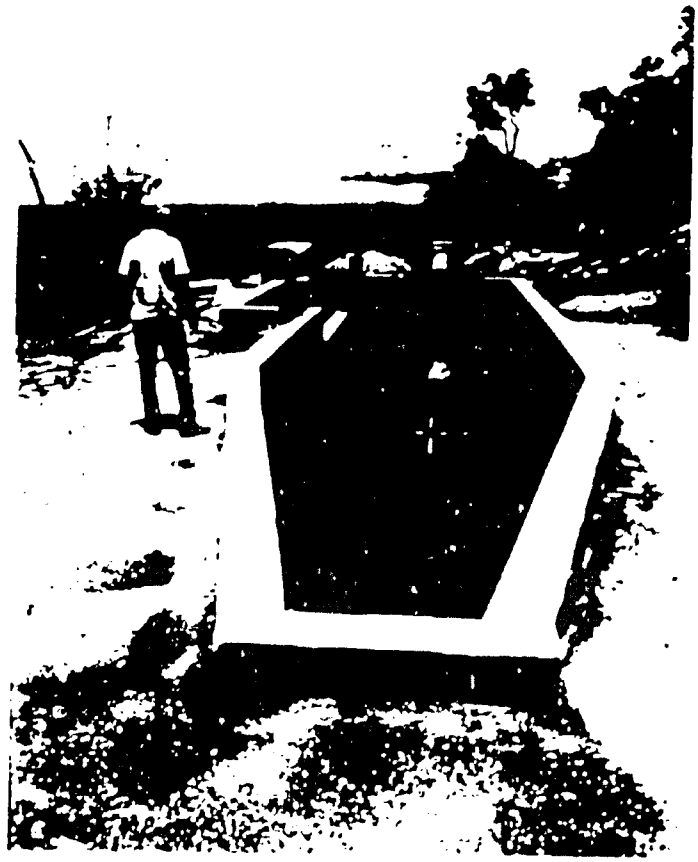


Exhibit C.18
Khlong Lam
Plok Sand
Sluice

inspection, we found the shotcrete on the aprons to be rather thin and brittle leaving one to wonder how long it would last. The area just below the sand sluice also did not appear to be well stabilized.

(d) Penstock (see Exhibit C.19)

The penstock appeared to be close to completion.

(e) Powerhouse (see Exhibit C.20)

The powerhouse excavation was just recently completed. Since the base is rock, extensive blasting was required.

(f) Tailrace

No work on the tailrace had been done.

(g) Access Roads

The access road was completed and is in good condition.

Environmental Impact:

Flow reduction in the stream will be approximately 30% under average stream flow conditions and at maximum power plant operation. However, about 40% of the time, the stream will be entirely diverted because of low flow. This should not have a major impact since there is little wildlife and few people in the area.

One question which remains unresolved is sedimentation. Certainly during the construction phase there will be sediment problems, particularly in the stream below the weir where it should have no impact on the power plant itself. However, it is difficult to forecast what the sediment load might be upstream of the weir. It will be important to keep settlers from moving into the catchment area for agriculture. Since this is a park area this should not be a problem.

Procurement:

The bid announcements for civil works, E-M equipment and transmission line were released by NEA in April of 1984. The transmission line bids were opened in August of 1985 with only two firms submitting proposals. The winner was U-Tah Engineering which agreed to build the 2.9 km of 33 kV line for 1.1 million Baht.

Civil works bids were also opened in August of 1985 with four firms submitting proposals. The winner was Boonsahakarn Srang Part. Ltd. which proposed building the civil works in 300 days for a cost of 18.53 million Baht beginning September 30, 1985.

Exhibit C.19 Khlong Lam Plok Penstock

Exhibit C.20 Khlong Lam Plok Powerhouse Excavation

Because of rain and Royal Forestry Department problems, the civil works contractor has asked for a 260 day extension to the original contract. This puts project completion well into 1988.

The E-M procurement process proved to be more complex. Since only one bidder responded initially, the bid was canceled in June 1986. It was rebid and again only one bidder responded. The bid again was canceled because it was over what NEA budget. Another round of bidding followed in late 1986 with two proposals again received. Layne & Bowler had a bid of 29.2 million Baht and won the competition. The other firm protested, charging that NEA did not assess the bids properly by not removing the import duties. Since a large fraction of the other firm's equipment package was imported, the duties were higher thereby raising the price. In addition the other firm was proposing a "new technology" for speed control which was not required by the NEA specifications. Upon further close examination by AID and NEA, the Layne & Bowler bid was still the lowest with or without the duties and taxes.

Socio-Economic Analysis

The electrified village of Ban Toong Nua located about 1 kilometer from the site is predominately Muslim and relatively prosperous. The villagers grow rubber trees and to a lesser extent, rice and fruit trees. They are relatively wealthy. Most households own a motorcycle.

About 69 of the 72 households are connected to the grid. Although the lines only reached the village about one year ago, the villagers were familiar with electricity from its use in a village 5 km away. Also, the PEA talked with the villagers about the use of electricity prior to stringing the lines to the village. The villagers were not involved in stringing lines but three of the villagers were trained by PEA to do the house wiring.

The village supply is a low voltage single phase distribution. As a result, power outages occur 3 to 5 times a month although the period of outage is at most one night. PEA has plans to upgrade the main distribution line to 33 kV.

SITE SUMMARY

KHLONG LAM PLOK

Physical Data:

1. Location	A. Yan Ta Khao C. Trang
2. Status	Grid connected
3. Catchment Area, km2	20
4. Net Head, m	176.4
5. Design Discharge, m3/s	0.90
6. Installed Capacity, kW	2 x 590
7. Dependable Capacity, kW	253
8. Annual Energy, GWh/y	7.761 [7.111]
9. Transmission Line, km	1.32
10. Access Road, km	1.35

Socio-Economic Data:

1. No. of Villages Served	10
2. No. of Households Served	1,037
3. No. of People Served	6,041
4. Population Growth Rate, %	5.5
5. Annual Household Income, B/y	64,784
6. Principal Economic Activity	Rubber & Rice

Financial Economic Data: U.S. $ (1000's)

1. Civil Works and Powerhouse Costs	784
2. Transmission Line Costs	22 [17]
3. Electromechanical Costs	989 [844]
4. Admin. & Design	458
5. Total System	2,253 [2,103]
6. Cost per kW Installed	$1,909 [1,779]

Note: Numbers in brackets were provided in May 1987 but revised in November 1987.

KHLONG DUSON

Site Characteristics:

The Khlong Duson site is located near Satun, in the southern part of Thailand, near the Malaysian border. This area is largely Moslem and supports itself through rubber and fruit production. Rice has to be imported into the area.

The plant is located in a hilly forested area, above several small communities which have had electricity from one to three years. The area is served by PEA using a single phase 33 kv line which will be upgraded to 3 phases.

Construction Progress to Date:

The site is only about 10 to 15% complete and was only started in February of 1987 (see Exhibit C.21). Civil works are scheduled for completion in May or June 1988 with operation to begin in December of the same year. No concrete work has been done but the area for the power house, penstock and access road has been cleared. No road yet exists up to the inlet or headrace but excavation and road building continue despite imminent rains.

Little additional information can be given regarding the site since it is in the early stages of construction. One can speculate on possible future problems that could occur. The area around the powerhouse for example, will need to be stabilized, perhaps with shotcrete, which is quite popular in Thailand (see Exhibit C.22). If this is not done, area around the structure may rapidly fill in with sediment. Construction so far has been carried out by Boon Saha Karnsang Co. Ltd., of Bangkok.

Several new design approaches will be featured at this site. The design evolution of inlet, weir, flow control structures and the use of steel pipe for the headrace, show significant progress in the engineering design of minihydro plants since Nam Mae Hat.

Environmental Issues:

A baseline environmental survey should also have been taken before excavation began. This would have given planners an indication of how the environment has been affected. However, there are no people living close to the plant nor is there any agriculture close by. The plant is being constructed in a virgin forest area.

Exhibit C.21 Khlong Duson Access Road

Exhibit C.22 Khlong Duson Powerhouse Site

Socio-Economic Analysis

The village of Kok Sai Nua has had electricity for about 4 months. It is located along a dirt road a few kilometers from the site. The villagers are primarily Moslem. They grow rubber trees as their principal crop and are self sufficient in rice. They are relatively prosperous with most households owning a motorcycle and 7 households owning pickup trucks.

Prior to the extension of the grid to the village, there were four households which used Honda generators. Now about 120 of the 174 households in the village are hooked to the grid. Those which are not connected tend to be located far from the grid. The large percentage of hookups is attributed to the fact that these four households had demonstrated the benefits of electricity. The average cost for a hookup was about 1500 Baht. House wiring was done by seven villagers who were trained by PEA.

Most houses have a rice cooker in addition to fluorescent lighting and about 40 houses have televisions. Prior to electrification there were 12 battery-powered televisions, but the batteries had to be taken to the amphoe to be charged. There are no commercial establis[1] ments with refrigerators, but 8 households use them. The average monthly charge per household is about 55 Baht. The low volume users spend about 12 Baht per month.

The productive uses of electricity in this village were the most extensive observed. There are about 10 electric water pumps used for pumping water from open wells for small scale irrigation and household uses. Previously the village used a gasoline pump for small scale irrigation, the pump was an award from the government. There are four shops in the village for repairing vehicles which recently opened and which use electric arc welding. There is a rice mill which recently replaced its old diesel engine with an electric motor. There are also some electric planers used for house construction and the local barbers now use electric razors. Public uses of electricity include lighting for the school house and the wat which are paid for by the teachers and the monks, respectively.

The villagers do not like to borrow money and do not have access to a Bank for Agriculture and Cooperatives. They paid cash for their appliances which were purchased in the town rather than from salesman in the village. Many of the villagers are familiar with concrete work and wood work. At present about 20 are employed at the NEA construction as carpenters and receive 100 Baht per day.

The village leader is extremely dynamic and has received recognition for his achievements for the last 3 years. Among the recent development efforts are the installation of modern toilets, locally constructed filters for drinking water, and construction of a village meeting hall. The village has a PA system for organizing small events. Larger activities are arranged by a vote in the village council.

SITE SUMMARY

KHLONG DUSON

Physical Data:

1. Location	A. Khuan Ka Long C. Satun
2. Status	Grid connected
3. Catchment Area, km2	29
4. Net Head, m	75.4
5. Design Discharge, m3/s	1.20
6. Installed Capacity, kW	2 x 340
7. Dependable Capacity, kW	145
8. Annual Energy, GWh/y	5.84 [4.29]
9. Transmission Line, km	1.24
10. Access Road, km	1.3

Socio-Economic Data:

1. No. of Villages Served	8
2. No. of Households Served	991
3. No. of People Served	6,386
4. Population Growth Rate, %	
5. Annual Household Income, B/y	41,782
6. Principal Economic Activity	Agriculture, 94%

Financial Economic Data: U.S. $ (1000's)

1. Civil Works and Powerhouse Costs	918
2. Transmission Line Costs	27
3. Electromechanical Costs	490 [588]
4. Admin. & Design	142
5. Total System	1,577 [1,675]
6. Cost per kW Installed	$2,319 [2,464]

Note: Numbers in brackets were produced in May 1987 and subsequently revised in November 1987.

HUAI LAM SIN

Site Characteristics:

This site is located close to Phathalung, in the Southern part of Thailand, also not far from the border with Malaysia. It is a hilly, forested area. The plant will be grid connected. The region is primarily a rubber and rice growing area.

Construction Progress to Date:

The site is about 90% complete missing only the power house and electromechanical equipment. All civil work is scheduled to be finished early 1988. The upper portion of this project, weir, headrace and forebay had to be built without vehicle access. This required a process similar to building the Pyramids in Egypt, backbreaking labor. Some component details are given below:

(a) Intake (see Exhibit C.23)

The intake was completed within the last month (June). Its design was unique, primarily an inlet set in bedrock at the side of the stream, without a weir or spillway traversing the stream.

(b) Headrace (see Exhibit C.24 and C.25)

The headrace is complete. It is an elevated steel pipe 55 cm in diameter. In some areas, the concrete foundations do not appear to be on solid rock. In one case we found the concrete foundation resting on a large boulder with a crack in it.

(c) Forebay (see Exhibit C.26)

The forebay is completed. Finishing details do not appear to be as well done as other plants the team visited. In part, this may be due to the fact that no access road to this area exists, making it difficult to carry out construction work which depends on mobile equipment.

(d) Penstock (see Exhibit C.27 and C.28)

The penstock is completed except for the last section before the powerhouse. Along its lower portion, the penstock is located in a large trench which may have erosion problems. We were told that there will provisions for drainage and the walls covered with shotcrete (much of this has apparently been done as of November 1987.

Exhibit C.23
Huai Lam Sin
Intake

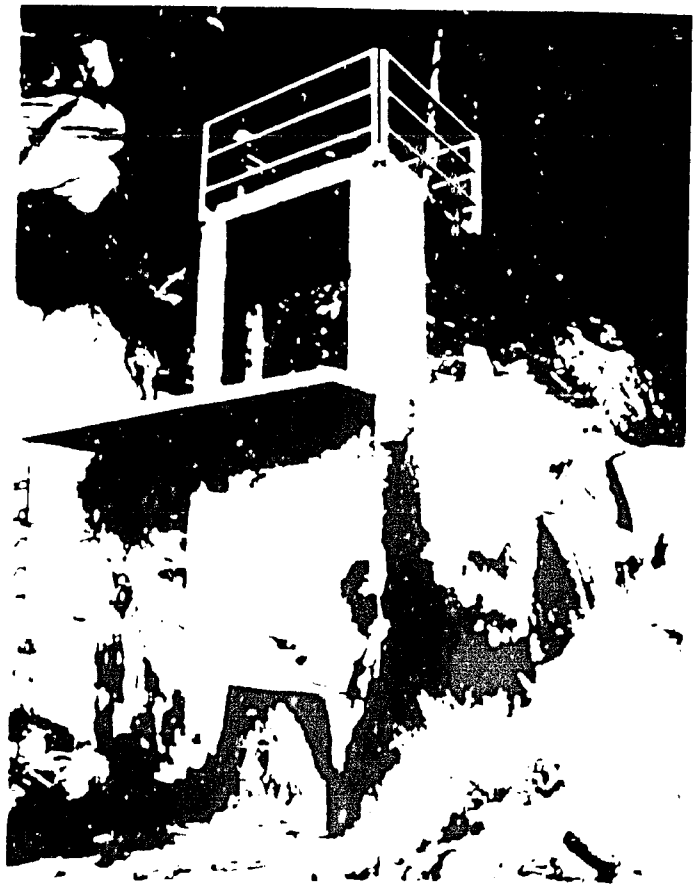


Exhibit C.24
Huai Lam Sin
Headrace
Support

Exhibit C.25 Huai Lam Sin Headrace Section

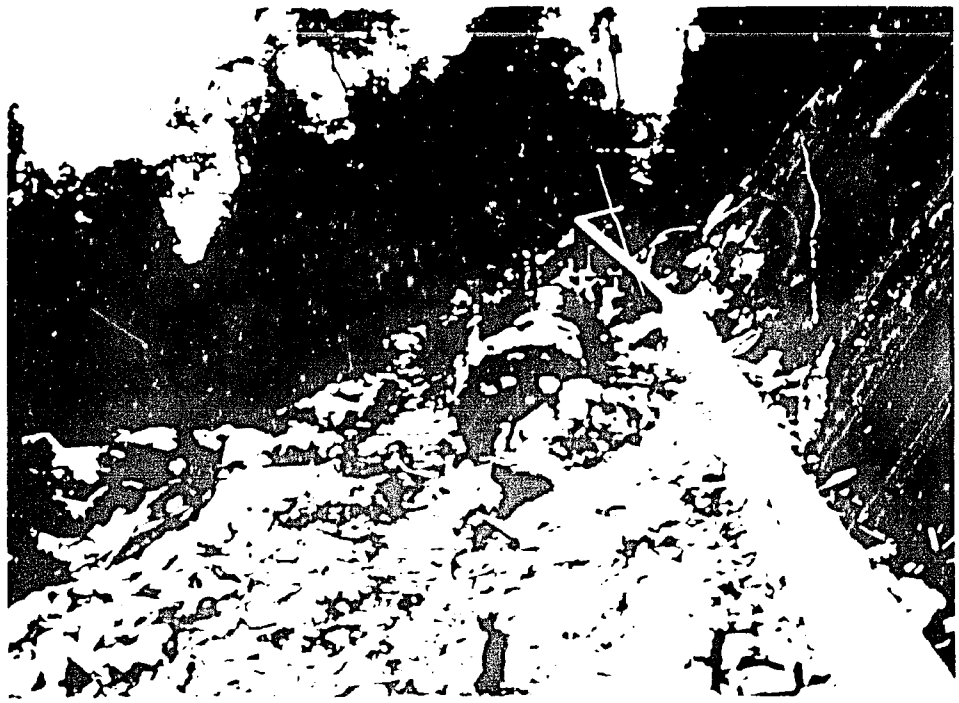


Exhibit C.26 Huai Lam Sin Forebay

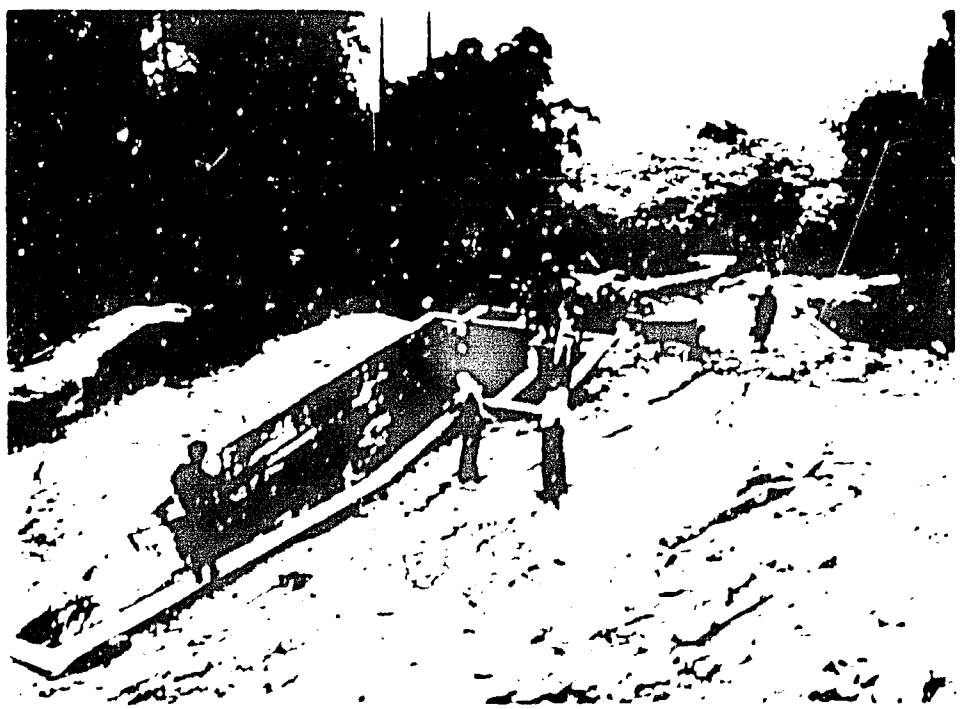
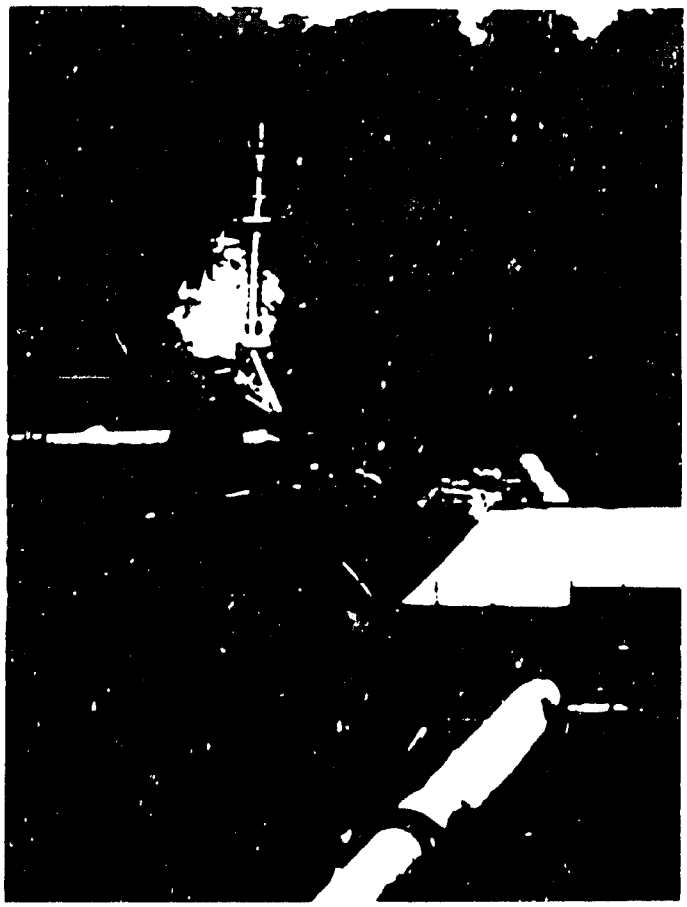


Exhibit C.27
Huai Lam Sin
Penstock

Exhibit C.28
Huai Lam Sin
Penstock
and Joints



(e) Powerhouse

The area has not been completely excavated for the powerhouse. Two Pelton turbines, being built by Siam Tech will be installed as soon as the powerhouse is finished.

(f) Tailrace

No work on the tailrace has been done.

(g) Access Road

There is good access to the powerhouse and site offices but no road exists to the headrace and weir. The terrain is very rugged and Team Consultants has not laid out a feasible road. NEA feels it can service the forebay, headrace and inlet without an access road since it was built without one. The cost for such a road might be prohibitive since it will be rather long and located in rough terrain.

Environmental Impact:

As with the other sites, the environmental impact after project completion should be minimal. A great deal will depend on how quickly and how effectively the vegetation reestablishes itself. No environmental survey was made prior to starting this project.

Procurement:

Specifications and drawings for the civil works and transmission line were submitted to AID for approval in August of 1984. AID approval came immediately and in September of 1984, work on the administrative buildings began through Phathalung Team Work Part. Ltd. Bids for the civil works were opened in August of 1985 with four firms submitting proposals. Summit Grade Part. Ltd. was the winner with a bid of 9.47 million Baht and a construction period of 10 months beginning September 30, 1985. Actual field work begun in January 1986. U-TAH Engineering won the contract to build the transmission line at a cost of 0.445 million Baht in November 1985.

For the E-M equipment, bid documents were submitted to AID in January 1986 and were approved immediately. Two bids were received, from Siam Tech. and another bidder in April 1986. The successful bidder was Siam Tech., with a bid of approximately 23 million Baht. After negotiations, the bid was reduced to 18.8 million Baht.

Socio-Economic Analysis

The village of Baan Ton is located in the Tambon of Lamsin. The villagers are primarily Bhuddist. The principal crop is rubber trees and the villagers must import rice.

This village, as well as the other villages in the mini-hydro service area, is electrified. It has had electricity for three years. Initially about half of the households were connected and now 116 of the 126 households are connected. Those not connected tend to be located far from the PEA lines. Five villagers were trained at the local wat by PEA to do house wiring.

The rapid rate of connection is difficult to explain since there were no villages in the area which were previously electrified and no generators in the village. Also the connection charge was relatively high, 2000 to 3000 Baht including house wiring. There was some demonstration effect since a few villagers owned battery-powered televisions. At present most households have rice cookers and about 20 have televisions. Also four establishments own refrigerators and pay about 200 Baht per month.

The villagers do not like to borrow, in part because they previously had a bad experience with a bank foreclosure. They buy their appliances in Patalun rather than from the salesman who come to the village. The average household pays about 30 Baht per month.

Village development activities are organized through the village development council. Labor for these projects is voluntary. Typical projects include repairing the road and cleaning up the area around the school and the wat. The village also has a cooperative grocery which was recently organized. The villagers pay 50 Baht per share and receive a part of the profits at the end of the year.

SITE SUMMARY

HUAI LAM SIN

Physical Data:

1. Location	A. Kong Rha C. Phathalung
2. Status	Grid connected
3. Catchment Area, km2	17.0
4. Net Head, m	238.0
5. Design Discharge, m3/s	0.53
6. Installed Capacity, kW	2 x 479
7. Dependable Capacity, kW	370
8. Annual Energy, GWh/y	6.115 [7.735]
9. Transmission Line, km	1.58
10. Access Road, km	1.98

Socio-Economic Data:

1. No. of Villages Served	10
2. No. of Households Served	1,053
3. No. of People Served	5,902
4. Population Growth Rate, %	1.6
5. Annual Household Income, B/y	36,215
6. Principal Economic Activity	Rice & Rubber

Financial Economic Data:	**U.S. $ (1000's)**
1. Civil Works and Powerhouse Costs	432 [462]
2. Transmission Line Costs	22 [26]
3. Electromechanical Costs	614 [737]
4. Admin. & Design	457
5. Total System	1,525 [1,682]
6. Cost per kW Installed	$1,588 [1,756]

Note: Numbers in brackets were provided May 1987 and revised in November 1987.

Ban Kum Pong

The village of Ban Kum Pong, northeast of Chiang Mai, is one of the sites in which a microhydro facility was built as part of the NonConventional Renewable Energy Project. The method of organization for this facility presents an interesting counterpoint to that of the mini-hydro sites.

The facility was constructed about three years ago. Prior to that there were 4 household generators (3 - 1kW and 1 - 4kW) being used in the village. The village sought a way to electrify and looked at other local systems, but then NEA came to the village offering to set up a microhydro facility.

The villagers participated in the construction of the weir and powerhouse under the direction of an NEA engineer. They undertook the land clearing, earth work and form work. They also cut the poles to be used for distribution, and assisted the NEA engineer in stringing the power lines. Three of the villagers were trained by NEA in how to wire houses. Each family contributed one person who was assigned to a specific task. The labor was accounted as an in-kind payment from the villagers which was converted to a 40% ownership in the facility. The total cost for the facility was on the order of 3 million Baht or about $6000 per installed kilowatt. Once the second turbine is installed this cost will fall to about $4000 per installed kW.

The village maintains the system, collects the tariff and shares the profits with the NEA through a cooperative headed by the village headman. The system is maintained by three committees which are responsible for the water diversion system, the distribution poles, and the distribution lines. The NEA assumes responsibility for maintenance of the equipment.

The system is operated between 4pm and 7am on weekdays and 24 hours per day on the weekend. The facility is operated by one villager who is paid 700 Baht per month. there are two reserve operators. All three were trained by the NEA. The secretary of the cooperative reads the meters. Another villager is responsible for collecting the monthly bills.

The hookup rate for the 168 house holds has reached 72%. The houses not connected are those which were not formerly included in the boundary of the village, but now the lines are being extended to reach these houses. The villagers are charged 2 Baht per kilowatt-hour with a minimum of 10 Baht a month. The hookup charge included 300 Baht for the meter. The total charge for two outlets and the meter was about 900 Baht.

The unit was designed for 40 kW, but at present only one of the two 20kW units has been installed. Distribution is by 3.5 kV, 3 phase lines, Two phases are sent to each housing cluster in an effort to balance the load. The facility serves the village and a mushroom growing project nearby. Plans are underway to extend the line to an adjoining village.

Conclusions from Socio-Economic Survey

1. PEA rarely provides any promotional support or advice to the villages on the use of electricity, but does provide training in housewiring.

2. The PEA system does not use local inputs of any kind for installing the lines. The fabrication of the poles, the land clearing and the erection are all performed by PEA personnel although most villagers have some of the necessary skills.

3. The basic consideration in connecting a house to the grid is the cost for connection relative to household wealth. Typical costs for hookups range from 1500 Baht to 2500 Baht with an additional cost of a few hundred Baht for housewiring.

4. The rate of connection is also influenced by proximity to other villages which have electricity. The demonstration effect is very strong in this regard.

5. The selection of appliances is very much determined by what other households in a cluster purchase. For example, the decision on whether to use 20 or 40 watt fluorescent bulbs is generally based on what the leader of the village or of a housing cluster purchases.

6. There does not appear to be a very good understanding of electricity economics. Not surprisingly, there is little awareness of the unit charge while there is an awareness of the average cost per month. More disturbing is the lack of understanding between the size of appliances and resulting electricity consumption and energy charges.

7. Most of the promotional activities with regards to the use of electricity in the home, commercial establishment and industry is undertaken by the private sector, especially the suppliers of electrical appliances and equipment.

APPENDIX D: PROJECT COSTS AND COST ESTIMATING PROCEDURES

Cost Estimating

The estimates for construction of the mini-hydro sites were broken down into four categories:

1. Civil Works which includes power house, mobilization and site preparation
2. Mechanical and electrical equipment including switchgear
3. Transmission lines
4. Design and administration

The latter was calculated as 10% of the total of the first three. In addition, 20% of the civil works cost (exclusive of site preparation) was added for contractor's indirect costs. Contingency allowances were 20% for civil works, 20% for mechanical and electrical equipment and 15% for transmission lines. These contingencies were adjusted for the second round of sites to 8%-20% for civil works, 15%-20% for electrical and mechanical equipment and 8%-20% for transmission lines, depending on the site. The design and administration cost was also reduced to between 4% and 10%, depending on the site.

The first round of cost estimates generally over-estimated the costs for civil works and transmission lines but significantly underestimated the costs for electrical and mechanical equipment. The result was a serious underestimate for Nam Mae Hat and Huai Lam Sin versus a slight overestimate for Khlong Lam Plok as shown in Exhibit D.1. Part of this disparity can be explained by the delay from the time of the estimates to the receipt of bids for the E-M equipment which covered a period of significant inflation and a devaluation of the Baht. In addition, little was known about this size of equipment and there was no provision in the project scope for foreign technical assistance in this area. The detailed physical specifications prepared by TEAM consultants probably lead to a higher cost of the E-M equipment then would have applied if performance specifications had been used.

In the second round of sites, the Thai consultants and NEA benefited from earlier experience and from the relatively short period of time between cost estimates and receiving bids. As a result, the estimates total costs were remarkably close to the bids. Again there was a tendency to underestimate the costs of the E-M equipment balanced by overestimates of the costs of civil works and transmission line construction. It appears that the combination of TEAM and NEA has been successful in improving their cost estimating ability.

Exhibit D.1

Original and Final Cost Estimates for the First Six Sites

Cost Estimate for First Six Projects
(mn. Baht)

	Nam Mae Hat	Huai Lam Sin	Khlong Lam Plok	Khlong Duson	Nam Kha Mun	Lam Pra Plerng
Current Estimate						
Civil Works and Power House	16.7	11.8[a]	20.0[a]	23.4	21.4	7.9
Transmission Line	8.1	0.7	0.4	0.7	1.0	
Turbine Generator	18.6	18.8	21.5	15.0[b]	22.0	26.4[b]
Admin. & Design	10.8	11.7	11.7	3.6	3.7	3.5
000's Baht/kW	66.4	44.8	45.4	62.8	46.7	44.4
Original Estimate						
Civil Works and Power House	17.0	18.3	49.5	23.6	22.9	8.2
Transmission Line	11.4	2.5	0.9	0.3	2.8	
Turbine Generator	8.3	7.1	11.6	11.0	14.0	21.7
Admin. & Design				7.4[c]	6.3[c]	8.4[c]
000's Baht/kW	44.9	29.2	52.5	62.2	44.6	45.0
% difference Current vs. original	48%	54%	-14%	1%	5%	-1%

For current costs the administration were estimated for 1988, otherwise all costs are based on bids unless otherwise noted.

a. Power house estimated
b. Estimates for mechanical and electrical
c. Includes contingencies

Operating and Maintenance Costs

The annual operating and maintenance costs for the mini-hydro facilities were estimated using 1% of the costs for civil works and 1.5% of the electrical and mechanical equipment. Using the costs presented in the previous table, this results in the following:

Exhibit D.2

Estimated Operations and Maintenance Costs for the Six Sites currently under Construction, (000's Baht/year)

Nam Mae Hat	578
Huai Lam Sin	353
Khlong Lam Plok	586
Khlong Duson	432
Nam Kha Mun	503
Lam Pra Plerng	410

Assuming a round-the-clock operation involving nine full-time operators at a cost of 2,200 Baht/month per operator, the annual cost just for labor would be about 250 thousand Baht/year. This amount does not appear to have been properly accounted for. It should be added to the costs for repair and maintenance of the civil works, equipment, transmission lines and the access and O&M roads for which the estimates in Exhibit D.2 appear reasonable. Thus the total O&M costs are on the order of 750 thousand Baht per year. Since a large portion of the costs are associated with the civil works and the operation, there would be a relatively small variation in these cost with the capacity of the facility.

Costs of Competing Facilities

The units costs used to estimate the costs for alternative generating systems were as shown in Exhibit D.3. There are some problems with these costs. The capital costs for the diesel generators appear to be low by about 15-25% but the generators were oversized by a factor of 200% to 300% (see discussion in Appendix G). For the diesel generators analyzed for the first round of sites, the estimated fuel costs varied considerably without any clear rationale. In the second round of sites, the problem was corrected by using a constant fuel cost per kWh for all the sites. The costs for fuel were reasonable at the time the estimates were prepared but now they are about double the current economic cost for both the diesel generators and the oil-fired thermal plants.

The downward adjustment in fuel prices would clearly favor these two alternatives relative to the mini-hydro.

Exhibit D.3

Economic Costs for Alternative Generating Systems *

Diesel Generator		
Capital Cost (000's Baht/kw)		9.500
O & M cost (000's Baht/kW/year)		0.285
5 year renewal cost (000's Baht/kW)		4.275
Fuel Cost (Baht/kWh)	- Phase I	1.9-9.2
	- Phase II	2.3
Grid Extension		
Transmission Line		
Capital Cost (000's Baht/km)	- Phase I	370.0
	- Phase II	336.5
O & M cost (000's Baht/km/year)	- Phase I	2.368
	- Phase II	3.365
Power Generation		
Capital Cost (000's Baht/kW)	- Phase I	12.144
	- Phase II	15.370
O & M Cost (000's Baht/kW/year)	- Phase I	0.304
	- Phase II	0.384
Fuel Cost (Baht/kWh)	- Phase I	0.965
	- Phase II	0.962

* Based on numbers used in previous economic evaluations rather than the assumed values presented in the following text.

APPENDIX E: SITE SELECTION PROCEDURE

The Proposed Site Selection Model

The site selection model proposed in the PP involved a three stage process: preliminary screening, feasibility analysis, and final engineering. The goal of this model was to provide a procedure which was simple and robust so that it would make efficient use of technical personnel to analyze a large number of sites with different conditions. The preliminary screening was to involve a desktop study of alternative sites to determine whether they met specific criteria. These criteria included:

1. Appropriateness of micro or mini hydro, i.e. capacity of 1000 kw or less based on the estimated head.

2. For mini-hydro, the possibility of connection to the grid especially for the larger units.

3. For micro-hydro and for mini-hydro not connected to the grid, sufficient population within the anticipated service area.

4. The existence of diesel generating sets within the service area which could be replaced by the hydro facility.

The desktop study would make use of topological maps and local census data regarding population and commercial activities. Criteria #1 and #3 would be used to accept or reject sites whereas the other two criteria would be used to set priorities for those sites which were not rejected.

A subset of the sites which passed the preliminary screening would then be subjected to field studies to determine the technical feasibility of these sites. The size of this subset would be based on the budget for development of sites and the expected rejection rate for the sites to be studied.

The field studies would include both physical and social surveys. They would preceded by a review of the available data on the rainfall and hydrological conditions in the area of the sites and of the results from previous socio-economic surveys in these areas. The control and use of the land at the site would then be determined along with the mechanisms for acquiring the rights to develop the site for hydro-electric power generation.

These field studies would start with a visual inspection of the site to confirm the assumptions which were used in the desk study. If these assumptions were correct, then

a field survey team would be brought the site to perform simple topological, geological and hydrological surveys. The principal data collected would be:

a. The stream flow for average, flood and drought conditions using physical measurements of the stream bed, observations on stream velocity, rain gauge data and the recollection of villagers.

b. The actual head for different locations of the diversion and the power house.

c. Soil conditions at the location of the proposed headrace and power station using surface observation and test pits.

d. Potential for soil erosion along the access road, headrace and penstock based on topology and proposed construction.

e. Stream bed load.

f. Present use of stream flow between proposed diversion and tail race.

The results of these surveys would be used to compute the power generation potential of the site. At the same time, a village survey would be conducted to collect data on the expected demand in the service area. This survey would involve an initial interview with a village leader (phuyaban, teacher, etc.) followed by a household survey to be given to a random sample of households with a total sample size of 5%-10% of the village. Although sample questionnaires were presented in the PP the use of the data obtained from the questionnaires results for determining demand was not set out in the paper. The basis for the demand analysis, was presented in vague terms in the PP (see Appendix F). PP also included sample forms to be completed as part of the power calculations.

The field surveys were meant to conclude with an analysis of the most appropriate organizational structure for development of the site, the most efficient method for controlling power distribution and the proper pricing policy to insure efficient use of the system. However, the objectives of and procedures for this analysis were presented in vague terms.

If the field surveys confirmed that there was sufficient demand to justify the development of the site and that the site could provide sufficient power to meet this demand without backup systems, then the final phase of the site selection process, the financial/economic analysis, would be performed. This analysis would determine the least cost generation alternative for the site and the viability of that alternative given the proposed tariff for residential and commercial use. The least cost analysis would be based on a comparison of hydro-power, diesel generation and an extension of the grid.

A format for this comparison was presented in the PP in the form of a worksheet and a fairly detailed set of costing assumptions including:

a. 12% discount rate,

b. Constant costs net of subsidies and taxes, (for economic analysis)

c. 30 year life for hydro generation system,

d. Capital costs incurred in the first year,

e. Annual hydro O&M costs computed as 2% of capital costs,

f. 225,000 Baht/km for 22 kV distribution,

g. Transmission line O&M costs of 1% of capital costs,

h. 24-hour power availability which requires two diesel units,

i. 450,000 Baht for a complete 50 kW unit,

j. Five year life for diesel engine with replacement cost of 200,000 Baht,

k. Diesel unit annual O&M equal to 3% of capital costs,

l. 24,500 Baht/kW capacity cost for grid extension and 0.7 Baht/kWh generation cost for grid.

m. 15% tax to be deducted from the cost of fuel, and

n. 3% rate of increase in the real cost of diesel fuel.

The comparison was meant to be based on economic costs and benefits, however, in order to simplify the analysis, the benefit side was not computed and the comparison was limited to the costs. The economic costs were determined by eliminating known taxes and subsidies and, where appropriate, by introducing a shadow price for labor.

The analysis of financial viability was to use similar assumptions but included debt service calculations based on "available financing". The income flow was to be estimated from the demand forecast and the proposed tariff. The evaluation of viability was to be based on the internal rate of return for the net cash flow with a hurdle rate of 8%.

If the hydro-power alternative met both criteria, economic least cost and financial viability, then the development of the sites would commence by identifying the appropriate operating agency (PEA, NEA, tambon or village organization) and proceeding to detailed design.

The First Round of Site Selection

The first round of the site selection process was carried out as part of the preparation of the PP. A set of twenty-two sites were selected based on topological data from the NEA and the Thai Royal Forestry Department. These sites were then subjected to a review of available physical data and topographical maps. Some of the sites were dropped from consideration because of lack of topological or hydrological data. The remaining sites were then visited by NEA and ARD engineers who performed both physical and socio-economic surveys and prepared preliminary cost estimates. These results were then presented in the project paper in September 1982. The six recommended sites were Nam Mae Hat, Nam Mae Suk, Nam Mae Aep, Mae Chon Luang, Khlong Ta Riu, and Khlong Ra.

