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# Interconnection of Sugar Mills to the Thailand Electric Power rid

## Issues and Prospects

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# INTERCONNECTION OF SUGAR MILLS TO THE THAILAND ELECTRIC POWER GRID: ISSUES AND PROSPECTS

## EXECUTIVE SUMMARY

### Background

This report contains the findings of a team sent to Thailand by USAID in November 1989 to assess the short term feasibility of cogenerating surplus electricity at agricultural processing facilities for sale to EGAT. The rationale for this mission was to provide support for the Royal Thai Government's Working Group on Cogeneration. In particular, the government wanted to know the immediate and short term (<5 years) potential for such facilities to generate power for the Kingdom's system. The major issue of interest was whether such mills could be successfully interconnected with the existing EGAT and PEA[(1)] transmission and distribution systems.

Review of captive biomass wastes at existing agricultural processing facilities in advance of the team visit showed the largest potential to be at sugar factories.[(2)] Consequently, as a basis for the current work, the team used a substantial body of data which had been generated by an earlier cane energy project (1986).[(3)] The 1986 team found that cane electricity could be feasible if generated efficiently using low cost field residues. Opportunities for higher capacity investments were analyzed briefly and found to merit additional consideration. Interconnection issues were treated as an adjunct to the fuel and generation concerns.

In 1989 Thailand's torrid pace of economic growth started to outpace the additions to the capacity of the electric power system made earlier in the decade. At the same time, the government decided that more than half of the investment required by the electric power system in the 1990's should come from the private sector.

### Issues Addressed

In the very short term, the Thai government wished to know how new suppliers of electricity might be connected to the EGAT and PEA systems and whether any appreciable amounts of electricity could be produced cost-effectively in existing facilities with modest capital expenditures. The concerns voiced were of three types:

1. The speed at which interconnection can be carried out including the potential for the immediate and short term

2. The impacts which interconnection will have on the PEA distribution network locally and nationally

3. The cost of interconnection

To address these concerns, USAID provided a team from Winrock International. The team looked at four alternatives:

1. Immediate short term interconnection - maximize use of existing equipment with minimal investment for metering and protection devices which could go on stream in about six months.

2. Immediate permanent interconnection - investments for 1-5 MW which could go on stream in 12-18 months.

3. Short term investments - investments in new generating and interconnection equipment of 5-25 MW which could supplement existing mill operations. These investments could go on stream in 24-36 months.

4. Short term investments - investments in new dedicated generating and interconnection equipment of approximately 25 MW which could supersede existing mill power plants. These investments could go on stream in 24-36 months.

Marginal investments - investments for 10-25 MW which have the salient features of options 3 and 4, can be added when factories upgrade equipment or when new or relocated factories are set up.

In the first two cases, interconnection was based on the existing tie lines to the PEA system. In the latter two cases, interconnection would usually consist of dedicated tie lines into high voltage sub-transmission or transmission lines. Exports up to 5 MW appear to be the practical limit for power to be exported into the 22 kV distribution lines of PEA. Plants with capacities of as much as 10 MW can be absorbed directly into PEA substations. Plants with capacities above 10 MW would tie directly into the EGAT system.

Guidelines for the Winrock team on prices to use for electric power sales were given by the cogeneration working group. These prices differ considerably from those used in the 1986 report. Consequently, the results differ substantially as to the relative financial and economic attractiveness of various options. However, the technical elements of the 1986 work remain valid.

## Major Findings

The team analysis encompassed generation, pricing, and investment issues. However, the findings given below are limited to the generation and interconnection issues which occasioned the study.

### Immediate Term Potential

With regard to the feasibility of immediate term interconnection, the team found that:

1. There are no serious design or installation problems involved with small tie lines. Virtually all of the mills already have small lines.

2. The volumes of power that can be pushed into the PEA system are not sufficient to cause load management or stability problems. Mills will need to be dispatched by PEA.

3. Even for relatively minor modifications, a minimum of six months might be required for design, procurement, and installation.

4. Other equipment modifications and changes which are necessary for exporting power in the immediate term could be effected within the time required to obtain transformers, switching equipment, and meters.

5. The total cost of the interconnection is about $85-150/kW (ß2,200-3,800).

This means that:

1. In the immediate term (i.e., 1990-1991) little or no additional power can be supplied from agricultural processing facilities in Thailand to the EGAT and PEA systems.

2. The small volumes of power (<5 MW) generated by the mills will go into the PEA sub-transmission system.

3. To obtain additional power supplies in the 1992 peak demand season, contracts with cogenerators will need to be signed by March 1991.

**Short Term Generation Options**

The short term and marginal investments for export of 5 MW or more of capacity call for different approaches to the interconnection issue. Investments are larger and the outputs from the exporting mills are more substantial relative to the capacity of the local system. The team found that:

1. Mills generating in excess of 5 MW and up to at most 10 MW would need to export their power to the 22 kV PEA transmission system. This requires, among other things, dedicated tie lines and transformers.

2. Larger mills, those exporting more than 10 MW, would need to make a dedicated tie in to the 115 kV EGAT system.

3. Such mills would need to be dispatched by EGAT so as to maintain system stability.

4. Investment costs for interconnection will remain in the range of $100-125 per kW (ß2,525-3,150). Interconnection costs decline as a proportion of the total investment costs for the larger export options.

The implications of these findings for short term and marginal investment options[(4)] are as follows:

-- Interconnection can be carried out at least as quickly as the generation-side and sugar mill investments that will generate the power.

-- The costs of investment for interconnection are small relative to the overall capital requirements for the large scale options.

-- Power supplied by larger (>5 MW) cogenerators will go directly into the EGAT system rather than through PEA. EGAT becomes the focus of the technical and contractual concerns since power will be best inserted at high voltage.

-- Institutional issues such as pricing and contracting loom larger than technical ones with regard to the success of a cogeneration program.

**Financial Feasibility**

The final set of finding concerns the financial feasibility of investments in generation by sugar mills. Using recently published proposed tariffs and investment costs calculated by the team's generation and interconnection experts, the following conclusions emerge:

-- Non-firm power purchase prices are not sufficient to induce any investments in supply by sugar mills but may induce those with excess capacity to provide power to the EGAT system on a "casual" basis.

-- A number of investment options, in sizes ranging from 2.5-25 MW may be attractive for longer term (>10 years) firm power supply contracts.

-- Whenever a mill decides to enlarge or replace its boilers and turbogenerators, the marginal investments to make the plant a supplier to the EGAT system are relatively small. The financial returns from these marginal investments are extremely attractive.

-- Sugar mills can purchase bagasse or cane tops/trash at prices that are attractive to suppliers, even relative to such other uses as fiberboard.

-- Fuel oil is an unlikely fuel, even for the mills with the greatest efficiencies.

## 1.0 BACKGROUND AND INTRODUCTION

### 1.1 Previous Efforts

The three sections that follow represent the analysis and findings of a four person team of consultants which visited Thailand in November, 1989. The team was supported by USAID to assist the Royal Thai Government in its efforts to create viable policies to promote the cogeneration of electricity for sales to EGAT. The present work builds upon previous efforts by USAID in the Thai sugar sector, most notably those of 1986. The work in 1986 focussed specifically on the feedstock issue - the collection of cane trash and residues - and the economics of continuous operation based on such fuels.

In contrast, the present effort looks specifically at the electrical and generation options for cogeneration and sales to the grid. It is assumed in this study that fuel is available as needed either as bagasse or cane trash. The analytical approach that was taken for the present work is quite similar to that which was used in 1986. However, virtually all of the data that are used on investment costs, performance, and interconnection were generated specifically for this study. In addition, the analytical models used to derive the economic and financial results in Section 4 are new.

### 1.2 Thailand's Electricity Situation

In the early-mid 1980s, Thailand's peak electricity demand was rising at a rate of about 200 MW annually. With total system capacity under 6,000 MW and an ongoing investment program using domestic lignite and gas, EGAT sat on a comfortable reserve margin of as much as 35%.

In the later part of the decade, two events changed the world in which EGAT operates. The first was an extremely rapid growth in peak power demand and the second was the government's decision to have EGAT finance about 65% of its system expansion program from private sources.

At the present time, EGAT has an installed generating capacity of just over 8,000 MW with a peak demand of about 7,300 MW. However, the rapid growth in power demand, as much as 500-600 MW annually,[(5)] is expected to reduce reserve margins to perilously low levels in early 1991.[(6)] EGAT's ability to meet the projected increases in demand by itself is made more complicated by the government's decision to fund only about 35% of the ß200 billion ($8 billion) generation expansion program. The remainder of the program will need to be funded from other sources. These sources could include:

-- Flotation of EGAT shares

-- Joint ventures with private/foreign investors (build-own-sell or build-own operate)

-- Purchase of power from cogenerators

-- Purchase of power from independent power producers

This paper is concerned with cogeneration investment options and the interconnection requirements for such a program.

### 1.3 Cogeneration Opportunities in the Sugar Industry

The USAID team which studied Thailand's sugar industry in 1986 identified more than 250 MW of installed capacity in that industry. Of that total, about 140-200 MW was thought to be suitable for

power export. The latter figure includes only those plants with sufficient current installed capacity (generally above 5 MW) so that no significant investments in generation will be needed. It is clear that much more electricity can be generated if new investments are made.

### 1.3.1 Generation Options

In the present work, the consultant team looked at four options. The last two options require significant investment in new generation capacity. The first three options assume that the only fuel to be used is bagasse which is made available at the factory. These options are:

1. Immediate term - this option uses existing factory boiler and turbine generator equipment as well as the existing tie line and electrical interconnection equipment. A mill can export as much as 1 MW under this option using surplus boiler and backpressure turbine generator capacity. Investment is required in protective equipment for the PEA system and for the mill and in meters and transformers. Installation time is 6-10 months.

2. Immediate term - This option again relies on existing factory equipment plus a new interconnection transformer at the sugar mill. Additional condensing capability is needed for an export capacity of up to 5 MW. Total investment design and installation would require up to 18 months.

3. Short term - This option includes new steam and turbogenerator equipment and a 22 kV dedicated tie line to the PEA system. This investment program could export up to 10 MW. The design, procurement, and installation would require about 24 months.

4. Medium term - This option is a completely new large high efficiency boiler with requisite turbine generator equipment. The system described in Section 2.1 is sized at 25 MW. The investment cost includes a dedicated tie line to the EGAT 115 kV system since it is beyond the capacity of most PEA substations. This unit is efficient enough to use either residual oil or coal should cane bagasse or residues not be available in sufficient supply. Total elapsed time for design, procurement, and installation is 36 months.

Within options 3 and 4, two "marginal" investment options were considered, 3a and 4a. These cases are identical in size, scope, and export potential to cases 3 and 4. However, the generation expert looked only at the additional investment required for export generation at the 10 and 25 MW levels beyond what new equipment designed solely for sugar production would ordinarily cost. A discussion of these options is presented in Section 4.

### 1.3.2 Discussion of Generation Options

The generation and interconnection options were determined jointly by the consultant's two experts in those areas. Although the focus of the report is on interconnection, it is only sensible to examine such options in concert with likely generation side investments. For that reason, the discussion of generation precedes that of interconnection. Each of the four options is presented in detail in Section 2 while specific interconnection issues are covered in Section 3.

The options are laid out in 2.1. For those readers interested in further discussions of generation activities, Section 2.2 goes over the process changes that are required in the following systems for each of the generation options:

1. Boiler heat recovery systems

2. Process evaporators

3. Dilution of cane juices

4. Venting of process steam

5. Steam cycle design

Where bagasse is a valuable resource, the above systems are easily modified so that existing factories can have as much as 30% of total bagasse produced available as surplus. This "surplus" bagasse provides all of the fuel for both the immediate and short term options.

The export capabilities for each of the options is presented in Section 2.3 and is a crucial element in understanding the interconnection costs. A methodology for calculating export capability is presented in 2.4 and is applied in Annex 3 in a case study of three specific mills.

### 1.3.3 Discussion of Interconnection Issues

A discussion of interconnection issues is given in Section 3. The first two parts of that section are aimed at industry professionals. Discussions of short and long term interconnection issues along with an enumeration of potential problems and issues are presented in Section 3.3-3.6. Detailed cost estimates for each type of export option, *solely for interconnection*, are also shown in Section 3. Annex 4 provides schematics and one line diagrams for each of the export options and is based on the PEA and EGAT substations visited in November, 1989. Each of the mills visited is modeled as well.

## 1.4 Economic Analysis of Investment and Interconnection Options

A final section of the main report contains a discussion of the economic and financial implications of each of the options discussed in the technical sections. In Section 4 the consultants examine the implications of various contractual arrangements on the feasibility of each of the investment options presented earlier.

The economic and financial scenarios are consistent with the options developed by the generation and interconnection specialists. The economic analysis annex lists the results of the financial and cash flow calculations with regard to different contractual and investment options.

# 2.0 GENERATION OPTIONS AND CAPITAL COSTS

## 2.1 Introduction

This section outlines the types of investments that are necessary to export electricity from Thailand's sugar mills. The consultant team's generation expert worked together with the interconnection specialist to devise a set of likely investment options that could suit the types of sugar mills found in Thailand. These options were described above in Section 1.3.1. Case studies of three mills may be found in Annex 2.

The team briefly visited two sugar factories in October, 1989. No direct measurement of process variables was possible since the factories were in their overhaul or off season periods and, therefore, not processing cane. Interviews were held with operating personnel from three sugar factories wherein process variables were obtained. Certain process variables which are critical to estimating export capability, such as quantities of surplus bagasse, boiler flue gas excess air and temperatures, evaporator supply juice densities, and bagasse ash and moisture variability either were not routinely measured or were subjectively reported. This is not unusual for sugar factory operations since their main concern is the efficient processing of cane and sugar, not the generation of electric energy for export.

Predicting the export electric power and energy for a sugar factory requires a detailed analysis of factory operations. Heat balances must be conducted to determine export levels with sufficient precision to substantiate investment decisions. The predictions contained herein were made without benefit of such detailed analyses.

There are, however, a series of typical export electric energy options available to most sugar factories of the types and sizes in Thailand. These are described below.

### 2.1.1 Option 1

This option takes advantage of existing factory boiler and turbine generator equipment as well as the existing interconnection equipment, including the tie line to PEA's system and the interconnection transformer at the sugar factory. Based on the equipment reported or observed, an export capability of 1,000 kW appears feasible for most factories. Additional electrical protective devices would be required as shown in Section 3.0. Export of electric energy would occur during factory processing periods only by utilizing surplus boiler and backpressure turbine generator capacity.

This option could be accomplished in the nearest term since it requires only the installation of electrical protective devices, which would require approximately 6 months.