Twenty-two months later, the project contract was signed and a second effort at site investigations began. At this time 12 more sites were added to the list for investigation. One of these was subsequently eliminated after a review of the topographic maps and another eight were eliminated as a result of the findings of the field reconnaissance, four because of low discharge, poor water quality or unfavorable topography, two because of constraints on land use and two because of high development costs. Of the remaining nine sites, only seven were studied in detail. These sites included five of the six recommended in the project paper (Khlong Ra was eliminated because of poor water quality) and two new sites Khlong Lam Plok and Huai Lam Sin. At this time the capacity of the seven mini-hydro facilities were adjusted to reflect the more accurate data available form the field surveys.

The results of this least cost analysis are shown in Exhibit E.1. Although four of the seven sites did not meet the least-cost criteria, two of these four, Nam Mae Chan Luang and Huai Mae Suk, had costs for hydro within the range of accuracy of the least cost alternative. As a result of this analysis, Huai Mae Aep which had been earlier downgraded from a 120 kW mini-hydrosite an 80 kW micro-hydro site was dropped. The Khlong Ta Riu site was marginal but was included in the subsequent financial analysis.

In the final phase of site selection a financial analysis was performed this analysis was performed using the USAID loan conditions and the "normal" loan condition of 10% interest, 7 year grace period, principal repayment over 22 years. The results of this analysis indicated that Nam Mae Hat was not financially viable and the Mae Chon Luang would be viable only if constructed with volunteer labor. For Mae Suk, the hydro and grid options are comparable.

The seven sites were then subjected to an "economic" evaluation if the mini-hydro met the least-cost criteria. The least cost analysis used several assumptions, only some of

Exhibit E.1

Results First Round "Economic" Evaluation

Site	NPV of System Costs (10^6 Bhat) Hydro	Diesel	Grid	Capacity (kW)	Energy (GWh/yr)	Distance to Grid (km)
Name Mae Hat	26.9	84.5	44.1	2 x 408	2.83	24
Nam Mae Chon Luang	12.3	12.4	11.7	1 x 132	0.29	24
Huai Mae Suk	23.0	59.2	22.0	2 x 235	2.51	3
Huai Mae Aep	23.3	21.3	19.4	2 x 40	0.27	16
Khlong Ta Riu	48.6	131.6	43.6	4 x 357	6.20	0
Khlong Lam Plok	45.1	166.5	58.9	2 x 633	7.80	0
Huai Lam Sin	20.4	124.7	49.6	2 x 371	6.12	0

which were consistent with those included in the Project Paper. A list of these assumptions is given:

1. For diesels twice the capacity of the hydro option, installed to allow for 24 hour a day operation

2. The economic conversion factors for the hydro facility were 0.74 for the civil work and the transmission line, 0.77 for the electromechanical systems, 0.79 for all operation and maintenance and 0.87 for diesel fuel (recommended by Project Paper?)

3. The economic cost for a diesel generating system was 9,500 Baht per installed kW.

4. The economic cost of expansion of grid capacity is 12,144 Baht per installed kW.

5. Cost for diesel fuel of 6 to 8.3 Baht per liter depending on the site.

6. Diesel fuel consumption 0.33 liters/kWh except at Mae Hat where consumption is 0.79 liter/kWh and at Nam Mae Aep where consumption is 0.83 litre/kWh (probably due to input errors).

7. Grid fuel consumption 0.965 Baht/kWh.

8. A 12% discount rate.

9. Operation and maintenance costs equal to 3% of capital costs for diesel generator, 1% of capital cost for transmission and distribution.

The sites which had the highest financial return were Khlong Lam Plok and Huai Lam Sim. These two were selected for construction. In addition, for reasons that were unrelated to financial concerns, Nam Mae Hat was also selected for construction. Huai Mae Suk and Khlong Ta Riu were rejected because an extension of the grid offered a similar economic return.

The Second Round of Site Selection

The second round of site selection occurred during 1986-87. Six sites were proposed. These sites were selected from a total of 137 sites which had previously received preliminary study as part of efforts by NEA's Planning and Investigation Division, by TEAM consultants as part of a diesel replacement study for NEA, and by a Japanese-funded study undertaken by NEA. These studies plus additional desktop studies performed by NEA all contained preliminary estimates of the Benefit/Cost ratio for the projects. However, the basis for these ratios was not consistent since some were based

on a comparison with diesel generators, others were compared with prevailing tariffs, and still others with the cost of connection to the grid. The only consistent point in these analyses was the use of a 12% discount rate. The selection was made by choosing those sites with a Benefit/Cost ratio greater than 1.0. The resulting set of 34 sites were then given priorities based on achieving a regional distribution and on meeting three criteria, as follows.

1. Isolation from the grid
2. Replacement of diesel generators
3. If not isolated, then close to the grid

The seven sites with the highest priority were Lam Pra Plerng (Korat), Nam Kha Mun (Phitsanulok), Khlong Duson (Satun), Huai Mae Sot (Tak), Huai Nam Tap (Loei), Nam Mae Usu (Tak), and Muai Mae Ping (Mae Hongsorn). These seven sites were then subjected to field surveys to collect both physical and socio-economic data. This information along with the preliminary cost estimates was used to eliminate three sites; Huai Mae Ping because of sedimentation problems and low economic return, Nam Mae Usu because the generating capacity was too large (1.2 megawatts) and Huai Nam Phan because it lacked water during 5 months of the year. The remaining sites were all grid connected. The results of the economic evaluation for all sites except Huai Mae Ping are shown in Exhibit E.2.

Nam Kha Mun and Khlong Duson were selected for implementation because they had favorable financial rates of return as well as the minimum economic cost. Despite an economic evaluation, Lam Pra Plerng had a very high financial rate of return, and was included in the sites to be implemented. The economic evaluation for Huai Mae Sot was marginal as was its financial rate of return so it was excluded. Huai Nam Tap was not the least cost, although within the margin of error, but also had a marginal financial rate of return and was excluded. For Nam Mae Usu, the mini-hydro option was least cost and had a high financial rate of return but the service area was already connected to the grid, so it was excluded.

The Third Round of Site Selection

The final round of site selection was undertaken after the contract with Stanley consultants was completed and the POU had been effectively disbanded. In this round, three sites, suggested by NEA, were considered. These were subjected to the site screening process with the exception of the socio-economic survey. Two additional sites were found to be economically and financially feasible, however, due to budget limitations only one was selected, Yam Muk which is also an isolated site.

Exhibit E.2

Results of Second Round "Economic" Evaluation

Site	NPV of System Costs (10^6 Baht) Hydro	Diesel	Grid	Capacity (kW)	Energy (GWh/y)
Lam Pra Plerng	28.6	80.5	24.5	870	3.27
Nam Kha Mun	33.9	120.3	39.8	1034	5.25
Khlong Duson	30.7	93.1	32.5	680	4.29
Huai Mae Sot	22.2	69.5	22.6	660	3.01
Huai Nam Tap	15.8	53.1	15.4	515	2.21
Nam Mae Usu (2)	49.6	96.2		1450	10.16

Conclusions

The site selection procedure has evolved since it was first proposed in the project paper. The major force for change has been the fact that all of the sites are mini-hydro sites and most of these are to be grid connected. Since the physical survey techniques and power calculations are relatively standard and already well known to the Thai engineers, there appears to have been little change in these procedures. However, the economic analysis has evolved to include sensitivity analysis with respect to the discount rate. In the current NEA-funded effort to develop a National Mini-hydro Master Plan, the economic analysis has been modified by TEAM to conform to the standard procedures for grid-connected mini-hydro projects (for details see Appendix G).

The socio-economic survey also appears to have been simplified. Since demand forecasting has little purpose for grid-connected sites, the forecasts appear to have been dropped in the second round. The whole socio-economic survey seems to have been discontinued in the third round. Given the results of the review of the site selection methodology process included in Appendices F, G, and H, it would appear that an unnecessarily complex and often inappropriate methodology was gradually modified and improved through the efforts of NEA and the TEAM consultants.

APPENDIX F: DEMAND FORECASTING

Many of the mini-hydro projects were initially designed to provide electricity to several un-electrified villages in the vicinity of the site. In addition, the majority of the sites were designed to be connected to the grid and to sell the surplus electricity to PEA. The forecasting of local demand for electricity is not essential in the case where the sites are connected to the grid, however, it is worthwhile to review the demand forecasting procedures because they are useful to:

1. NEA when evaluating micro-hydro projects,

2. USAID and NEA for evaluating a phased approach to the introduction of electric generation, and

3. PEA for setting priorities and scheduling the extension of the grid.

Before examining specific procedures, it is important to consider the nature of the demand for electricity. In the residential sector, the electricity is used:

1. For lighting, generally fluorescent lighting, which replaces kerosene lamps,

2. For colored televisions which are purchased following the introduction of electricity or which replace battery powered black and white televisions,

3. For cooking, specifically with rice cookers, which are purchased after a house is electrified and which substitute for (but not other foods) wood or charcoal used with traditional Thai stoves,

4. For cooling, principally with small electric fans, which are purchased when the house is electrified and which introduce a benefit not previously available to the household,

5. For food preservation, with a refrigerator again providing a new benefit

In the public sector, the electricity provides services similar to the residential sector for the wat, the school and public gathering places. In the commercial sector, the electricity is used to provide lighting of establishments, refrigeration/cooling for food and beverages and rice cooking for village food, shops and restaurants, to power cutting devices for barbers and beauty salons, to supply energy for arc welders in auto/-motorcycle repair shops, and to power tools used for wood working and house construction.

In the agricultural sector, the electricity is used for water pumping and for milling. In the rural industries, the electricity is used primarily to provide lighting but can also be used to provide shaft power for wood cutting, metal working, mixing and forming ceramics, etc.

In order for these uses to be realized, the villager must first make the necessary expenditure for a hookup and for wiring the household or work place and must then purchase the appliances and equipment to use the electricity. Once these expenditures are made then the level of consumption will be adjusted according to the villagers' ability to pay. Therefore, the forecasting of demand must take into account the rate at which hookups will occur, the time delay associated with the capital investment in appliances and equipment and the responsiveness of demand to changes in prices and income. A simplified formulation of this relationship would be:

$$E_k = H_k(t,i,p_1)\, P_k(t)\, e_k(t,i,p_2,p_3)$$

where E_k = total consumption of electricity in sector k

H_k = the percentage of potential users in sector k which are connected

P_k = number of potential users in sector k as measured by number of households or number of commercial enterprises

e_k = average consumption per connected user in sector k

t = period of time following the introduction of electricity to the village

i = a measure of the wealth, gross income or net income of the average potential user

p_1 = relative price of a connection

p_2 = relative cost of electricity versus substitute sources of energy

p_3 = relative price of electrical appliances and equipment.

This formulation demonstrates the three factors which should be considered in forecasting demand:

1. A relevant measure of number of potential users and their projected rate of growth,

2. The time constants associated with the rate of acceptance by users and the period over which capital investments in consumer durables are made, and

3. The effects of income and prices on the level of use of electricity after hookup and purchase of appliances and equipment.

The first factor is generally the easiest to forecast since projections of growth in population and economic activity are regularly prepared by governments. The growth

rates of population and economic activity are generally expressed as annual percentage increases.

The time constants are particularly important since the financial and economic viability of rural electrification is very much determined by the buildup in consumption in the first few years following the electrification of the service area.

The effects of income and relative prices are usually expressed in terms of elasticities of demand. A common, though not necessarily correct assumption is that these elasticities are constant over a wide range of income and price levels. In the following paragraphs, the various methods of forecasting used in the project will be reviewed to determine how well they account for these factors.

Method Proposed in Project Paper

The Project Paper proposed a general formulation for the growth in residential demand using the exponential growth associated with population and a constant elasticity with respect to average income. The PP recommended an elasticity of 1.2. The baseline data on household income was to be collected as part of the socio-economic survey. The rate of growth in income was to be estimated from sources such as:

> "...the potential for expansion of the primary income occupation in the village, knowledge of planned future developments in or near the village (new road, irrigation improvements, etc.), subjective impressions furnished by the village head and households surveyed, and district data will be particularly relevant."[1]

A similarly vague prescription was provided for estimating growth in business and public service demand. The first year's demand was to be estimated from specific, albeit limited, data collected in the socio-economic survey, while the growth rates were to be formulated subjectively. Sample forecasts prepared in the Project Paper annexes used a uniform set of assumptions for all sites except Mae Hat where higher initial rates of consumption were used. The growth rates were derived from a comparison of MEA and PEA growth rates by average consumption per hookup. The relationship between energy demand and capacity requirements was derived using an PEA publication formulation. Clearly, the forecasting methodology presented in the project paper was meant to provide a general approach, rather than a specific procedure. As part of the project, the project's load forecasting specialist applied three different methodologies to forecast demand in the hopes of achieving some convergence of estimates. These methods are described below.

1 Project Paper Annexes Micro/Mini Hydroelectric Project, Section 3.3.3

Time Series Method

The Time Series method was borrowed from EGAT which used the approach to estimate national demand. The formulation is a relatively simple one in which regression analysis is used to derive the constants for the following equation.

$$E = a_1 + a_2 t + a_3 t^2$$

where E = total demand in GWh

a_i = regression coefficients

t = time in years

This equation attempts to take into account two factors:

1. the expansion in the grid and thus the number of hookups as a constant amount per year ($a_2 t$)

2. an economic growth factor, which is approximated by the square of the time factor ($a_3 t^2$)

The demand was separated into five sectors as follows: residential, small business, industrial, street lighting, and other uses. The constants for the equation were the same as those developed by EGAT and these were applied to the actual energy consumption figures for 1983. Demand was computed on a provincial level and then allocated to the service area using the percentage of households in that service area.

The power requirements were determined assuming an initial load factor (LF) which increases to 85% using an exponential rate of growth. The equation used for this calculation is shown below. The initial constant and the rate of increase were determined by using provincial constants derived by EGAT.

$$LF = 0.85(1 - e^{a_1 + a_2 t})$$

This methodology is clearly inappropriate for computing the demand in a newly electrified area. It ignores the time constants associated with increasing hookups and investments in appliances in a newly connected area. It also ignores the elasticities associated with the per capita (or per household) income and the relative prices of alternative sources of energy. The projections produced by this method should overestimate demand in the service area since the equation is derived from data on relatively mature markets.

ARE.1 Method

The second method used to forecast the village demand was the same as had been used to predict the demand in the first phase of the Accelerated Rural Electrification Project of PEA, which was directed at electrifying villages in the Northeast. This method identified five sectors, residential, commercial, rice mills, irrigation pumping and water supply. For each sector a typical consumption pattern was developed which described the consumption and power demands for the average user over a 30 year period starting when the village is electrified. The increase in consumption per typical customer was approximately linear for all four sectors with the initial loads and annual increases shown in Exhibit F.1. These typical consumption patterns were applied to all sites. The number of users was determined as follows;

1. For households - the number of households was determined in the socio-economic survey; the percentage of hookups was expected to be 42% in the first year, 65% in the 10th year and 100% in the 20th year after electrification; the population was expected to grow at a rate decreasing from 2.5 per annum to 2% per annum over the 20 years;

2. For commercial establishments - the number of existing establishments was used without any allowances for an increase in their numbers and with the assumption of 100% hookups from the first year;

3. For rice mills - the consumption and power demands were computed on a per village basis and the number of users was set equal to the number of villages in the service area; and

4. For irrigation and water supply pumping - an approach similar to that for rice mills was used.

The weakness of this method is readily apparent. No allowance was made for the difference in income between villages or even between service areas. The rate of hookups was assumed standard without regard to the marketing data collected as part of the socio-economic survey. Elasticities with respect to income and price were not treated. The effect of number of households on the requirement for water supply was not included. Rice milling and irrigation requirements were assumed equivalent without regard for the principal form of agriculture in the region or the number of households in the village.

While this approach is directed more towards newly electrified villages, then the previous method, it assumes that all villages will have a similar demand regardless of their geographic location, major form of agricultural activity, principal source of income or relative wealth. With the exception of the residential demand. This methodology has little to recommend it and even the residential demand assumes a uniformity of

Exhibit F.1

ARE.2 Constant Load Growth Factors

	Annual Growth (kWh/mo)	Initial Load (kWh/mo)
Residential	2.5	10
Commercial	11.5	192
Rice mills	17.4	485
Irrigation pumping	40.7	97
Water supply	5.9	41

consumption which the other methodologies do not. Considering that the base data for the consumption and power demand estimates was obtained from villages in the Northeast while none of the sites were located there, further reduces the usefulness of this approach.

ARE.2 Method

The third forecasting methodology was derived from the second phase of the Accelerated Rural Electrification Study (ARE.2) which was concerned with the extension of rural electrification to areas in southern, central and northern Thailand. The demand forecasting methodology was much more detailed than that used in ARE.1. First, the demand was estimated separately for seven sectors, the five used previously plus power tools and social facility loads. Next, the consumption and power requirements for individual sectors were forecast using data collected from the service areas as part of the socio-economic survey.

The forecast of the residential demand was made using predictive equations derived from a regression analysis of demand as a function of various components of household income. Unfortunately, the linear regression was done incorrectly. Not only are the resulting coefficients illogical (e.g. a negative correlation between electricity consumption and total income) but the explanatory variables are themselves correlated (e.g. total household income and income by component, total expenditure and expenditure by component).[2] These equations were used to compute the base-year consumption. An annual rate of growth of 9% decreasing to 4.6% over the next 30 years was assumed for all provinces. The percentage of households connected was assumed to be 33% in the first year and to increase at 5.85% per year reaching 100% in the 13th year.[3]

The initial consumption in the commercial sector was estimated based on the average annual total cash income of the village shops. The predictive equations, which were of the form

$$E = a_1 + a_2 I$$

where I = average income/shop/year

were computed separately for each area of the country using linear regression and the data collected as part of the ARE.2 project. The percentage of hookups was not

2 This is a common error in which the pursuit of a high regression coefficient is substituted for a more careful examination of model rationale and a closer examination of the related regression statistics including the corrected R_2, the t statistic and the degree of auto correlation

3 While this relationship was derived from the ARE.2 survey data, it is not clear why a consistent calculation of household connections was not applied in the second and third forecasting methods

forecast separately and the annual growth in average consumption was assumed to be 3.5% per year for the first 20 years and 1.5% thereafter.

For rice mills, the rate of conversion from diesel engines to electrical motors was assumed to increase at a relatively constant rate reaching 100% after 30 years. The average consumption per rice mill was estimated assuming a 7.5 hp motor for 869 hr/yr. However, the comparison between electric and diesel rice mills on which this estimate was based, does not seem consistent.

For portable tools, portable water pumps and irrigation water pumps an average consumption per user was calculated to be 0.134 MW-hr, 0.136 MW- hr, and 0.448 MW-hr respectively. The percentage of households owning an electric power tool was assumed to increase from 1.5% at the end of the first year to 5% at the end of the 25th year. For portable water pumps, the number of users appear to have been computed based on the average number of pumps per household as measured in the ARE.2 survey. For irrigation pumps, the number of pumps was also determined on a per household basis from the ARE.2 survey. The rate of conversion from diesel to electric pumps was assumed to increase from 3% at the end of the first year to 18% at the end of the 30th year. The ARE.2 method is likely to underestimate the total demand because it does not allow for new activities and the initial household consumption appears to be relatively low.[4]

Comparison of Forecast Results

A comparison of the results from the three forecasting method[illegible] shown in Exhibit F.2 for three potential sites. The data indicate that the time series [illegible]thod produced estimates which were higher by a factor of 3 relative than the next highest forecasts which tended to be the ARE.1 forecasts. The fact that the time series data is based on consumption in a mature market explains the overestimates produced by this method.

The ARE.2 method produced the lowest estimates except for the residential sector in Nam Mae Hat. This is due in part to the relatively conservative growth rate in hookups and the limited rate of growth in ownership of equipment and machinery which could be electrified. The wide discrepancy between the results of these models and the weaknesses in the causal relationships used in these models suggests that significant improvements could be made. A review of the forecasting efforts of PEA and EGAT provide some insight into the direction which improvements could be made.

4 In the ARE.2 project paper, a 15 hp diesel engine operating 1,159 hours per year was compared with a 7.5 hp motor operating 875 hours per year

Exhibit F.2

Alternative Demand Forecasts, (GWh)

Site	Sector	Residential			Commercial			Total		
		1986	1992	2002	1986	1992	2002	1986	1992	2002
Nam Mae Hat	Time Series	0.45	0.78	1.57	0.52	0.96	2.04	1.09	1.93	3.93
	ARE.1	0.11	0.25	0.67	0.18	0.25	0.32	0.40	0.65	1.28
	ARE.2	0.16	0.41	0.96	0.05	0.07	0.11	0.27	0.59	0.13
Nam Mae Chon	Time Series	0.13	0.23	0.46	0.15	0.28	0.60	0.32	0.56	1.15
	ARE.1	0.03	0.07	0.20	0.05	0.06	0.09	0.11	0.18	0.35
	ARE.2	0.01	0.03	0.06	0.02	0.03	0.04	0.04	0.07	0.14
Huai Mae Suk	Time Series	0.09	0.16	0.33	0.11	0.20	0.43	0.23	0.41	0.82
	ARE.1	0.02	0.05	0.14	0.05	0.07	0.09	0.11	0.17	0.32
	ARE.2	0.01	0.04	0.08	0.01	0.02	0.03	0.04	0.08	0.17

EGAT and PEA Forecasting Efforts

EGAT produces load forecasts in which it incorporates the projections of PEA, MEA, and the large customers who purchase electricity together with its own macro modeling effort. Separate macro models have been developed for the five sectors, residential, industrial, commercial, street lighting and other. The expressions used are listed below.

Residential

$$\ln E = a_1 + a_2 \ln P + a_3 \ln N$$

where E = electricity consumption in the sector
P = price index for average rate (GDP deflator)
N = number of customers

Industrial, Commercial

$$\ln E = a_1 + a_2 \ln P + a_3 \ln N + a_4 \ln I$$

where I = Gross Domestic Product

Street Lighting

$$\ln E = a_1 + a_2 N$$

Others

$$E = a_1 + a_2 I + ER[t-1]$$

where ER[t-1] = residential energy demand lagged by one year

Clearly these formulas are more logical than those originally obtained from EGAT by project personnel. They require a separate forecast of growth in hookups and, at least in the case of industrial and commercial demand, they treat the elasticity with respect to price and with respect to income.

The PEA, on the other hand, appears to have adopted the earlier EGAT formulation using time series analysis and the predictive variables t and t^2. Five separate equations are used for the residential, small business, large business, small industrial and large industrial sectors.

While the EGAT and PEA methods may provide useful results for understanding system-wide energy requirements, they do not provide a useful approach for estimating demand for areas which are newly electrified.

Exhibit F.3

Appliance Ownership in Selected Locations

Surin		Nakhan Ratchsima		Khan Kaen	
94.7	Radio	96.4	Radio	95.3	Radio
0.8	Television	8.7	Television	3.7	Television
0.1	Telephone	0.4	Telephone	0.2	Telephone
1.0	Refrigerator	5.6	Refrigerator	2.5	Refrigerator
2.4	Electric-fan	12.1	Electric-fan	7.7	Electric-fan
0.7	Airconditioner	1.1	Airconditioner	0.7	Airconditioner
51.1	Bicycle	42.3	Bicycle	45.3	Bicycle
7.5	Motor-cycle	9.8	Motor-cycle	9.4	Motor-cycle
1.7	Motor-car	3.9	Motor-car	2.3	Motor-car
0.1	Motor-boat	0.3	Motor-boat	0.6	Motor-boat

Source: 1980 Population and Housing Census. National Statistical Office.

Conclusions

The project has made a start in developing a reasonable model for forecasting electricity demand in the early years of electrification. However a more careful analysis of the relationships involved and a better selection of predictive variables is required. A simplified measure of income, to include cash and in-kind income and a supporting measure of household wealth should be used for predicting both the initial values and rates of growth for hookups and the average energy consumption per hookup. Separate analyses of appliance ownership as a function of income and period of electrification and energy consumption as a function of appliance ownership should be prepared as a basis for designing demand forecasting models (see sample data in Exhibit F.3). These analyses could be combined using two-staged leased squares or be used to develop categories of use with the Box-Jenkins method.

Clearly a more careful research effort should be undertaken if this type of forecast is to be useful in evaluating isolated minihydro facilities and in setting priorities for PEA's planned extensions of the grid. In order to reduce the overhead costs associated with the planning for these projects, a directed marketing study involving discussions with village leaders and small electrical product review groups should be used to provide the basic data. Also a standard analysis procedure formulated for use on the micro-computer should be developed to reduce the time and effort required for evaluation of individual villages.

APPENDIX G: APPROACH TO ECONOMIC AND FINANCIAL ANALYSIS

The financial and economic analyses used in the site selection process were set out in some detail in the project paper. This procedure was then followed in the first round of site selection. In the second round, this procedure was simplified in recognition that most of the sites would be connected to the grid; however, the calculations performed were similar to those used in the first round.

This annex considers the methodology used for these analyses with a view to correcting certain conceptual problems. A general objective of developing a simplified procedure for financial and economic analysis is well worth pursuing considering the size and dispersed nature of the investments in micro-hydro and mini-hydro facilities. In order to achieve this objective, it is necessary to set out the basis for the economic and financial analyses used in project evaluation.

Tenets of Economic Analysis

Economic project evaluation provides a means for establishing if the resources used for a project could be better used in other activities. Although the frame of reference for the evaluation can vary, the viewpoint most frequently used is the national one. Therefore, the measure used to determine if one allocation of resources is better than another is the resulting change in the welfare of society.[1]

In practice, the process of economic project evaluation involves three steps. The first is to define what would happen if the project were not undertaken. The second is to determine the benefits achieved and costs incurred from undertaking a project rather than continuing on without the project. The third is to rank alternative projects according to their net benefits relative to the "no-project" scenario and then to select the project or projects which produce the greatest net benefits.

For electricity generation projects, the definition of the benefits depends on the definition of the "no-project" scenario. If the result of not undertaking the project is that the additional electricity would not be available, then the benefits of the project are determined by the willingness-to-pay of the final consumers who would otherwise not have access to electricity. If the result of not undertaking the project is that existing capacity would be more fully utilized to provide the additional electricity, then the benefits of the project are the savings in operating costs resulting from using the new facility rather than the existing system. If the result of not undertaking the project is

1 The measure of the welfare of society is itself based on the Pareto criterion which states that an activity is worthwhile if it makes at least one member of society better off in his own judgment and none worse off. For project analysis, this criteria is modified to the allow for a transfer of money between those who benefit from the project and those who incur a cost (loss of benefits) in order to meet the Pareto criteria even though this transfer may not occur. Thus, the criteria becomes that those better off from the investment would be willing to compensate those who are worse off as a result of the investment. Given this criterion, the willingness to pay of the gainers and the willingness to accept compensation of the losers are the measures which should be used to evaluate a project.

that the final consumers would provide their own capacity, then the benefits of the project are the savings in construction and operating costs which would be incurred by the consumers.

The evaluation of electricity generation projects frequently skips this first step and begins with a determination of the least-cost method of expanding the electricity generation system capacity to meet the project demand. Alternative methods of generation, different size facilities, and different sources of fuel are considered and their relative capital and operating costs are compared. After the least-cost alternative has been identified, then the evaluation returns to the first step and the issue of what would happen if additional capacity of this type were not provided is addressed. Normally it is assumed that without the project, the increase in electricity would not be available and therefore a simple estimate of the willingness-to-pay is produced by estimating the revenues from the additional electricity generated.

Tenets of Financial Analysis

The objective of the financial analysis is to identify projects in which the assets purchased are worth more than their cost. The worth of a project is measured in terms of the discounted flow of net revenues resulting from implementation of the project. The discounting is done using a discount rate which reflects the opportunity cost of capital to the investor.[2] This rate includes an allowance for inflation and for the riskiness of the project.

The normal approach is to discount the expected stream of incremental costs and revenues resulting from the project and then to sum these in order to determine the Net Present Value (NPV) of the project. When the NPV is positive, the project has a worth in excess of its costs. If alternative projects are being compared, then the project with the largest NPV is preferable.

When comparing projects using financial analysis, two additional factors should be considered. First, if there is a budget constraint, then the selection of projects must consider not only the respective NPV's but also the size of the required investments. Capital budgeting techniques can be used to select those projects which in combination will yield the highest NPV given a specific budget constraint. Second, if the source of financing and resulting cost of funds is different for individual projects, then this difference should be reflected in the rate used to discounted the revenues and costs.

Problems with the Economic Analysis

The economic analysis as applied in this project has several conceptual problems. In order to be more specific in identifying these problems and in presenting the correct

2 The expected rate of return on comparable investments

procedures for evaluating mini/micro hydro-power projects, we need to consider the differences between projects involving grid-connected mini-hydro, isolated mini-hydro, and isolated micro-hydro. The following discussion points out the major differences in the application of economic analysis for these three types of investments. The principal failing of the economic analysis performed for this project was that it did not differentiate between these three types of systems.

Grid-Connected Mini-Hydro

The project components, in their final form, were almost exclusively gridconnected mini-hydro facilities. The relevant "no-project" scenario for the economic analysis would be either the increased use of the existing system or the unavailability of electricity for a certain portion of the national demand. However, given the pattern of growth in demand and the relatively small size of the proposed facilities, it can be assumed that additional capacity would be provided. Therefore a comparison should be made with the construction of additional capacity based on a least-cost expansion plan which excludes mini/micro hydro. The economic cost for this alternative included both the long-run marginal costs for additional capacity plus the short-run marginal operating costs for the plant which would otherwise have been used.[3]

The determination of the long-run marginal cost depends on whether the facility is to be treated as a baseload or a peaking plant. There is a widespread belief in Thailand that the hydro-electric facilities are peaking units. These facilities units are being used for multiple purposes and are available only part of the time for electricity generation. They are used, whenever possible, to generate electricity during the broad period of high demand. If, however, the rule of economic dispatch were applied, the existing hydro-electric facilities would be treated as baseload capacity. Since the mini-hydro facilities being constructed for this project are not multiple-purpose units and do not have storage, they will be operated continuously. Therefore, they should be treated as baseload units. The long-run marginal cost for baseload generation capacity in Thailand was developed from EGAT data describing typical generating plants.[4] The amount of baseload capacity provided by these minihydro facilities is their dependable capacity. This is equal to the minimum amount available from the facility during the year.

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3 This approach has been introduced by TEAM consultants in the preparation of the National Mini hydro Master Plan. The use of the short run marginal costs for a single substitute plant is not entirely correct. The short run marginal cost should be estimated by comparing the total system costs of generating the required electricity when the system includes the mini/micro hydro facility and when it does not. Because this project is being undertaken by SEA rather then EGAT, the variation in total system costs could not be determined and a simpler approach was used.

4 The least cost expansion plans with and without mini hydro were not available. An estimated capital cost of 1[illegible].5 thousand Baht per installed kW, the economic cost for a thermal power plant using fuel oil as described in Exhibit A-10 was used for the long run marginal costs. A combined cycle plant using natural gas with economic capital cost of 13.5 thousand Baht per installed kW could have been used but this would presume a government policy to continue increasing the use of domestic supplies of natural gas for electricity generation.

The mini-hydro facilities generate more electricity than would be generated by a thermal plant with a capacity equal to the "dependable capacity". The additional amount of electricity would be produced by the existing system's baseload plants. The cost for this additional electricity includes the costs for fuel, operations and maintenance and transmission losses. In order to estimate the costs, the same fuel-oil thermal plant has been used that was used for the long-run marginal cost. This plant has a fuel consumption of 0.233 lit per kilowatt-hour. At a cost of 3.45 Baht/liter for fuel oil, the resulting fuel cost would be 0.804 Baht per kilowatt-hour.(see Exhibit A.8).[5]

The transmission losses could be determined by comparing the distance to the service area from the mini-hydro and from the nearest large power plant on the grid and the relative losses in the 22 kv distribution used at the mini-hydro sites versus the 230 kv distribution used in the grid. Because the output of the mini-hydro facility will be sold to EGAT at the busbar, therefore the analysis can be simplified by assuming that the losses in distribution are the same for any generating unit attached to the grid including the mini-hydro facilities.

The final format for the economic analysis of the grid-connected minihydro systems is presented in annex I together with the results. A slightly different format was developed by the TE-AM consultants as shown in Exhibit G.1. This analytical model, which is a considerable improvement over the methodology presented in the PP will be made available to NEA in the near future.

Isolated Systems

There are two types of isolated hydro-electric systems considered in this project, the mini-hydro facility serving several villages and the microhydro facility serving a single village or at most two adjoining villages. For isolated hydro-electric systems, the "no-project" scenario for the economic analysis can be one of the following:

a. the village(s) continue to use kerosene and batteries for lighting and appliances,

b. the village(s) introduce some form of auto-generation, presumably using diesel generators, or

c. the grid is extended to the village(s).

In the first case, the benefits of the hydro-electric facility are not only the cost savings

5 The use of this plant may cause a slight under-estimation of benefits since marginal baseload unit would probably have a higher fuel consumption rate

PROJECT NAME : Huai Khi II (2)
PROJECT NO. : 685
CASE STUDY : I
- Grid Extension

Exhibit G.1

HYDROPOWER PROJECT
==========

Installed Capacity = 3807 kW
Dependable Capacity = 571 kW
Annual Generated Energy = 18.982 GWh
Plant Factor = 0.569
Transmission Line :
- Extend to Grid 25 km Size 50 sq.mm
- Extend to Local Village 0 km Size 50 sq.mm
- Reconduct. to 120 sq.mm 0 km
- Reconduct. to 185 sq.mm 0 km

Disbursement of Construction Cost (Economic)

Cost in Million Baht

Year	1	2	3	4	Total
Civil Work	0.000	22.428	17.444	9.968	49.840
Electro-Mechanical	0.000	4.733	0.000	42.597	47.330
Transmission Line	0.000	0.000	0.000	3.970	3.970
Eng.Fee and Admin.	5.606	0.906	0.906	3.193	10.011
Total	5.606	28.067	18.350	59.728	111.151

Annual O&M Cost = 1.135 MB

GRID EXTENSION : a
==========

1.Thermal Plant
- Capacity Compared with : Lignite Thermal Plant
- Energy Compared with : Heavy Oil Thermal Plant
- Investment Cost = 25.493 MB/MW
- Energy Value = 0.5164 B/kWh (1987 Price)
- Power Required = 633 kW
- Firm Energy Required = 4.739 GWh
- Secondary Energy = 15.242 GWh

Economic Costs :
- Investment Cost = 16.137 MB
- O&M Cost of Plant = 0.484 MB/yr
- Fuel Cost for Energy Generation = 10.318 MB/yr
- O&M Cost of Secondary Energy = 0.762 MB/yr

2. Loss Save

	Power(kW)	Energy(GWh/yr)
- Loss in PEA's System	0.000	0.000
- Loss in EGAT's System	17.130	0.569
- Power Required for Loss	18.981	0.599

Economic Costs :
- Investment Cost = 0.484 MB
- O&M Cost of Plant = 0.015 MB/yr
- Fuel Cost for Energy Generation = 0.310 MB/yr (1987 Price)

3. Beneficial Villages
- No.of Beneficial Villages = 0
- Length of Transmission Line = 0 km

Economic Costs :
Cost of Transmission Line = 0.000 MB
O&M Cost = 0.000 MB/yr

Exhibit G.1 (continued)

DATA FORMAT FOR ECONOMIC EVALUATION
==========

PROJECT NAME : Huai Khi Ti (2)
PROJECT NO. : 685
AMPHOE : Thong Pha Phum
CHANGWAT : Kanchanaburi

HYDROPOWER PROJECT
==========

Installed Capacity	3897	kW
Dependable Capacity	571	kW
Annual Energy	18.982	Gwh/yr

Transmission Line :System Voltage	22 kV		
- Extend to Grid	25 km,	Size	50 sq.mm
- Extend to Local Villages	0 km,	Size	50 sq.mm
- Reconduct. to 120 sq.mm	0 km		
- Reconduct. to 185 sq.mm	0 km		

CONSTRUCTION COST (FINANCIAL COST)
==========

Cost in Million Baht

Year	1	2	3	4	Total
Civil Work	0.000	25.486	19.823	11.327	56.636
Electro-Mechanical	0.000	6.068	0.000	54.512	60.620
Transmission Line	0.000	0.000	0.000	4.841	4.841
Eng.Fee and Admin.	5.441	0.985	0.985	3.471	10.882
Total	5.441	32.539	20.808	74.251	133.039

Annual O&M Cost = 1.234 MB

	Capacity (MW)	Energy (GWh/yr)
Loss Save in PEA's System	0.0000	0.0000

Select Case Study = 1 (See Notes Below)

Note :
1 = Hooked to Grid
2 = Hooked to Grid and Served Unelectrified Villages
3 = Hooked to Grid and Replaced Diesel Plant
4 = Hooked to Grid ,Served Unelectrified Villages and Replaced diesel
5 = Served Unelectrified Villages
6 = Replaced Diesel Plant

UNELECTRIFIED VILLAGES
==========

- No.of Villages to Be Served = 0
- Transmission Line Length :
  Local Trans.Line = 0 km
  Grid to Local Tran.Line = 0 km

PROJECT NAME : Huai Khi Ti (2) AMPHOE : Thong Pha Phum
PROJECT NO. : 685 CHANGWAT : Kanchanaburi

Exhibit G.1 (continued)

Alternative Plant :- Power = Heavy Oil Thermal Plant
Energy = Heavy Oil Thermal Plant

Case Study = I
- Grid Extension

Year	Hydropower Invest.	Hydropower O&M	Hydropower Total	Alternative Plant Invest.	Alternative Plant O&M	Alternative Plant Fuel	Loss Save Inv.+O&M	Loss Save Fuel	Beneficial Villages Invest.	Beneficial Villages O&M	Replaced Diesel Inv.+O&M	Replaced Diesel Fuel	Total Combined Cost	Net Benefit
1	5.006		5.006											
2	28.067		28.067										0.000	-5.006
3	18.350		18.350										0.000	-28.067
4	59.728		59.728	9.780			0.293						0.000	-18.350
5	0.000	1.135	1.135	0.000	1.007	12.072	0.007	0.362					10.073	-49.655
6	0.000	1.135	1.135	0.000	1.007	12.457	0.007	0.374					13.448	12.313
7	0.000	1.135	1.135	0.000	1.007	12.855	0.007	0.386					13.845	12.710
8	0.000	1.135	1.135	0.000	1.007	13.265	0.007	0.398					14.254	13.119
9	0.000	1.135	1.135	0.000	1.007	14.245	0.007	0.427					14.677	13.542
10	0.000	1.135	1.135	0.000	1.007	15.298	0.007	0.459					15.687	14.552
11	0.000	1.135	1.135	0.000	1.007	16.428	0.007	0.493					16.771	15.636
12	0.000	1.135	1.135	0.000	1.007	17.643	0.007	0.529					17.935	16.800
13	0.000	1.135	1.135	0.000	1.007	18.946	0.007	0.568					19.186	18.051
14	0.000	1.135	1.135	0.000	1.007	19.854	0.007	0.596					20.529	19.394
15	0.000	1.135	1.135	0.000	1.007	20.805	0.007	0.624					21.463	20.328
16	0.000	1.135	1.135	0.000	1.007	21.801	0.007	0.654					22.443	21.308
17	0.000	1.135	1.135	0.000	1.007	22.846	0.007	0.685					23.469	22.334
18	0.000	1.135	1.135	0.000	1.007	23.940	0.007	0.718					24.545	23.410
19	0.000	1.135	1.135	0.000	1.007	25.087	0.007	0.753					25.672	24.537
20	0.000	1.135	1.135	0.000	1.007	26.288	0.007	0.789					26.853	25.718
21	0.000	1.135	1.135	0.000	1.007	27.548	0.007	0.826					28.091	26.956
22	0.000	1.135	1.135	0.000	1.007	28.867	0.007	0.866					29.388	28.253
23	0.000	1.135	1.135	0.000	1.007	30.250	0.007	0.907					30.747	29.612
24	0.000	1.135	1.135	0.000	1.007	31.699	0.007	0.951					32.171	31.036
25	0.000	1.135	1.135	0.000	1.007	33.217	0.007	0.997					33.664	32.529
26	0.000	1.135	1.135	0.000	1.007	34.808	0.007	1.044					35.228	34.093
27	0.000	1.135	1.135	0.000	1.007	36.476	0.007	1.094					36.866	35.731
28	0.000	1.135	1.135	0.000	1.007	38.223	0.007	1.147					38.584	37.449
29	0.000	1.135	1.135	0.000	1.007	40.054	0.007	1.202					40.383	39.248
30	0.000	1.135	1.135	0.000	1.007	41.972	0.007	1.259					42.269	41.134
31	0.000	1.135	1.135	0.000	1.007	43.983	0.007	1.319					44.245	43.110
32	0.000	1.135	1.135	0.000	1.007	46.089	0.007	1.383					46.316	45.181
33	0.000	1.135	1.135	0.000	1.007	48.297	0.007	1.449					48.486	47.351
34	0.000	1.135	1.135	0.000	1.007	50.611	0.007	1.518					50.760	49.625
SUM	111.151	34.050	145.201	9.780	30.198	825.924	0.513	24.778	0.000	0.000	0.000	0.000	891.192	745.991
NPV @	82.328	7.308	89.636	6.680	6.481	126.658	0.247	3.800	0.000	0.000	0.000	0.000	143.866	54.229