### 2.1.2. Option 2

This option uses the existing factory boilers, turbine generators and tie line to PEA, plus a new interconnection transformer at the sugar factory. Additional condensing capability has been included since some factories indicated they believe their existing evaporator sets are limited while processing and are under repair during the off season. These factories believe the evaporators cannot be used for the additional condensing associated with power export. A fan-cooled air condenser is included to accomplish the additional condensing associated with power export, however this may be a site-specific requirement. A schematic of the suggested steam system is shown in figure 2.1. The proposed interconnect system is shown in Section 3.0.

*This option would permit export during both the processing season as well as the off-season up to 5,000 kW.*

Exporting up to 5,000 kW appears to be the practical limit if the power is to be absorbed into existing 22 kv distribution lines. Larger amounts might disturb the system.

### 2.1.3 Option 3

This option presumes new steam and turbogenerator equipment, a new interconnection transformer and a dedicated 22 kV tie line from the sugar factory to the nearest PEA substation. In effect, this is a "stand-alone" option dedicated to export electric energy sales. The steam and power generation system is shown in figure 2.2.[(7)] This option would permit export during both the processing season as well as the off season. The cost information is based on a nominal 10,000 kW plant. An export level of 10,000 kW appears to be a practical limit to absorb into PEA' s substations without resorting to export from PEA into the EGAT system.

### 2.1.4 Option 4

This option includes a new large boiler; double automatic extracting, condensing, turbogenerator; 30 MVA tie transformer at the sugar factory and a dedicated 115 kv tie line connected to the EGAT system. The steam system is shown in figure 2.3. The interconnect system is shown in Section 3.[(8)] This system is nominally sized for an export of 25,000 kW. Larger systems may be installed depending on the factory processing capacity.

*Fig 2.1. Air Condenser arrm't for Option 2 (1000 kW Export)*

*Fig 2.2. Typical High Efficiency Steam Cycle - Stand Alone -Option 3 (5000 kW Export*

*Fig 2.3. Typical High Efficiency Steam Cycle -Option 4 (25,000 kW Export)*

This system could export during both the processing and the off season and would also be reasonably efficient on residual oil or lignite coal.

With this magnitude of export it is doubtful that many of the PEA substations could absorb the peak output at all times, hence the interconnect is presumed to be made at 115 kv into the EGAT system. To some extent this approach may be site-specific since the load profile of the PEA system may, in the case of certain factories, be able to absorb scheduled dispatch of electric energy from such factories. It is not uncommon to dispatch such facilities at load varying from 4:1 (turndown to 25%).

### 2.1.5 Capital Costs

Table 2.1 indicates the current installed costs for each option and the anticipated time required to design, procure, and install each option.

A range of export capabilities is given for options 2 and 3. For Option 3, the lower level represents the capacity to export during the factory off season with no usage of existing factory power or condensing equipment[(9)] The higher level represents the tie line capacity and also indicates a level which might be achieved during processing by utilizing the existing power and condensing equipment.

## 2.2 Processing Changes for Various Options

Sugar factories in Thailand are designed to produce that amount of steam and electric energy needed from bagasse fuel to operate the factory. During off seasons, electric energy is purchased from PEA at various levels to support off season maintenance activities. The capacities of the interconnects for the factories are generally limited to 1,000 - 3,000 kW.

No factories reported burning fuel oil to support operations. Sufficient surplus bagasse is stored for start up of the boilers each season and for steam production during brief periods where the process is interrupted or for white sugar refining during the off season.

The sugar factories are essentially "balanced" or even slightly in surplus with regard to bagasse. That is, they produce more bagasse than is consumed for boiler fuel. The amount of surplus bagasse is generally estimated by observation of the quantity of bagasse stored in huge open air piles. Too little surplus bagasse raises the threat of burning oil to support the process. Too much bagasse can create a major disposal problem.

**Table 2.1. Summary Of Installed Costs Of Various Options (US$ x 1000)**

Option: 1 2 3 4

Item Export Capacity (MW): 1 2.5 10 25

A. Boiler & Auxiliaries 0 0 2,455 10,450

B. Turbogenerator & Piping 0 0 3,617 9575

C. Cooling System 0 164 674 1,150

D. Factory Modifications 0 120 390 390

E. Electrical Interconnections 86 227 223 292

F. Tie Line Transformer 0 148 398 796

G. Tie Line 0 0 406 2,154

H. Design/Proj. Management 24 50 430 1,300

I. Contingency 10 59 788 2,413

J. Duty 24 141 2,100 5,600

K. Total Cost 145 909 11,484 34,120

L. Design, Procure, Install, (man months) 6 18 24 36

Note: The marginal costs for exporting power are significantly lower than the full installation costs. In the case of Option 3, these costs would total $4.410 million instead of $11.5 million. For Option 4 these costs would total $11.1 million rather than $34.1 million. The major savings are in the first three categories - boiler, turbogenerator, and cooling system.

In general, cane sugar factories control surplus bagasse by the design and operation of their energy producing and consuming devices in the factory. There are a number of ways surplus bagasse can be controlled by modifying one or more of the following variables:

1. Boiler heat recovery systems

2. Process evaporators

3. Dilution of cane juices

4. Venting of process steam

5. Steam cycle design

Where bagasse is treated as a valuable resource, either for fuel or for byproduct usage, all of the above areas offer potential for increasing the quantity of surplus bagasse. Conversely, where bagasse creates a disposal problem, these same areas permit a considerable degree of operational control over surplus bagasse quantities. Control of these parameters can vary the quantity of surplus bagasse from zero to 30% or more of total bagasse produced.

The Thailand sugar factories studied do not have condensing turbogenerators and therefore lack the ability to generate significant quantities of surplus electric power as a means to control surplus bagasse quantities. Further, the process equipment is designed for high production rates with minimal interruptions at relatively low initial cost.

The various options presented herein require relatively minor changes in process equipment or operation.

### 2.2.1 Option 1

There are no process equipment changes required in this system. All factories studied had adequate steam and power generation capabilities to produce an export of 1,000 kW periodically or continuously, and to do so without resorting to burning fuel oil. It is necessary to 'force' the existing evaporators to absorb the additional 10 - 20 ton/hour of turbogenerator exhaust steam during periods of export. Alternatively, exhaust steam or first evaporator vapors may be vented, or vacuum pans switched from vapors to exhaust steam, depending on the size and condition of the evaporator system. Since this option is considered to be used only during processing and generally to assist EGAT in meeting peak demands, this option is suggested solely for near term implementation. This option does, however, represent a low cost means to assist in controlling surplus bagasse, provides some additional revenues, and provides a small amount of peaking capacity to EGAT.

### 2.2.2 Option 2

This option requires that live and exhaust steam systems and the respective condensate system for one boiler and one turbogenerator be isolated from the rest of the factory piping in order to permit isolated operation during the off season. An air condenser is included which could be used both while processing as well as during the off season. This option would have no negative impact on processing capabilities. It would, however, offer a greater means to control surplus bagasse than Option 1.

Expanding the capacity of the air condenser from 1,000 kW (10-20 Ton/Hr) to 5,000 kW (50-100 Ton/Hr) would not be prohibitively expensive. Alternately, the process evaporators may be used

to absorb the additional condensing load for export during the off season if provisions can be made for off season maintenance.

There are a variety of ways to provide additional condensing capability other than using the existing evaporators or an air condenser. The use of the existing cooling ponds or some degree of spray pond or cooling tower for cooling using a surface condenser can be considered.

Some factories do not use deaerating feedwater heaters. Installation of a deaerating feedwater heater not only increases condensing capability but improves boiler and steam cycle performance and efficiency.

The specific equipment provided to increase export from 1,000 kW to the 5,000 kW capacity of the proposed interconnect would depend on each particular factory's equipment arrangement as well as the actual quantities of surplus bagasse presently available.

### 2.2.3 Option 3

A 10,000 kW stand-alone plant, utilizing only bagasse for fuel is the basis for this option. Surplus bagasse is increased by additional flue gas heat recovery devices on each existing boiler coupled with additional control devices to measure and control excess air to a minimum. In factories where no deaerating feedwater heater exists, one would be added to serve all existing boilers. During off season, the surplus bagasse remaining is used to maintain export of electric energy.

The three factories studied had flue gas temperatures ranging from a low of 190C (374F) to a high of 250C (482F). A target exit gas temperature of 177C (350F) can be reasonably obtained with an engineered mix of economizers and air heaters. Excess air reportedly ranged from 30% to 70%, based on measurements of carbon dioxide. There is some question of the validity of these reported readings since carbon dioxide analyzers were found inoperative at the two factories visited. It is not unusual to find flue gas analyzing instruments to be either inoperative or out-of-calibration since they are generally difficult to maintain and calibrate. A target average excess air of 50% is reasonable provided boilers are equipped with air flow measurement and feedback control as well as reliable flue gas analyzers. In-situ oxygen analyzers are recommended for flue gas analysis as they are simpler to maintain than carbon dioxide analyzers and more sensitive in the low excess air ranges.

No change to sugar process equipment is required although some minor modifications in equipment and management practices may yield additional surplus bagasse.

### 2.2.4 Option 4

Processing changes for Option 4 are similar to Option 3. Some reduction in output from existing boilers can be anticipated depending on the size of existing equipment and the new equipment selected for export purposes.

This option, which involves a single high pressure, high temperature boiler, can be expanded to completely displace all existing boilers and turbogenerators. This would be advisable in the event a new factory is constructed or a relocation of a factory is planned. In such a case, a factory which normally consumes 300 Ton/Hr of steam would produce 25,000 kW from the high pressure section of the turbogenerator alone at an extremely low heat rate (5,000 BTU/kW hr) while processing.

## 2.3 Range of Export Capabilities for Various Options

As has been stated previously, each factory is unique. Processing rate, total tons of cane processed, cane quality and equipment arrangements dramatically affect the amount of bagasse energy available for producing electric energy for export. For purposes of this investigation a range of export is given for general guidance only. This range represents the capabilities of plants which process less than 1,000,000 tons per year of cane up to plants which process 2,000,000 tons of cane. Exact predictions of export capabilities can only be achieved following an in-depth investigation of individual factory equipment, operations, and heat balances.

Table 2.2 summarizes those probable ranges of export power and energy for each option, utilizing existing supplies of bagasse.

From Table 2.2, it can be concluded that burning of oil in existing boilers (Options 1 and 2) is prohibitive except under extreme emergencies. Additionally, the export of electric energy from bagasse during the off season in those factories with high heat rates makes sense only if there is no alternate market of higher value. These are factories where the boiler steam pressures are 15 $kg/cm^2$ or less.

**Table 2.2. Ranges of Export Options for Power and Energy**

**Option Option Option Option**

**1 2 3 4**

**Cane Processed,**

**Ton/Yr (x $10^6$) 0.8 - 2.0 0.8 - 2.0 0.8 - 2.0 0.8 - 2.0**

**Avg Net Export While**

**Processing, MW 1 1 - 3.9 5 - 10 20 - 25**

**Avg Net Export Off**

**Season, MW 0 0.66 - 3.9 5 - 10 20 - 25**

**Net Export Annual,**

**kWh/Yr (x $10^3$) 3,775 6,938 - 26,325 19,734 - 56,875 109,500 - 164,250**

**Bagasse Consumed for**

**Export, Ton/Yr 12,000 40,000 46,000 - 93,240 78,000 - 136,731**

**NPHR-Bagasse-**

**Grinding (x $10^3$) 27.5 - 40 27.5 - 40 20 16**

**NPHR-Bagasse-Off**

**Season (x $10^3$) 40 - 80 40 - 80 20 16**

**NPHR-Oil-Off**

**Season (x $10^3$) 30 - 60 30 - 60 14 13**

**Note: NPHR=Net Plant Heat Rate, BTU/kWh.**

## 2.4 Recommended Methodology for Determining the Export Capability of Each Investment Option

Predicting the magnitude of export capability for each factory requires that the factory steam and electric system be initially modeled to reflect current equipment and current operation as closely as possible. The modeling follows standard procedures used throughout the sugar industry.

It is important in preparing the initial model to represent a typical production year using typical cane processing rates and process parameters. A field visit while processing is necessary not only to check and verify recorded parameters but also to understand normal operating practices for such activities as refining, responding to unexpected process interruptions, and cleaning evaporators.

The initial model should be prepared in the field, immediately following the field visit, to check the model against actual operations and correct any discrepancies. The model can then be modified to predict export capability.

### 2.4.1 Option 1

Modify the initial model by increasing the throttle flow to one or more turbogenerators to increase electric energy generation by 1,000 kW. Increase dilution of clarified juice to condense additional steam through the evaporators and check to see that heat transfer rates on evaporators are within normal guidelines. Calculate annual surplus bagasse remaining during processing. In the event the model shows more bagasse consumed than produced, iterate electricity export downward until surplus bagasse at the end of processing is zero or that amount required for off season refining.

The goal of the Option 1 model is to consume all surplus bagasse while processing up to the limit of the existing intertie transformer, which would normally be 1,000 kW.

### 2.4.2 Option 2

Where factories have considerable surplus bagasse and where use of process evaporators during the off season is not possible, modify the model by increasing main steam production as in Option 1. Consume all excess bagasse at a fixed export level for 11 months/year, allowing a one month outage for maintenance on the power generation equipment which is required during the off season. Do not increase dilution or in other ways modify boiling operation. Utilize the air condenser to condense the additional steam required for export. An "off season", straight-condensing sub-model is required.

The goal of this option is to consume all surplus bagasse over an 11 month period.

### 2.4.3 Option 3

Recalculate existing boiler efficiencies based on 50% excess air, 177C exit gas temperature.

Modify the initial model to predict surplus bagasse resulting from improved boiler efficiency and any other process modifications uncovered in the field investigation (i.e. venting of steam, clarified juice dilution, etc.) that can reduce factory energy requirements.

Prepare sub-model for the proposed stand alone boiler/turbogenerator and input various export loads until all surplus bagasse is consumed over an 11 month period. It may be necessary to remodel using lower boiler efficiencies for existing boilers if export is found to be greater than 10,000 kW as may be the case for some large factories.

The goal of this option is to consume all surplus bagasse in 11 months.

### 2.4.4 Option 4

Modify the initial model to include revised boiler efficiencies as in Option 3. Add any realignment of boiling systems to reduce low pressure steam consumption to a minimum. Reduce or eliminate all venting, use of pressure reducing valves, excess dilution, non-essential use of auxiliary hand valves on mechanical drive steam turbines. Include a double- automatic extracting/condensing turbogenerator and a high pressure - high temperature boiler, deaerating feedwater heater and high pressure feedwater heater. Send all exhaust steam condensate from evaporators to deaerating heater. Recover boiler blowdown and steam trap flash energy to low pressure steam system.

Establish the maximum bagasse storage capacity for off season usage. Run the model at various export levels during the season so that this quantity of surplus bagasse remain at the end of the season. Under Option 4, the system could be sized to consume all surplus bagasse or a mixture of bagasse and other fuels during the off-season.