LEAST COST ALTERNATIVE AT 10% = HYDROPOWER PLANT
PRESENT WORTH OF NET BENEFIT (N) = 129.678 MB
PRESENT WORTH OF INVESTMENT (K) = 75.449 MB
(N)/(K) RATIO AT 10% = 1.719
(B)/(C) RATIO AT 10% = 1.605
INTERNAL RATE OF RETURN = 15.146%

PROJECT NAME : Huai Khi Ti (2) AMPHOE : Thong Pha Phum
PROJECT NO. : 685 CHANGWAT : Kanchanaburi

Exhibit G.1 (continued)

Alternative Plant :- Power = Lignite Thermal Plant Case Study = I
Energy = Heavy Oil Thermal Plant - Grid Extension

Year	Hydropower Invest.	Hydropower O&M	Hydropower Total	Alternative Plant Invest.	Alternative Plant O&M	Alternative Plant Fuel	Loss Save Inv.+O&M	Loss Save Fuel	Beneficial Villages Invest.	Beneficial Villages O&M	Replaced Diesel Inv.+O&M	Replaced Diesel Fuel	Total Combined Cost	Net Benefit
1	5.006		5.006										0.000	-5.006
2	28.067		28.067										0.000	-28.067
3	18.350		18.350										0.000	-18.350
4	59.728		59.728	16.137			0.484						16.621	-43.107
5	0.000	1.135	1.135	0.000	1.246	12.072	0.015	0.362					13.695	12.560
6	0.000	1.135	1.135	0.000	1.246	12.457	0.015	0.374					14.092	12.957
7	0.000	1.135	1.135	0.000	1.246	12.855	0.015	0.386					14.501	13.366
8	0.000	1.135	1.135	0.000	1.246	13.265	0.015	0.398					14.924	13.789
9	0.000	1.135	1.135	0.000	1.246	14.245	0.015	0.427					15.933	14.798
10	0.000	1.135	1.135	0.000	1.246	15.298	0.015	0.459					17.018	15.887
11	0.000	1.135	1.135	0.000	1.246	16.428	0.015	0.493					18.182	17.047
12	0.000	1.135	1.135	0.000	1.246	17.643	0.015	0.529					19.433	18.298
13	0.000	1.135	1.135	0.000	1.246	18.946	0.015	0.568					20.775	19.640
14	0.000	1.135	1.135	0.000	1.246	19.854	0.015	0.596					21.710	20.575
15	0.000	1.135	1.135	0.000	1.246	20.805	0.015	0.624					22.690	21.555
16	0.000	1.135	1.135	0.000	1.246	21.801	0.015	0.654					23.716	22.581
17	0.000	1.135	1.135	0.000	1.246	22.846	0.015	0.685					24.792	23.657
18	0.000	1.135	1.135	0.000	1.246	23.940	0.015	0.718					25.919	24.785
19	0.000	1.135	1.135	0.000	1.246	25.087	0.015	0.753					27.100	25.965
20	0.000	1.135	1.135	0.000	1.246	26.288	0.015	0.789					28.338	27.203
21	0.000	1.135	1.135	0.000	1.246	27.548	0.015	0.826					29.635	28.500
22	0.000	1.135	1.135	0.000	1.246	28.867	0.015	0.866					30.994	29.859
23	0.000	1.135	1.135	0.000	1.246	30.250	0.015	0.907					32.418	31.283
24	0.000	1.135	1.135	0.000	1.246	31.699	0.015	0.951					33.911	32.776
25	0.000	1.135	1.135	0.000	1.246	33.217	0.015	0.997					35.474	34.339
26	0.000	1.135	1.135	0.000	1.246	34.808	0.015	1.044					37.113	35.978
27	0.000	1.135	1.135	0.000	1.246	36.476	0.015	1.094					38.831	37.696
28	0.000	1.135	1.135	0.000	1.246	38.223	0.015	1.147					40.630	39.495
29	0.000	1.135	1.135	0.000	1.246	40.054	0.015	1.202					42.516	41.381
30	0.000	1.135	1.135	0.000	1.246	41.972	0.015	1.259					44.492	43.357
31	0.000	1.135	1.135	0.000	1.246	43.983	0.015	1.319					46.563	45.428
32	0.000	1.135	1.135	0.000	1.246	46.089	0.015	1.383					48.733	47.598
33	0.000	1.135	1.135	0.000	1.246	48.297	0.015	1.449					51.007	49.872
34	0.000	1.135	1.135	0.000	1.246	50.611	0.015	1.518					53.390	52.255
SUM	111.151	34.050	145.201	16.137	37.386	825.924	0.919	24.778	0.000	0.000	0.000	0.000	905.145	759.944
NPV @	82.328	7.308	89.636	11.022	8.024	126.658	0.424	3.800	0.000	0.000	0.000	0.000	149.927	60.29

LEAST COST ALTERNATIVE AT 10% = HYDROPOWER PLANT
PRESENT WORTH OF NET BENEFIT (N) = 131.267 MB
PRESENT WORTH OF INVESTMENT (K) = 70.976 MB
(N)/(K) RATIO AT 10% = 1.849
(B)/(C) RATIO AT 10% = 1.673
INTERNAL RATE OF RETURN = 15.948%

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from substitution of electricity for kerosene and batteries but also the benefits associated with:

a. an increased use of lighting and appliances and,

b. the new activities which are undertaken because of the availability of electricity.

While the cost savings can be estimated directly, the benefits from the new activities and from the increase in existing uses must be determined through a forecast of future consumption.

In the second case, the benefits are the lower costs of using mini-hydro rather than diesel generators to provide electricity to the consumer. If this lower cost is reflected in a lower average price per kilowatt hour, then there would be additional benefits due to the higher level of consumption. In order to estimate these benefits, separate forecasts of consumption would be required for the projected prices of the two alternatives.

Additional benefits would be realized because of the greater availability of electricity from the isolated hydro-electric systems. The proposed diesel generators would be relatively large units which would provide service to a number of villages through medium voltage distribution. Some similar, publicly-operated systems already exist in Thailand but these tend to be less than 0.5 MW with load factors of 20% or less. While it would be possible to have larger units operated by agencies such as NEA or PEA that would distribute power to several villages, 24 hours-per-day, a restricted period of operation is more likely given the absence of significant loads between 10 p.m. and 5 a.m. These facilities would have sufficient capacity and reliability to supply most light industrial and commercial uses. They would have an advantage in terms of capital cost because the generators could be sized for the expected demand and the capacity could be added to over time as demand increases.

In the third case, the benefits are the savings in costs of extending a transmission line to the villages and maintaining service for a relatively low level of demand.[6] The option of extending the grid requires more than calculations of economic costs for the extension of the grid. The marginal costs for generating the electricity and the change in transmission losses must also be determined. In addition, the benefits of electricity provided by the grid would be greater than for electricity provided from an isolated system because the former provides a more reliable supply and is able to handle industrial and peak loads at lower costs (because of the peaking units included in the national system). Also the grid provides 24-hour-per-day service, whereas the isolated systems cannot because of the marginal costs of operating during the late night and early morning period. Refrigeration loads could be introduced if electricity was provided from the grid.

6 There would be significant losses associated with "energizing" this extension to the system

The "no-project" scenario in which villages continue without electricity or with small household generators is the most difficult to analyze because it requires information on:

a. the current patterns of energy consumption,

b. new uses which would occur if electricity were introduced, and

c. the villagers' willingness-to-pay for electricity for different uses.

The first item is determined through rural energy use surveys. The latter two items require forecasts based on the results of the user survey and experience from other rural areas where electricity was introduced. This scenario must be considered because the two previous "no-project" scenarios involve some form of investment. Therefore, a comparison was being made between alternative investments. It is necessary to establish the economic viability of making any investment by comparing the proposed investment with a "no-project" scenario involving no investment.

The differences between the alternative forms of generation lead to a difference in the types of users which can be served and the amount of local resources used in the construction, operation and maintenance of the system. While it is possible to conceptualize diesel, mini-hydro and grid extensions which would provide the same level of service, one or more of the resulting systems would be inefficient. If each alternative provides a different level of service, then it is necessary to calculate the incremental benefits and costs associated with each. The demand forecasts should provide information not only on the future electricity consumption but also on the benefits which would be realized from electrification.

Isolated Mini-hydro Systems

The methodology presented in the PP for isolated mini-hydro facilities compared the costs and benefits of these facilities relative to those associated with a multiple-village diesel generating system operated by a public agency. There were four serious errors in the application of this approach.

The first error was that the proposed isolated mini-hydro facilities were designed with excess capacity. Since an isolated system cannot sell excess electricity to the grid, it should be sized to provide a "dependable" capacity throughout the year. The isolated systems are all run-of-the-river units so the period of low flow determines the dependable capacity. For example, the dependable capacity for Nam Mae Hat is 407 kW. Although the PP proposed a capacity of 440 kW, this figure was subsequently revised to 818 kW to take advantage of peak flows, even though it was to be an isolated system. This increase in capacity cannot be justified unless there are extremely large loads which occur only during the period of peak generation. A similar problem was experienced with the design of other isolated systems (see Exhibit G.2).

The second error is related to the excessive design capacities. It was assumed that all of the electricity which was generated could be sold, but no seasonal demands were identified that could have used the additional capacity during the high water season. This caused an overestimate of demand. Now that the plans have been changed to allow for grid connection at all sites, this problem has been eliminated and the first error is much less significant. However, the evaluation methodology should be revised to insure that the analysis of future isolated mini-hydro systems avoids these two problems.

Exhibit G.2

Comparison of Design and Dependable Power For Isolated Systems

Site	Design (kW)	Dependable (kW)	Percentage
Nam Mae Hat	817	407[7]	50%
Nam Mae Chon Luang	132	84	64%
Huai Mae Aep	79	57	72%
Nam Mae Usu	1,450	587	40%

The third error was caused by the assumption that the diesel generating system in the "no-project" scenario should be equivalent in size to the mini-hydro's peak generating capacity. Instead, the diesel plant should be designed to match the "dependable capacity" of the mini-hydro facility. In addition, the assumption that the diesel plant should be provided with a 100% backup capability is clearly not realistic. Supply reliability is accomplished by having multiple generators with a standby unit which can handle the load if one or two of the generators drops out.[8] As a result of this error, the diesel option had a capacity and capital cost which was 2.5 to 3.5 times greater than would be required to provide comparable service.

The fourth error was that the level of consumption was assumed unchanged for the isolated mini-hydro project and the diesel generator system. The operating regime for the two systems would be different as discussed above and, therefore, the level of consumption would differ. Also the price charged for electricity from the mini-hydro facility would, presumably, be lower leading to a higher level of consumption. Both of these factors would argue for an increase in the benefits to consumers with the investment in a mini-hydro facility rather than a diesel generating system.

7 More recent estimates for Nam Mae Hat indicate a dependable capacity of 606 kW, but the basis for this revision was not clear.

8 This is not to say that a reasonable backup is not required, in fact, the hydro facility should also have a backup capability. In both cases, a balance must be struck between level of reliability and the cost of the backup

Isolated Micro-Hydro

For micro-hydro projects, the "no-project" scenario was again assumed to involve the installation of a diesel generator or the extension of the grid. If an isolated micro-hydro facility is to be compared with these two alternatives, then it is necessary to consider the difference in benefits of introducing electricity to the service area using the three alternatives.

Micro-hydro facilities are, per force, stand-alone units. They are constructed by a public agency but with a significant input of local labor and resources. Because of their size, they are operated collectively by the villagers rather than by a public utility. They can be operated more hours per day with greater reliability than a diesel generator while remaining financially viable. They tend to be larger capacity systems but are limited to serving household needs and light commercial and industrial loads. They cannot be used for refrigeration since the cost of labor is too great to permit round-the-clock operation. This type of facility has a large initial cost and requires a large base load from the time it is brought on-line if it is to be financially viable. The generating capacity of these systems can be expanded over time but only if the civil works have been designed to accommodate this expansion.[9]

Village-level diesel units would probably operate for 4 to 6 hours a day because of the higher cost of labor and fuel. They tend to be smaller generating sets limited to serving only household needs and light commercial loads. Such a village-level unit was observed in one of the villages within the Nam Mae Hat service area, but most villages that have autogeneration are limited to small diesel or gasoline generators which serve only a few houses during the night time.

Alternatives Not Considered

Another problem with the economic analysis performed for this project was the limited number of options considered for each site. The economic analysis compared the mini-hydro with a full-scale diesel system or a grid extension, but this all-or-nothing approach leads to an artificial limitation on system design. In fact, there are a range of options. A logical option for the diesel generator plants would be to initially install a smaller unit sized to the expected level of demand over the first five years of operation. At the end of the economic (though not necessarily physical) life of the diesel engine, it would be possible to replace this unit with a larger generating plant. Alternatively, complementary generating units could be introduced as new service areas are opened up. It would also be possible to replace the diesel generating system with a mini-hydro facility or with connection to the grid after the consumer base had been established

9 Such a system would generally have the civil works including weir, headrace, penstock, powerhouse and tailrace designed for the full capacity but the generators and turbines would be installed as the demand required. Here the decision to purchase the generators and turbines in stages would have to be justified in terms of the savings from delaying capital investment relative to the higher costs incurred through separate contracts for each turbine-generator set.

using the diesel generator and after the villagers had become familiar with the various uses of electricity. This would insure a higher level of benefits once the hydro-electric facility was installed. Considering that the time required for design and construction of a mini-hydro facility involves several years, the option of building up demand through a diesel system would appear attractive.

The all-or-nothing option also leads to an overestimate of the costs for the grid extension. Although the cost for transmission lines would be incurred initially, the introduction of additional generating capacity and the installation of the step-down transformers could be done over time as the demand builds up.

Finally, the all-or-nothing approach ignores the marginal costs and benefits of constructing a mini-hydro system which will be connected to the grid. Many of these systems include the construction of power lines from the hydro facility to un-electrified villages as well as from the facility to the grid. From an economic viewpoint, these projects should be analyzed as two separate projects. The first is the addition of the mini-hydro facility to the national generation system. The second is the extension of the grid to the un-electrified villages. The first project would be evaluated relative to the cost for alternative forms of power generation used in the national system. The second project would be evaluated relative to the cost of installing and operating village-level generation systems.

Shadow Pricing

The shadow prices introduced by the consultants were determined using

standard conversion factors provided by the Mekong Committee. These factors were meant to account both for taxes and subsidies and for market distortions. The resulting numbers are on the order of 0.76, considerably lower than those determined in an earlier study[10] which had factors closer to 0.88 as shown in Exhibit G.3. Because this project makes very little use of rural labor, and since most of the civil works use local materials, it is not be reasonable to use such low conversion factors. Assuming that local inputs account for about 40% of the project costs and the remainder are imported, a median conversion factor of 0.82 was selected.

10 "Shadow Prices for Economic Appraisal of Projects: An Application to Thailand", IBRD Working Paper 609. Sadiq Ahmed, 1983.

Exhibit G.3

Standard Conversion Factors

Mekong Committee		IBRD Working Paper	
civil works	0.74	construction	
transmission line	0.74	-public utilities	0.92
electrical equip	0.77	- general	0.88
O & M	0.79	- machinery	0.85
		imported capital goods	0.83

Problems with the Financial Analysis

The problems with the financial analysis are less complex, since the benefits are limited to the revenues from sale of the electricity. The financial analysis performed as part of the site evaluation did have a major weakness. The consultants appear to have confused financial analysis with cash flow analysis. The latter involves calculating the net income for each year after allowing for direct operating expenses, debt service and taxes. This analysis is generally used to determine the ability of the borrower to meet the debt service and to calculate the loans required to meet operating expenses during the period of construction and the first few years of operation. The financial analysis, on the other hand, determines whether the project is a good investment relative to other available alternatives. To answer this question, the discounted costs and revenues must be compared.

For the financial analysis, the costs and benefits are reported in the year they are incurred. The method recommended in the PP and applied by the consultants did not use this approach. Instead they capital costs were amortized over the life of the expected loan using the rate of interest for the USAID loan. This procedure distorts the flow of costs and produces an over-estimate of the net present value of the project. It will also produce an incorrect value of the internal rate of return.[11] The rate of return will be lower if the actual IRR is below the rate of interest and higher if the actual IRR is above this rate of interest.

11 To see this one need only consider the million situation in which a project involves a first year capital cost of $1 million and a total income of $1.2 million received in the following year. Clearly the internal rate of return is 20%, however, if the capital cost is amortized over 20 years at a 10% rate of interest then the internal rate of return on the cash flow will be 12.8%.

Sensitivity Analysis

The economic analysis as presented in the project report failed to consider the sensitivity of project viability to changes in costs, primarily those for fuel and capital.

The capital costs estimates for the first round sites were off by about 50% (see Annex C) due to delays in construction and the rapid rate of inflation in the intervening period. In the second round, the cost estimates proved to be much closer to the final costs. This was due to a decline in the costs of civil works caused by competitive pressures in the industry and to the short time which elapsed between the preparation of the estimates and the start of construction. It is important to consider the effects on project feasibility of changes in construction costs of at least ±25%. This range allows for the potential inaccuracies in preliminary site surveys as well as the variation in unit costs due to changes in the supply and demand for contracting in the country.

The sensitivity of project viability to fluctuations in fuel prices was ignored despite the fact that at the beginning of the project there was a widespread expectation that petroleum prices would continue to escalate in real terms. In fact, by the end of the project, the real price had fallen by nearly 50%. While it is not clear that the magnitude or direction of the change in prices could have been predicted, an awareness of the sensitivity of the project's feasibility to changes in fuel prices should have been established. An assessment of this risk could then have been included in the decision regarding the priority to be given to the project.

Since the economic evaluation of the project was based on the Net Present Value of the costs for alternative electricity supply schemes, it is important to perform a sensitivity test on the discount rate. In the first round, a 12% discount rate was used, but no sensitivity test was performed and no attempt was made to confirm that this was an appropriate rate. In the second round, a sensitivity test on the discount rate was performed. This test indicated that the non-hydro options were preferable at higher discount rates, because of the high initial costs for mini-hydro relative to diesel generators or extension of the grid.

The financial analysis performed for the mini/micro hydro project failed to consider the sensitivity of project viability either to capital costs or to the electricity tariff rate. For grid-connected mini-hydro, the buyback rate for electricity is set by EGAT at a rate equal to that charged PEA for supplying electricity to the grid. This rate has declined steadily in real terms and was reduced by 24% in nominal terms in early June 1987.

For isolated mini-hydro facilities, the setting of the tariff would not be constrained by EGAT or PEA rates. However, the NEA proposes to use a uniform rate for all projects even where the cost of alternative sources of energy is much higher. In fact, the cost of lighting using kerosene is considerably higher than the charge levied for the use of 40w fluorescent lamps. In those villages visited by the evaluation team which were supplied

by existing micro-hydro facilities or diesel-generator units, the average price for electricity was considerably higher than the PEA tariffs on a per kilowatt-hour basis.[12]

For the cash flow analysis conducted as part of the project, sensitivity tests were performed on the discount rate and tariff. However, these tests were limited. For the discount rate, two separate cash flow statements were prepared assuming a USAID loan and a normal commercial loan. For the tariff rate, the results of the USAID loan calculation were computed separately for tariffs of 1.46 and 10.6 Baht/kW-hr.

Revision of the Financial/Economic Analysis

The problems associated with the economic, financial and cash-flow analysis are relatively easy to fix. The evaluation procedure as used by NEA and TEAM could be revised to produce separate procedures for microhydro projects and for isolated mini-hydro projects.[13] A further revision would be required where the project is being undertaken by a utility rather than an organization which would sell power to the utility. The correct use of cash flow and financial analysis is a simple procedural adjustment. On the other hand, correct shadow pricing and the proper use of sensitivity analysis requires more thought.

The correct procedure for estimating the benefits resulting from alternative investments would also require greater effort. However, it should be possible to introduce a rough calculation of the benefits associated with the introduction of different sources of electricity into a village. The ARE.2 Project provides some guidance on how to estimate such benefits although some of the assumptions used in their analysis are questionable.

The major problem that has to be overcome in the application of the financial and economic analysis is one of substance rather than form. The financial and economic analysis has been used in this project (as in most projects) to accept or reject a certain type of investment. Clearly, the limitations of the project scope argue for this approach. However, to the extent that the site selection model is used to determine if a mini-hydro facility would provide the most economically efficient source of electricity, it should also be able to identify the most economically efficient alternative. In a situation where the executing agent has greater latitude in its investments, this model could then serve as a useful planning tool for screening alternative investments. The issue of identification of logical alternative investments is one that can be resolved by applying a broader spectrum of technical skills.

12 For a discussion of these villages see Annex B

13 The development of a proper methodology has already begun with the effort performed by TEAM.

Revised Financial and Economic Evaluation

For this review, we have revised the financial and economic analysis by taking into account some of the previous comments and by updating the information regarding the costs and benefits of the project components. A summary of this analysis is presented in Exhibit G.4. A more detailed presentation is given in Annex I along with a discussion of the results.

Exhibit G.4

Results of Revised Economic and Financial Analysis

	Financial Analysis			Economic Analysis		
	IRR %	NPV 10^6 Baht	B/C	IRR %	NPV 10^6 Baht	B/C
Nam Mae Hat	7.1	(3.6)	0.94	11.8	(.5)	0.99
Khlong Lam Plok	8.4	1.8	1.03	11.1	(2.5)	0.94
Huai Lam Sin	10.4	7.6	1.19	14.9	5.0	1.16
Khlong Duson	9.1	3.5	1.08	11.6	(0.7)	0.98
Nam Kha Mun	5.3	(8.8)	0.81	7.5	(8.5)	0.75
Lam Pra Plerng	2.7	(12.0)	0.66	11.8	(0.2)	0.99

APPENDIX H: ENVIRONMENTAL IMPACT OF MINI-HYDROPOWER IN THAILAND

General Development Strategy

Of special concern in rural areas of Thailand is the early establishment of productive land use which is sustainable and non-exploitative of the natural resource base (soil, water, forests, fish, wildlife, etc.). In certain areas, local development should be based on agriculture, while in others, resources make them most suited for forestry or mining. However, inadequate consideration of an appropriate development strategy could, in the long term, cause problems that would negate many of the benefits of rural electrification.

There is a common tendency in many developing countries to colonize forested hinterlands and to expand the agricultural frontier in order to improve economic conditions and reduce rural-to-urban migrations. When neither adequate analysis is made of the potential productivity of these areas nor appropriate orientation given to the colonization process, the new frontier frequently turn into degraded and eroding wastelands that take their toll on small farmers. In their wake, it is normal to find depleted forests, fish, and wildlife (upon which the colonists have had to subsist) and perhaps the initiation of watershed imbalance that will likely get worse if land use practices do not improve.

Rural electrification can play a decisive role in the promotion or deterrence, success or failure, of a rural village. Land use capabilities and general resource potential must be determined on a reconnaissance level for those areas where development is desired. In Thailand, some areas are rich agricultural and/or forest resource areas and should be opened up. Others are too steep with poor soils or too wet, and should best be kept in protected forests. Many of the minihydro sites are located in these marginal areas.

For all sites, the availability of adequate year-round stream flows to ensure efficient and reliable hydroelectric power generation is a fundamental criterion that must be satisfied at the prefeasibility stage. Ideally, recent, accurate records of stream flow and sediment discharges for a minimum 2-3 year period (preferably longer) should be available in order to determine the appropriate size and type of turbines and to predict the daily and seasonal supply of water for generation of electricity. Stream flow and sediment recording installations, suitable to the conditions of each particular site, should be installed as early as possible for all sites that are being considered. In Thailand however, at many of the data sites being developed, little stream flow is available and often unit hydrographs for larger catchment areas are used.

Ideally,eve effort should be made at the prefeasibility stage to identify all existing or potential public and private water users (including minimum flows necessary to support

fish and other aquatic organisms) that affect flows in the stream. The location of all water intakes and discharges in the affected area, as well as the respective flow rates and nature of the effluents, should be determined also. At the sites, the team visited, no other competitive uses for the water exist.

If a protected river or area (for example, a national park, forest reserve, wildlife preserve, sanctuary, or refuge) is threatened by construction of a mini-hydro plant, it may be legally impossible or inadvisable to develop at that site, whatever the projected benefits. Two of the sites currently under construction are in such protected areas, Nam Mae Hat and Nam Kha Mun. As early as possible in the planning and development, it is important that natural resource management agencies be in agreement with the project and provide lands for the project site and road rights-of-way. For certain projects, a protection watershed may need to be established and the local or national government may have to provide these areas.

Potential Impacts

This section deals with environmental considerations that should be taken into account during the feasibility study. On a global basis, mini-hydro plants will encompass a wide range of facility designs and environmental settings. For example, the basic criterion of a mini-hydro plant in Thailand is a generation capacity up to 6,000 kW. This can be satisfied by either high head/low flow or low head/high flow installations. The environmental impacts for these two designs are likely to be quite different. Five of the six sites visited by the team are in the high head category, with Lam Pra Plerng being the exception.

Similarly, the creation of a reservoir to store water for reliable, year-round generation is only required at Lam Pra Plerng and not at the other sites. This single factor is of fundamental importance to the assessment of environmental effects, since impoundment of water can result in a number of physical, chemical, and biological changes in the stream that will not occur if a run-of-the-river design is used. However, impacts associated with impoundments have already occured at Lam Pra Plerng since the dam was built in the 1960s.

The magnitude of environmental impacts is generally related to the size of the facility. That is, a 100 kW facility is likely to cause fewer problems than a 1,000 kW facility, simply because the amounts of construction material, watershed disturbance grading, and diverted water are less for the smaller facility. Of equal importance, however, is the amount of water diverted relative to the total flow in the stream. A 100 kW plant may have a greater impact if it withdraws a proportionately larger amount of the flow from a small stream than a 1000 Kw plant located on a large river. The significance of environmental impacts can vary seasonally; a 100 kW plant may have little adverse impact during high stream flows in the rainy season but may represent a significant stress to the aquatic system during times of low flow. These variable conditions must be

considered during the conduct of the feasibility study in order to arrive at a reliable evaluation of environmental impact.

The following are the basic impacts the planner must consider during the feasibility study process.

Flow Disruption:

All mini-hydro installation will cause a disruption of the natural stream flow. Depending on facility design, the amount of runoff available, and the extent of groundwater recharge, the impact may involve a complete stoppage of flow for a certain distance downstream to the powerhouse where the flow is returned to the stream. In fact, this is the situation at several of the sites the team visited, particularly during periods of low flow.

Operation and design factors have a mjaor influence on the extent of flow disruption. The potential for flow regulation is greatest for mini-hydro plants that utilize mainstem impoundments for water storage, since down stream flow may be curtailed on a daily or seasonal basis as the reservoir is filled. However, this is not the case in Thailand since most mini-hydro plants are run-of-the-river, have no water storage reservoir, and return diverted water to the same stream at a lower elevation. There is no net gain or loss of water with this type of installation, and the only stretch of river affected by reduced flow is the reach between weir and powerhouse.

Site-specific topographical features can also modify flow disruption impacts. For example, substantial groundwater recharge and/or tributary inflows downstream from an impoundment can reduce the potential adverse impacts of flow cessation. In general, flow disruption impacts will be greater for drier regions or smaller streams and less for wetter climates or large streams.

Sedimentation:

The sediment discharge of a watershed basin is related to several factors, including climate and geology. Proper land use is of utmost importance in maintaining erosion rates as close to their natural geologic rates as possible. When improper land use occurs, especially the deforestation of steep lands and subsequent establishment of grazing or agriculture, erosion rates are generally accelerated and sediment transport in the stream is generally increased.

Sedimentation impacts are important from two points of view. High suspended sediment loads in the stream can affect operation and maintenance of the turbine and the raceway (i.e., sediments cause turbine pitting and accelerated wear). Second, sediment loads resulting from project construction and operation can have adverse impacts on the aquatic system.

Turbines are subject to excessive wear and pitting when coarse-grained sediment is entrained in the water. In general, it is most desirable to maintain as high a physical water quality as possible. This can be attained by proper watershed management and strict control of project construction impacts (road building, excauation, etc.). Information on sediment loads should be an important criterion for both feasibility determination and the design of the engineering structures, however, this information was not available for the sites in this project.

Sediment transport affects both the physical characteristics of water quality and the biotic community in the stream. Where impoundment or decreased water velocities occur, sediment loads will drop out and fill up engineering structures (irrigation canals, reservoirs), thereby increasing maintenance costs or decreasing their useful life. For this reason, all the plants in this project have adequate sediment removal provisions through design and periodic maintenance.

Sedimentation can have adverse impacts on aquatic organisms by burying rock or gravel fish-spawning areas, and smothering clams, mussels, other bottom-dwelling organisms, fish eggs, and rooted aquatic plants. By changing the texture and composition of the substrate, sedimentation will cause a shift in the composition, abundance, and distribution of aquatic biota, generally in a negative manner. The severity of these impacts are modified by (1) the amount and rate of sediment transport, (2) the velocity, turbulence, and flow rates of the stream, and (3) the frequency and magnitude of naturally occurring erosion and sediment deposition.

However, at all the sites visited, it appears that sediment transport is not a severe problem because the watersheds are well covered with vegetation. Only during the rainy season (June-September) does sedimentation pose a threat. As mentioned above, the hydraulic structures in the projects are designed to remove a major portion of the sediment.

Alternative Water Uses:

Since the operation of a run-of-the-river, no-impoundment mini-hydro plant does not consume water or significantly alter its quality, the major impact with regard to alternate water uses will result from the fact that water is temporarily diverted from the stream. This raises the possibility that other users which withdraw water from that section of the stream will not obtain adequate quantities during all or part of the year. The affected section could serve as a source of water for irrigation, human and livestock consumption. However, the distances that water is diverted from the stream is minimal and in all cases. At the plants the team visited there were no other uses between the intake and tailrace, so this is not an issue.

Under certain circumstances, groundwater resources can be depleted by such diversion. Where diversion occurs from an effluent stream (one that is above the water table and therefore contributes to groundwater supplies) it is likely that groundwater recharge

will be diminished in that stream reach between the points of diversion and discharge. This could affect water availability in wells and in the stream channel. The team could not determine if such circumstances exist at the project sites.

Flood Control:

A small hydro plant which temporarily diverts a portion of streamflow for power production can be expected to have little or no effect on either diminishing or increasing the quantity of flood flows. The plant however, must be designed to withstand floods.

Water Quality:

Operation of run-of-the-river, non-impoundment minihydro facilities will have little or no effect on water quality. Such water quality paramenters as temperature and concentrations of dissolved gases and minerals will not be altered by diversion and passage through the penstock and turbines. While turbidity and suspended solids levels in the diverted waters may be reduced in those plant designs which incorporate sand and sediment traps, in most cases this will not have a negative impact on receiving waters.

Direct water quality impacts could occur, however, at those sites whose designs include creation of a substantial impoundment of water above the intake structure. Most of the plants in this project have a weir and the impoundment will tend to be small, without the problems of thermal stratification and anoxic benthic conditions associated with large reservoirs.

Impacts to Aquatic Organisms:

There are impacts to aquatic organisms that should be considered when evaluating the feasibility of a site. Some impacts, such as turbine-related fish mortality can be a potential problem. Interference with upstream migration of fish is generally of concern when water is impounded for a store-and-release type of operation. Upstream fish migration is not an issue at the sites under consideration in Thailand.

Turbine mortality occurs when organisms are carried into the intake structure along with diverted water and pass through the turbines before being discharged back into the receiving stream. These organisms, including drifting aquatic insects, zooplankton, and fish eggs, larvae, and juveniles, are subjected to sudden and extreme pressure changes, turbulence, shear forces, abrasion against the walls of the penstock and contact with the turbine blades.

Organisms which are too large to pass through the intake debris screen, yet cannot avoid the flow, may be trapped against the screen in a process called impingement. These animals, commonly downstream-migrating fish, eventually suffer mortality due to asphyxiation and physical damage if not removed or by passed.

Temporary diversion or impoundment of water for hydroelectric power generation results in decreased flow in that portion of the river downstream from the intake structure and upstream of the turbine discharge. Under low streamflow conditions, this can result in a significant decline in the natural flow available to support fish and bottom-dwelling animals in that stretch of river. In extreme cases the river may dry up due to complete diversion or impoundment for power generation, resulting in a loss of these bottom organisms and a potential blockage for upstream and downstream migration fish.

Maintenance dredging, to remove sediment deposits from the sand trap and the area around the intake structure, may result in temporary increases in suspended material and turbidity, low dissolved oxygen, high concentration of dissolved minerals and toxic contaminants. If dredged material is allowed to enter the receiving stream, silt and sand deposition and the alteration of substrate and bottom habitat will result. However, the design of the intake structures are such that little maintenance dredging should be required. They are essentially selfcleaning.

Waterborne Diseases and Parasites:

As with water quality impacts, the operation of mini-hydropower facility per se is not expected to affect the transmission of waterborne diseases. Although the self-purifying capacity of water moving quickly in a non-turbulent flow through a headrace and penstock may be reduced relative to movement of that same parcel of water over the natural streambed, this factor will probably not be significant in most cases. The impoundment of water in a hydro-electric reservoir could enhance survival of disease organisms, since those factors which are critical to self-purification of water in a stream (turbulence, sunlight penetration, oxygenation) are reduced or eliminated in a reservoir. Finally, water impoundments provide increased habitat for mosquitoes (which are vectors of such diseases as malaria, encephalitis, yellow fever, and dengue) and snails (which are alternate hosts of animal and human parasites such as schistosomiasis). However, at these sites, the amount of impounded water will be limited to that behind the weir and therefore these consequences should not occur.

Construction Impacts:

The effects of minihydro construction on the aquatic environment fall into two categories: (1) turbidity and sedimentation, and (2) water quality degradation. Construction of a road to provide access to the site, dams for water impoundments, and on-site construction of the various components of the facility, will result in the

disturbance and movement of erodible soils. Unless mitigative measures are taken, such as the construction of dikes to retain stormwater runoff, this soil will eventually be washed into the streams. The effects of the resultant increases in turbidity, suspended solids, and sedimentation on aquatic organisms have been described.

In addition, oils, greases, and chemical wastes from the construction of the concrete canals and turbine building may be carried into the streams and seriously degrade water quality, especially under low flow conditions. The toxic effects of these chemical wastes would cause stress or death to aquatic animals.

Road construction providing access to the site is normally responsible for much more earth movement and disturbance than site preparation activities. The magnitude of the siltation impact, which will principally effect stream hydrology and aquatic communities, can be reduced by sound engineering practices of road construction. When properly constructed and stabilized, a road may cease to produce significant amounts of sediment in a short time period (2-5 years) At the sites the team visited, all the above negative impact were evident. Planning in this area was not well carried out and some negative conequences could have been avoided. Perhaps the biggest problem was construction of the access road.

The passage of transmission lines between facility and points of energy consumption may give rise to a series of impacts relating to both land use and wildlife resources. The establishment and operation of transmission lines requires the clearing and maintenance of relatively vegetation-free corridors, resulting in exclusion of alternative land uses that would be incompatible with transmission line uses. Such devegetation and land use restrictions may imply limited but nonetheless significant impacts under certain circumstances. However, the lines going to these sites are only 22 kV on concrete poles. No serious negative impacts are envisioned.

Potentially, the most detrimental long-term impact of road and mini-hydro construction, is the opening up of forest protection and critical watershed areas to spontaneous human colonization. For example, a common experience in water resource development projects has been that colonization has resulted in erosion and torrential flooding. Spontaneous colonization of marginal protection areas produces innumerable impacts on soil, water, forest and wildlife resources, both on-site and downstream. However, in the areas where these plants are located the hydro units serve existing villages. Development has already taken place and appearsto have stabled.

Land Use and Development:

Proper land use in the watershed is critical to the avoidance of a complex series of impacts that could far outweigh the total direct impacts of mini-hydro construction and operation. These long-term impacts, which basically have to do with improper land use and deforestation of steep uplands and watershed degradation, will lead to erosion and sediment discharges, torrential flow regimes, and decreased dry season base flows.

These impacts will have negative effects on plant operation and maintenance costs and will thereby affect the mini-hydro's useful life.

The promotion of proper land use in the project area is an activity that offers multiple opportunities for benefits. Potable water supplies, recreation areas, forest reserves with certain restricted possibilities of wood product extraction, and other compatible uses could be promoted so that the community appreciates and takes advantage of environmentally-sound multiple use possibilities. It is extremely important that the community develop both (1) an understanding of the relationships between proper land use and the maintenance of good water quality, quantity and timing, and (2) a feeling of responsibility toward the management and protection of "their own watershed."

Nutrient and Sediment Trapping:

Small hydropower facilities with reservoirs are sediment and nutrient traps. However, the sites we are considering, do not have water storage since they are run-of-river facilities.

Aquatic Weeds and Eutrophication:

This problem is also associated with impounded water and trapped nutrients in sediments. The team does not envision such problems developing at the sites which they visited.

Wildlife Impacts:

Mini-hydro installations will also have some impacts on terrestrial habitats and wildlife, although these effects have been less well studied than aquatic impacts. Construction and maintenance will involve some land disturbance through clearing for access roads, transmission lines, and on-site structures. The resultant alteration in vegetation and habitat may have negative or positive impacts on wildlife, depending on the particular site. For example, site clearing may be detrimental to wildlife by eliminating critical habitat, whereas in other cases it may be beneficial by creating greater habitat diversity in homogeneous environments. Construction noise and activities may interfere with nesting activities of birds or migratory movements of terrestrial animals.

Secondary Impacts:

In addition to the primary, direct impacts on environmental resources that have been discussed in previous section, the provision of electricity to rural areas is likely to have a number of secondary effects. For example, establishment of new roads, small industries, irrigation capabilities, and immigration into undeveloped areas are all

potential social benefits derived from rural electrification which could, in themselves, have effects on the environment of greater magnitude than the mini-hydro facilities per se.

The development of the mini-hydro plants will impose restrictions upon land use at the construction site and ideally also in the catchment area above the intake structure, i.e., watershed protection. On the other hand, it will create resource opportunities (hunting, recreation, alternative water supply uses), the extent of which depends upon the manner in which the area of influence of the project is managed.

Secondary impacts of rural electrification may have great significance to aquatic resources in the project area. Regional developments following electrification could include increases in the human population (either by promoting immigration or stemming emigration), agricultural (irrigation) activities, livestock production, and industries, any of which could have important consequences to the water and land use patterns in the region. Population increases in the regions served by electricity will create a greater demand for potable and/or irrigation water and water treatment. Small communities that presently have no drinking or waste water treatment facilities may encounter increasing problems with wateborne diseases as the population increases and the ability of the environment to assimilate their wastes decreases.

Irreversible and Irreparable Impacts:

Irreversible and irreparable impacts will occur most commonly when mini-hydro development involves impoundment of water. Irreversible commitment of soil resources will result from impoundment and consequent flooding of river valley bottoms. Depending on the site, geological, archaeological, historical, and cultural resources may also be lost to flooding. In addition, the creation of an impoundment will normally result in s ltation in the reservoir and an irreversible alteration in the topography of the valley bottom.