### 2.4.5 Other Iterations of the Model

With the above mentioned models, it is possible to predict various combinations of export levels including firm energy intended to address EGAT's load curve as well as the burning of oil or lignite to meet unusual conditions.

It is also possible to size Option 4 large enough to consume all bagasse as it is produced and to burn other fuels during the off season.

In the case of a new or relocated factory, it is also possible to size Option 4 to meet steam required while processing.

# 3.0 ELECTRICAL INTERCONNECTION ISSUES

## 3.1 Introduction: General Issues

Interconnection of electrical service for export of excess power generated by utility company customers requires mutual agreement by the parties involved - the generator, the purchasing utility, and possibly the distribution utility. On the utility side, this will generally be the generation/transmission company, EGAT, or the distribution company, PEA. Such agreement must be clearly understood by both parties so that they will cooperate with each other and thereby meet their respective objectives and their contractual obligations.

What follows is an outline of routine procedures for implementing interconnection. These procedures provide the basis for agreement between the cogenerator and the utility company. Consequently, it may be used as a checklist of the steps toward arriving at a system for exporting power to the utility company.

### 3.1.1 Purchase Rates

A first step in reaching agreement with a utility is determining appropriate rates.[(10)] These rates must cover the following areas:

a. Energy

b. Demand

c. Power Factor

Normally, a power purchase contract will contain a power factor figure in kilovar-hours. If the delivery of kilovar-hours is less than agreed upon, then the utility incurs costs due to line losses and voltage drops. In contrast, if the kilovar-hours delivered are in excess of what was contractually require then the utility will face a smaller line loss and voltage drop. Adjustment for power factor should be based on kilovar-hours in excess (or deficit) of the amount required to arrive at the ratio to kilowatt-hours corresponding to the power factor at which power shall be delivered.[(11)]

### 3.1.2 Interconnect Cost

Responsibility for costs on both sides of the interconnection point should be established separately from the responsibilities for the design and installation. For example, installation costs for equipment to protect other utility customers which would otherwise not be required should be borne by the power exporter, even though the utility company would be responsible for the design and installation of such equipment.

### 3.1.3 Design and Review Process

The responsibilities for design and review of the interconnect facility should be established. This will minimize controversy over the performance of both parties in accomplishing the necessary work to finalize the actual interconnection of the systems for exporting power to the utility.

Generally, the point of interconnection establishes the design boundary for each party, except for revenue metering, which almost always remains the responsibility of the utility. Review of the other party's design should be scheduled at appropriate phases so that the designs for the interconnection are coordinated to complement each other.

### 3.1.4 System Characteristics

System characteristics should be carefully evaluated to insure the system installed permits the intended operation in all respects. This matter is critical and requires understanding of design requirements for the following three items:

1. Voltage rating of equipment, in particular transformer ratios, taps and requirements for load tap changing.

2. Insulation coordination, i.e. basic insulation level and lightning arrester rating.

3. System grounding, from the point of maintaining an effectively grounded system in the situation when the utility supply becomes disconnected and other customers remain connected to the cogeneration supply. This means that sugar factories with existing transformers with delta connected high voltage windings which were appropriate for purchasing power only may now be required to have transformers with solidly grounded primary windings.

In each mill, there will be some unique features of the generation and export situation. Mills that export only during the milling season will require attention to the tie transformer ratios. The tie transformers will be stepping-up large amounts of power during export. Thus the high voltage to low voltage winding ratio may need to rise to compensate for the voltage drop through the transformer. However, during the off season, power may need to be imported by the mill with a consequent need to reduce the high voltage to low voltage winding ratio in order to raise the voltage on the factory side of the transformer.

With regard to the tie line, the insulators and lightning arresters must carry the appropriate rating in order to avoid nuisance trips. These trips may arise because of flashovers which result from the connection of generators to the system through ungrounded tie transformers.

### 3.1.5 System Arrangement

Arrangement of interconnection circuits must be evaluated to maintain system reliability, redundancy and expandability.

### 3.1.6 Protective Relaying Philosophy

The protective relaying schemes should be carefully evaluated to maintain system integrity during faults. Current, voltage, frequency and power flow responses to faults should be analyzed to select the proper relay settings to isolate faults and protect equipment from damage.

### 3.1.7 Operating Procedures

Operating procedures for exporting power must be established so that the operation of the system can be maintained reliably, thereby avoiding outages and damage due to improper procedures. Before attempting interconnection, operators should make sure that conditions are normal and that the tie-in to the utility system can be accomplished successfully. After interconnection, operators should be thoroughly familiar with both normal and abnormal conditions in the system and with the appropriate measures to account for abnormal conditions, including disconnection from the utility system. Both power and voltage fluctuations and frequency excursions may be either normal or abnormal depending on the amount of the fluctuation and the time of day. Operators will need to be trained in the differences between normal fluctuations and abnormal variations in these factors, In order to make sure that the

generation plant is operating correctly with respect to the rest of the system, operators must be instructed and trained to perform the following tasks:

-- Synchronizing

-- Increasing and decreasing power output

-- Coordinating operation with utility company dispatchers through appropriate communication channels

### 3.1.8 Instruction and Training

Before the system can be put into operation, operators must be fully instructed and trained in the operational requirements. It is important that instruction cover the basic principles of the following subjects so that operators can anticipate conditions and take appropriate action:

a. Generation

b. Excitation

c. Isochronous operation

d. Parallel operation

e. Load flow

f. Power factor

## 3.2 Interconnection Equipment

The interconnection equipment requires additional metering devices, protective relays and where not provided, synchronizing equipment. (See Annex 4.1). Depending on the export capacity desired, additional transformer and line capacities may have to be added.

### 3.2.1 Metering

Basic metering will involve one set for import and one set for export. Under cases where metering must be performed for a wide range of power (which can occur where the amount exported will be many times greater than the amount purchased), appropriate current transformer ratios and service factors and/or metering devices must be utilized.

### 3.2.2 Protective Relays

Additional protective relays must be provided to protect the utility system and the sugar factory generating equipment during parallel operation. Generators will now be subjected to utility company conditions and must be protected against reverse power, negative sequence currents due to unbalanced phase currents and loss of excitation (reverse vars).

### 3.2.3 Synchronizing Equipment

It is recommended that synchronizing equipment include a synchronizing check relay to prevent operator error and mis-synchronizing with rapid changes in frequency during attempts to synchronize.

### 3.2.4 Tie Transformer

The tie transformer must be correctly sized to be able to export the total available capacity with sufficient extra capacity to tolerate power swings. Also important are the voltage ratings on both the high voltage side and the low voltage side. Voltage ratings should take into account the voltage drop through the transformer and the voltage variation of the utility system. It may be necessary to provide tap changing under load capabilities where regulation requirements cannot be met. Winding connection must also be determined to allow grounding as required. Impedance of the transformer should be evaluated relative to regulation requirements and for limiting short circuit.

### 3.2.5 Grounding Transformer

It may be necessary to provide a grounding transformer for maintaining effectiveness of grounding for insulation requirements and for ground fault relaying. Requirements will be dictated by the winding connections provided for the tie transformer and the grounding method for the generators.

### 3.2.6 Tie Line Controller

A tie line controller will greatly assist in regulating the export of power. Power swings will occur with changes in utility frequency, changes in terminal voltage due to utility load changes and changes in plant loading. A tie line controller will compare the output power against the setting and adjust the generator output accordingly.

## 3.3 Implementation of Interconnections

Implementation time for interconnection depends on the equipment already provided at the plants and the amount of power capacity desired. All plants appear to have at least 1500 kVA tie transformer capacity presently utilized only for off-season power and start-up. Implementation time for additional capacity depends on delivery time for major equipment such as circuit breakers and transformers, which may be as long as ten months after the order is placed. For systems with dedicated lines, implementation time also depends on the installation time for high voltage transmission lines.

### 3.3.1 Short Term Interconnection

For the short term interconnection, the existing transformer may be utilized with minimum provision for metering and protection during operation. Equipment required should be available from the utility companies or available from manufacturers' stock if not available locally. Refer to Table 3.1 for electrical capital cost estimate and Annex 4.1 for the electrical schematic.

### 3.3.2 Long Term Interconnection

Long term interconnection may be classified into three groups:

1. The first group involves providing a new tie transformer to provide a capacity to export between 1 to 5 MW. The existing 22 kV line is expected to be utilized and a tie line controller provided to

regulate power export during grinding and during the off-season. Refer to Table 3.2 for electrical capital cost estimate and Annex 4.1 for the electrical schematic.

2. The second group involves providing additional generating capacity for 5 to 10 MW continuous export to utilize surplus bagasse. In addition to the investments required for the smaller plant, this option will involve providing a new tie transformer and installing a dedicated 22 kV line to the PEA switching station. Process changes are expected to be minimal. Refer to Table 3.3 for electrical capital cost estimate and Annex 4.1 for the electrical schematic.

3. The third group involves providing additional generating capacity for more than 10 MW continuous export and improved conversion efficiency. The tie transformer will require tap changing under load equipment and the transmission line will be 115 kV running to the EGAT substation. Factory process changes are expected to be substantial, considering the existing systems were designed and installed to handle the operating load of the plant only, and since there was no benefit to provide extra capacity other than for foreseeable plant or process expansion. Refer to Table 3.4 for details on capital costs and the types of equipment and issues that are involved in making long term interconnection for systems exceeding 10 MW. Refer to Annex 4.1 for the electrical schematic.

### 3.4 Conditions for Feasibility

Technical and economic feasibility cannot be established a priori. Each plant will be different in terms of its location vis-à-vis the grid, and its abilities to export power and energy. The following factors should be evaluated by the utility and/or the cogenerator in the design analysis to determine the adequacy of existing installations and the results of any equipment and operational changes.

**Table 3.1. Capital Cost: Typical Short Term Interconnection - Up to 1 MW**
Not Available in HTML

Notes: 1. Estimated cost in U.S. dollars ($1.00 = ß25.725). 2. Material cost at U.S. prices. 3. Labor cost at Thailand prices.

**Table 3.2. Capital Cost: Typical Long Term Interconnection - 1 to 5 MW**
Not Available in HTML

Notes: 1. Estimated cost in U.S. dollars ($1.00 = ß25.75). 2. Material cost at U.S. prices. 3. Labor cost at Thailand prices. 4. 3.3/6.6 kV switchgear and transformer may not be required if existing plant equipment can be utilized. 5. Grounding transformer and resistor recommended for grounding with delta connected secondary tie transformer.

**Table 3.3. Capital Cost: Typical Long Term Interconnection - 5 to 10 MW**
Not Available in HTML

Notes: 1. Estimated cost in U.S. dollars ($1.00 = ß25.75). 2. Material cost at U.S. prices. 3. Labor cost at Thailand prices. 4. 11 kV switchgear cost may not be reduced by 50% if existing main breaker can be utilized. 5. Tie transformer cost may be reduced by 28% if LTC is determined not to be required.

**Table 3.4. Capital Cost: Typical Long Term Interconnection - More than 10 MW**
Not Available in HTML

Notes: 1. Estimated cost in U.S. dollars ($1.00 = ß25.75). 2. Material cost at U.S. prices. 3. Labor cost at Thailand prices.

### 3.4.1 Capacity of System

It will be necessary to check the capacity of all equipment for continuous and short time ratings against probable conditions. These include voltage, current let through and interrupting ratings.

### 3.4.2 Performance of System

This can be established by simulating maximum import and export conditions. The engineers can then determine if resulting voltages impose any operating problems at the plant and/or to other utility company customers.

### 3.4.3 Arrangement of System

Engineers should analyze utility system arrangement for conditions during utility outages when the cogenerator supply remains connected to the utility system.

## 3.5 Anticipated Problems

Any project can be adversely affected by problems arising out of conditions not taken into consideration during the planning phase. The following items can all have an impact on the installation schedule, construction and operation of the system.

1. Availability of equipment

2. Delivery of equipment

3. Engineering and design support

4. Site conditions, including available space, obstructions, soil conditions, seismic conditions and atmospheric conditions

5. Climatic changes

6. Operation conditions

7. Maintenance practices

8. Availability of labor

9. Competence of operating personnel

10. Management goals

In the present case, the time required for delivery and installation of equipment is a major obstacle to the immediate term export of power to the grid.

Proper training of operating personnel on both the utility side and the exporter's side cannot be overemphasized. Each side must understand each other so that communication can be effective.

This means knowledge of the subject matter, including the terms and expressions relative to the actions required by each side.

### 3.6 Relevance for Prospective Cogenerators

The items discussed above apply equally to prospective cogenerators in other industries. However, requirements for cogenerators using induction machines are not as stringent. Induction machines will normally require excitation by the utility system and must only address the consumption of vars. Consumption of vars becomes undesirable to the utility company when found at the end of long distribution and transmission systems because of line loss and voltage regulation problems. Such considerations are of particular relevance to sugar mills, many of which are located in rural areas.

## 4.0 ECONOMIC ISSUES

### 4.1 Introduction

Although the focus of this work was on the mechanics of the electrical interconnection, economic questions invariably loom large. On the supply side (the sugar mills), the three main question involve:

1. Investment costs

2. Fuel costs

3. Returns on investment

For the utility, there are two major economic issues. These are the level and structure of the purchase prices, and the stability and management of the distribution grid in the areas where power will be exported to the system.

The power purchaser, in this case, PEA or EGAT naturally wants to have control over dispatch. This means that the owner of the power generating unit must allow the total number of hours of power sales to be determined by EGAT or PEA (within the limits of the contractual framework). This has several implications. First, it rules out the type of casual or occasional power sales that many factories might prefer. Second, it places most of the financial risk onto the generator. Third, it imposes costs on the generator in terms of staffing and equipment in return for the higher prices that may accompany centralized dispatch.

From the utility company's point of view, control over dispatch is crucial to the job of running a reliable and cost-minimizing electric power system. Several factors influence the utility's desire to control dispatch:

-- The costs of other generating units in the system owned by EGAT may vary throughout the year. This is especially true in the case of hydro but will also apply to some extent to generating units that consume fuel oil.[(12)]

-- The utility must be able to schedule maintenance around its least cost generation program to make sure that there is sufficient reserve power in the peak demand periods.

-- The utility will need assurance that a non-utility source will be available when it is needed regardless of the processing situation at the sugar mill itself.

For the generators, there are several financial implications of dispatch coming from the purchaser. These are:

-- Uncertainty about the number of hours which will be purchased in any given month

-- Competition with the utility's own generation units, especially hydro, during periods favorable to the utility's own facilities

-- Calls on the mill to give priority to electricity production during the sugar milling season

Each one of these factors is reasonable and can be covered in an appropriate contract. However, one of the net results of the utility gaining control over dispatch is that the uncertainty may be borne to an additional degree by the generator.

In the text that follows, the first subsection deals with the generation side issues. The next subsection is concerned with purchase price issues and the resultant returns on investment for the congenerators.