Construction of mini-hydro plants without impoundments will normally not result in irreversible or irreparable commitments of resources except in cases of alteration of unique waterfalls or wild rivers. With adequate planning and project designs, these impacts can usually be avoided or minimized.

Again, the sites which being constructed in Thailand, have no irreversible impacts because they are small and run-of-river.

Checklist of Environmental Information

This section describes the types of potential environmental impacts that should be considered when evaluating the feasibility of mini-hydro site for development. The checklist in this section provides suggestions for the types of information that should be

collected and analyzed in order to assess the relative significance of these impacts at a given site. Most of the necessary information is at the reconnaissance level, that is, it can usually be obtained quickly by examining existing maps, reports, and publications. The items requested by the checklist are intended to represent a broad spectrum of information needed to cover a wide range of potential sites and environmental settings.

(1) Are topographical maps available (1:25,000 if possible) which show the location of the facility components and, if a water impoundment is planned, the bathymetry of the future reservoir?

(2) Are low-level aerial photographs of the site and watershed available?

(3) Are stream flow data available for a number of years in order to ensure both the maintenance of minimum flows in the stream and reliability of mini-hydro operation?

(4) What rainfall data exist for the study area? Do rainfall intensity values also exist?

(5) How much water will be withdrawn for mini-hydro operation and where will the intake and discharge structures be located?

(6) If a water storage impoundment is part of the project design, what will be the timing of reservoir releases on a daily basis? Seasonal basis?

(7) What are the alternative water uses in the area, the location of all water intakes or discharges in the affected areas, and determine flow rates and nature of effluents.

(8) Are there important wetlands that could be affected (for example, drained or filled with sediment) by construction and operaton of the plant?

(9) Are there important alluvial floodplains that will no longer be seasonally flooded due to reservoir flow regulations?

(10) What other water bodies (lakes, reservoirs, etc.) are associated with the surface waters of the study area? What special geologic (geomorphologic or tectolinear) relationships might exist between these?

(11) According to the Life Zones (Ecological) map of the country, what Life Zones occur in the watershed under study? What runoff distribution could naturally be expected from each Life Zone (or other appropriate ecological classificaton unit) according to water balance estimations? How many effectively dry months are there in each water year?

(12) Is there a map of actual land use for the area? What are the predominant land uses? If not, can the information be obtained from aerial photographs or field reconnaisance?

(13) Are there land use capability or land use potential maps developed for the general study area? What resource use potentials exist for the watershed of concern?

(14) What land use and watershed protection plans can be developed in order to minimize adverse secondary impacts?

(15) Are there any important soil, geological, historical, cultural, or archaeological resources that will be lost by site construction? Access road construction? Transmission line construction? Impoundment?

(16) Is the site near a protected area (preserve, sanctuary, refuge dedicated area) that may require special consideration?

(17) Are stream waters near the site used for fish spawning, nursery, or feeding areas, or as fish migration routes?

(18) Are any rare, endangered, or commercially or recreationally important species present in the region?

(19) What are the principal aquatic species present in the area affected by construction and operation?

(20) What species are harvested for sport or commercial purposes in the area? What is the harvest level and seasonality of harvest? What fishes or shellfishes are harvested from the stream for food by the local community?

(21) What waterborne diseases or parasites are endemic to the area? What is the possibility of spreading or accentuating disease problems by mini-hydro development?

(22) Are there species of aquatic plants in the area that could interfere with hydroelectricity production and alternate water uses?

(23) Are there any pre-existing (natural or man-induced) environmental stresses in the area? Are any future developments planned for the area that might add additional stresses? Characterize and, if possible, quantify these stresses.

(24) What is the nature and size of suspended sediments in the stream? What is the bedload of the stream?

(25) Are any water quality data available, especially regarding temperature, dissolved solids, salt, nutrient, and dissolved oxygen levels, or the presence of toxic materials or disease organisms?

(26) What projected or active mining activities occur in the study area? Are these open pit or tunnel mines and how are wastes handled?

(27) Are there any unique plant design features (impoundment, trans-basin diversion) which would necessitate special consideration with regard to environmental impacts?

(28) What are the possibilities for avoiding, reducing, or mitigating environmental impacts of mini-hydro site development by adequate prior planning?

Summary

Small-scale hydroelectric facilities have a number of advantages over other sources of power as a means of providing electricity to rural areas in developing countries

As with other energy technologies, however, there are potential environmental impacts associated with the construction and operation of mini-hydro facilities. Discussions of impacts ranging from land use changes to water quality degradation have been provided along with a checklist of the types of information that should be gathered at an early stage in site selection and project planning in order to judge the significance of these impacts. It should be noted that the discussions are intended to cover a range of sites and designs which are appropriate for Thailand.

Since decisions about the significance of environmental impacts at a candidate site will be largely judgemental, both the prefeasibility and the feasibility stages of site selection should be conducted by individuals with formal training in an environmental field (e.g., natural resources management, ecology, forestry) and experience in impact assessments.

In summary, the principal objective of incorporating environmental concerns into overall site selection methodology should not be to hinder the provision of electricity to rural areas, but rather to orient development in an environmentally sound manner. To the degree that mini-hydro plants promote the intensification of rural industries and improve the lot of the small farmers without entering into conflict with basic environmental resources, they will assist in the rural development process.

APPENDIX I: ECONOMIC AND FINANCIAL SENSITIVITY ANALYSIS

This viability of the eight proposed mini-hydro facilities can be examined from three different perspectives. At the simplest level, a cash flow analysis can be performed to determine if the NEA will be aole to meet its debt service requirements as a result of these investments. At a more detailed level, a financial analysis of the individual facilities can be performed to determine if the expected revenues are greater than the expected expenditures and if these projects will provide a reasonable rate of return on the investment. From a national perspective, an economic analysis of each project can be performed to determine if the resources allocated to each facility could have been better used for other projects in the economy.

Of the eight facilities being constructed as part of the NEA programme, only six were in a state of final planning at the time of the field visit and only these have been described in the text. Since this section is being prepared several months later, planning data is available on the other two sites. The basic physical description of the eight projects is show in Exhibit I.1 based on the current NEA engineering data. The total proposed capacity is 6.92 MW and the expected average annual output at the busbar is 42.2 GWh. The operational dates for these facilities are based on NEA's schedule as of November 1987.

Exhibit I.1

Physical Characteristics of Mini/Micro Hydro Facilities

Facility	Nominal Capacity (kW)	Dependable Capacity (kW)	Expected Output (MWh)	Transmission Line Length (km)	Start of Operations month/year
Nam Mae Hat	818	636	6795	27.0	2/88
Khlong Lam Plok	1182	253	7761	1.3	3/89
Huai Lam Sin	958	370	6115	1.6	7/88
Lam Pra Plerng	850	850	3044	0.0	4/89
Nam Kha Mun	1030	184	4809	8.3	4/89
Khlong Duson	680	145	5838	1.2	5/89
Huai Mae Sot	660	143	3359		5/89
Name Ya Mo	738	212	4434		
Total	**6916**	**2793**	**42155**		

The total capital costs for the eight facilities is currently estimated to be US$12.8 million exclusive of administration, technical design and import duties as shown in Exhibit I.2. The capital costs for the first three facilities in this table are based on the bids of the selected contractors. The capital costs for the next four facilities are also based on the contractors' bids with the exception of the costs for the electro-mechanical

The total capital costs for the eight facilities is currently estimated to be US$12.8 million exclusive of administration, technical design and import duties as shown in Exhibit I.2. The capital costs for the first three facilities in this table are based on the bids of the selected contractors. The capital costs for the next four facilities are also based on the contractors' bids with the exception of the costs for the electro-mechanical equipment. The capital cost for the final facility is based on estimates provided by the NEA, but their recent estimates have proved reliable.

The economic and financial analyses were limited to the original six sites which the team visited and for which reliable data is available. It is assumed that the capital costs for these six sites will be incurred in equal amounts over the two year period preceding the operational date. The economic life of these facilities is assumed to be in excess of 40 years. It is also assumed that major renewals of equipment or facilities will not be required during the 25 year period used in both analyses.

Exhibit I.2

Capital Costs for the Eight Mini/Micro Hydro Facilities

(000's US$)

Facility	Civil Works	Trans-mission	E&M Equipment	Admin, Design*	Total
Nam Mae Hat	682	400	657	424	2163
Khlong Lam Plok	784	22	989	459	2254
Huai Lam Sin	432	22	614	459	1527
Lam Pra Plerng	311	0	863	137	1311
Nam Kha Mun	836	37	718	145	1736
Khlong Duson	918	27	490	141	1576
Huai Mae Sot	1045	30	562	164	1801
Name Ya Mo	1490	110	785	239	2624
Total	**6498**	**648**	**5678**	**2168**	**14992**

* estimated

The operating and maintenance (O&M) costs for these facilities were estimated assuming a repair and maintenance cost equal to 1% of the cost of civil works and 1.5% of the equipment costs. The operating costs for each site were assumed to be 250 thousand Baht per year for a three-shift, two-man operation. The O&M costs for the eight sites are summarized in Exhibit I.3.

Both the cash flow analysis and the financial analysis assume that all of the electricity generated by the mini-hydro facilities will be purchased by EGAT at the standard buyback rate of 1.03 Baht per kWh. It is assumed that this buyback rate will be adjusted annually in proportion to the rate of inflation. Each facility is assumed to require a six-month break-in period during which the total output will be limited to 70% of the expected level.

Exhibit I.3

Operating Costs
(000's Baht/Year)

Facility	Operating Labor	O&M Costs
Nam Mae Hat	250	578
Khlong Lam Plok	250	86
Huai Lam Sin	250	353
Lam Pra Plerng	250	310
Nam Kha Mun	250	503
Khlong Duson	250	432
Huai Mae Sot	250	483
Name Ya Mo	250	708
Total	2000	4053

Cash Flow Analysis

The cash flow analysis compares the revenues from sales of electricity to EGAT with the sum of the OM expenses and the debt service for the entire project. No effort was made to estimate changes in accounts receivable or payable during the period of operation.

The debt service requirements are based on the current arrangements between USAID and RTG. These stipulate that USAID will lend up to US$8 million to cover 50% of the costs for the electro-mechanical work and technical assistance. Disbursements of the USAID loan are made on a facility-by-facility basis at the time each facility becomes operational. The costs of construction are borne fully by NEA prior to the time these disbursements are made. The NEA will cover its share of the construction costs through its annual budget. The USAID loan has a 10 year grace period during which an interest of 2% is paid and then a 30 year period during which the principal must be repaid and an interest rate of 3% is charged on the outstanding balance. The loan is repayable in US$.

Interest during construction was assumed to be paid by the contractor and included as part of the capital cost to the NEA. The contributions of the RTG to the project are made through NEA as part of the normal budget process and are assumed to form part of the project's equity.

Since the loan repayment schedule for USAID is set and repayment must be made in US$, it is necessary to include the effects of inflation and changes in exchange rate in the cash flow analysis. An average rate of inflation of 4% has been assumed over the life of the project. This is in line with published estimates of the increase in consumer price index over the last five years. There is no reason to assume that it will, on average, greatly exceed this amount in the next 40 years. The general rate of inflation is assumed to affect the costs for O&M for the facilities. An additional 1% a year increase has been included in the costs of labor to account for economy-wide increases in productivity which will affect the rates paid to the operators of the mini-hydro facilities. No inflation adjustments were included for the capital costs of the mini/micro hydro facilities since nearly all these costs are based on bids and reflect the contractor's own expectations regarding inflation.

The exchange rate for the Baht is maintained in a small trading range relative to the US$ and major revaluations are made by government policy. The exchange rate relative to the dollar had been relatively stable up until 1982 when the first of two devaluations was introduced. Currently, the Baht's value relative to the US$ is about probably undervalued. Nevertheless, a conservative position has been taken in which the Baht is assumed to decline relative to the US$ by 1% a year over the life of the project. While an increase relative to the US$ could just as easily occur, the net effect the cash flow is relatively minor.

The cash flow analysis records the change in cumulative surplus over the life of the project. During the final years of construction of the eight sites, this surplus will be negative for a few years. It is assumed that government borrowings will be used to cover the deficit during this period. Therefore an interest charge equal to the government borrowing rate is charged during this period. The accrued interest as well as the deficit are paid off using net operating revenues.

A summary of the assumptions used in the cash flow analysis are shown in Exhibit I.4. The results of the cash flow analysis are shown in Exhibit I.5. Two general comments are in order:

First, the deficits shown for 1986 and 1987 were covered by the NEA out of previously allocated funds. Since the USAID disbursements and RTG equity contributions are assumed to be disbursed at the time of project completion, the NEA will have to cover the cost of the progress payments in 1988 and 1989, while the two remaining sites are under construction. This is assumed to be done through government borrowings, and, therefore, interest on short-term loans are incurred during the period 1988 through 1990.

Exhibit I.4

Assumptions Used in Cash Flow Analysis

1. 25.5 Baht = 1 US$
2. terms of USAID loan
   a. 10 year grace period
   b. 2% interest during grace period
   c. 3% interest thereafter
   d. total payback period 30 years
   e. loan cap of $5 million
   f. disbursements on a facility by facility basis when the facility is completed
3. remaining financing by RTG as equity contribution
4. no interest charges during construction
5. annual inflation rate 4% p.a.
6. increase in real cost of labor 1% p.a.
7. annual deficits covered with short term loans
8. short term interest rates 8% p.a.
9. no interest income associated with surpluses
10. buyback rate of 1.03 Baht per kw hr

    For commercial loans

    a. 10 year payback period
    b. 8% rate of interest
    c. equal annual payments
    d. 10% interest for short term loans

Second, the rapid build up of the surplus over the life of the project is unavoidable for the following reasons:

- The government provides about 1/3 of the capital cost as an equity contribution without a specified contribution required in return.
- USAID provide loans at a negative real rate of interest, i.e. the interest rate is less than the rate of inflation
- The revenues from sale in electricity are expected to increase with inflation as are the maintenance and labor costs
- Both maintenance and labor costs are relatively small and no major renewals are expected during the life of the project.

As a result, the project would generate about 80 million Baht (in 1990 value) from 1990 to 1988 and from then on would generate about 27.5 million Baht (in 1990 value) for the next 30 years as shown in Exhibit I.6. This is without allowing for reinvestment of

EXHIBIT I.5

RESULTS OF CASH FLOW ANALYSIS

Cash Flow Analysis (000's Baht)	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Receipts												
Revenues from Buyback	0	0	9,004	35,557	48,841	50,795	52,827	54,940	57,137	59,423	61,800	64,272
Borrowings - Commercial Loans	34,326	154,105	151,711	31,931	0	0	0	0				
Sub-total	34,326	154,105	160,715	67,488	48,841	50,795	52,827	54,940	57,137	59,423	61,800	64,272
Payments												
Capital Expenditures												
Civil Works	10,457	64,675	72,415	18,198	0	0	0	0	0			
Transmission	4,411	7,312	3,868	966	0	0	0	0	0			
E/M Equipment	11,545	60,668	60,840	11,717	0	0	0	0	0			
Admin and Design	7,913	21,450	14,588	1,050	0	0	0	0	0			
Debt Service Payments												
Principal on LT loans	0	2,369	13,197	24,725	28,907	31,220	33,718	36,415	39,328	42,474	45,872	44,427
Interest on LT loans	0	2,746	14,885	25,966	26,543	24,230	21,732	19,035	16,122	12,976	9,578	5,908
Interest on ST loans	0	269	1,633	3,950	6,151	8,123	10,126	12,155	14,205	16,271	18,347	20,157
Operating Expenditures												
Maintenance	0	0	761	3,526	4,493	4,673	4,860	5,054	5,257	5,467	5,686	5,913
Labor	0	0	416	1,839	2,318	2,435	2,557	2,686	2,822	2,964	3,113	3,270
Sub-total	34,326	159,490	182,602	91,937	68,412	70,681	72,993	75,345	77,733	80,152	82,596	79,675
Net Operating Revenues	0	0	7,827	30,192	42,030	43,687	45,409	47,199	49,059	50,992	53,001	55,089
Investments Expenditures	34,326	154,105	151,711	31,931	0	0	0	0	0			
Cumulative Long Term Borrowings	34,326	188,431	340,142	372,073	372,073	372,073	372,073	372,073	372,073	372,073	372,073	372,073
Outstanding Principal (begin year)	0	34,326	186,061	324,576	331,782	302,874	271,654	237,937	201,522	162,194	119,720	73,847
Outstanding Principal (end year)	34,326	186,061	324,576	331,782	302,874	271,654	237,937	201,522	162,194	119,720	73,847	29,421
Change in Net Working Capital	0	(5,385)	(21,888)	(24,448)	(19,571)	(19,886)	(20,167)	(20,406)	(20,596)	(20,729)	(20,796)	(15,403)
Cumulative Surplus (begin of year)	0	(5,385)	(27,272)	(51,721)	(71,291)	(91,178)	(111,344)	(131,750)	(152,346)	(173,075)	(193,871)	
Cumulative Surplus (end of year)	0	(5,385)	(27,272)	(51,721)	(71,291)	(91,178)	(111,344)	(131,750)	(152,346)	(173,075)	(193,871)	(209,274)
Average Overdraft	0	(2,692)	(16,329)	(39,497)	(61,506)	(81,234)	(101,261)	(121,547)	(142,048)	(162,710)	(183,473)	(201,573)

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EXHIBIT I.5 (continued)

Cash Flow Analysis (000's Baht)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Receipts												
Revenues from Buyback	66,843	69,516	72,297	75,189	78,196	81,324	84,577	87,960	91,479	95,138	98,943	102,901
Borrowings - Commercial Loans												
Sub-total	66,843	69,516	72,297	75,189	78,196	81,324	84,577	87,960	91,479	95,138	98,943	102,901
Payments												
Capital Expenditures												
Civil Works												
Transmission												
E M Equipment												
Admin and Design												
Debt Service Payments												
Principal on LT loans	25,014	4,406	0	00	0	0	0	0	0	00		
Interest on LT loans	2,354	352	(0)	0	0	0	0	0	0	0	0	0
Interest on ST loans	20,456	18,154	13,928	8,754	2,989	0	0	0	0	0	0	0
Operating Expenditures												
Maintenance	6,149	6,395	6,651	6,917	7,194	7,482	7,781	8,092	8,416	8,753	9,103	9,467
Labor	3,435	3,608	3,790	3,981	4,182	4,392	4,614	4,846	5,091	5,347	5,617	5,900
Sub-total	57,408	32,916	24,369	19,653	14,364	11,874	12,395	12,939	13,507	14,100	14,719	15,367
Net Operating Revenues	57,258	59,513	61,856	64,290	66,821	69,450	72,182	75,022	77,972	81,038	84,224	87,534
Investments Expenditures												
Cumulative Long Term Borrowings	372,073	367,667	367,667	367,667								
Outstanding Principal (begin year)	29,421	4,406	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Outstanding Principal (end year)	4,406	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Change in Net Working Capital	9,434	36,600	47,928	55,536	63,832	69,450	72,182	75,022	77,972	81,038	84,224	87,534
Cumulative Surplus (begin of year)	(209,274)	(199,840)	(163,240)	(115,312)	(59,776)	4,056	73,506	145,688	220,710	298,682	379,720	463,944
Cumulative Surplus (end of year)	(199,840)	(163,240)	(115,312)	(59,776)	4,056	73,506	145,688	220,710	298,682	379,720	463,944	551,478
Average Overdraft	(204,557)	(181,540)	(139,276)	(87,544)	(29,888)	0	0	0	0	0	0	0

the surplus. The results would be only slightly affected if there were a change in exchange rates as shown in Exhibit I.7. In effect, this project is profitable primarily because of the largest of the RTG and USAID.

Exhibit I.6

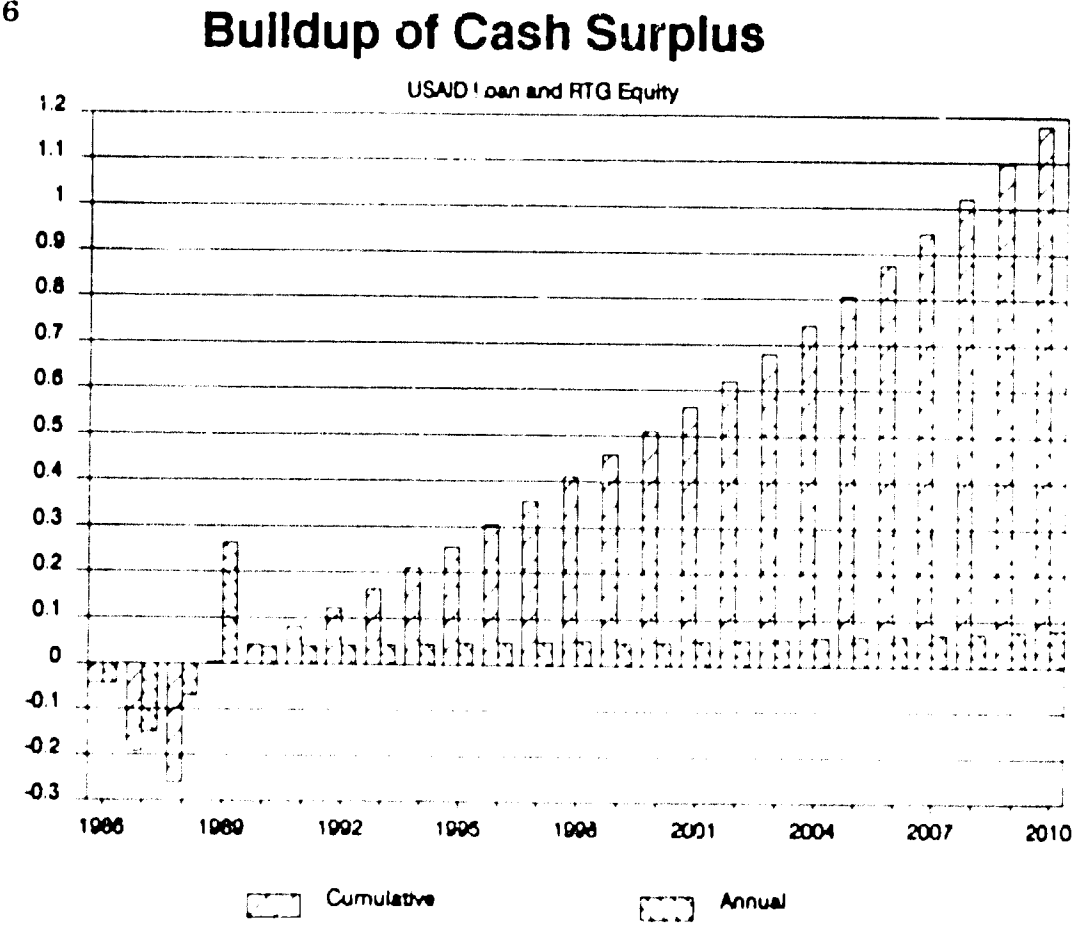


Exhibit I.7

Sensitivity of Cash Flow to Changes in Exchange Rate

Exchange Rate annual change in $ vs. Baht	Surplus 1990	Established 2000	(10^6 Baht) 2010
-2%	41.5	518	1,217
-1%	41.4	514	1,200
0%	41.4	510	1,180
1%	41.3	506	1,156
2%	41.3	501	1,129
3%	41.2	495	1,098

An important question is whether it would be viable using commercial financing. The cash flow analysis was repeated for the same eight sites, assuming that:

- the interest rate on the short-term loans used to cover temporary deficits is 10% per year (slightly below the current prime rate),
- long-term loans are used to finance the capital investment at a rate of interest of 8%,
- the repayment period for the long-term loans is 10 years with equal annual payments and without an initial grace period.

The results as shown in Exhibit I.8 indicate that the project would finally breakeven in 2003. The overdraft would rise to 205 million Baht in 1999 but would then decline as the long-term debt service decreased. With the long-term debt paid off in 2000, the annual net operating surplus of 69.5 million Baht (in 1993 value) would quickly eliminate the overdraft and then build up a considerable surplus as shown in Exhibit I.9.

Exhibit I.8

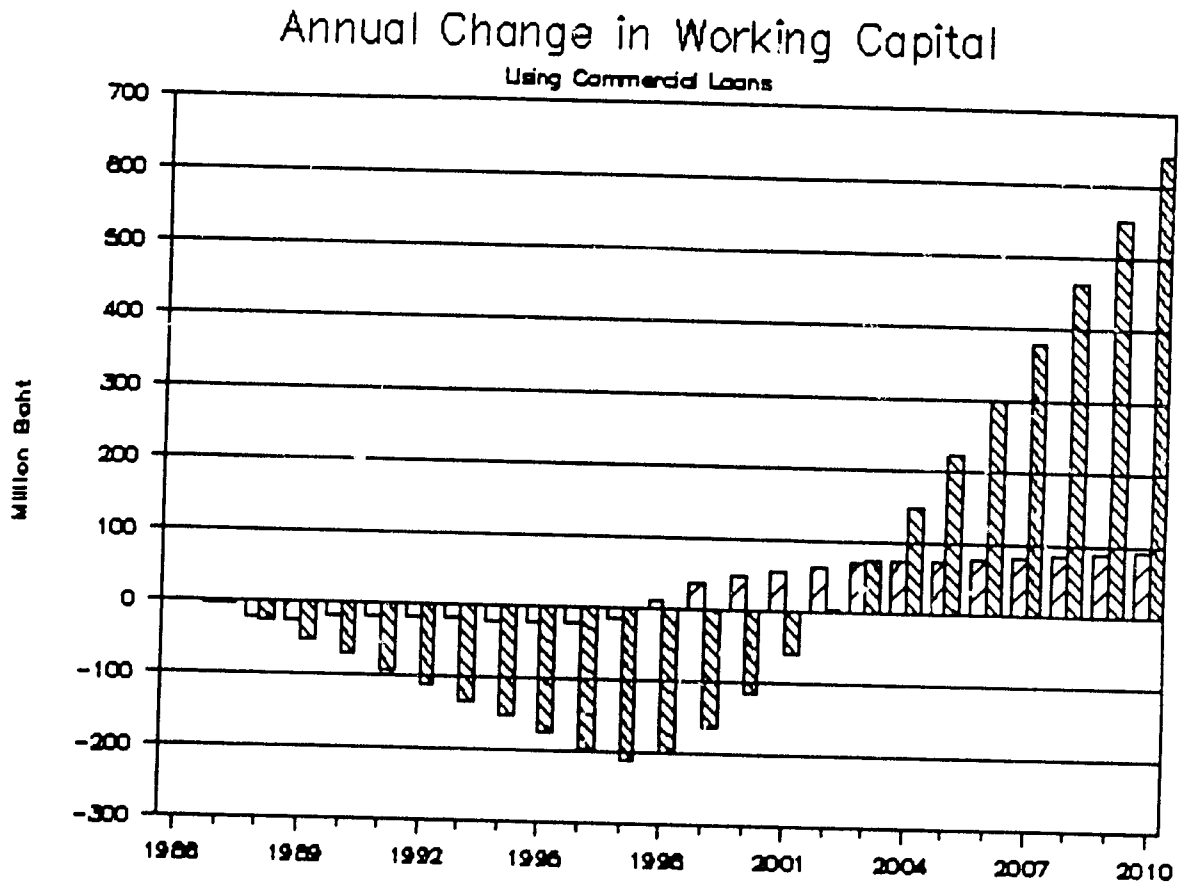
Cash Flow Analysis for Commercial Loans

Cash Flow Analysis (000's Baht)	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Receipts												
Revenues from Buyback	0	0	9,004	35,557	48,841	50,795	52,827	54,940	57,137	59,423	61,800	64,272
Borrowings - USAID Loans	0	0	81,083	122,917	0	0	0	0				
Government Equity Contribution			30,828	155,096								
Sub-total	0	0	120,914	313,569	48,841	50,794	52,826	54,939	57,137	59,422	61,799	64,271
Payments												
Capital Expenditures												
Civil Works	10,457	64,675	72,415	18,198	0	0	0	0	0			
Transmission	4,411	7,312	3,868	966	0	0	0	0	0			
E/M Equipment	11,545	60,668	60,840	11,717	0	0	0	0	0			
Admin and Design	16,575	16,575	32,088	1,050	0	0	0	0	0			
Debt Service Payments												
Principal on LT loans												
Interest on LT loans			826	1,793	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080
Interest on ST loans			18,114	10,425	0	0	0	0	0	0	0	0
Operating Expenditures												
Maintenance	0	0	761	3,526	4,493	4,673	4,860	5,054	5,257	5,467	5,686	5,913
Labor	0	0	416	1,839	2,318	2,435	2,557	2,686	2,822	2,964	3,113	3,270
	42,988	149,230	189,328	49,514	10,891	11,188	11,497	11,821	12,158	12,511	12,879	13,263
Net Operating Revenues	0	0	7,827	30,192	42,030	43,687	45,409	47,199	49,059	50,992	53,001	55,089
Investments Expenditures	42,988	149,230	169,211	31,931	0	0	0	0	0			
Cumulative Borrowings		0	81,083	204,000	204,000	204,000	204,000					
Outstanding Principal (begin year)			0	81,083	204,000	204,000	204,000	204,000	204,000	204,000	204,000	204,000
Outstanding Principal (end year)			81,083	204,000	204,000	204,000	204,000	204,000	204,000	204,000	204,000	204,000
Change in Net Working Capital	(42,988)	(149,230)	(68,414)	264,056	37,950	39,607	41,329	43,119	44,979	46,912	48,921	51,009
Cumulative Surplus (begin of year)		(42,988)	(192,218)	(260,632)	3,424	41,373	80,981	122,310	165,429	210,408	257,320	306,240
Cumulative Surplus (end of year)	(42,988)	(192,218)	(260,632)	3,424	41,373	80,981	122,310	165,429	210,408	257,320	306,240	357,249
Average Overdraft	(21,494)	(117,603)	(226,425)	(130,316)	0	0	0	0	0	0	0	0

Exhibit I.8 (continued)

Cash Flow Analysis (000's Baht)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Receipts										
Revenues from Buyback	66,843	69,516	72,297	75,189	78,196	81,324	84,577	87,960	91,479	95,138
Borrowings - USAID Loans										
Government Equity Contribution										
Sub-total	66,842	69,516	72,296	75,188	78,196	81,324	84,577	87,960	91,478	95,137
Payments										
Capital Expenditures										
Civil Works										
Transmission										
E/M Equipment										
Admin and Design										
Debt Service Payments										
Principal on LT loans		6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800
Interest on LT loans	4,080	4,080	3,944	3,808	3,672	3,536	3,400	3,264	3,128	2,992
Interest on ST loans	0	0	0	0	0	0	0	0	0	0
Operating Expenditures										
Maintenance	6,149	6,395	6,651	6,917	7,194	7,482	7,781	8,092	8,416	8,753
Labor	3,435	3,608	3,790	3,981	4,182	4,392	4,614	4,846	5,091	5,347
	13,665	20,884	21,185	21,506	21,848	22,210	22,595	23,003	23,435	23,892
Net Operating Revenues	57,258	59,513	61,856	64,290	66,821	69,450	72,182	75,022	77,972	81,038
Investments Expenditures										
Cumulative Borrowings										
Outstanding Principal (begin year)	204,000	204,000	197,200	190,400	183,600	176,800	170,000	163,200	156,400	149,600
Outstanding Principal (end year)	204,000	197,200	190,400	183,600	176,800	170,000	163,200	156,400	149,600	142,800
Change in Net Working Capital	53,178	48,633	51,112	53,682	56,349	59,114	61,982	64,958	68,044	71,246
Cumulative Surplus (begin of year)	357,249	410,427	459,060	510,171	563,854	620,202	679,316	741,299	806,256	874,300
Cumulative Surplus (end of year)	410,427	459,060	510,171	563,854	620,202	679,316	741,299	806,256	874,300	945,546
Average Overdraft	0	0	0	0	0	0	0	0	0	0

Exhibit I.9



These results are sensitive to the assumptions regarding level of income. If the average buyback rate is less by 10%, then the project would not bread-even until 2007 and the maximum overdraft would be 290 million Baht. A 10% higher income would mean that the project would breakeven in 2001 and the maximum overdraft would be only 130 million Baht. The results of the cash flow for commercial loans are also sensitive to the assumptions regarding the rates of inflation. The sensitivity to both buyback and inflation are shown in Exhibits I.10 and I.11.

Financial Analysis

The financial analysis assumes that the NEA is investing in generation capacity and is selling the output to EGAT or PEA. The price of power at the busbar is fixed by the utility which will purchase all of the electricity generated regardless of the time of day or the season.

Exhibit I.10

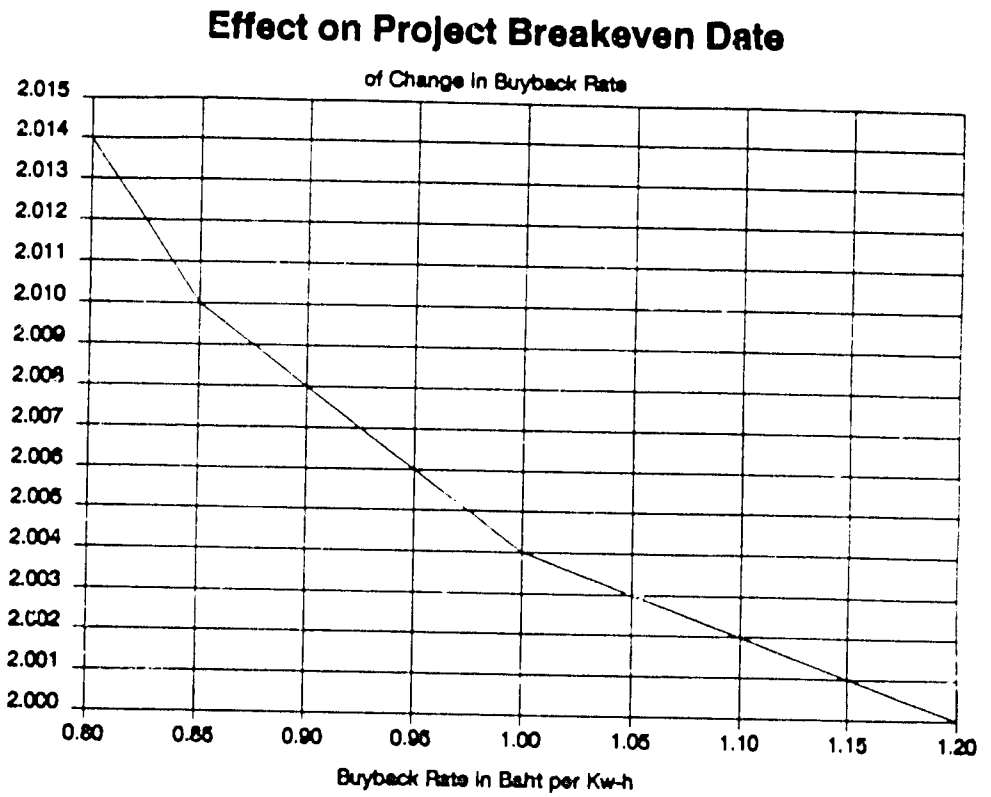
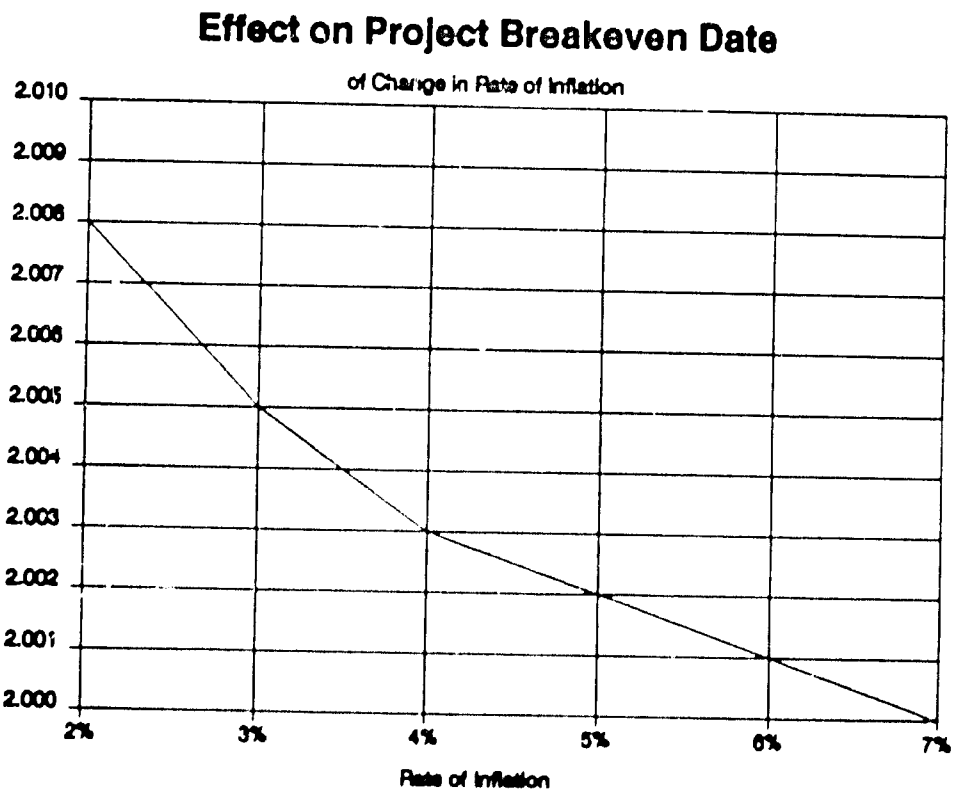


Exhibit I.11



The financial analysis compares the stream of revenues from the sales to EGAT with the stream of O&M and capital costs on a facility-by-facility basis. Revenues and costs are computed in constant value. These are discounted at a rate of 8% to determine the Net Present Value for each facility. Capital costs are expensed in the year in which they occur. For the benefit/cost ratio, the benefits are the revenues for electricity sold at the busbar. The analysis for each facility is shown in Exhibit I.12 through I.17.

The financially viable projects include Khlong Lam Plok, Huai Lam Sin, and Khlong Duson.

Khlong Lam Plok is financially viable with an internal rate of return of 8.4% and a net present value of 1.8 million Baht. The facility is very sensitive to the discount rate as shown in Exhibit I.18. The project would require only 1 Baht per kw-hr or a load factor of 70% in order to breakeven as shown in Exhibits I.19 and I.20.

Huai Lam Sin is financially viable with a net present value of 7.6 million Baht. The internal rate of return is 10.4% and the effect of discount rate on viability is fairly significant as shown in Exhibit I.24. The project would require only 0.9 Baht buyback rate or a load factor over 60% in order to be financially viable as shown in Exhibits I.25 and I.26.

Khlong Duson is also financially viable with an internal rate of return of 9.1% and a net present value of 3.5 million Baht. The results are relatively sensitive to changes in discount rate as shown in Exhibit I.30. The facility would be feasible with a buyback rate of only 0.95 Baht per kw-hr as shown in Exhibit 31. However, the load factor is assumed to be very high and the facility would not be financially viable when the load factor drops below 90% as shown in Exhibit I.32.

Nam Mae Hat is almost financially viable assuming a relatively high load factor. The internal rate of return is 7.1% and the net present value is -3.6 million Baht. The sensitivity of the results to the discount rate is shown in Exhibit I.36. The project would require a 1.1 Baht buyback rate to break even as shown in Exhibit I.37. The results are relatively sensitive to load factor as shown in I.38. At a less optimistic load factor such as 0.75, the facility would have a net present value of -14.7 million Baht.

Lam Pra Plerng is not financially viable because of the relatively low output compared to the available capacity. The internal rate of return is only 2.7% and the net present value at the 8% discount rate is -12 million Baht. The sensitivity of the results to discount rate is shown in Exhibit I.42. the project would require a 1.7 Baht buyback rate or a load factor over 60% in order to breakeven as shown in Exhibits I.43 and I.44.

Nam Kha Mun is not financially viable and has an internal rate of return of only 5.3%. The net present value of the project using the 8% discount rate is -8.8 million Baht. This loss increases with the discount rate as shown in Exhibit I.48. The project would require a 1.3 Baht buyback rate or a load factor over 65% in order to break even as shown Exhibits I.49 and I.50.