## 4.2 Generation Costs

In Table 2.1 (see Section 2.1), detailed cost estimates were given for the four major generation options. Using those cost estimates, the consultant team's economist was able to estimate the likely generation costs under a variety of investment and plant utilization scenarios. There are three major elements of generating cost:

1. Investment in boilers and turbogenerators

2. Rate of utilization of the plant

3. Fuel costs, which consist of the purchase price of the fuel as well as the net heat rate (fuel consumption per kWh) of the power plant

Interest rates may have an important impact on generation costs for some of the more sizable options which involve new plant and equipment. In addition, the availability of feedstocks may prove an important issue when it comes to whether an investor will go forward.[13] In this study, we have simply assumed that the required volumes of fuel will be available at a price that is sufficient to ensure their supply.[14]

### 4.2.1 Investment Requirements

There are essentially two approaches to using the power production of a sugar mill for export. First, the mill can simply use its existing equipment, possibly with minor modifications. Second, the mill can invest in new boilers and turbogenerators, specifically intended to supply power at high reliability and efficiency.

The first approach can be implemented within one year, a period referred to as the immediate term. Investment in new plant and equipment takes longer, 18-36 months, and is referred to as the short term. Options 1 and 2, described in Section 2.1, are both immediate term options. Options 3 and 4 are short-medium term options, involving greater investment and power output.

-- Option 1 simply produces a surplus of 1 MW continuously during the grinding season. No process changes are made nor is there any modification to the boilers and tubogenerators.

-- Option 2 requires isolation of the exhaust steam and condensate systems for one boiler and turbogenerator unit. The modification is intended to permit the export of up to 5 MW of power during both the processing and off seasons.

-- Option 3 concerns investment in a new 10 MW boiler and turbogenerator, using only bagasse for operation throughout the year. Considerable changes might be required in some factory operations.

-- Option 4 involves the addition or replacement of the existing boilers with a single high pressure, high capacity boiler and turbogenerator. The system would permit the use of surplus bagasse or fuel oil, if necessary, to maintain continuous output of 25 MW throughout the year.

For both of the larger investments, Options 3 and 4, there exists the possibility of making the electricity export investments concurrently with mill modernization, expansion or relocation. Naturally, these costs are marginal to the costs that the plant will have in any event. They are discussed below as Options 3a and 4a.

*Option 1*

This investment is designed to export electricity only during the grinding season. It is low efficiency (60,000-80,000 BTU per kWh) and will consume all of a mill's surplus bagasse during the grinding season. A typical plant configuration, designed to export 1MW during the grinding season, has the investment and operating costs that are shown in Table 4.1.

**Table 4.1. Option 1: Investment Costs and Operational Parameters**

Baht $

*Investment* (1 MW)

Mechanical (includes plant modifications) 1,500,000 59,000

Electrical (Includes metering and switchgear) 3,700,000 86,000

*Generating Costs*(per kWh)

Fuel @ $2/tonne (ß50) 0.198 0.008

@ $4/tonne (ß00) 0.397 0.016

@ $6/tonne (ß150) 0.595 0.024

Capital Charges @ 25% plant factor 0.297 0.012

@ 15% plant factor 0.461 0.018

@ 10% plant factor 0.698 0.028

*Total Costs* (per kWh)

Low 0.495 0.02

Medium 0.858 0.034

High 1.293 0.052

Note: The base case assumption includes a 10% interest rate and a 20% return for the equity portion of the investment. No use of cane tops or trash is assumed, and the heat rate for the boiler is assumed to range from 27,500-40,000 BTU/kWh during the grinding season and approximately 80,000 BTU/kWh in the off season.

The total investment, ß3.7 M ($145 k), is just a fraction of the cost of new generating capacity. However, the low investment cost is tempered by two considerations. First, the fuel consumption is high. Second, the plant has a low utilization rate, certainly less than 25%,[(15)] compared with the 60% or more that EGAT's large new facilities show. A small investment amortized over a small output can still be expensive relative to EGAT's facilities. In general plant factors below 10-15% turn out to be uncompetitive relative to EGAT's costs. However, if the plant is used, more than 20% of the total year, its net capital costs turn out to be quite low (see the 25% utilization case). Thus, low utilization of the plant corresponds with high costs. Conversely, high utilization corresponds with low capital costs.

Table 4.1 shows the capital costs of generation for Option 1. The High, Medium, and Low categories combine fuel and capital costs.

The Table shows that at low utilization rates (10%), the 1 MW plant opting for immediate export will have capital charges of about ß0.7 per kWh. When combined with the low thermal efficiency of the boiler and turbogenerators in such a mill, the overall costs of generation could go as high as ß1.2 per kWh (see Table 4.1). At the operating efficiencies typical of such mills and with bagasse valued at ß100/tonne ($4/tonne), the cost of fuel comes to roughly ß0.4 per kWh.

With low investment in the mill's generation system, the costs of interconnection dominate the total investment charge. Figure 4.1 shows the total generation cost from the three cases examined in Option 1. These are coupled with the other immediate term alternative, Option 2, for slightly larger power export capacity. Figure 4.2 shows how large a fraction of total investment costs are taken up by the interconnection equipment and installation. It is instructive to look at how these costs vary by option as a proportion of the total investment.

*Option 2*

This generation choice requires that the mill make a greater investment in its internal generation system. In addition, there will be some modifications of plant operations to accommodate the greater net export of power, up to 2.5 MW. In comparison to the first option, both the mechanical and electrical investments appear to be far greater. However, the investment is expected to be amortized over a greater operating year. In an optimistic case, such a plant could operate as frequently as existing thermal power stations, 65%. The required investments for this option are show in Table 4.2.

For the purposes of presentation, the net export of power is assumed to be 2.5 MW, although the actual output with this level of investment could range from 1-5 MW, depending on specific conditions of any particular mill. Assuming 25 MW net export, on a per MW basis, these investments work out to ß5.4 M ($214 k) and ß3.8 M ($150 k), respectively. Once the greater plant utilization is accounted for, the unit (per kWh) costs should be generally lower than is the case for Option 1. The range of capital charges and fuels costs is shown in Table 4.2. The median value of the capital costs, ß0.35 per kWh is about one fourth less than the median capital cost in the first option.

If the plant is utilized at a 65% rate, the net capital charges will be as low as ß0.25 per kWh. With higher efficiency overall, Option 2 shows fuel costs of just ß0.27 per kWh when bagasse is ß100/tonne ($4/tonne). Total generation costs, shown at the bottom of Table 4.2, range from just under ß0.4 per kWh to ß1.078 per kWh. The median value is ß0.6 per kWh. The Low, Medium,

and High cases are profiled in Figure 4.1 alongside those from the first Option. The second Option is less costly for each of the cases examined due to the relatively high fixed cost of interconnection in the first Option.

**Table 4.2. Option 2: Investment Costs and Operational Parameters**

Baht $

*Investment* (2.5 MW)

Mechanical (includes plant modifications) 13,500,000 534,000

Electrical (Includes metering and switchgear) 9,500,000 375,000

*Generating Costs* (per kWh)

Fuel @ $2/tonne 0.125 0.005

@ $4/tonne 0.251 0.01

@ $6/tonne 0.376 0.015

Capital Charges @ 65% plant factor 0.27 0.011

@ 50% plant factor 0.348 0.014

@ 25% plant factor 0.702 0.028

*Total Costs* (per kWh)

Low 0.396 0.016

Medium 0.598 0.024

High 1.078 0.043

Note: The base case assumption include a 10% interest rate and a 20% return for the equity portion of the investment. No use of cane tops or trash is assumed and the heat rate for the boiler is assumed to range from 27,500-40,000 BTU/kWh during the grinding season and ~80,000 BTU/kWh in the off season.