Economic Analysis

The economic analysis assumes that some investment in additional electricity generating capacity is justified based on the growth in national demand for electricity. This analysis compares the investment in mini-hydro facilities with investments in alternative generating capacity, specifically oil-fired, large-scale thermal plants. The dependable capacity of the mini-hydro facility is assumed to substitute for a similar amount of oil-fired thermal plant capacity, with an estimated capital cost of 15,450 Baht per kW.

The electricity generated by the mini-hydro facility is assumed to substitute for electricity which would be generated using the same type of thermal plant, therefore, there is a savings in fuel and variable O&M costs. The rate of fuel consumption is assumed to 0.233 kg per kWh and the marginal O&M costs are assumed to be 1/2 of average O&M costs. The latter are estimated to be equal to 2.5% of capital costs per year. The marginal lines losses are assumed to be 15% for remote areas relative to an average system-wide loss of 11%.

The estimated market costs for construction and maintenance were adjusted to economic costs using a uniform conversion factor of 0.82. This factor assumes that about 60% of capital costs involve direct purchase of imports and that the remaining 40% have some component of imported material and equipment. The economic costs for the labor used for construction and for operation and maintenance of the facilities were assumed to be equal to the market prices. The economic cost of the fuel was determined by taking the estimated CIF price for fuel oil delivered to Thailand at the end of 1987 of 3.05 Baht per liter and adding a land transport charge of 0.4 Baht per liter.

All of the facilities are economically viable, or nearly so, with the exception of Nam Kha Mun and Khlong Lam Plok. However, for all projects taken together the net present value is -7.5 million Baht.

Khlong Lam Plok has an internal rate of return of 11.1% but the net present value is -2.5 million Baht. The economic viability of the system is very sensitive to the -2.5 million Baht. The economic viability of the system is very sensitive to the discount rate as shown in Exhibit I.18. The facility breaks even with a fuel price 0.86 Baht per kw-hr or with a load factor of 80% (see Exhibits I.20 and I.21).

Nam Kha Mun has an internal rate of return of only 7.5% and a net present value of -8.6% million Baht. The net present value is relatively sensitive to the discount rate as shown in Exhibit I.48. The facility would not be economically viable unless the fuel price rose to 1.1 Baht per kw-hr or the load factor increased to 72% (see Exhibits I.51 and I.50).

Nam Mae Hat is not economically viable although the internal rate of return of 11.8% and the net present value of -0.5 million Baht are easily within the range of error.

These results are, however, very sensitive to the discount rate as shown in Exhibit I.36. The effects of fuel price and load factor on economic viability are shown in Exhibits I.38 and I.39. The facility breaks even with a load factor of 91% or a fuel cost of 0.82 Baht per kw-hr.

Lam Pra Plerng has the same internal rate of return as Nam Mae Hat and the net present value is only -0.3 million Baht. The net present value varies with the discount rate but not as much as for Nam Mae Hat as shown in Exhibit I.42. The breakeven point for the fuel price is also the same but the breakeven point for the load factor is only 45% (see Exhibits I.44 and I.45).

Khlong Duson is also very close to being economically viable with an internal rate of return of 11.6% and a net present value of -0.7 million Baht. The net present value is relatively sensitive to the discount factor as shown in Exhibit I.30. The facility would be economically viable if the fuel price increased to 0.82 Baht per kw-hr. On the other hand, if the expected high load factor were not achieved, then the net present value for the facility would drop significantly (see Exhibits I.32 and I.33).

Huai Lam Sin has the highest internal rate of return, 14.9%, but only a 5 million Baht net present value. These net present value remains positive for a wide range of discount factors as shown in Exhibit I.24. The project would be economically viable even if the fuel price dropped to 0.66 Baht per kw-hr or the load factor was only 62% (see Exhibits I.26 and I.27).

Exhibit I.12

Results of Financial Analysis for Khlong Lam Plok

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	1182 kW
dependable capacity	253 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	75.0%

Year	**1**	**2**	**3**	**4**
Financial Costs (000's Baht)				
capital	28720.0	28720.0		
R&M			586.0	586.0
operations			250.0	250.0
Subtotal	**28720.0**	**28720.0**	**836.0**	**836.0**
Financial Return (000's Baht)				
power generated (MWh)			7765.7	7765.7
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**6798.9**	**6798.9**
Economic Costs (000's Baht)				
capital	23550.4	23550.4		
R&M			480.5	480.5
operations			250.0	250.0
Subtotal	**23550.4**	**23550.4**	**730.5**	**730.5**
Economic Benefits (000's Baht) *				
capacity savings		3908.8		
O&M savings			48.9	48.9
fuel savings			6243.7	6243.7
Subtotal	**0.0**	**3908.8**	**6292.5**	**6292.5**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

Results - Khlong Lam Plok

	Financial	**Economic**
NPV	1,804	(2,462)
IRR	8.4%	11.1%
B/C	1.03	0.94

Exhibit I.13

Results of Financial Analysis for Huai Lam Sin

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	958 kW
dependable capacity	369 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	72.9%

Year	1	2	3	4
Financial Costs (000's Baht)				
capital	19465.0	19465.0		
R&M			353.0	353.0
operations			250.0	250.0
Subtotal	**19465.0**	**19465.0**	**603.0**	**603.0**
Financial Return (000's Baht)				
power generated (MWh)			6117.8	6117.8
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**5356.2**	**5356.2**
Economic Costs (000's Baht)				
capital	15961.3	15961.3		
R&M			289.5	289.5
operations			250.0	250.0
Subtotal	**15961.3**	**15961.3**	**539.5**	**539.5**
Economic Benefits (000's Baht) *				
capacity savings		5701.0		
O&M savings			71.3	71.3
fuel savings			4918.7	4918.7
Subtotal	**0.0**	**5701.1**	**4990.0**	**4990.0**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

Results - Huai Lam Sin

	Financial	Economic
NPV	7,552	4,954
IRR	10.4%	10.1%
B/C	1.19	1.16

Exhibit I.14

Results of Financial Analysis for Khlong Duson

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	680 kW
dependable capacity	145 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	98.0%

Year	1	2	3	4
Financial Costs (000's Baht)				
capital	20100.0	20100.0		
R&M			432.0	432.0
operations			250.0	250.0
Subtotal	20100.0	20100.0	**682.0**	**682.0**
Financial Return (000's Baht)				
power generated (MWh)			5837.7	5837.7
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**5110.9**	**5110.9**
Economic Costs (000's Baht)				
capital	16482.0	16482.0		
R&M			354.2	354.2
operations			250.0	250.0
Subtotal	**16482.0**	**16482.0**	**604.2**	**604.2**
Economic Benefits (000's Baht) *				
capacity savings		2240.3		
O&M savings			28.0	28.0
fuel savings			4693.5	4693.5
Subtotal	**0.0**	**2240.3**	**4721.5**	**4721.5**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

Results - Khlong Duson

	Financial	Economic
NPV	3,536	(736)
IRR	9.1%	11.6%
B/C	1.08	0.98

Exhibit I.15

Results of Financial Analysis for Nam Mae Hat

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	818 kW
dependable capacity	636 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	94.8%

Year	1	2	3	4
Financial Costs (000's Baht)				
capital	27565.0	27565.0		
R&M			578.0	578.0
operations			250.0	250.0
Subtotal	**27565.0**	**27565.0**	**828.0**	**828.0**
Financial Return (000's Baht)				
power generated (MWh)			6793.1	6793.1
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**5947.3**	**5947.3**
Economic Costs (000's Baht)				
capital	22603.3	22603.3		
R&M			474.0	474.0
operations			250.0	250.0
Subtotal	**22603.3**	**22603.3**	**724.0**	**724.0**
Economic Benefits (000's Baht) *				
capacity savings		9826.2		
O&M savings			122.8	122.8
fuel savings			5461.6	5461.6
Subtotal	**0.0**	**9826.2**	**5584.5**	**5584.5**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

	Results - Nam Mae Hat	
	Financial	**Economic**
NPV	(3,637)	(400)
IRR	7.1%	11.8%
B/C	0.94	0.99

Exhibit I.16

Results of Financial Analysis for Lam Pra Plerng

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	850 kW
dependable capacity	850 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	40.9%

Year	1	2	3	4
Financial Costs (000's Baht)				
capital	16720.0	16720.0		
R&M			410.0	410.0
operations			250.0	250.0
Subtotal	**16720.0**	**16720.0**	**660.0**	**660.0**
Financial Return (000's Baht)				
power generated (MWh)			3045.4	3045.4
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**2666.3**	**2666.3**
Economic Costs (000's Baht)				
capital	13710.4	13710.4		
R&M			336.2	336.2
operations			250.0	250.0
Subtotal	**13710.4**	**13710.4**	**586.2**	**586.2**
Economic Benefits (000's Baht) *				
capacity savings		13132.5		
O&M savings			164.2	164.2
fuel savings			2448.5	2448.5
Subtotal	**0.0**	**13132.5**	**2612.7**	**2612.7**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

Results - Lam Pra Plerng

	Financial	Economic
NPV	(11,978)	(233)
IRR	2.7%	11.8%
B/C	0.66	0.99

Exhibit I.17

Results of Financial Analysis for Nam Kha Mun

Assumptions

financial discount rate	8.0%
economic discount rate	12.0%
shadow price (SCF)	82%
design capacity	1030 kW
dependable capacity	184 kW
buyback rate	1.03 Baht/kWh
economic cost of capacity	15.45 000's Baht/kW
% O&M rate for this capacity	1.25%
economic cost of fuel replaced	0.804 Baht/kWh marginal lines
losses	15%
load factor	53.3%

Year	1	2	3	4
Financial Costs (000's Baht)				
capital	22190.0	22190.0		
R&M			503.0	503.0
operations			250.0	250.0
Subtotal	22190.0	22190.0	**753.0**	**753.0**
Financial Return (000's Baht)				
power generated (MWh)			4809.2	4809.2
price (Baht/kWh)			1.03	1.03
Total Revenue	**0.0**	**0.0**	**4210.4**	**4210.4**
Economic Costs (000's Baht)				
capital	18195.8	18195.8		
R&M			412.5	412.5
operations			250.0	250.0
Subtotal	**18195.8**	**18195.8**	**662.5**	**662.5**
Economic Benefits (000's Baht) *				
capacity savings		2842.8		
O&M savings			35.5	35.5
fuel savings			3866.6	3866.6
Subtotal	**0.0**	**2842.8**	**3902.1**	**3902.1**

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

	Results - Nam Kha Mun	
	Financial	**Economic**
NPV	(8,829)	(8,552)
IRR	5.3%	7.5%
B/C	0.81	0.75

Exhibit I.18

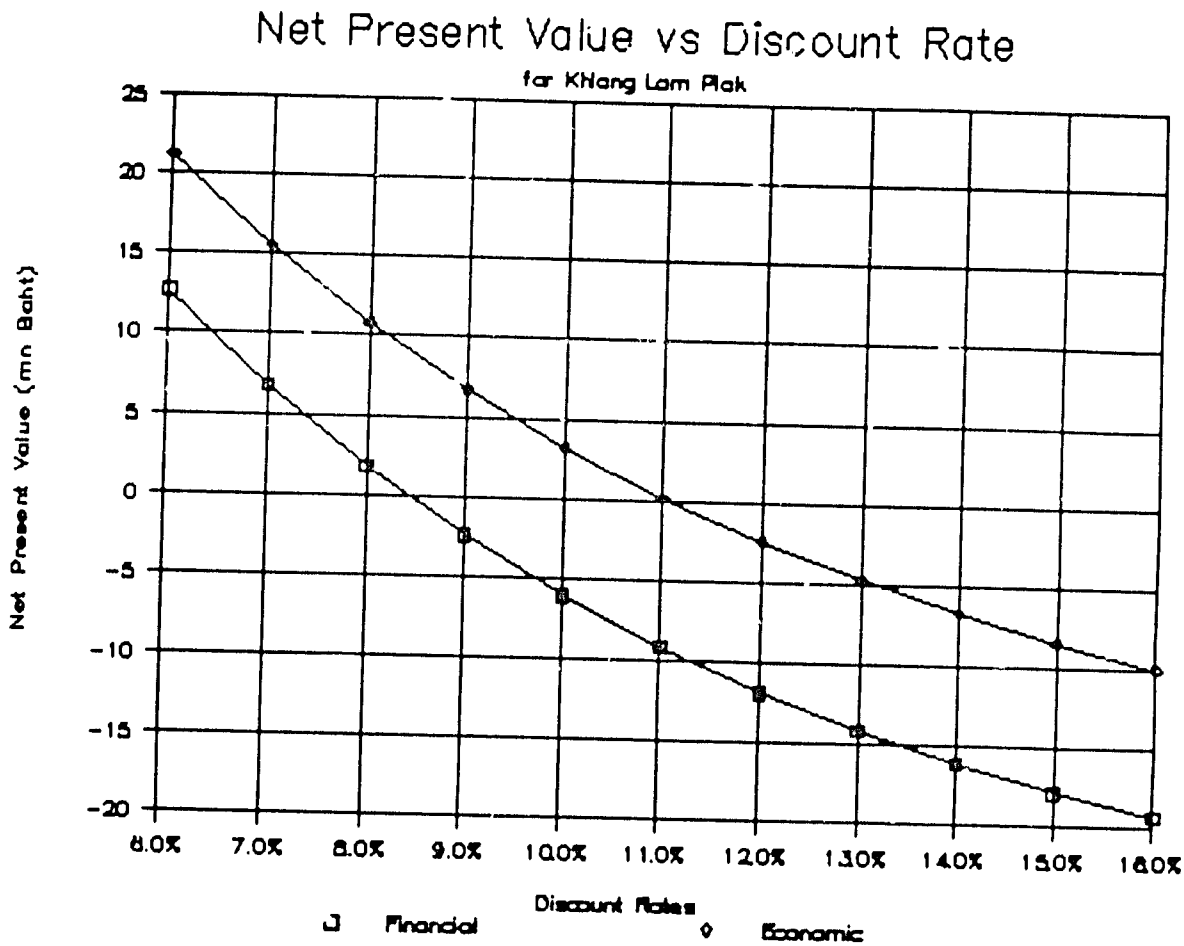

Net Present Value vs Discount Rate
for Khlong Lam Plak
Net Present Value (mn Baht)
25
20
15
10
5
0
-5
-10
-15
-20
6.0%
7.0%
8.0%
9.0%
10.0%
11.0%
12.0%
13.0%
14.0%
15.0%
16.0%
Discount Rates
Financial
Economic

Exhibit I.19

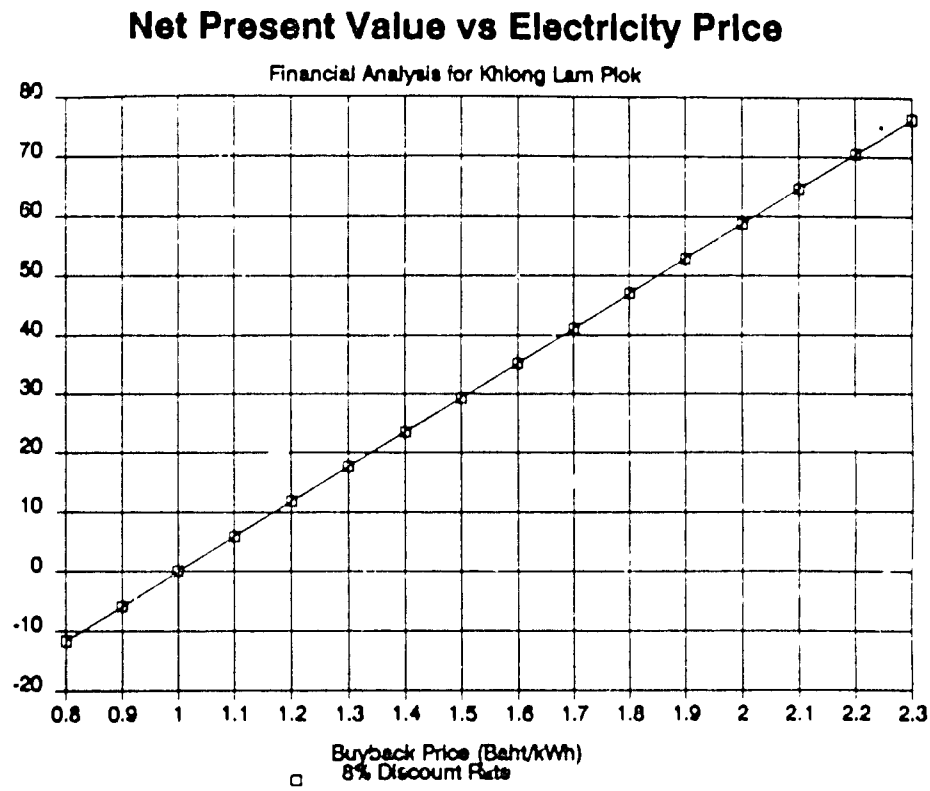


Exhibit I.20

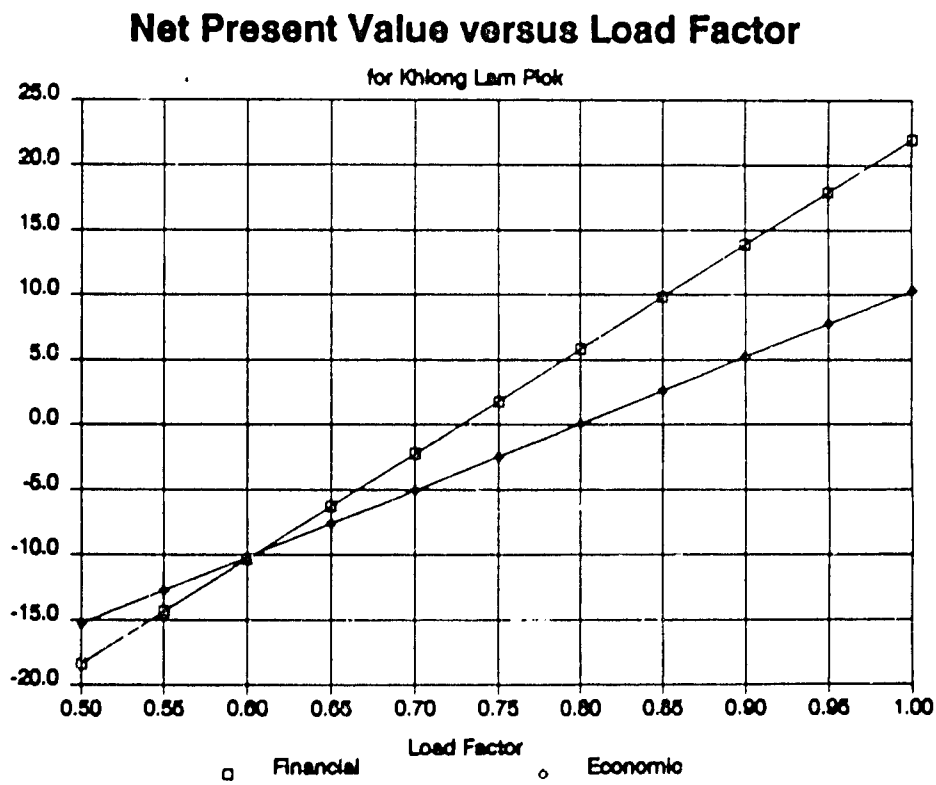


Exhibit I.21

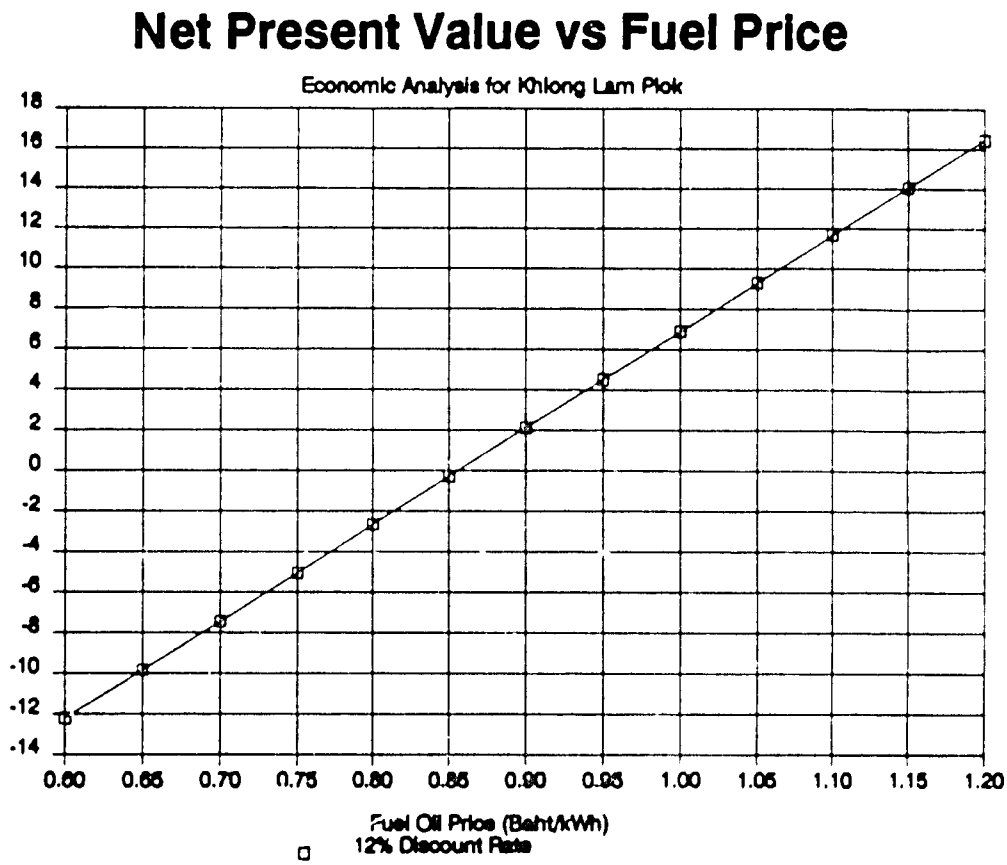
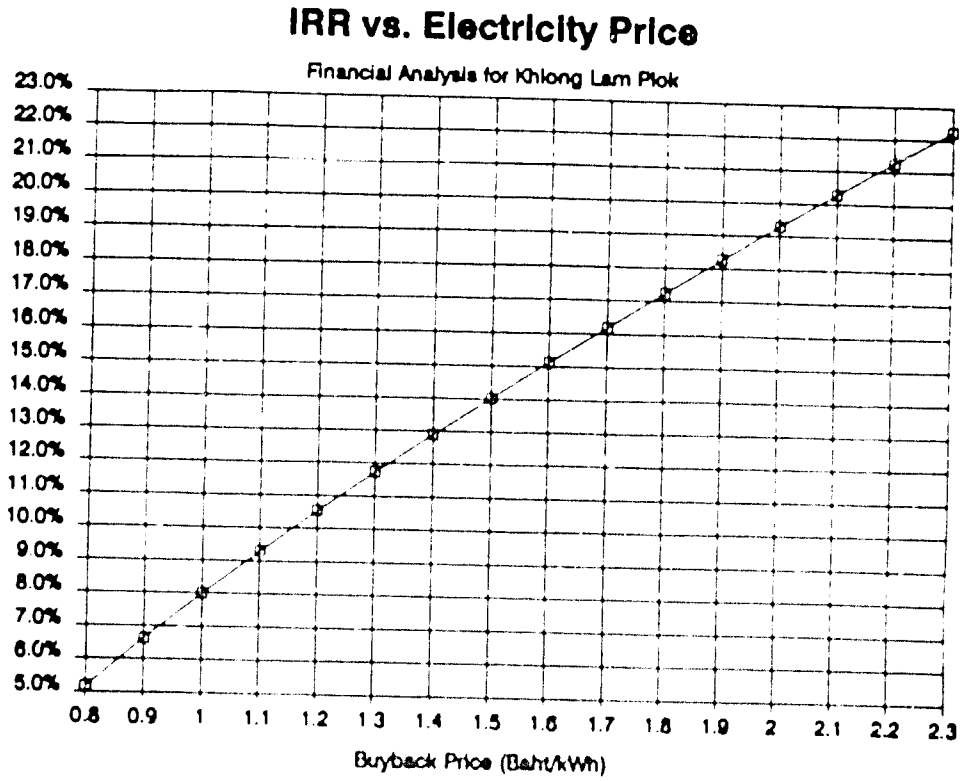

Net Present Value vs Fuel Price
Economic Analysis for Khlong Lam Plok
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
Fuel Oil Price (Baht/kWh)
12% Discount Rate

Exhibit I.22



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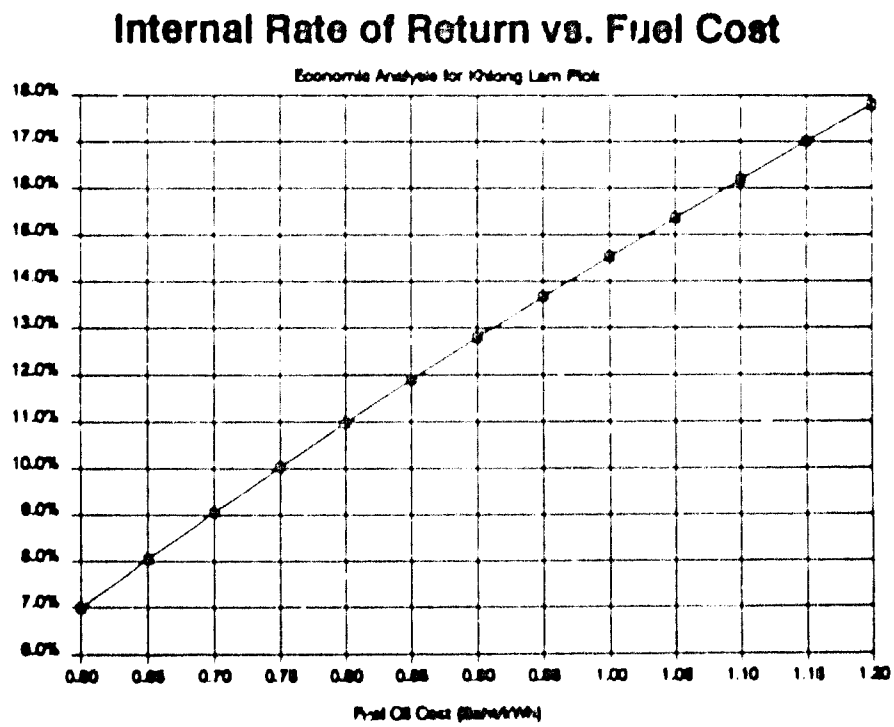

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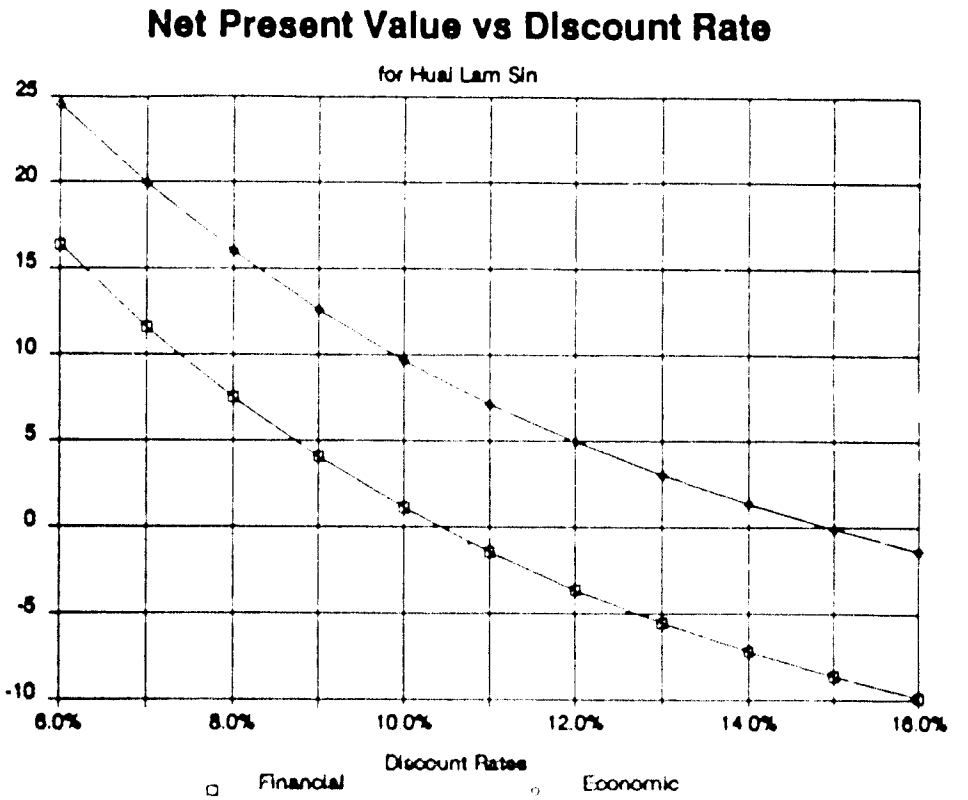

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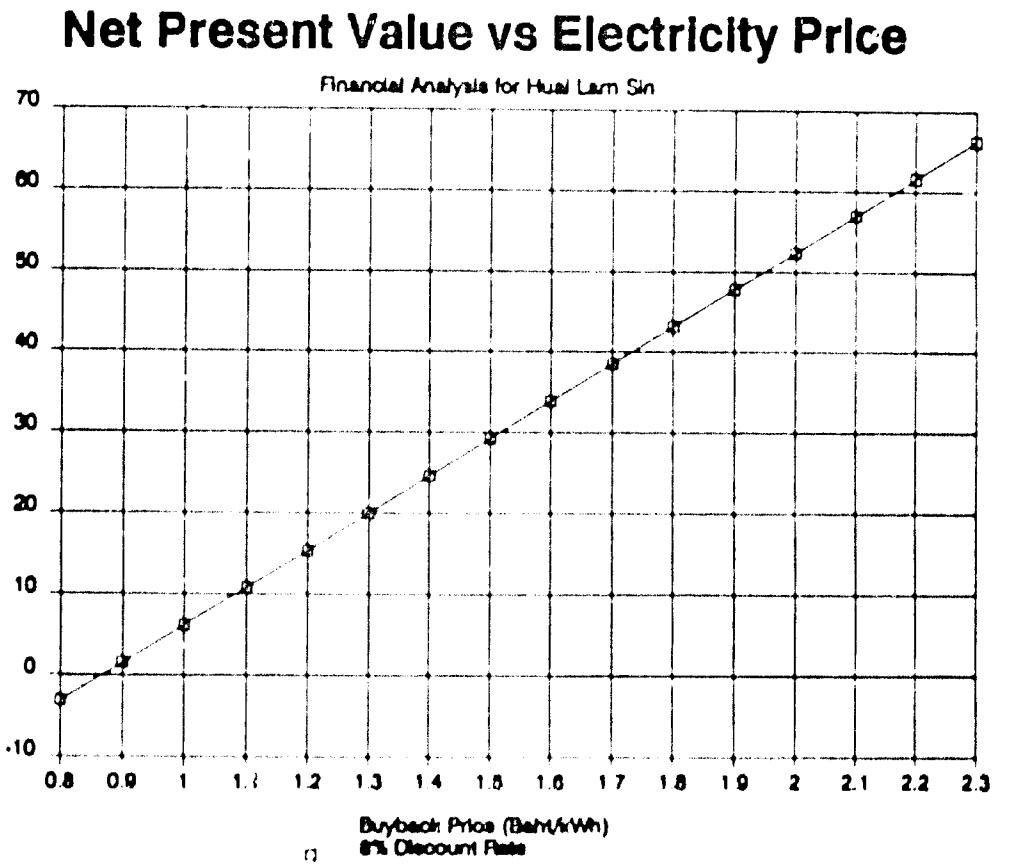

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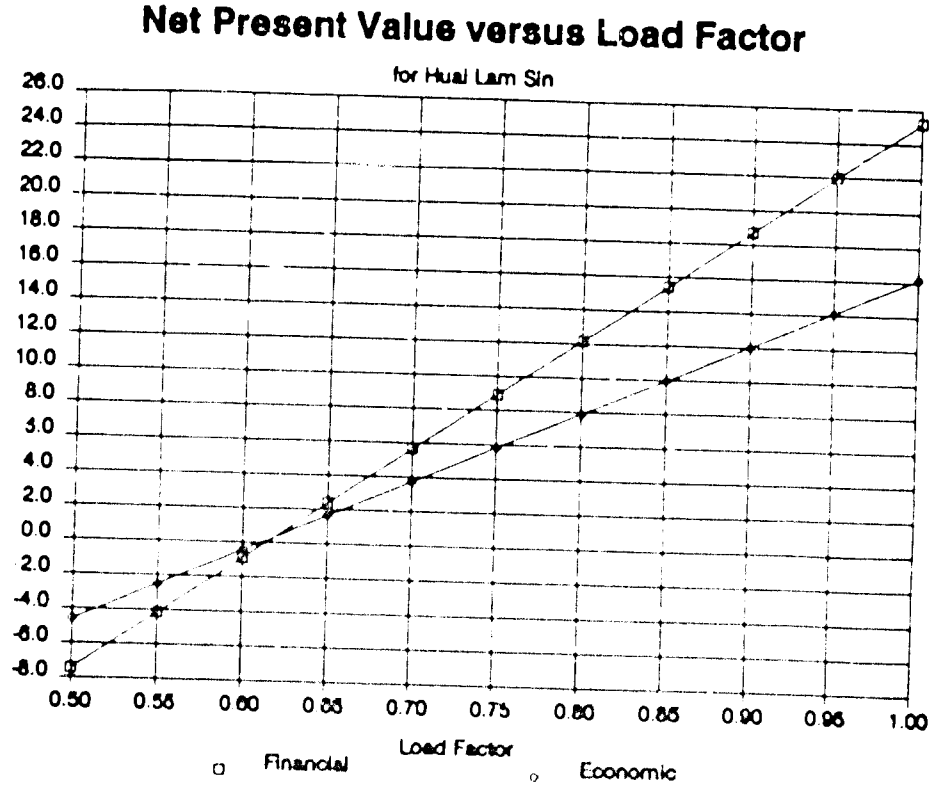

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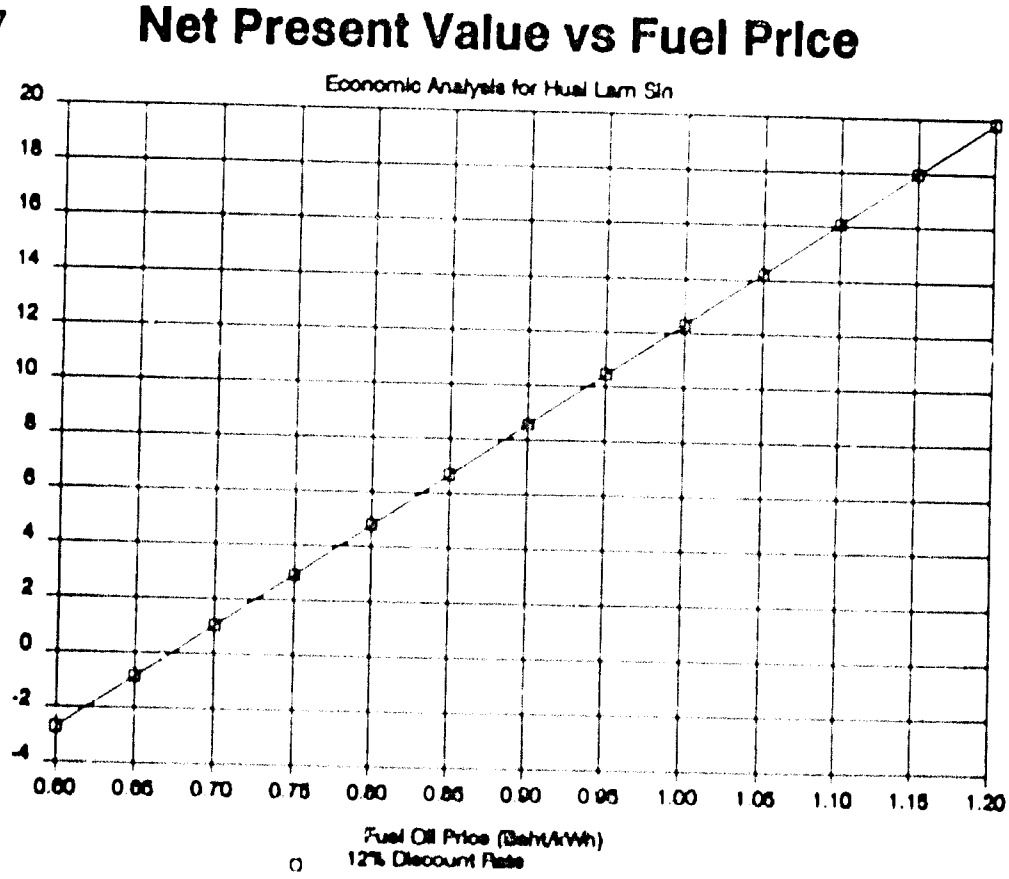

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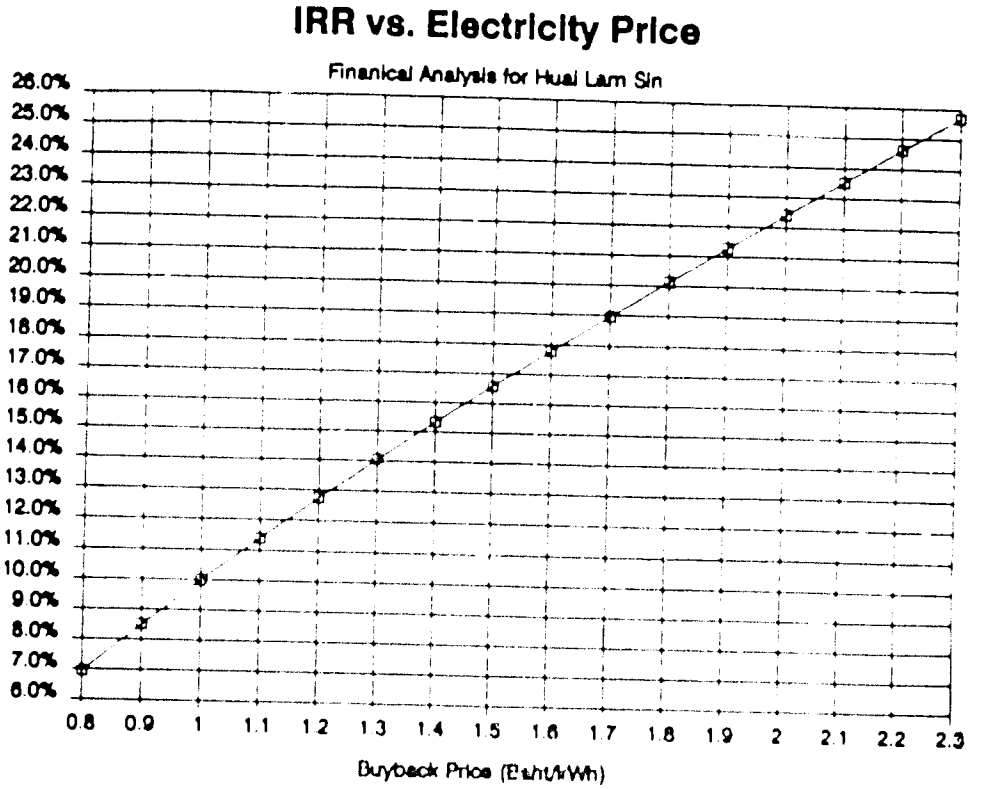

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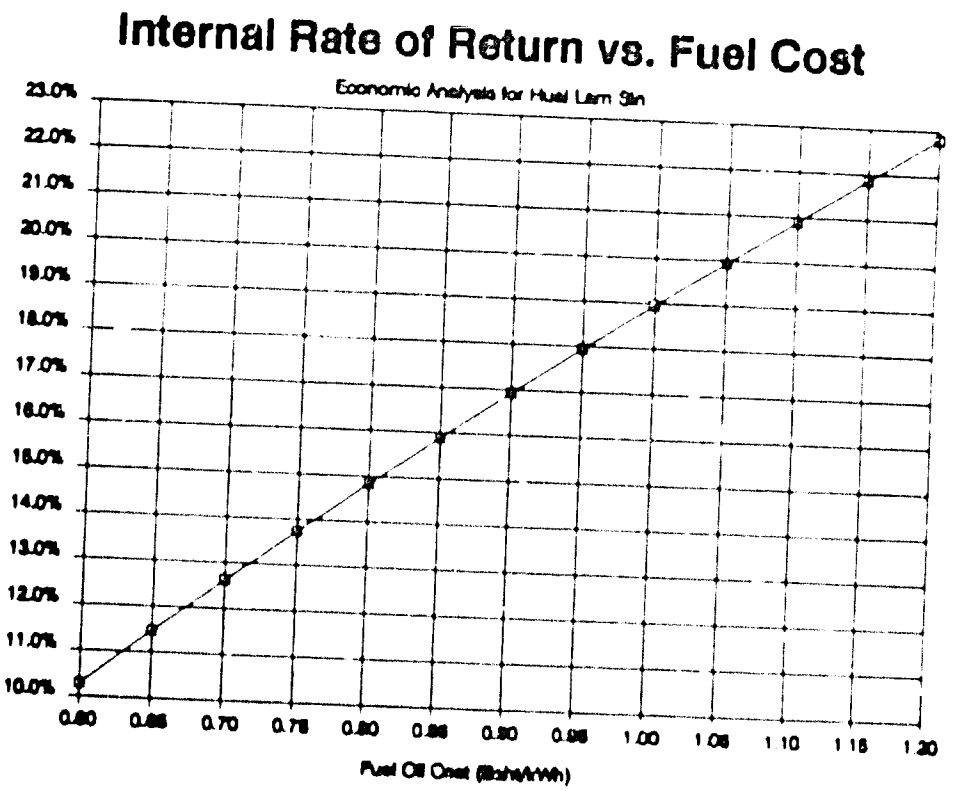

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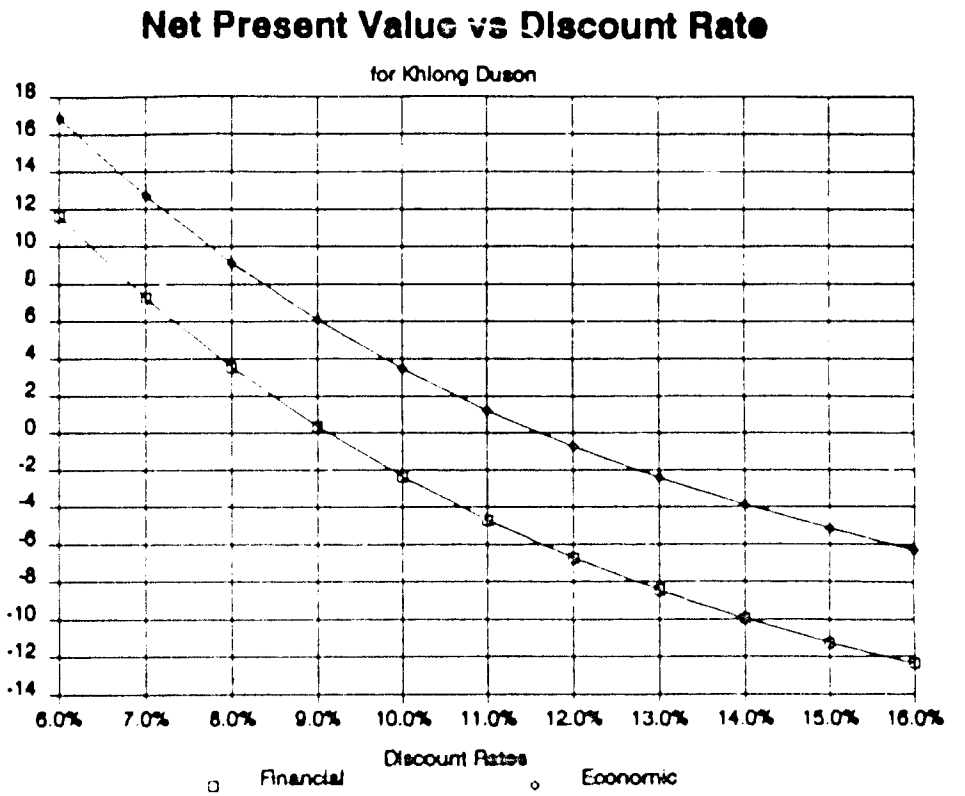

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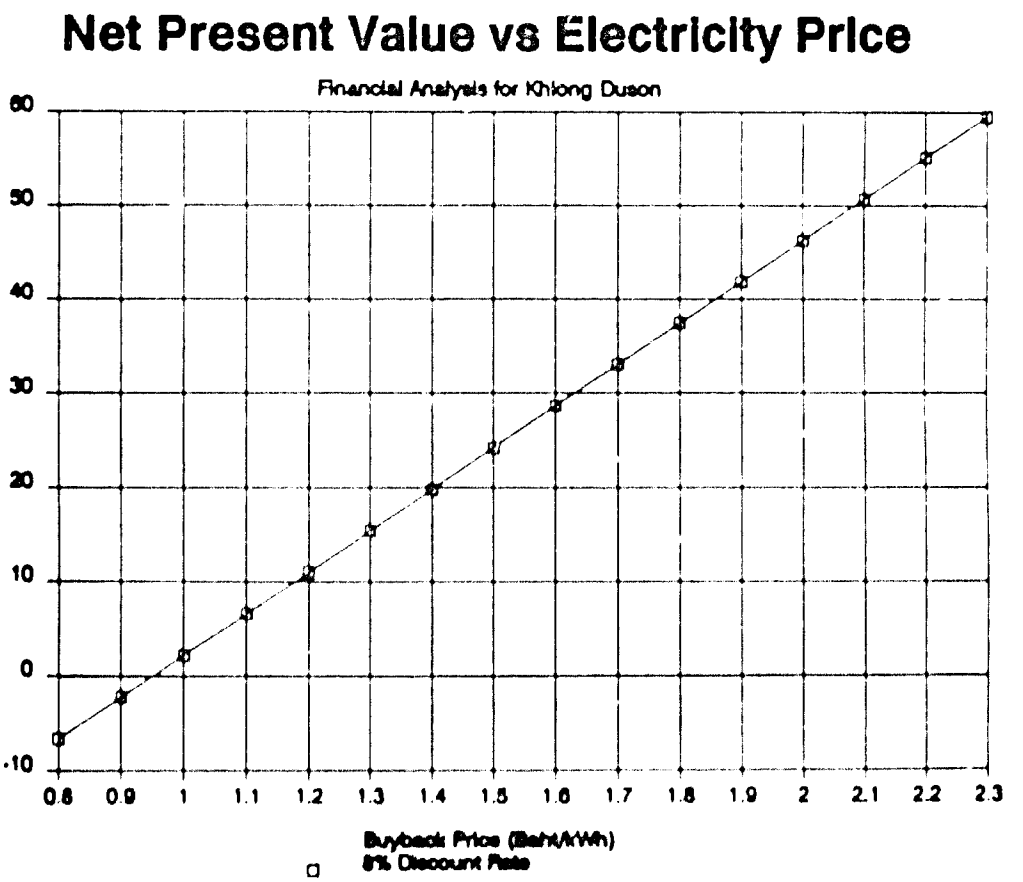

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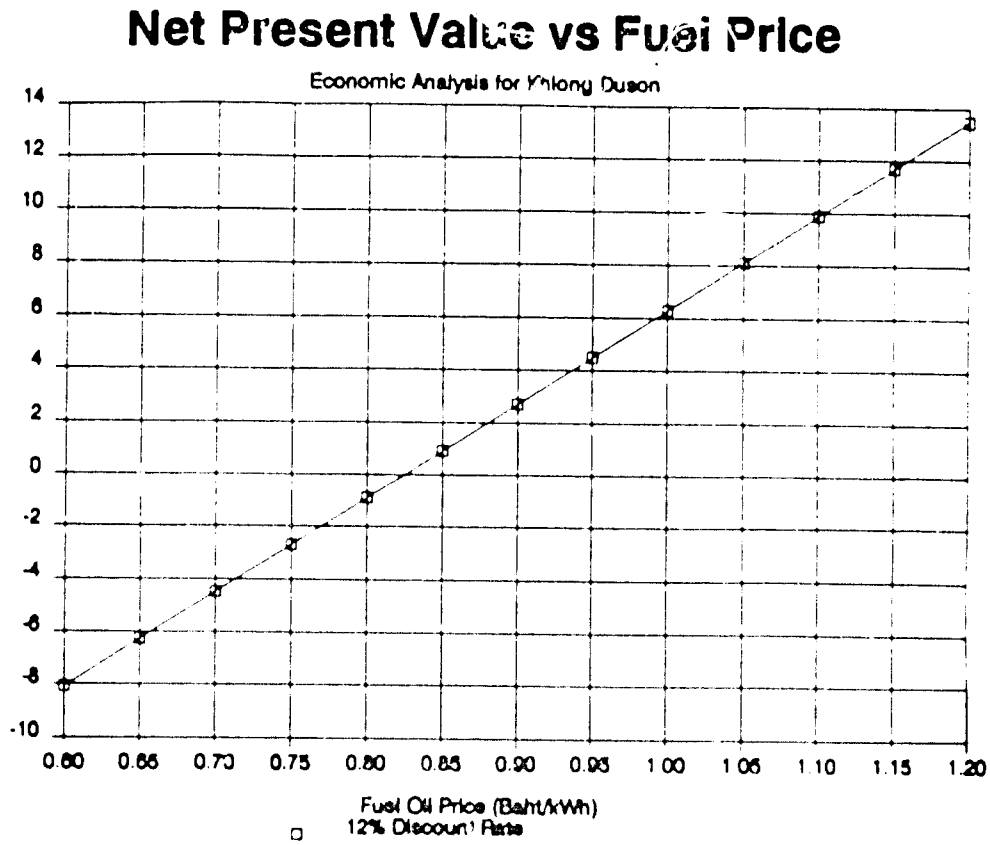

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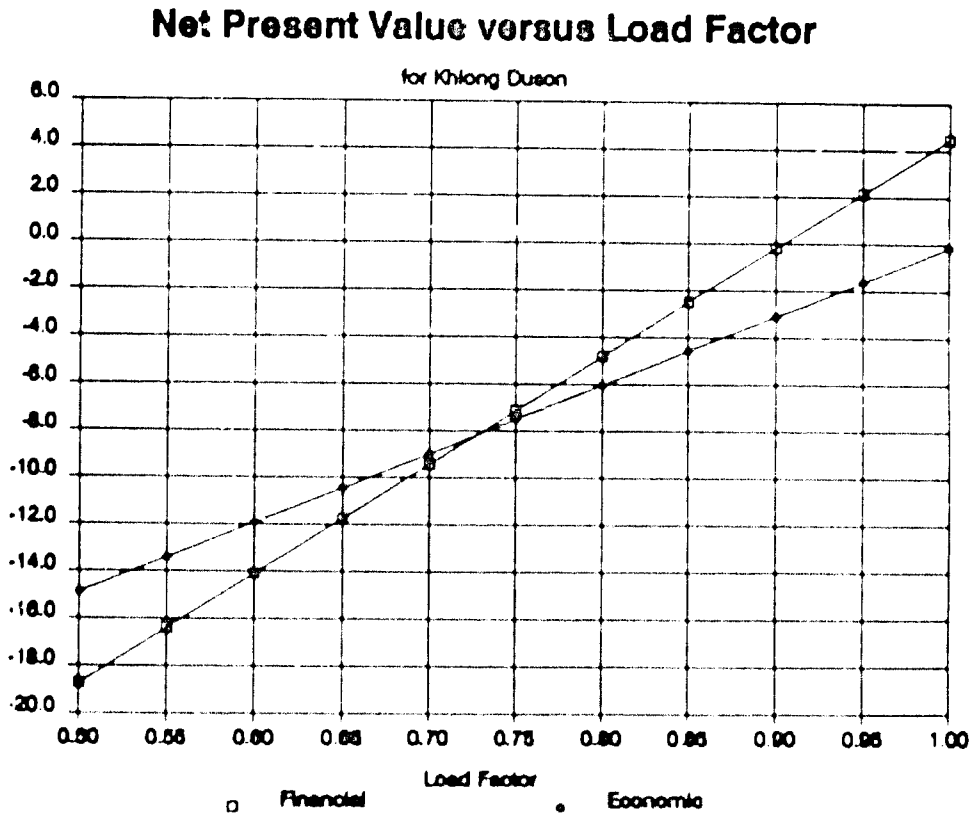

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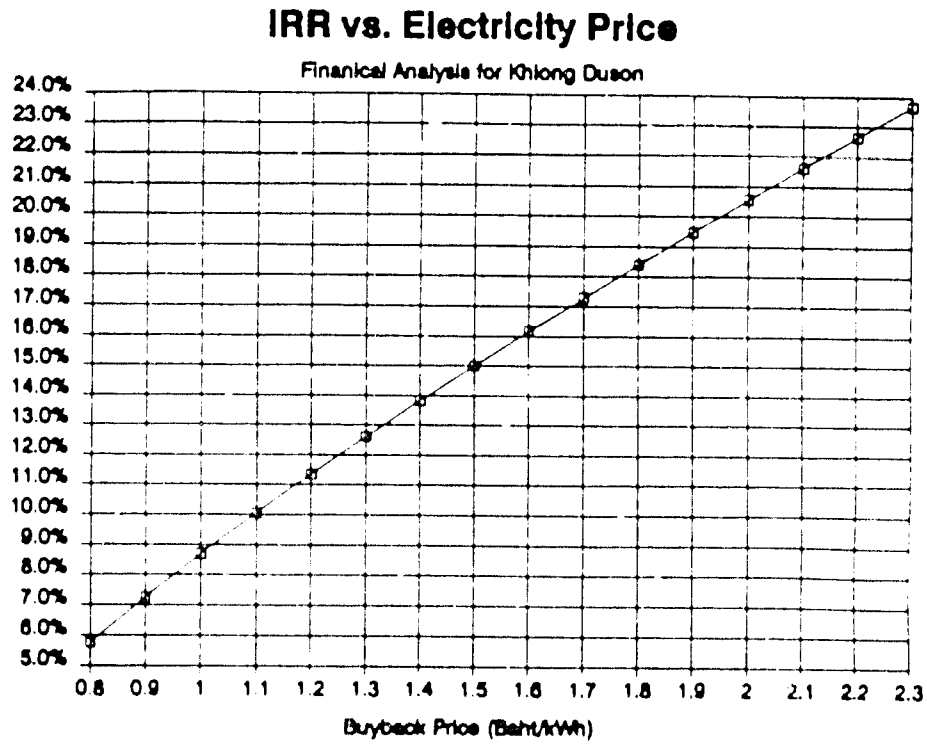

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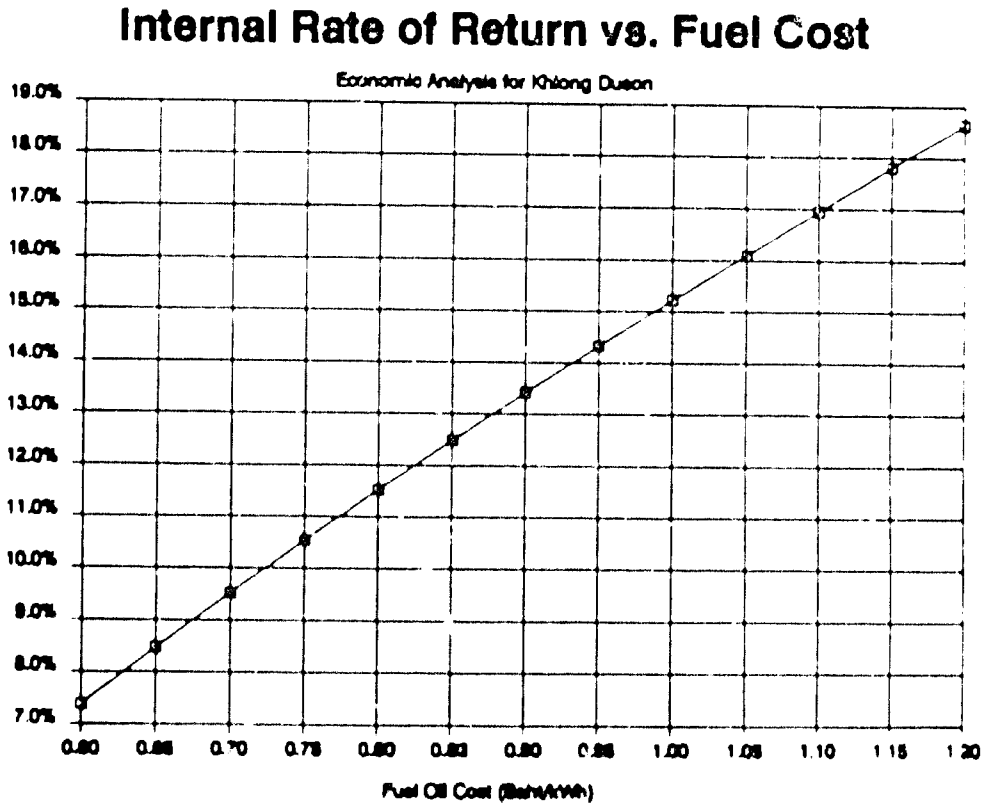

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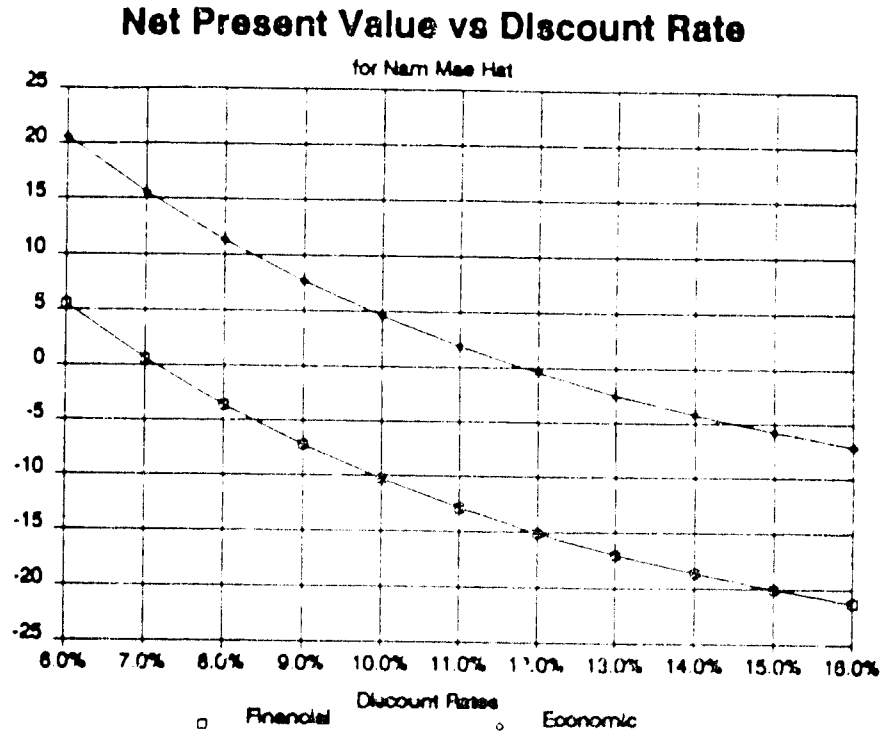

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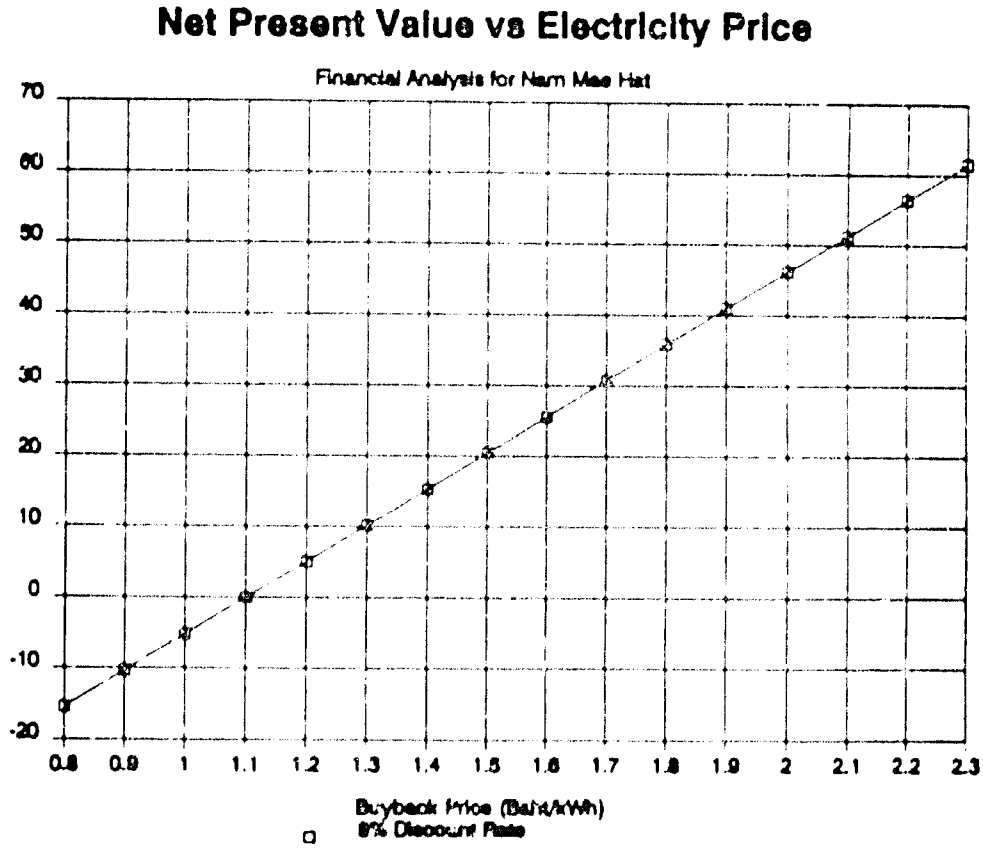

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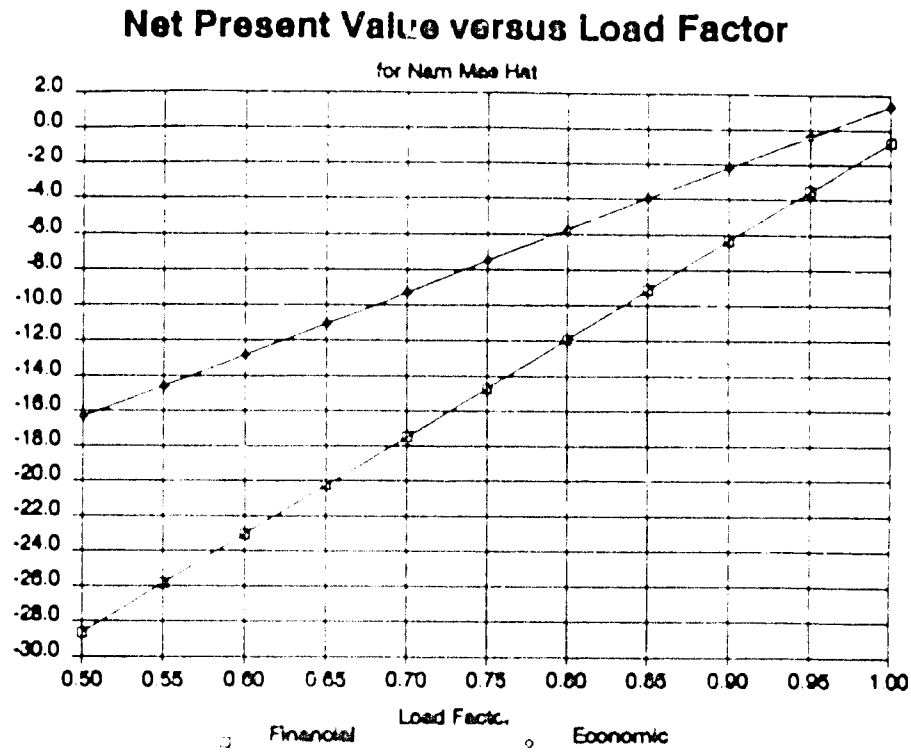

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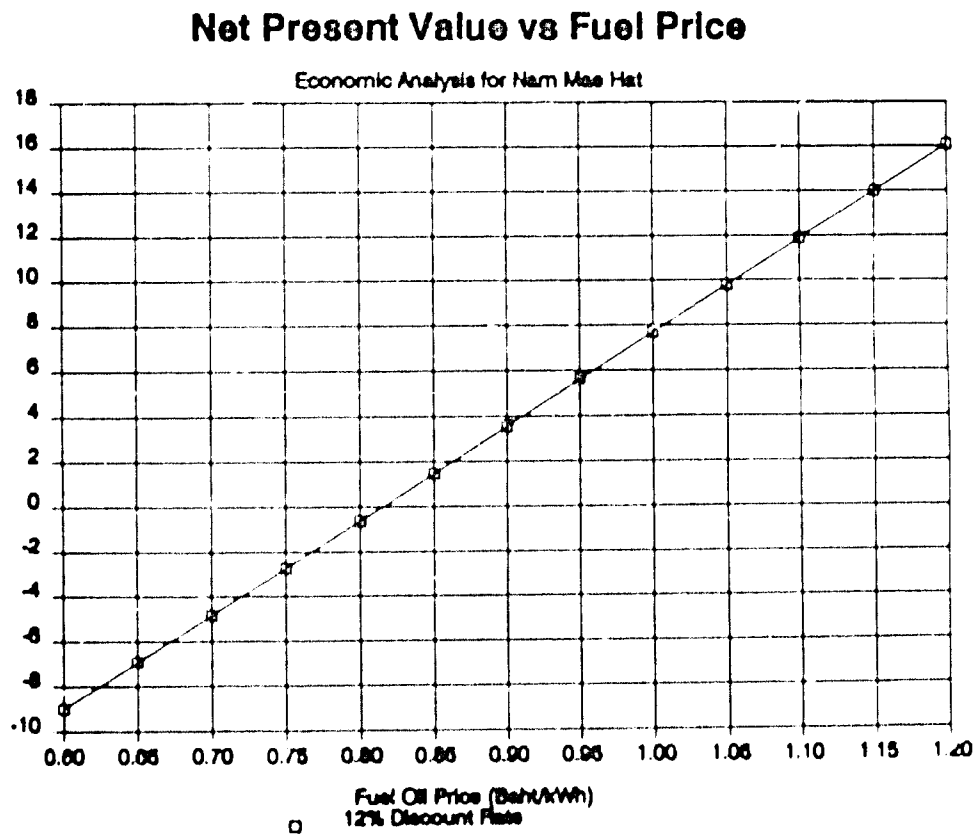

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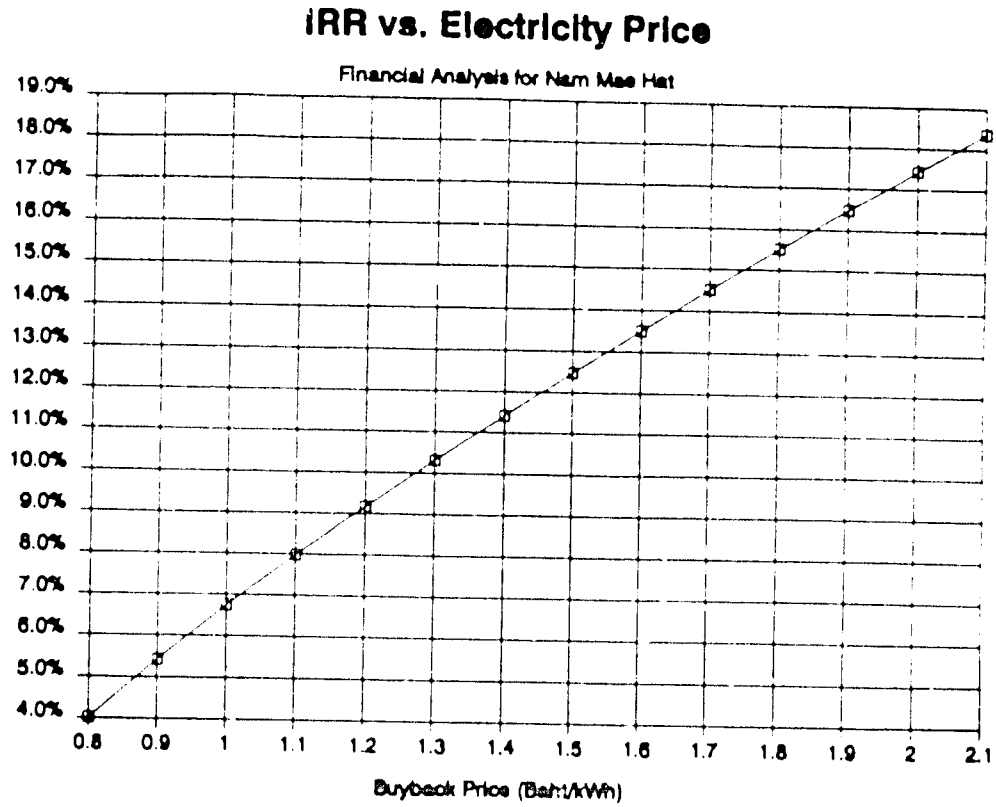

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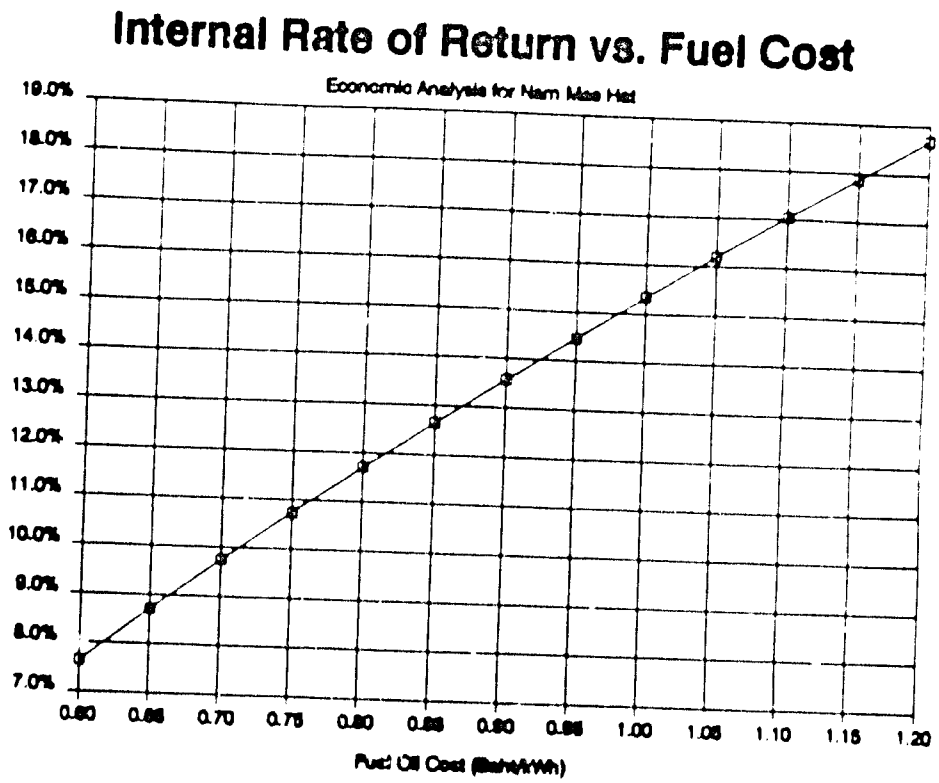

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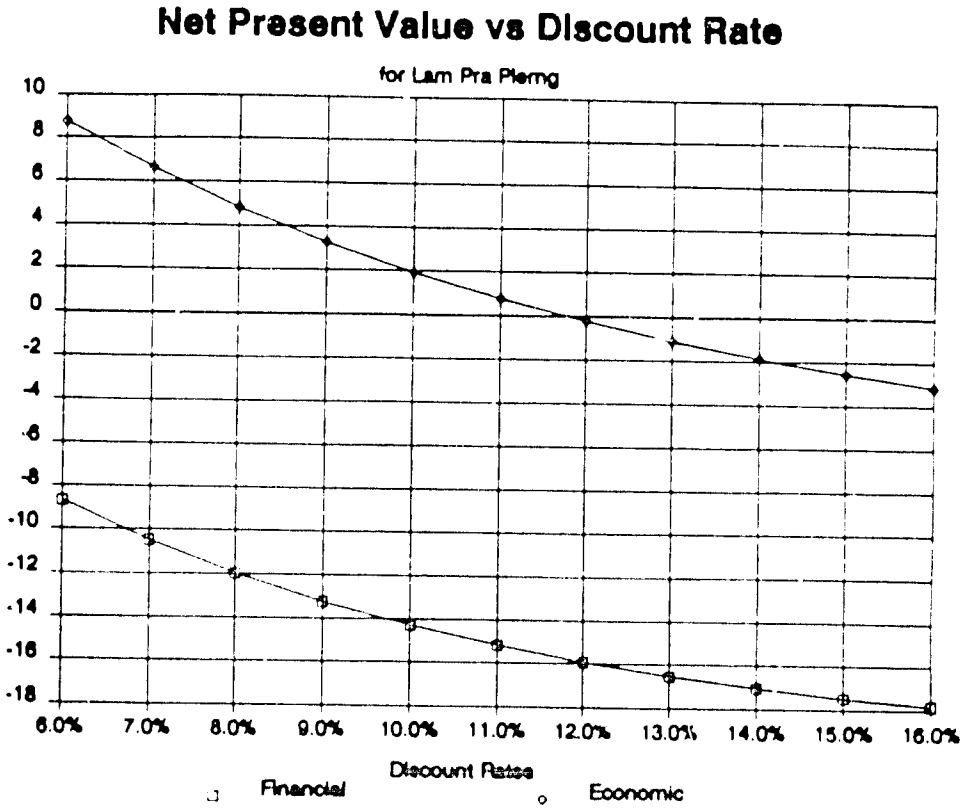

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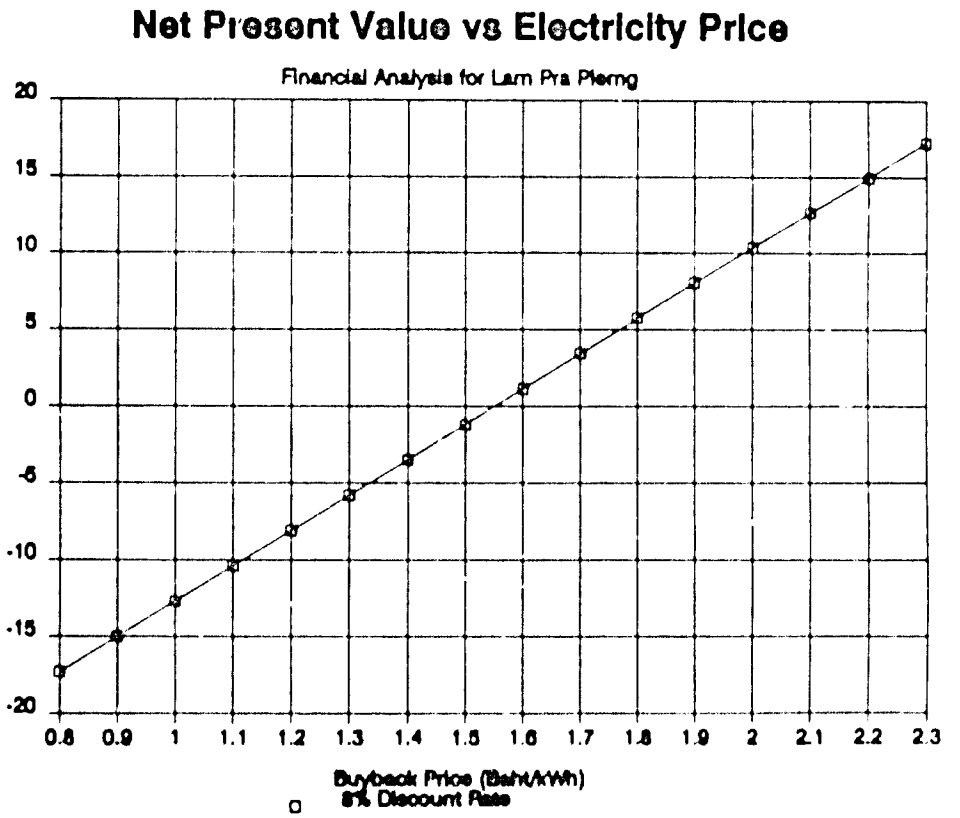

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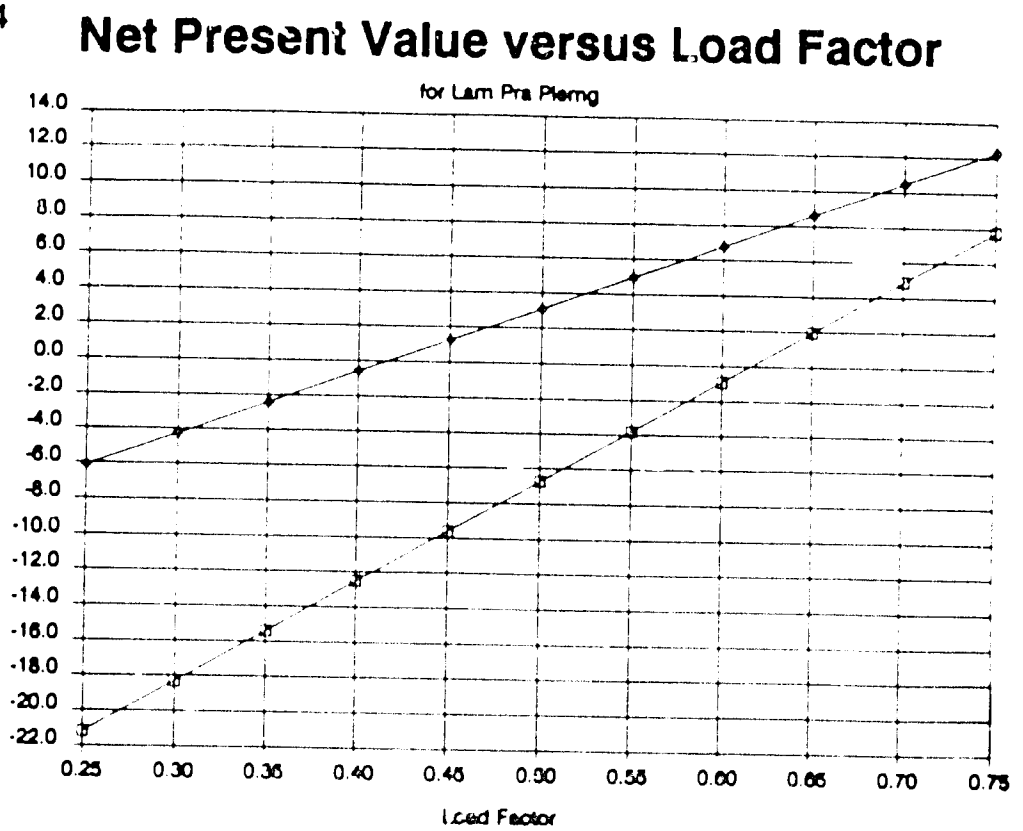


Exhibit I.45

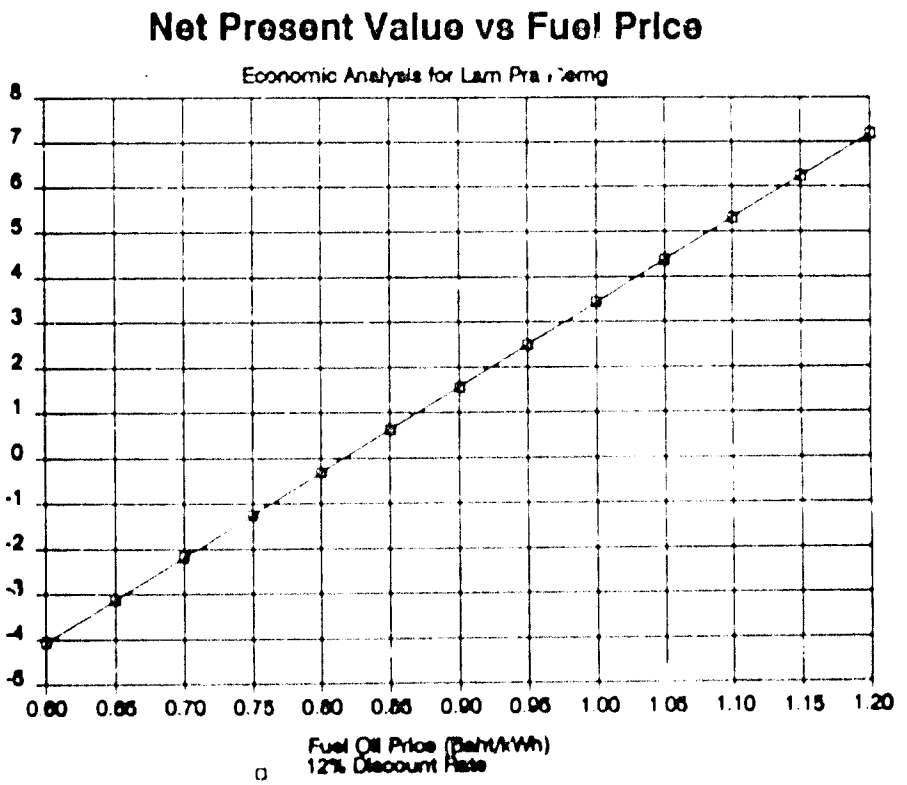


Exhibit I.46

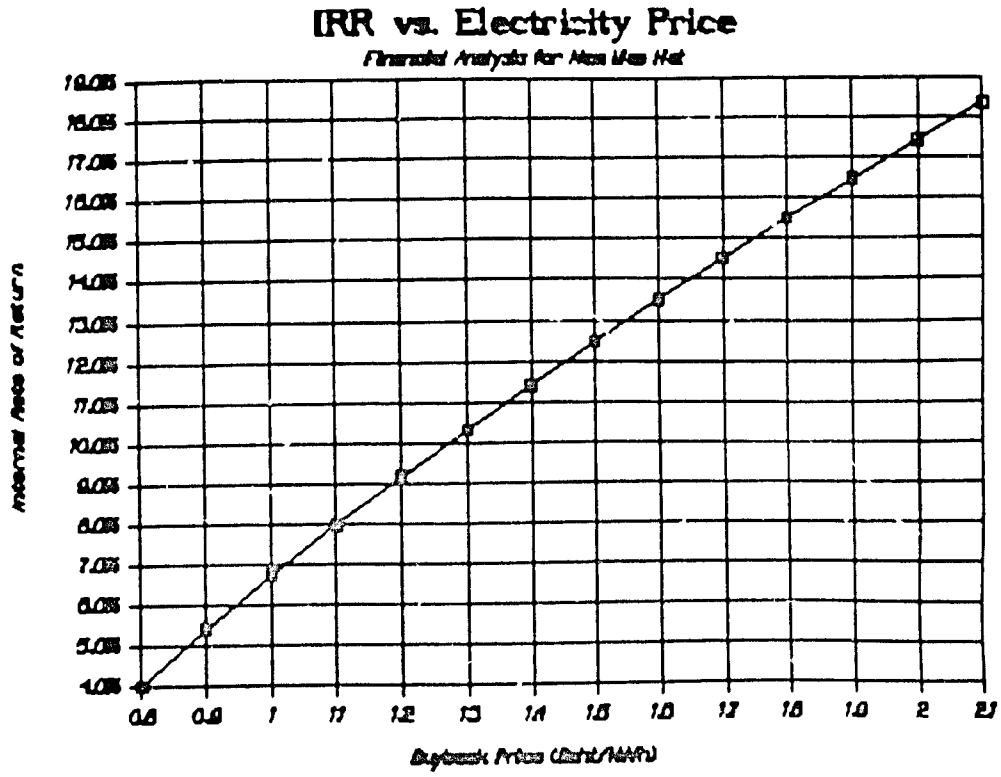


Exhibit I.47

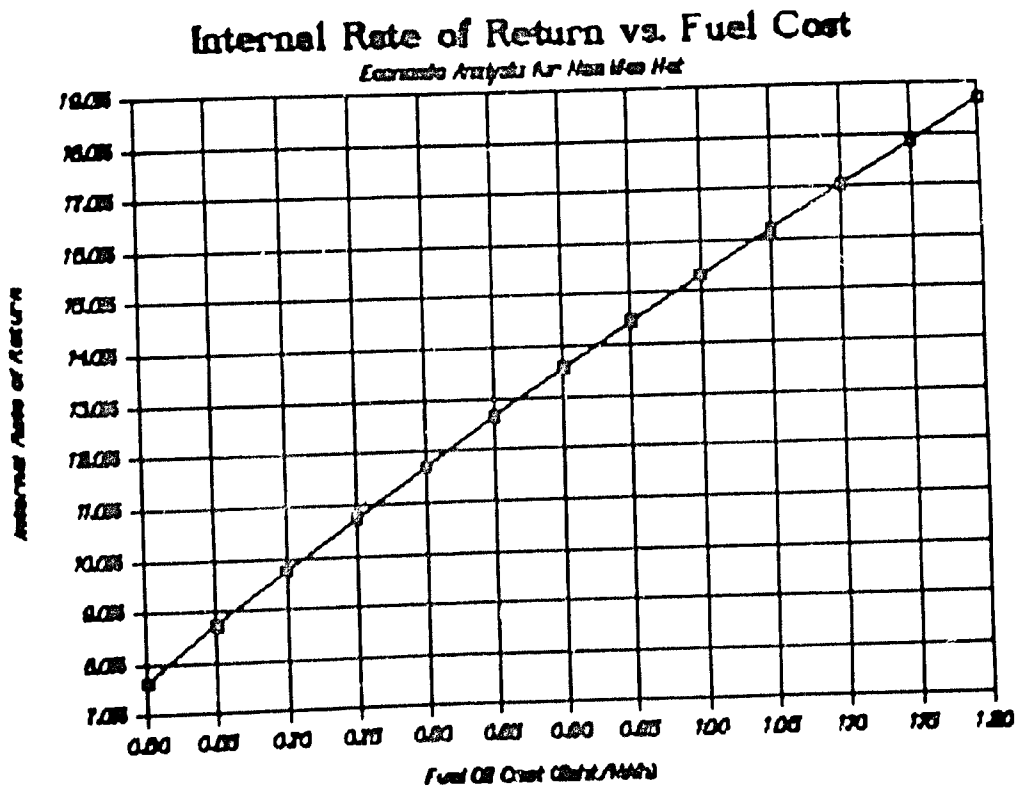
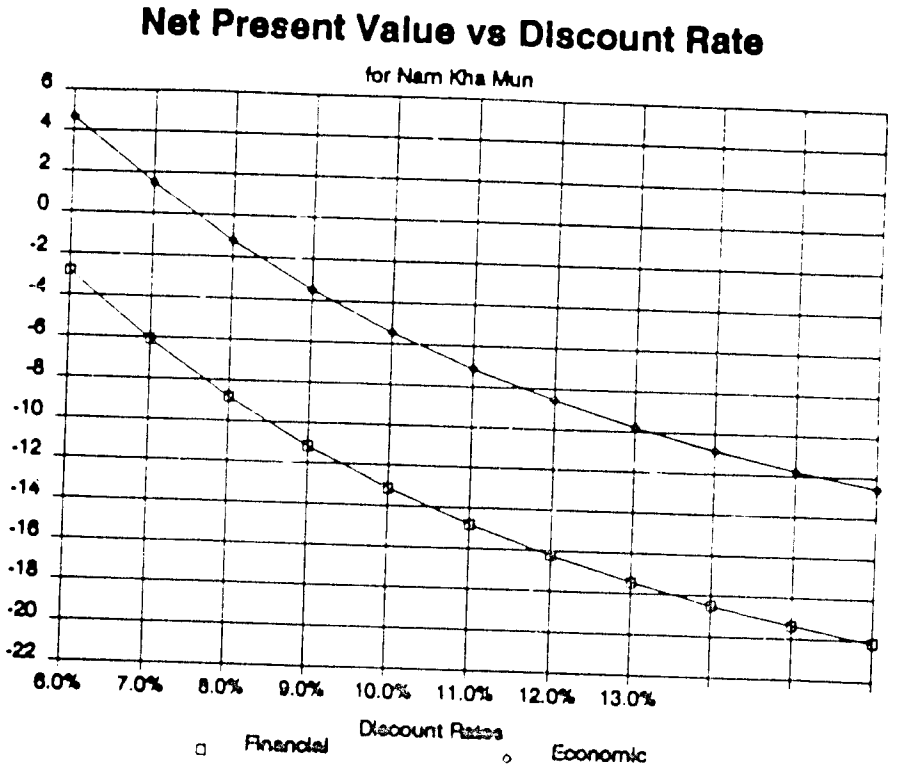


Exhibit I.48



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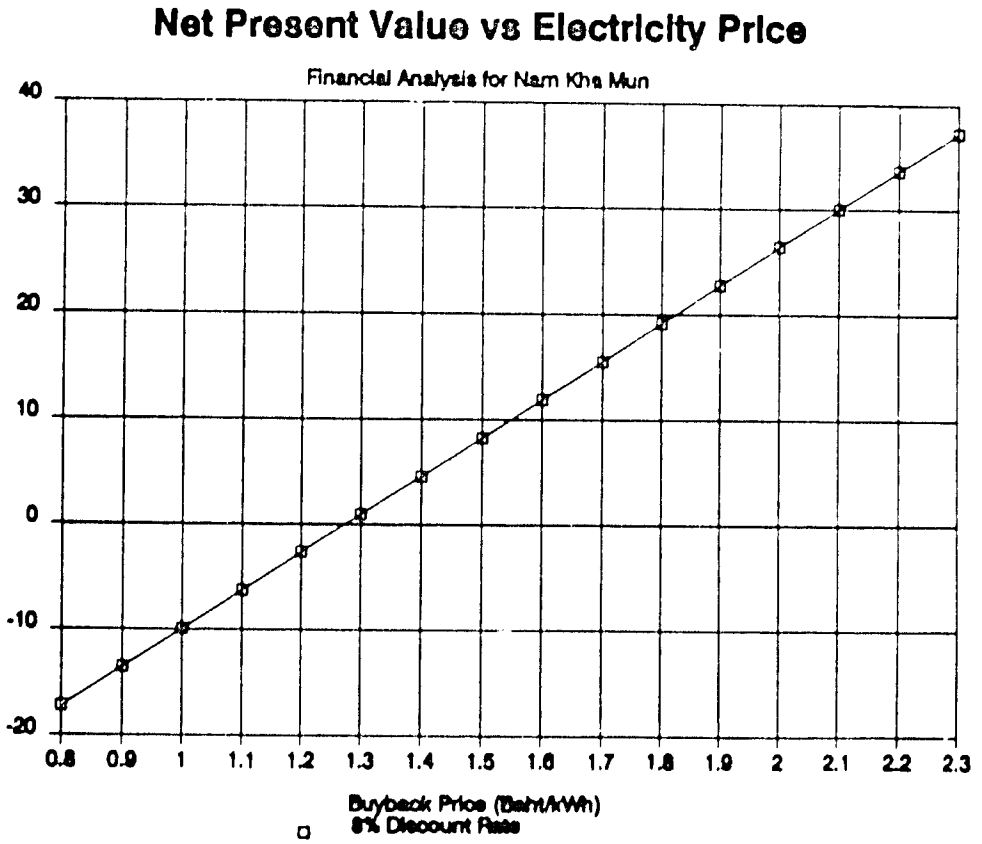
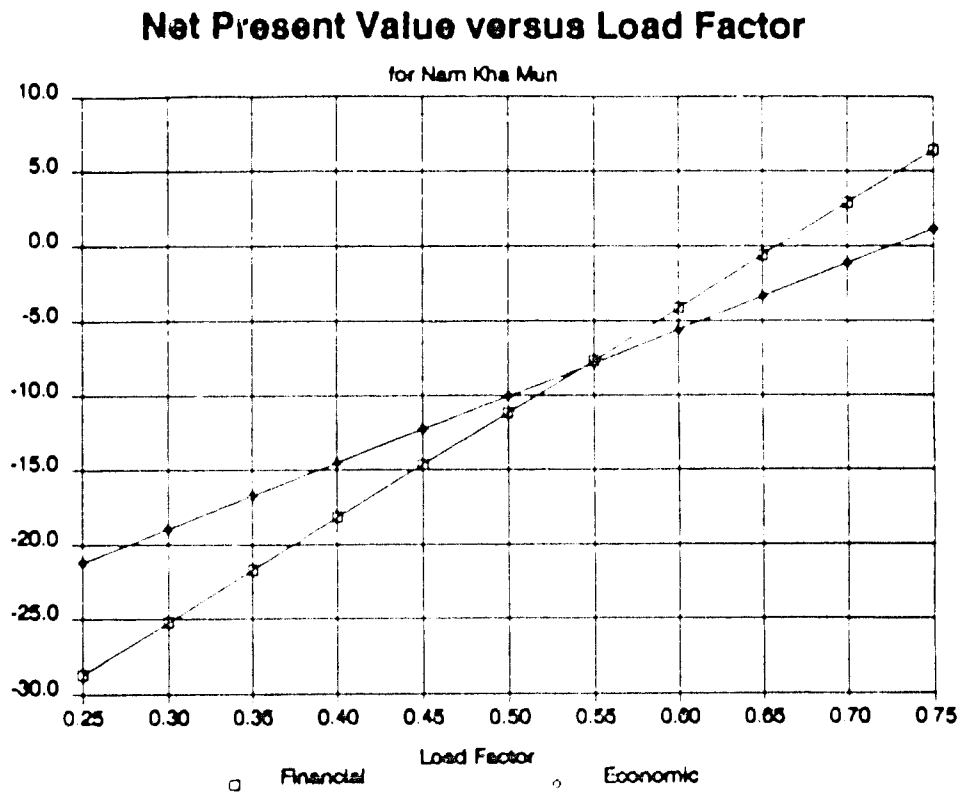


Exhibit I.50



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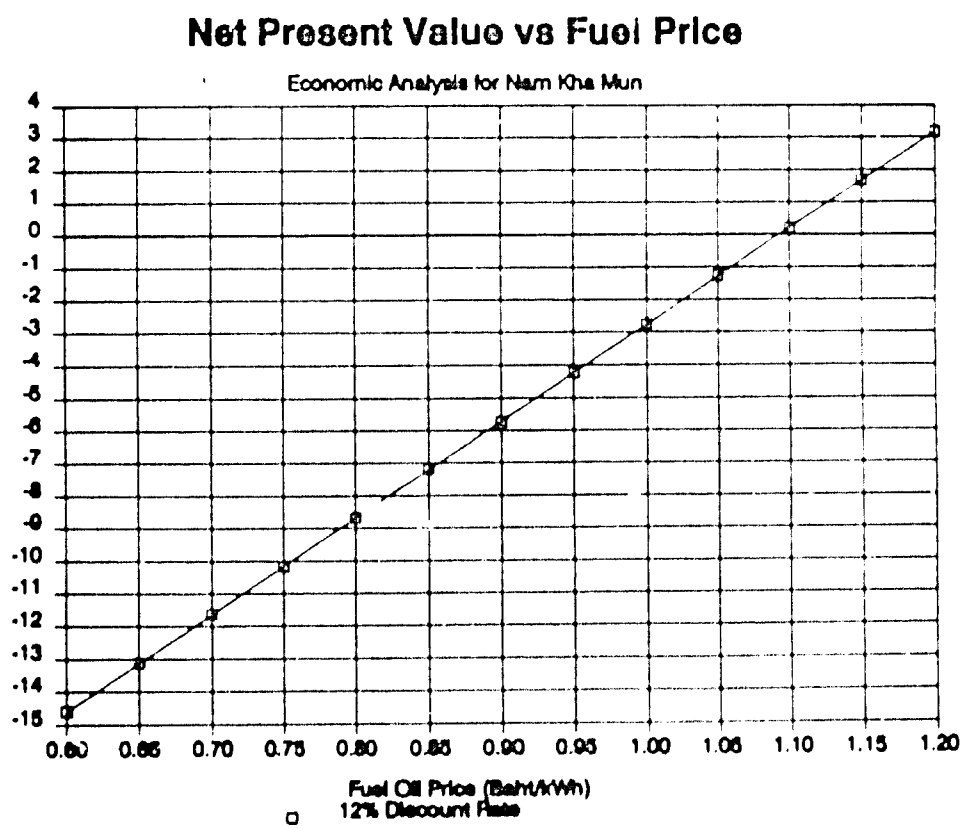

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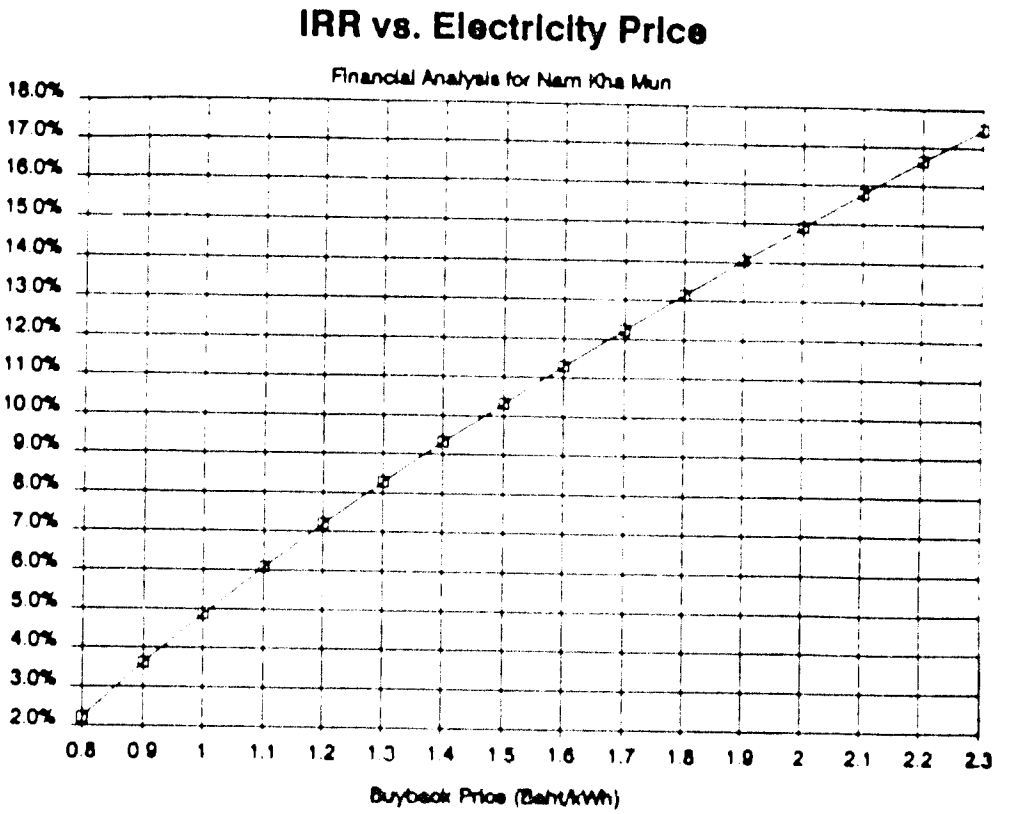

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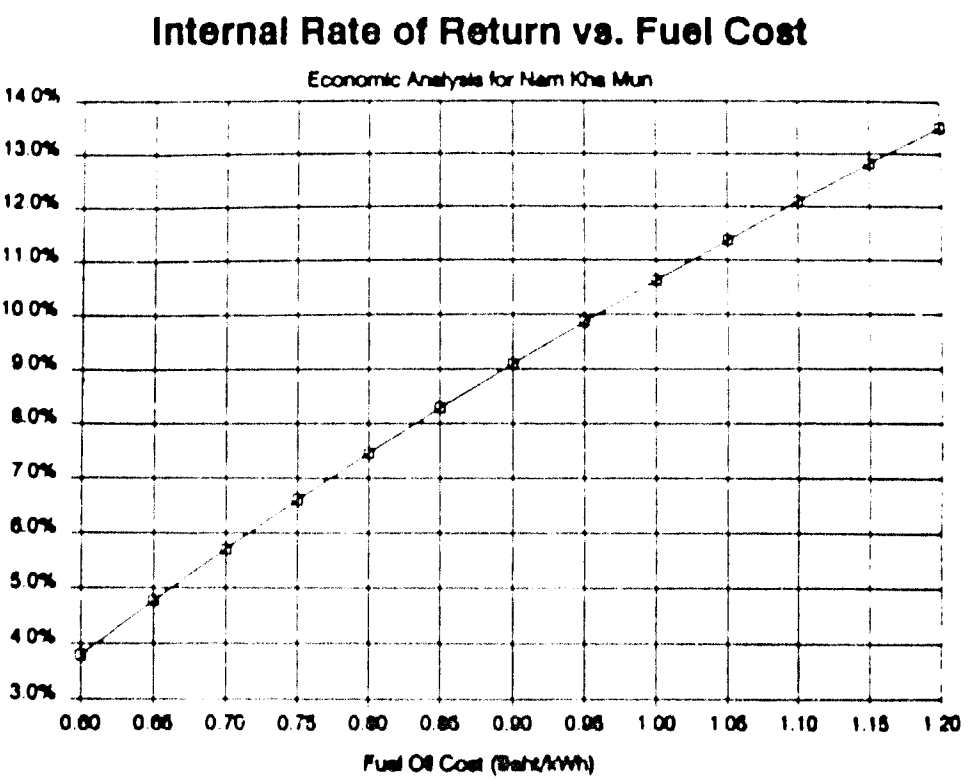

APPENDIX J: MODEL FORMATS

Financial and Economic Analysis of Current Projects

Name of Site Huai Lam Sin

financial discount rate	8.0%	
economic discount rate	12.0%	
shadow price (SCF)	82%	
design capacity	958	kW
dependable capacity	369	kW
buyback rate	1.03	Baht/kWh
economic cost of capacity	15.45	000's Baht/kW
% O&M rate for this capacity	1.25%	
economic cost of fuel replaced	0.804	Baht/kWh
marginal lines losses	15%	
load factor	72.9%	

year	1	2	3	4	5
Financial Costs (000's Baht)					
capital	19465.0	19465.0			
R&M			353.0	353.0	353.0
operations			250.0	250.0	250.0
subtotal	19465.0	19465.0	603.0	603.0	603.0
Financial Return (000's Baht)					
power generated (MWh)			6117.8	6117.8	6117.8
price (Baht/kWh)			1.03	1.03	1.03
total revenue	0.0	0.0	5356.2	5356.2	5356.2
Economic Costs (000's Baht)					
capital	15961.3	15961.3			
R&M			289.5	289.5	289.5
operations			250.0	250.0	250.0
subtotal	15961.3	15961.3	539.5	539.5	539.5
Economic Benefits (000's Baht) *					
capacity savings		5701.1			
O&M savings			71.3	71.3	71.3
fuel savings			4918.7	4918.7	4918.7
subtotal	0.0	5701.1	4990.0	4990.0	4990.0

* based on oil fired thermal plant

Financial and Economic Analysis of Current Projects

Results - Huai Lam Sin

	Financial	Economic
NPV	7,552	4,954
IRR	ERR	14.9%
B/C	1.19	1.16

Exhibit J.2

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Project Constants

Inflation rates		
· ave. domestic inflation (CPI)	4.0%	CPI
· Thailand relative to US	1.0%	INFBAHT
· labor costs relative to CPI	1.0%	INFLAB
USAID loan terms		
· grace period (years)	10	GRACET
· grace period interest (%)	2.0%	GRACEI
· payback period (years)	30.0	PAYBACKT
· payback period interest (%)	3.0%	PAYBACKI
· max. loan amount (000's US$)	8,000	MAXLOAN
· coverage of civil works	50.0%	PCTCIVIL
· coverage of E/M equipment	100.0%	PCTEQUIPM
· coverage of transmission	50.0%	PCTXMIS
· coverage of Adm and design	50.0%	PCTADMIN
· technical assistance	100.0%	PCTTA
Government financing		
· interest rate for overdraft	8.0%	GOVNTINT
Base Year Constants		
· exchange rate (Baht : US$)	25.5	EXRATE
· buyback rate (baht/kWh)	1.03	BUYBACK

Project Details

Project Name	Nam Mae Hat	Khlong Lam Piok	Huai Lam Sin	Lam Pra Plerng	Nam Kha Mun	Khlong Duson	Huai Mae Sot	Nam Ya Mo
Completion Date	12/87	12/88	5/88	2/89	2/89	3/89	3/89	6/89
Loan Disbursement Date	2/88	3/89	7/88	4/89	4/89	5/89	5/89	8/89
Nominal Capacity (kW)	818	1182	958	850	1030	680	660	738
Reliable Capacity (kW)	407	253	369	850	184	145	143	212
Expected Annual Output (MWh)	2843	7761	6115	3044	4809	5838	3359	[illegible]
Cost for Civil Works (mn Baht)	17.38	19.98	11.02	7.94	21.38	23.41	26.63	[illegible]
Cost for Transmission (mn Baht)	10.20	0.55	0.55		0.99	0.70	0.77	[illegible]
Cost for Equipment (mn Baht)	16.75	25.21	15.66	22.01	18.31	12.49	14.33	[illegible]
Cost for Admin&Design (mn Baht)								

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Project Cost Stream	1986	1987	1988	1989	1990	1991	1992	199
Civil Works (mn Baht)								
Nam Mae Hat	7.24	8.69	1.45					
Khlong Lam Plok		9.99	9.99					
Huai Lam Sin	3.22	5.51	2.30					
Lam Pra Plerng		3.31	3.97	0.66				
Nam Kha Mun		8.91	10.69	1.78				
Khlong Duson		8.78	11.70	2.93				
Nam Mae Sot		9.99	13.32	3.33				
Nam Ya Mo		9.50	19.00	9.50				
Total	10.46	64.67	72.42	18.20				
Transmission (mn Baht)								
Nam Mae Hat	4.25	5.10	0.85					
Khlong Lam Plok		0.28	0.28					
Huai Lam Sin	0.16	0.28	0.11					
Lam Pra Plerng								
Nam Kha Mun		0.41	0.49	0.08				
Khlong Duson		0.26	0.35	0.09				
Nam Mae Sot		0.29	0.38	0.10				
Nam Ya Mo		0.70	1.40	0.70				
Total	4.41	7.31	3.87	0.97				
Equipment (mn Baht)								
Nam Mae Hat	6.98	8.37	1.40					
Khlong Lam Plok		12.60	12.60					
Huai Lam Sin	4.57	7.83	3.26					
Lam Pra Plerng		9.17	11.00	1.83				
Nam Kha Mun		7.63	9.15	1.53				
Khlong Duson		4.69	6.25	1.56				
Nam Mae Sot		5.37	7.17	1.79				
Nam Ya Mo		5.00	10.01	5.00				
Total	11.55	60.67	60.84	11.72				
Design and Admin (mn Baht)								
Nam Mae Hat								
Khlong Lam Plok								
Huai Lam Sin								
Lam Pra Plerng								
Nam Kha Mun								
Khlong Duson								
Nam Mae Sot								
Nam Ya Mo								
Total								
Labor Operating Costs (000's Baht)								
base rate with inflation		250.0	262.6	275.8	289.7	304.3	319.7	335.8
Nam Mae Hat			262.6	275.8				
Khlong Lam Plok				275.8				
Huai Lam Sin			153.2	275.8				

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Lam Pra Plerng		229.9				
Nam Kha Mun		229.9				
Khlong Duson		206.9				
Nam Mae Sot		206.9				
Nam Ya Mo		137.9				
Total with inflation	415.8	1838.9	2317.9	2434.7	2557.4	2686.3

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Domestic Maintenance Costs (mn Baht)							
Nam Mae Hat		0.53	0.53	0.53			
Khlong Lam Plok			0.58	0.58			
Huai Lam Sin		0.20	0.35	0.35			
Lam Pra Plerng			0.34	0.41			
Nam Kha Mun			0.42	0.50			
Khlong Duson			0.32	0.43			
Nam Mae Sot			0.37	0.49			
Nam Ya Mo			0.35	0.71			
Total with inflation		0.76	3.53	4.49	4.67	4.86	5.0
Eligible Foreign Loan Disbursements (mn Baht)							
Nam Mae Hat		30.54					
Khlong Lam Plok			35.47				
Huai Lam Sin		21.44					
Lam Pra Plerng			25.97				
Nam Kha Mun			29.49				
Khlong Duson			24.55				
Nam Mae Sot			28.03				
Nam Ya Mo			40.42				
Technical Assistance		17.85					
Total eligible		69.83	183.94				
Total Disbursements with max. limit		69.83	134.17				
Government Disbursements		19.58	121.35				
Energy Generated							
Nam Mae Hat		2,417	2,843	2,843			
Khlong Lam Plok			6,597	7,761			
Huai Lam Sin		2,629	6,115	6,115			
Lam Pra Plerng			2,070	3,044			
Nam Khe Mun			3,270	4,809			
Khlong Duson			3,503	5,838			
Nam Mae Sot			2,015	3,359			
Nam Ya Mo			1,552	4,434			
subtotal		5,046	27,965	38,203	38,203	38,203	38,203
Buyback Rate	1.03	1.071	1.114	1.159	1.205	1.253	1.303
Exchange Rate	25.5	25.5	25.8	26.0	26.3	26.5	26.8

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Cash Flow Analysis (000's Baht)	1986	1987	1988	1989	1990	1991	1992	1993
Receipts								
Revenues from Buyback			5,405	31,154	44,262	46,033	47,874	49,789
Borrowings - USAID Loans			69,833	134,167				
Government Equity Contribution			19,578	121,346				
Sub-total								
Payments								
Capital Expenditures								
Civil Works	10,457	64,675	72,415	18,198				
Transmission	4,411	7,312	3,868	966				
E/M Equipment	11,545	60,668	60,840	11,717				
Admin and Design	16,575	16,575						
Debt Service Payments								
Principal on LT loans								
Interest on LT loans			688	1,636	4,162	4,204	4,246	4,288
Interest on ST loans			17,859	10,821	651			
Operating Expenditures								
Maintenance			761	3,526	4,493	4,673	4,860	5,054
Labor			416	1,839	2,318	2,435	2,557	2,686
	42,988	149,230	156,847	48,703	11,625	11,311	11,663	12,029
Net Operating Revenues			4,229	25,790	37,451	38,925	40,457	42,048
Investments Expenditures	42,988	149,230	137,124	30,881				
Cumulative Borrowings			69,833	204,000	204,000	204,000	204,000	
Outstanding Principal (begin year)				69,833	206,040	208,100	210,181	212,283
Outstanding Principal (end year)			69,833	206,040	208,100	210,181	212,283	214,406
Change in Net Working Capital	(42,988)	(149,230)	(62,031)	237,964	32,638	34,721	36,211	37,760
Cumulative Surplus (begin of year)		(42,988)	(192,218)	(254,249)	(16,285)	16,353	51,074	87,285
Cumulative Surplus (end of year)	(42,988)	(192,218)	(254,249)	(16,285)	16,353	51,074	87,285	125,045
Average Overdraft	(21,494)	(117,603)	(223,234)	(135,267)	(8,143)			

Exhibit J.3

Cash Flow Model for Commercial Loan

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Project Constants

Inflation rates		
- ave. domestic inflation (CPI)	4.0%	CPI
- labor costs relative to CPI	1.0%	INFLAB
Commercial loan terms		
- short term rate of interest (%)	10.0%	INTERST
- long term rate of interest	8.0%	INTERLT
- payback period - long term loans	10	PAYBACK
Base Year Constants		
- exchange rate (Baht : US$)	25.5	EXRATE
- buyback rate (baht/kWh)	1.03	BUYBACK

Project Details

Project Name	Nam Mae Hat	Khlong Lam Plok	Huai Lam Sin	Lam Pra Plerng	Nam Kha Mun	Khlong Duson	Nam Mae Sot	Nam Ya Mo
Completion Date	12/87	12/88	5/88	2/89	2/89	3/89	3/89	6/89
Loan Disbursement Date	2/88	3/89	7/88	4/89	4/89	5/89	5/89	8/89
Nominal Capacity (kW)	818	1182	958	850	1030	680		
Reliable Capacity (kW)	636	253	369	850	164	145		
Expected Annual Output (MWh)	6795	7761	6115	3044	4809	5838		
Cost for Civil Works (mn Baht)	17.38	19.98	11.02	7.94	21.38	23.41	26.63	37.99
Cost for Transmission (mn Baht)	10.20	0.55	0.55		0.99	0.70	0.77	2.81
Cost for Equipment (mn Baht)	16.75	25.21	15.66	22.01	18.31	12.49	14.33	20.02
Cost for Admin&Design (mn Baht)								
Total Capital Costs (mn Baht)	44.33	45.74	27.23	29.96	40.68	36.60	41.73	60.82

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Project Cost Stream	1986	1987	1988	1989	1990	1991	1992	1993
Civil Works (mn Baht)								
Nam Mae Hat	7.24	8.69	1.45					
Khlong Lam Plok		9.99	9.99					
Huai Lam Sin	3.22	5.51	2.30					
Lam Pra Plerng		3.31	3.97	0.66				
Nam Kha Mun		8.91	10.69	1.78				
Khlong Duson		8.78	11.70	2.93				
Nam Mae Sot		9.99	13.32	3.33				
Nam Ya Mo		9.50	19.00	9.50				
Sub-Total	10.46	64.67	72.42	18.20				
Transmission (mn Baht)								
Nam Mae Hat	4.25	5.10	0.85					
Khlong Lam Plok		0 28	0.28					
Huai Lam Sin	0.16	0.28	0.11					
Lam Pra Plerng								
Nam Kha Mun		0.41	0.49	0.08				
Khlong Duson		0.26	0.35	0.09				
Nam Mae Sot		0.29	0.38	0.10				
Nam Ya Mo		0.70	1.40	0.70				
Sub-Total	4.41	7.31	3.87	0.97				
Equipment (mn Baht)								
Nam Mae Hat	6.98	8.37	1.40					
Khlong Lam Plok		12.60	12.60					
Huai Lam Sin	4.57	7.83	3.26					
Lam Pra Plerng		9.17	11.00	1.83				
Nam Kha Mun		7.33	9.15	1.53				
Khlong Duson		4.69	6.25	1.56				
Nam Mae Sot		5.37	7.17	1.79				
Nam Ya Mo		5.00	10.01	5.00				
Sub-Total	11.55	60.67	60.84	11.72				
Design and Admin (mn Baht)								
Nam Mae Hat								
Khlong Lam Plok								
Huai Lam Sin								
Lam Pra Plerng								
Nam Kha Mun								
Khlong Duson								
Nam Mae Sot								
Nam Ya Mo								
Sub-Total								
Total Capital Investment	26.41	132.66	137.12	30.88				

Labor Operating Costs (000's Baht)

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

base rate with inflation	250.0	262.6	275.8	289.7	304.3	319.7	335.8
Nam Mae Hat		262.6	275.8				
Khlong Lam Plok			275.8				
Huai Lam Sin		153.2	275.8				
Lam Pra Plerng			229.9				
Nam Kha Mun			229.9				
Khlong Duson			206.9				
Nam Mae Sot			206.9				
Nam Ya Mo			137.9				
Total with inflation		415.8	1838.9	2317.9	2434.7	2557.4	2686.3

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Domestic Maintenance Costs (mn Baht)							
Nam Mae Hat		0.53	0.53	0.53			
Khlong Lam Plok			0.58	0.58			
Huai Lam Sin		0.20	0.35	0.35			
Lam Pra Plerng			0.34	0.41			
Nam Kha Mun			0.42	0.50			
Khlong Duson			0.32	0.43			
Nam Mae Sot			0.37	0.49			
Nam Ya Mo			0.35	0.71			
Total with inflation		0.76	3.53	4.49	4.67	4.86	5.05
Energy Generated							
Nam Mae Hat		5,776	6,795	6,795			
Khlong Lam Plok			6,597	7,761			
Huai Lam Sin		2,629	6,115	6,115			
Lam Pra Plerng			2,070	3,044			
Nam Kha Mun			3,270	4,809			
Khlong Duson			3,503	5,838			
Nam Mae Sot							
Nam Ya Mo							
subtotal		8,405	28,350	34,362	34,362	34,362	34,362
Buyback Rate	1.03	1.071	1.114	1.159	1.205	1.253	1.303
Exchange Rate	25.5	25.5	ERR	ERR	ERR	ERR	ERR

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Loan Repayment Calculation								
1986 borrowings		6,406	6,406	6,406	6,406	6,406	6,406	6,406
1987 borrowings			22,240	22,240	22,240	22,240	22,240	22,240
1988 borrowings				20,435	20,435	20,435	20,435	20,435
1989 borrowings					4,602	4,602	4,602	4,602
1990 borrowings								
1991 borrowings								
1992 borrowings								
Total Repayment		6,406	28,646	49,082	53,684	53,684	53,684	53,684
Interest Payments								
1986 borrowings		3,439	3,202	2,945	2,668	2,369	2,046	1,698
1987 borrowings			11,938	11,114	10,224	9,263	8,225	7,104
1988 borrowings				10,970	10,213	9,395	8,512	7,558
1989 borrowings					2,470	2,300	2,116	1,917
1990 borrowings								
1991 borrowings								
1992 borrowings								
Sub-total		3,439	15,140	25,029	25,576	23,327	20,899	18,276
Principal Payments								
1986 borrowings		2,967	3,205	3,461	3,738	4,037	4,360	4,709
1987 borrowings			10,301	11,125	12,015	12,977	14,015	15,136
1988 borrowings				9,466	10,223	11,041	11,924	12,878
1989 borrowings					2,132	2,302	2,486	2,685
1990 borrowings								
1991 borrowings								
1992 borrowings								
Sub-total		2,967	13,506	24,052	28,108	30,357	32,785	35,408
Cash Flow Analysis (000's Baht)	1986	1987	1988	1989	1990	1991	1992	1993
Receipts								
Revenues from Buyback			9,004	31,583	39,812	41,405	43,061	44,783
Borrowings - Commercial Loans	42,988	149,230	137,124	30,881				
Sub-total	42,988	149,230	146,127	62,464	39,812	41,405	43,061	44,783
Payments								
Capital Expenditures								
Civil Works	10,457	64,675	72,415	18,198				
Transmission	4,411	7,312	3,868	965				
E/M Equipment	11,545	60,668	60,840	11,717				
Admin and Design	16,575	16,575						
Debt Service Payments								

CASH FLOW ANALYSIS FOR THAILAND MINI/MICRO HYDRO PROJECT

Principal on LT loans		2,967	13,506	24,052	28,108	30,357	32,785	35,408
Interest on LT loans		3,439	15,140	23,029	25,576	23,327	20,899	18,276
Interest on ST loans		337	1,806	4,295	7,039	9,889	12,899	16,083
Operating Expenditures								
Maintenance			761	3,526	4,493	4,673	4,860	5,054
Labor			416	1,839	2,318	2,435	2,557	2,686
Sub-total	42,988	155,974	168,752	89,622	67,534	70,686	74,001	77,507
Net Operating Revenues			7,827	26,218	33,001	34,297	35,643	37,043
Investments Expenditures	42,988	149,230	137,124	30,881				
Cumulative Long Term Borrowings	42,988	192,218	329,342	360,223	360,223	360,223	360,223	360,223
Outstanding Principal (begin year)		42,988	189,251	312,868	319,697	291,589	261,233	228,447
Outstanding Principal (end year)	42,988	189,251	312,868	319,697	291,589	261,233	228,447	193,039
Change in Net Working Capital		(6,744)	(22,625)	(27,158)	(27,722)	(29,276)	(30,940)	(32,724)
Cumulative Surplus (begin of year)			(6,744)	(29,368)	(56,527)	(84,248)	(113,524)	(144,464)
Cumulative Surplus (end of year)		(6,744)	(29,368)	(56,527)	(84,248)	(113,524)	(144,464)	(177,188)
Average Overdraft		(3,372)	(18,056)	(42,948)	(70,387)	(98,886)	(128,994)	(160,826)

APPENDIX K: SCOPE OF WORK FOR PROJECT PERSONNEL

ANNEX

PERSONNEL ASSIGNMENT AND SCHEDULE

B.1 PERSONNEL ASSIGNMENT OF DETAILED ENGINEERING DESIGN UNIT (DEDU) OF PART A SERVICES

(1) Team Leader: The Team Leader of the DEDU shall be responsible for the survey, investigation, detailed design and preparation of contract documents for the first tranche sites (up to six sites) of the Part A Services. His tasks shall be as follows:

- Coordination with the Project Manager and the SE/PC in the detailed engineering design of the first tranche sites.

- Exchanging information with the TAG in the development of integrated analytical (site selection) model. The DEDU shall supply engineering and cost information relating to engineering design to the TAG for the establishment of engineering and cost (sub) models.

- Responsible for the verification of feasibility studies and other completed works for the first tranche sites.

- Coordination with the Socio-economic Analyst and Load Forecast Specialist in the verification of previous feasibility studies.

- Coordination with the Project Manager, SE/PC, and the Construction Manager concerning the implementation schedule of the first tranche sites, i.e., construction of civil works, procurement and installation of electromechanical equipment.

- Preparation of engineering design report and design criteria for submission to NEA.

(2) Hydrologist/Water Resources Engineer: The Hydrologist/Water Resources Engineer shall make site visits and conduct streamflow measurement at each site to verify the design

- Collecting available streamflow data from other adjacent basins and/or in the region and make supplementary study to support the establishment of flow duration curves for the site.

- Utilizing field information to the maximum extent in establishing the flow duration curves, the minimum flows and the design flood peaks.

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- Supporting the DEDU in estimating the cross drainage requirements, if necessary, along the headrace and the potential of sedimentation damage and remedial measures.

- Investigating the identification of other water demands inter alia, irrigation diversion requirements in the stream reach between the weir and the powerhouse.

- Submitting his findings and recommendations including alternatives to the DEDU Team Leader for establishing the design criteria. Also work in close cooperation with the NEA hydrologist/water resources engineer.

(3) Hydropower Engineer: The Hydropower Engineer shall work closely with the Team Leader and the Hydrologist and the SE/PC. In addition, the Engineer shall be responsible for:

- Establishing the conceptual design and criteria including recommendation of the most appropriate hydraulic turbine.

- Setting of the machine, and other civil works.

- Assisting the Civil/Structural Design Engineers and the DEDU on the detailed engineering design and specifications preparation.

(4) Geologist/Construction Material Specialist: The Geologist/Construction Material Specialist shall make site visits to all 6 sites, making field observations on surface geology to reflect the foundation and construction conditions of the weir, intake, headrace, penstock, powerhouse, tailrace and access road (if necessary). Included in his tasks are also:

- Delineating a program for subsurface investigations at some key locations.

- Drawing up the program for exploration of construction materials which includes collection of samples such as sand, concrete aggregate, soil and laterite for laboratory testing.

- Studying the collected field data and preparing recommendations for foundation treatments and materials for construction.

(5) Chief Survey Engineer: The Chief Survey Engineer shall accompany the detailed engineering design field visit team to each site. He shall assist the field visit team in the selection of weir site, intake site, headrace and penstock route, powerhouse site and other necessary structures. He shall draw-up the plan for survey at each site and, during the field survey works, manage the logistics, provide at-site technical supervision and coordinate with the DEDU for

additional and/or change of on-going works. He shall be responsible for the preparation of survey maps for further detailed engineering designs.

(6) Civil/Structural Design Engineers (2 Engineers): The Civil/Structural Design Engineers shall make site visits and participate in the selection of the component sites, draw-up requirements and specifications for survey works, coordinate with the Geologist/Construction Material Specialist in preparing the investigation program. They shall assist the Team Leader in the preparation of design criteria and engineering report. They shall be responsible for the detailed design and production of construction drawings of civil works.

(7) Construction Plan/Schedule/Contract Documents/Cost Specialist: The Construction Plan/Schedule/Contract Documents/Cost Specialist shall assist the Team Leader in preparation of the construction plan and schedule, to be reviewed and approved by NEA. He is responsible for the preparation of contract documents and specifications, quantity and cost estimates of the first tranche sites. He shall assist the DEDU Team Leader in coordination with the Project Manager, the SE/PC and the Construction Manager for the construction contracting preparation.

(8) Mechanical Engineer: The Mechanical Engineer shall work with the Team Leader, the SE/PC, the Hydropower Engineer, the Civil/Structural Design Engineer and the Electrical Engineer for the selection of hydraulic turbine, other electro-mechanical equipment, layout of the power plant, and specifications for equipment procurement. He shall review the typical layouts and designs of the power plant done by NEA for previous projects in order to modify and/or adopt for this project. Also he shall assist the Team Leader in preparation of design criteria and final report.

(9) Electrical Engineers (No. 1 and No. 2): The Electrical Engineers shall primarily work with the Mechanical Engineer in the layouts and design of electrical equipment for the powerhouse, switchyard and transmission line, and for preparation of technical specifications for equipment procurement to be submitted to the Project Manager.

B.2 PERSONNEL ASSIGNMENT OF TECHNICAL ASSISTANT GROUP (TAG) OF PART B SERVICES

(1) Senior Engineer/Project Coordinator (SE/PC): The SE/PC shall work full-time during his assigned service period. His primary task shall include assisting and advising the NEA management and the Project Manager in developing daily work plans for the Project Operations Unit (POU) staff. He shall take the leading role and responsibility of the Part B Services in the development of the integrated analytical model for site selection and planning of the Micro/Mini Hydroelectric Projects. His responsibilities are listed as follows:

- Assisting and advising NEA and the Project Manager in all important aspects.
- Coordinating TAG with DEDU and NEA.
- Development of the day-to-day work plan for the POU staff.
- Responsible for the development of the site selection analytical model and its subsequent refinement.
- Working closely with other occasional specialists, including preparing scopes and schedule of works for additional specialists, if needed.
- Reviewing of final engineering designs, contract documents and specifications.
- Responsible for assisting NEA for contracting the construction services which should follow the agreed policy lines and contracting restrictions imposed by NEA and AID.
- Identifying other special training of utility for the POU staff and undertaking or arranging on-the-job training program.
- Preparation of Quarterly Reports, for NEA and AID, on the project work progress and scheduling.
- Preparing the project monitoring plans.
- Participation in preparation of plans for impact evaluation (from pre and post construction).
- Responsible for the final report preparation.

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(2) Construction Manager: The Construction Manager shall work full-time during his service period. His tasks shall be as follows:

- Assisting NEA and Field Engineers in preparation of construction work sites.

- Assisting SE/PC and the Project Manager in the contracting of the civil works construction services.

- Coordination with the Project Manager, Field Engineers and the SE/PC for the delineation of construction work plans and work schedules.

- Assisting the Project Manager in procurement of the power plant equipment.

- Sharing responsibilities with the Field Engineers in supervision of civil works construction drawings to suit the changing site condition, as necessary.

- Assisting the SE/PC in preparation of the Quarterly Reports.

(3) Socio-economic Analyst: The Socio-economic Analyst shall mainly work with the POU, the SE/PC and other occasional specialists. However, some coordination and assistance work with the DEDU are required. His tasks shall be as follows:

- Assisting the DEDU in the verification of the socio-economic feasibility of the approved 3 sites namely, Mae Hat, Mae Aep and Mae Chon Luang.

- Assisting the POU in the feasibility studies on the other 3 sites of the first tranche which may include review and modification, if necessary, of the work done on Mae Suk, Khlong Ta Riu and Khlong Ra.

- Closely working with the SE/PC, POU and other occasional specialists in developing the integrated analytical model (or site selection model) which includes engineering, socio-economics, management and environment together.

- Coordination with NEA computer specialists in developing the capacity on data processing and compilation and other analytical model applicable to the site selection process.

- Coordination with the SE/PC and the POU in preparation of the benchmark (baseline) socio-economic surveys (or pre-construction survey) of the 12 micro/mini hydro projects.

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- Together with NEA socio-economic managing the field socio-economic surveys.

- Assisting NEA Socio-economist in processing and compilation of the field information.

- Analyzing the compiled information and proposing the forecasting model, field survey and evaluation techniques, which are to be parts of the site selection model, that shall enlarge the capability of the POU in the feasibility studies of the second tranche sites and future projects.

- Undertaking the socio-economic analyses for selection of second tranche sites.

- Assisting and advising NEA and RTG on sectoral planning relating to development of micro/mini hydroelectric projects.

- Coordination with the SE/PC and the POU in preparation of the post construction socio-economic surveys for up to 6 sites.

- Analyzing and evaluating the compiled information and making adjustments to the site selection model prior to the termination of his services to NEA.

- Providing on-the-job training to the POU staff as deemed appropriate.

- Assisting the SE/PC in preparation of the Quarterly Reports.

(4) Consumer Promotion Specialist: The Consumer Promotion Specialist shall work with the SE/PC and the POU and other specialists in order to promote the production consumption of generated hydroelectric power of the 12 sites. His tasks shall be as follows:

- Making site visits to observe the conditions of the areas to be served by micro/mini hydroelectrification program.

- Identification of the potential of productive consumption of electrical power such as electric pumping irrigation schemes, local business establishments, local small scale industries, and other local plants.

- Study and analyzing the organizations of the potential electric consumers and their operational procedures.

- Identifying and evaluating needs for credits to such organizations and individual households (for lighting and home electrical appliances) including the supporting institutions concerned.

- Participation in planning for the power line distribution to the communities and estimating the connection costs to individual households and other types of consumers.

- Study and analysis of the appropriate tariff structure taking into consideration the RTG policy, socio-economic conditions of the service areas, operating and financial plans of each particular site.

- Identifying the needs for local training in view of both project operation, maintenance and administration program and consumer promotional program.

- Participation in implementation of consumer promotion activities.

- Participation in the planning and evaluation of impact evaluations (pre-construction program).

- Coordination with the Load Forecast Specialist for the feasibility study and model development.

- Recommendations for further necessary works.

- Assisting the SE/PC in preparation of the Quarterly Reports.

(5) Manufacturing Promotion Specialists (One Local Specialist, One Expatriate Specialist): The Manufacturing Promotion Specialists are to be working with the SE/PC and POU to promote local manufacturers to produce small hydropower equipment. Their tasks shall be as follows:

- Identify local manufacturers which presently produce small hydropower equipment, or who have developed locally the skills and resources needed for such manufacture.

- Visit the more promising manufacturing facilities to assess basic skills and current capabilities to produce probable hydroelectric turbine types. Consideration will be given to engineering capability, shop management, materials, fabrication, machining, assembly, quality control, transport preparation and other shop functions.

- Prepare an evaluation report which describes current in-country hydroelectric turbine manufacturing capability and provides recommendations for strengthening that capability if necessary.

- Identify interested U.S. manufacturers who are capable of providing technology transfer to strengthen local manufacturing capability.

- Identify competent U.S. manufacturers who are interested in producing for export, such equipment which may be needed for a particular project, but which may not be currently available in Thailand.

- Assessment of local production capabilities and technology in order to identify gaps which should be filled up by the interested U.S. manufacturers.

Two specialists shall be working in the Manufacturing Promotion Specialist position, i.e., local and expatriate specialists. The local specialist shall take responsibility on the local manufacturers while the expatriate (U.S.) specialist on the U.S. manufacturers. However, these two personnel shall coordinate and work together during the period while the expatriate specialist is in Thailand.

(6) Load Forecast Specialist: The Load Forecast Specialist shall work with the SE/PC, the POU, occasional specialists, and the DEDU for establishing the future electric power and energy demands appropriate for the integrated analytical model. His tasks shall be as follows:

- Coordination with the Socio-economic Analyst, the Consumer Promotion Specialist, the SE/PC and POU in formulating the key information required for the load forecast model.

- Establishing the load forecast model.

- Assisting and advising the DEDU in the load forecast study, whenever required, during the verification of the previous feasibility studies for the first tranche sites.

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B.3 PROJECT PERSONNEL ASSIGNMENT SCHEDULE

The project personnel assignment schedule of the Detailed Engineering Design Unit (Part A Services) shall be as specified in Figure B-1 while the Technical Assistant Group Personnel (Part B Services) is scheduled as shown in Figure B-2.

B.4 PROJECT ORGANIZATION

The project organization for the implementation of this Project shall be as delineated in Figure B-3.

APPENDIX L: COST-BENEFIT ANALYSIS FOR ARE.2

Table 1: ANNUAL BENEFITS IN LIGHTING COST PER ELECTRIFIED HOUSEHOLD

Item	Lighting Source (Baht)	
	Unelectrified (kerosene)	Electrified
Connection Cost:		
Blue-wire connection (by PEA)	-	50
Meter deposit (by PEA)	-	120
Inspection fee (by PEA)	-	40
House wiring with light fixtures and receptacles (by private contractor)		1,340
Total Connection Cost	-	1,550
Annual Fuel or Energy Cost	481	151 (1)
Annual Connection Recovery Cost	-	192 (2)
Total Annual Lighting Cost	481	343

Average savings in annual lighting cost per electrified household = B 138

(1) Assuming 3 fluorescent tubes that use 40 W each and burn 3 hours a day for 365 days per year at 1.15 per kWh.

(2) Using a 12% opportunity cost of capital and a 30-year life.

Average annual savings in lighting cost are estimated at B 138 per electrified household without taking into consideration benefits due to the superior quality of electric lighting.

B. Household's agricultural labor saving benefits from electricity lighting are attributable to additional working hours available during the peak agricultural season as evaluated below:

Table 2: ANNUAL BENEFITS DUE TO LABOR SAVINGS

	Assumption	Unit
Peak agricultural labor season	30	Days/year
Additional agricultural labor available during the peak season	1.5	Hours/day
Marginal value product of agricultural labor during the peak season	20	B/8-hour day
Percent of village households whose major occupation is agriculture	79	Percent
Average annual rural electrified household peak agricultural season labor savings	=	B 88

$$\frac{(30)\ (1.5)}{(8)}\ (20)\ (0.79) = 88$$

C. Household's lighting benefits from handicraft activities are attributable to productive labor input available during the evening hours. Synthesized average annual benefits from handicraft activities are estimated at B 58 as analyzed in Table 3:

Table 3: ANNUAL BENEFITS OF RURAL ELECTRIFIED HOUSEHOLD FROM HANDICRAFT ACTIVITIES

Case study	Average annual benefits per household	Weight	Weighted annual benefits per household
(1)	B 720	1/6	B 120
(2)	B 480	2/6	B 160
(3)	B 80	3/6	B 40
Weighted average annual benefits per household involved in handicraft activites		= B 320	
Percentage of households having people working in nonagriculture fields			18%
Annual benefits per household		= B 58	

(1) Case 1: Basket Making (Village of Tachamung, Province of Songkhla)

Without electrification: 2 families engaged together in a rattan basket cottage industry work until 19.00 or 20.00 hours making baskets.

With electrification: The same 2 families now work until 22.00 hours because of high quality electric lighting. Given 2 productive workers per family, each family now makes 2 extra baskets per day. The families sell the baskets for B 8 each and each family makes a profit of B 3 per basket.

Annual benefits = (B 6 per day x 120 days) = B 720.

(2) Case 2: Silk Weaving (Village of Phumriang, Province of Surat Thani)

Without electrification: a farm family engaged in silk weaving part-time does not work in the evening hours.

With electrification: The same farm family can now productively work an extra 2 hours each night because of high quality electric lighting. The family is able to make 1.6 extra meters of silk per day. The family sells the silk for B 40 per meter and makes a profit of B 2.5 per meter.

Annual benefits = (B 4 per day x 120 days) = B 480.

(3) Case 3: Mat Making and Pillow Making (Village of Bantum, Province of Falasin)

Without electrification: No cottage industry activities.

With electrification: The same farm family makes straw mats and stuffed pillows at night because of high quality electric lighting. The family makes a profit of B 20 per month with these cottage industry activites.

Annual benefits = (B 20/month) (4 months/year) = B 80.

D. Household's cooking benefits are due to cost savings for not having to buy or gather fuel for cooking. Average annual cooking benefits are estimated at B 146 per household as below:

Table 4: ANNUAL BENEFITS DUE TO COST SAVINGS IN COOKING

Item	Cooking Source (Baht)	
	Unelectrified	Electrified
Rice cooker	-	850
Annual fuel cost	457(1)	257(2)
Equipment recovery cost	30	171(3)
Total annual cooking costs	487	428
Average savings in annual cooking costs per electrified household	= B 59	

(1) Average household expenditures for charcoal and firewood.

(2) Assuming a 750 W rice cooker used 0.5 hours per day for 365 days per year at B 1.15 per kWh and a supplemental fuel cost of B 100 per year for other cooking purposes.

(3) Using a 12% opportunity cost of capital and an 8 years life.

E. In summary, total average indirect surplus benefits per electrified household are estimated at B 343 per year. Of this total, 40% (B 138) is due to lighting savings, 26% (B 88) due to agricultural season labor savings; 17% (B 58) due to handicraft activities; and 17% (B 59) due to cooking savings.

4. Surplus Benefits from Rural Shop Electrification

Indirect benefits from rural shop electrification include cost saving benefits and increased productivity benefits. Three different types of shops were analyzed with the following results:

Type of shop	Average percentage of shops	Average annual benefits per shop	Weighted annual benefits per shop
General goods	65%	B 1,003	B 652
Food	25%	B 1,247	B 312
Tailor	10%	B 1,467	B 141
	Total		B 1,105
	Less connection fee recovery cost		B 150
	Average annual benefit per electrified shop		B 955

5. Surplus Benefits from Rice Mill Conversion

The major benefits arising from rice mill conversion are stemmed from cost savings in annual maintenance and capital recovery, and improvement in the rice recovery. A synthesized case study is shown in Table 5.

Table 5: ANNUAL BENEFITS FOR RICE MILL CONVERSION

Item	Rice Mill		
	Unelectrified	Electrified	Unit
Horsepower	15	7.5	HP
Capital cost	25,500	7,700	B
Life Expectance	10	15	Years
Hours of operation per year	1,159	869	Hours
Consumption of fuel per hour	1.8	5.6	Liters/kW
Annual fuel cost	14,123 /a	7,825 /b	B
Annual maintenance cost	3,609	385	B
Annual capital recovery cost (@ 12% cost of capital)	(4,512)	1,131	B
Annual connection recovery cost	-	1,210	
Total annual cost to the miller	17,732	10,551	B
Paddy-rice conversion ratio	60.0	60.5	Percent
Paddy requirement per capita (165 kg of rice per capita)	275	273	Kilograms
Cost of paddy to consumer @ B 2.7/kg	743	737	B
Cost of paddy per rice mill service area (600 persons per mill)	445,800	442,200	B
Savings in annual costs to operator			B 7,181
Savings in rice costs to society			B 3,600
Total Average Annual Surplus Benefits			B 10,781

/a 1,159 x 1.8 x 6.77 B/liter = B 14,123.

/b 4,860 x B 1.61/kWh = B 7,825.

/c Not taking into account for rice mills already in operation.

6. Surplus Benefits from Use of Power Tools

Indirect tangible benefits from power tools include cost-savings benefits and increased productivity benefits. The case study in Table 6 demonstrates cost-savings for a rural private house builder from substituting a power plane for additional labors.

Table 6: ANNUAL BENEFITS OF POWER TOOLS

Item	Unelectrified	Electrified	Unit
Wood planning labor cost	B 100.00	B 35.00	B/day
Portable power tool recovery cost	-	3.40(1)	B/day
Fuel cost	-	3.50(2)	B/day
Connection recovery cost	-	1.70	B/day
Total Cost	B 100.00	B 43.60	

Average annual portable power tool cost-savings benefits = B 2,820 (3)

(1) Assuming a 12% opportunity cost of capital and an 8-year life for a 1 HP , 3" electric plane with an initial cost of B 2,000.

(2) (1.30 B/kWh) (3.6 hours/day) (1 hp) (0.746 kW/hp)

(3) [(B 100) - (B 43.60)] (50 days/year).

7. Surplus Benefits from Electrification of Agricultural Pumps

Average annual cost savings is estimated at B 2,132 per pump as shown in Table 7.

Table 7: ANNUAL BENEFITS OF ELECTRIFICTION OF AGRICULTURAL PUMPS

Item	Source of Power		Unit
	Unelectrified	Electrified	
Fuel cost per year	2,745 (1)	582(2)	B/year
Annual capital recovery cost	486	367	B/year
Annual connection recovery cost	-	150	B/year
Total Annual Cost	3,231	1,099	B/year

Average annual cost-saving benefits per electrified private agricultural water pump B 2,132

(1) Using a benz[illegible] cost of B 8.80 per liter after deducting a 15% excise tax and a 1% municipal tax; [(2 hr/day) (120 days/year) (1.3 liter/hr) [illegible] (B 8.80/ liter)].

(2) Average cost of B 1.30 kWh, [(B 1.30/kWh) (2.5 hp) (0.746 kW/hp) (2 hr/day) (120 days/year)].

Table 2: INTERNAL ECONOMIC RATE OF RETURN
(Unit: B million)

	Cost streams			Benefit streams							
					Indirect benefits						
Year	Capital cost	OMA cost	Energy cost	Direct benefits	House-holds	Shops	Rice mills	Power tools	Potable pumps	Agricul-tural pumps	Sub-total
1980	47.4	-	-	-	-	-	-	-	-	-	-
1981	318.7	4.5	18.4	34.4	21.6	2.5	0.9	0.7	-	-	25.7
1982	504.8	16.3	50.5	82.2	59.0	6.0	3.9	2.8	-	0.7	72.4
1983	1,056.1	40.2	125.6	203.7	146.4	19.0	12.2	8.2	0.3	1.8	187.9
1984	1,119.0	76.4	217.8	326.6	257.3	36.6	23.9	16.0	0.4	3.1	337.3
1985	925.0	112.8	301.0	418.1	357.6	55.1	38.1	25.0	0.7	4.4	480.9
1986	68.0	133.0	337.0	415.2	391.3	56.4	48.2	32.3	0.9	6.2	535.3
1987	180.7	139.1	368.1	444.7	413.9	57.8	57.6	39.6	1.2	7.7	577.8
1988	96.8	139.1	398.1	476.7	431.5	59.1	65.0	45.7	1.3	10.0	612.6
1989	125.2	139.1	426.2	506.3	441.7	60.0	71.4	50.5	1.3	12.1	637.0
1990	88.6	139.1	457.0	543.2	452.2	62.0	76.6	53.9	1.5	14.3	660.5
1991	86.5	144.5	489.6	584.2	462.9	63.5	82.5	56.5	1.6	16.9	683.9
1992	64.6	145.2	524.5	628.0	473.8	65.1	88.7	58.1	1.6	19.5	706.8
1993	43.4	148.0	561.5	674.4	485.0	66.6	95.3	59.5	1.8	21.8	730.0
1994	65.9	148.3	601.0	724.3	496.5	68.2	102.5	60.9	1.9	24.7	754.7
1995	55.5	151.9	652.3	794.4	515.6	71.0	111.9	63.3	2.1	27.9	791.6
1996	41.0	158.6	694.6	841.2	526.9	72.5	120.0	64.6	2.2	30.6	816.8
1997	86.0	161.6	738.3	896.8	538.4	74.1	128.8	66.0	2.4	33.9	843.6
1998	57.4	162.0	782.4	952.7	550.2	75.8	138.2	67.5	2.5	37.2	871.4
1999	61.1	164.9	827.5	1,008.0	562.2	77.4	146.4	68.9	2.7	40.2	897.8
2000	37.6	171.1	873.4	1,065.3	574.5	79.1	154.1	70.5	2.8	43.8	924.8
2001	53.8	180.2	915.1	1,114.9	587.1	80.9	159.9	72.1	3.0	45.7	948.7
2002	101.2	183.7	956.1	1,164.8	599.9	82.7	164.8	73.6	3.1	47.9	972.0
2003	76.2	187.4	993.7	1,210.1	613.1	84.5	168.6	75.2	3.2	49.2	993.8
2004	95.4	191.1	1,012.8	1,255.0	626.5	86.4	172.3	76.8	3.4	50.3	1,015.7
2005	83.8	195.6	1,078.3	1,322.5	648.3	89.5	178.5	79.6	3.5	51.8	1,051.2
2006	56.0	199.5	1,115.2	1,358.8	661.2	91.3	182.0	81.1	3.5	52.8	1,071.9
2007	109.8	203.1	1,152.5	1,404.8	674.5	93.4	185.7	82.7	3.8	53.9	1,094.0
2008	88.0	207.0	1,190.6	1,452.0	688.0	95.0	189.5	84.4	4.0	55.1	1,116.0
2009	98.4	210.9	1,229.7	1,500.6	701.7	96.9	193.2	86.1	4.1	56.1	1,138.1
2010	70.2	214.7	1,272.1	1,551.8	715.8	98.8	197.0	87.8	4.3	57.2	1,160.9

Internal economic rate of return = 15.3%.

APPENDIX M: PRINCIPAL CONTACTS

USAID/Thailand

James Sloan, Engineering Consultant
Lee Twentyman, Deputy Mission Director
Jeffrey Evans, Director, PDS
John Erickson, Mission Director
Roger Montgomery, Evaluation Specialist

NEA

Panich Pongpirodom, Project Manager, Micro/Mini Hydro Project
Chartdani Chartpolrak, Policy and Planning Division
Suvat Saguanwongse, Design Department
Itti Bijayendrayodhin, Energy Economics Division
Tammachart Sirivadhanakul, Deputy Secretary-General
Prapath Premani, Secretary General

Team Consultant Engineers

Peerawat Premchun, Executive Director
Lek Thanomkulbutra, Senior Civil Engineer
Pinit Chenyaparich, Water Resources Engineer

Layne & Bowler, Co, Ltd.

Naruenart Chaiwatanayon, Director

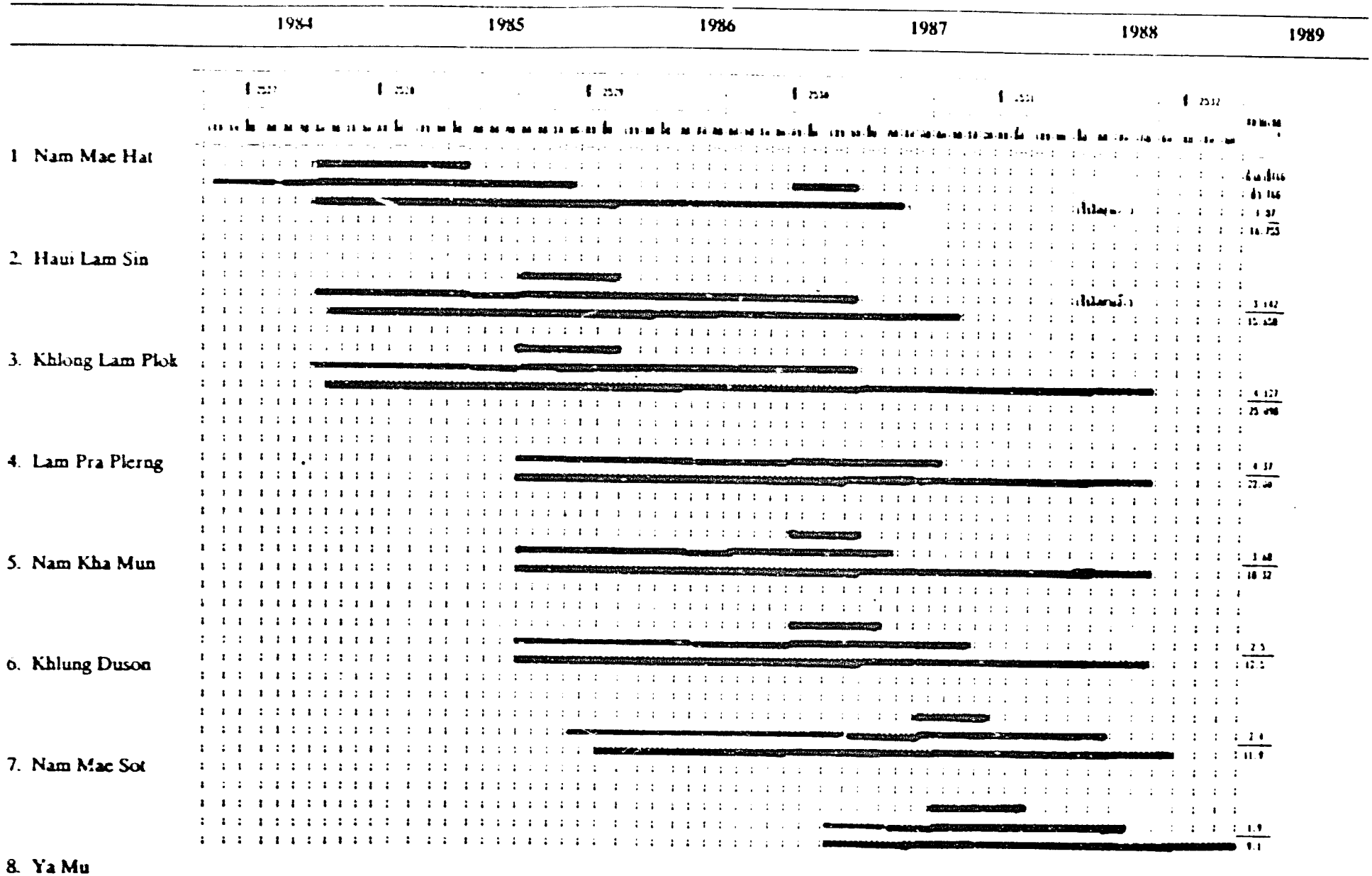
EGAT

Somkiet Phaloprakarn, Director, Systems Planning Department

NESDB

Kiatisak Madyamankura, Senior Economist

APPENDIX N: CURRENT PROJECT SCHEDULES


1984
1985
1986
1987
1988
1989
1. Nam Mae Hat
2. Haui Lam Sin
3. Khlong Lam Plok
4. Lam Pra Pleng
5. Nam Kha Mun
6. Khlung Duson
7. Nam Mae Sot
8. Ya Mu

APPENDIX O: LIST OF EXISTING MINI-HYDRO AND MICROHYDRO SITES

Existing NEA Hydroelectric Projects

Microhydro Project	Province	Installed Capacity KW.	Year of Completion
Doi Pui	Chiang Mai	7	1979
Khun Kong	"	12.5	1980
Nam Dang	"	50	1980
St. Paul	Chum Porn	15	1980
Mae Tia	Mae Hong Sorn	15	1981
Pu Muen	Chiang Mai	15	1981
Khun Wang	"	20	1982
Thung Luang	"	20	1982
Bo Keo	"	200	1983
Pang Bong	"	12	1983
Kam Pong	"	40	1983
Mae Chon Luang	"	40	1983
Mae Ton Luang	"	35	1984
Huai Pui	"	50	1984
Tung Lakorn	"	35	1984
Mae Hae	"	50	1984
At Kapoh	Na Ra Thiwat	100	1984
Pa Pae	Mae Hong Sorn	10	1985
Ban Mae KhunWang	Chiang Mai	10	1985
Huai Mo	"	20	1985
Nam Mae Mae	"	12	1985
Huai Nam Kun	Chiang Rai	25	1985
Nam Mae Loei	Chiang Mai	12	1985
Huai Nam Rin	Chiang Rai	15	1985
Mae Sa	Chiang Mai	15	1985
Ban Long Kod	"	120	1985
Huai Sat Yai	Prajuab Kiri Kan	130	1985
Ban Kud Chang	Chiang Mai	40	1985
Ban Gae Noi	"	20	1985
Ban Khun Lao	Chiang Rai	15	1986
Ban Pang An	Chiang Mai	10	1986
Huai Pong Pao	"	5	1986

Under Construction Project

Project	Province	Installed Capacity KW.	Year of Completion
Mae Tuen Noi	Chiang Mai	250	1987
Long Khod	"	100	1987
Mon Ngo	"	25	1987
Muang Kong	"	45	1987
Doi Lang	"	60	1987
Pang Hai	"	40	1987
Jae Chon	Lam Pang	20	1987
Mae Pai	"	20	1987
Ban Pok	Chiang Mai	20	1987
Mae Pae	"	25	1987
Ngae Sai	"	15	1987
Pang Chang	"	15	1987
Mae Kleun	Chiang Rai	25	1987
Nong Hoi	Chiang Mai	35	1987
Total	46 units	1.87 MW	

Minihydro Project Existing		Capacity (MW)
Nam Bung	Sakhon Nakon	6.0
Mae Hong Son	Mae Hong Son	1.0
Mae Khun Luang	Chiang Mai	3.2
Huai Mae Pong	Pha Yao	.86
Mae Sarieng	Mae Hong Son	1.2
Under Construction		
Mae Sap		1.36
Mae Mao		4.4
Mae Sa Nga		5.0
Planned for 1988 start		
Huai Prathao		4.0
Total 9 units		27.0 MW

APPENDIX P: SCOPE OF WORK FOR EVALUATION TEAM

PDC-5730-I-00-7022-00
Work Order No. 3

ARTICLE I - TITLE

Micro/Mini Hydroelectric Project
(Project No. 493-0324).

ARTICLE II - OBJECTIVE

The Objective of the Project are to assist the RTG to improve the institutional capacity of the implementing agency, the National Energy Administration (NEA), to develop an analytical capacity and methodology to better their small hydroelectric generation and site selection planning, analysis, construction methods and procedures.

ARTICLE III - STATEMENT OF WORK

1. Proposed Evaluation Tasks:

   A. Describe the status of the progress made to date indicating reasons for delay of implementation. Indicate the changes made in response to days and project schedule for completion of the Project. Assess the changes made to date and the question of completion of the Project by the proposed extended PACD.

   B. Provide recommendations to assure completion of the Project and attainment of objectives including the newly proposed completion date.

2. Site Selection/Application of Criteria:

   A. What process was followed that resulted in the replacement of some of the initial sites? How were the sites selected?

   B. Assess the development, effectiveness and use of the site selection methodology (including attention to financial viability, tariffs and local institutional issues such as the community role in collection).

   C. Assess the NEA capability to evaluate lessons learned from existing Micro/Mini Hydroelectric sites (including previous AID Renewable Non-Conventional Energy Project) with respect to:

   -- site selection

   -- tariff rates and financial viability of systems

   -- ownership/operation arrangements including local organizational involvement and NEA/PEA or EGAT roles.

   D. Assess NEA capability and performance regarding the collection of socio-economic baseline data on proposed sites and the evaluation of existing sites.

3. Design/Procurement/Construction:

Describe the initial and current processes for design, procurement and construction of systems. Identify changes and how they have or will improve site selection, timing and cost of construction.

4. Institutional Development:

A. Describe and assess the institutional development that has occurred to date and provide recommendations for remainder of the Project.

B. Hydroelectric Project identification: Has the change/improvement in site selection methodology been institutionalized? What was the role of the consultants and NEA in its development?

C. Micro/Mini Hydrolectric Program: The fifth five year plan included Micro/Mini Hydroelectric Development. How has this Project, particularly the site selection/analysis effort, affected national planning and investment in the latest plan? Have the methodologies developed improved NEA and RTG capability to plan in this energy subsector?

D. NEA Project Management: (i) assess the institutional relationship of NEA to PEA, EGAT, RFD, RID, local community organizations and private entities; (ii) assess NEA's role in the development of the Micro/Mini Hydroelectric energy plan and investment program; (iii) for proposed grid-connected systems. Indicate the work proposed or done to define the relationship (i.e., establish power sales agreements) between the hydro system and PEA.

E. Private Sector Capabilities: assess the institutional development of the consulting, engineering and manufacturing firms that have participated in the Project. Assess the Thai manufacturing capability to build hydroelectric systems up to 1 MW compared to US, ASEAN, and other regional systems available.

F. Local Community Capabilities: describe the local community roles to date and anticipated for the future; describe and evaluate the ownership/operation modes proposed for the initial systems.

G. Indicate the training done to date and assess the impact on NEA institutional development.

5. Economic/Financial Issues:

A. Site Selection Methodology: Review the integrated analytical site selection model developed by the POU from the guidance model prepared by the Project Paper team. Assess the quality of the model and its applicability to the goals of site selection, in lieu of EIRR or economic benefit-cost ratio method of site selection. Is this still the most attractive method? What can be said on a preliminary basis about the sites with respect to actual vs. projected costs?

B. What will be the result of efforts to foster higher load factors through productive demand promotion programs? Describe programs and their application to USAID projects and other projects. To what extent have efforts been made to integrate the Hydroelectric Projects with other rural development activities?

C. Has there been on-going program and project assessment in light of oil price uncertainty (cost of competing diesel fuel) and budgetary restraints that may affect grid extension? What are the results of such assessment?

6. Sub-Projects to be studied:

A. The evaluation will cover the following subprojects:

1. Nam Mae Hat
2. Khlong Lam Plok
3. Huai Lam Sin
4. Khlong Duson
5. Nam Khamun
6. Lam Pra Plerng
7. Huai Mae Sot (Tentative)
8. Nam Ya Mo (")

7. Key Questions:

A. 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 subprojects listed above:

(1) Is each Sub-Project cost-effective relative to diesel powered electricity generation?

(2) Is there compatibility with other resources of the area such as water resources, fish, wildlife, agricultural production, etc.?

(3) Are there identifiable social or ecological problems attached to the various subprojects?

(4) Will there be any effects on employment in the areas by virtue of the new power supply?

(5) Assess the results to date of the attempts made through this Project to:

a). formalize institutional development

b). provide an adequate site selection model

c). improve construction procedures and practices

d). influence or change other elements, such as the design of the subprojects, procurement practices, field supervision and construction management and supervision. Were public safety measures adopted for transmission and distribution? Have arrangements been completed between NEA and PEA for connection of those subprojects that will be hooked to the grid?

(6) 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?

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

(8) What will be the effects, positive or negative, of the project vis-a-vis women's access to forseen production inputs and markets, division of workloads, income, education and training, role in household and community, and health conditions?

(9) Though the initial environmental examination was negative, did experience show that there were detrimental impacts during implementation?

In addition, the Team will provide USAID with their recommendations concerning appropriate Project modifications they believe will assist in obtaining maximum overall effectiveness of the Project. The Team is to examine Hydro Energy Policy Planning measures implemented so far, their assessment of the adequacy of the measures, and their recommendations concerning issues to be addressed.

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).

Recommendations must be implementable. They should be keyed towards replication and promotion of micro/mini hydroelectric activities as well as to developing RTG institutional capacity to perform and sustain hydro energy policy planning and further implementation.

METHODS AND PROCEDURES:

1. Review of Project literature --- existing reports, monitoring reports, Project files, etc. which are available at USAID Office of Project Development and Support, Engineering Division and NEA.

2. Bangkok interviews with NEA and USAID personnel concerned.

3. Field interviews with site engineers, resident inspectors, affected villagers, etc.

4. Trips up-country to observe hydro installations being constructed under the Project.

Progress to Date:

The Loan Agreement (LA) was signed in mid-September, 1982, and Expressions of Interest were received from U.S. Architect/Engineering (A/E) firms in October. Requests for Technical Proposals were received from 9 firms on March 31, 1983, and were rank-ordered by the end of April. Negotiations with the selected A/E, Stanley Consultants, Inc., TEAM-KEC, began May 31, 1983, and continued until mid-April, 1984, when the TA Contract was finally executed, 1.5 years after the LA was effected. The Contract period called for the TA to complete the Site Selection Model in 22 months (February 1986) in lieu of the 3.75 person years (1 individual) envisioned in the Project Paper.

Field surveying and detailed engineering design began as the Project Operations Unit (POU) was formed, and design progress was in line with expectations. Snags began to appear when it became clear that the POU had not been given control over the approval process of the designs, since NEA regulations required that their Design Division had to approve the civil works designs as well as the POU, resulting in an additional time loss of an average of four months per Sub-Porject.

APPENDIX Q: REFERENCES

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