The design, procurement, and installation of the additional equipment could take as long as 12-18 months. In other words, an immediate decision to become a power exporter would not reach fruition until early-to-mid-1992. This rules out sugar mills as a current (early 1991) and painless addition to the Kingdom's generating mix.

In addition to the scheduling and dispatch issues (see Section 4.1), it is also necessary to consider the incentives aspect of the proposed rate structures for cogenerators. Given the small size of the proposed immediate term cogeneration schemes, it is unlikely that more than 5-10

mills would sign up in the next few months. That is, the potential additions to capacity in early-to-mid-1992 are probably less than 25 MW. If the experience of the early cogenerators is positive, then other mills might be induced to look at the larger scale short term investments. Options 3 and 4 represent two such investment opportunities. Both of these options include new boilers and turbogenerators, additional control devices to improve the mill's efficiency, and the necessary interconnection equipment that was described in Section 3.

*Option 3*

As with options 1 and 2, the third alternative is designed to integrate with an existing sugar mill. However, a new boiler and turbogenerator system would be added to the plant. The new equipment would be sized to use available surplus bagasse that could be generated with improvements in overall operational efficiency of a mill. In addition, the existing tie line would be replaced with one that would hook directly into the PEA's 22 kV system. With a new boiler and generator system, the thermal efficiency of the operation would be greatly increased. Such a mill might need perhaps half as much fuel to generate one kWh as either of the lower efficiency options. The investment requirements of Option 3 are large relative to the amount of power generated. Table 4.3, below, shows the costs and operational parameters for this investment.

**Table 4.3. Option 3: Investment Costs and Operational Parameters**

Baht $

*Investment* (10 MW) Mechanical (includes plant modifications) 264,124,000 10,450,000

Electrical (Includes metering and switchgear) 25,957,000 1,027,000

*Generating Costs* (per kWh)

Fuel @ $2/tonne 0.101 0.004

@ $4/tonne 0.202 0.008

@ $6/tonne 0.303 0.012

Capital Charges @ 75% plant factor 0.739 0.029

@ 65% plant factor 0.826 0.033

@ 50% plant factor 1.019 0.037

*Total Costs* (per kWh)

Low 0.84 0.033

Medium 1.028 0.041

High 1.322 0.05

Note: The base case assumption include a 10% interest rate and a 20% return for the equity portion of the investment. No use of cane tops or leaves is assumed and the heat rate for the boiler is assumed to be 20,000 BTU/kWh at all times and on either bagasse or fuel oil.

The total required investment for a 10 MW facility would be approximately ß290 M ($11,480 M). Of this total, about 10% goes for the interconnection cost. Figure 4.2 shows that this cost represents a relatively small proportion of the total investment. In the smaller options, 1 and 2, which operate for a lesser proportion of the year, the interconnection costs are substantial in relative terms. It is important to remember, though, that part of this high relative interconnection cost is due almost entirely to low plant utilization and that this figure can change dramatically if the mill is used for export more of the time. In the case of Option 3, the plant is expected to operate about 65% of the year, the same as an EGAT baseload unit.

As might be expected, the unit capital costs (i.e., ß/kWh) can be quite high, relative to the proposed prices that such generators might receive. Figure 4.3 shows the range of capital costs per kWh for Option 3. Even with a high plant factor (utilization rate), this option gives a median capital charge of ß0.82/kWh. With lower utilization, the capital charge could exceed ß1 per kWh. However, if PEA and EGAT found that power from sugar mills was high on their merit order of dispatch, that is, utilization of 75%, then the capital charge per kWh might be as low as ß0.75. The relatively high efficiency of the Option 3 boilers reduces fuel costs over the earlier options. With bagasse valued at ß100/tonne ($4/tonne), the average fuel cost per kWh is expected to be ß0.2. Even if fuel prices were to double, to ß200/tonne, the fuel cost would still be under the medium fuel expenditures of Option 1.

*Option 3a*

In spite of the high efficiency of Option 3, it is unlikely that mill owners would invest in such costly equipment, solely for the generation of power for export, at least at the going buyback prices. However, for a mill that intends to install new boilers and turbogenerators, the marginal cost of additional investments for power export may be attractive. The marginal option shows the additional costs of investment for electricity export when a mill must purchase a new boiler and power system. The investments that are additional to a standard sugar mill boiler and turbogenerator are:

-- Additional equipment for the boiler

-- Additional turbogenerator equipment and piping

-- Modifications to the mill itself so that the steam for the power generation system takes priority over the steam for the milling process

-- Tie line transformer and the tie line itself

The costs per installed MW of such marginal investments are:

Mechanical ß89,000,000 ($35,000,000)

Electrical ß22,000,000 ($850,000)

These marginal costs are about 38% of the cost of purchasing a new boiler and turbogenerator for the sole purpose of generating electricity. With total marginal plant costs of ß111 M ($4.4 M) for a 10 MW unit, the capital costs that are charged to the power export side of the mill are far lower than for the pure Option 3. Figure 4.3 shows that these capital charges range from ß0.3-0.5

per kWh, less than half the figures for the entire plant option. Figure 4.2 shows that interconnection costs are relatively more important for Option 3a than for Option 3, since the rationale for the investment is primarily power export. Using the same fuel costs as previously, the median generation cost would be ß0.52 per kWh. The high end of the range, ß0.62 per kWh, is still below the lowest cost for Option 3 and is about the same as the median for Option 2. These results are shown in Figure 4.3.

*Option 4*

At the high end of the cost and commitment scale is a dedicated large scale power plant of 25 MW export capability. This alternative is typical of the types of units that are installed in Hawaii as stand-alone power generating stations. Solid fuel boilers generating 25 MW of output cost about the same as a small coal-fired power station, $1,365 per installed kW. Operationally, the 25 MW plant would require that the sugar mill operate on a priority set by the power plant. Under power generation priority, the steam for the export generation would always take precedence over the steam for the mill's own needs. This unit would connect to the 69 or 115 kV substation in the EGAT system rather than to the 22kV PEA subtransmission system. Table 4.4 shows the investment and operational costs for this larger scale option. As with Option 3, the investment costs are high relative to other generation options in the EGAT system.[(16)] Table 4.4 shows that the unit capital charges are even higher for this option than for Option 3. The main advantage of the large single boiler is that it could be run efficiently on fuel oil as well as bagasse. This gives EGAT an option to dispatch such a unit on oil if sufficient supplies of bagasse are not available. With median unit capital charges of ß1 per kWh, Option 4 generates electricity at a total cost of ß1.16 per kWh. Infrequent operation can raise the total generation cost to as much as ß1.24/kWh.

***Table 4.4. Option 4: Investment Costs and Operational Parameters***

*Investment (25 MW)*

*Mechanical (includes plant modifications) 780,000,000 30,000,000*

*Electrical (Includes metering and switchgear) 82,500,000 3,250,000*

*Generating Costs (per kWh)*

*Fuel @ $2/tonne 0.078 0.003*

*@ $4/tonne 0.157 0.006*

*@ $6/tonne 0.235 0.009*

*Capital Charges @ 75% plant factor 0.878 0.035*

*@ 65% plant factor 1.032 0.041*

*@ 50% plant factor 1.318 0.052*

*Total Costs (per kWh)*

*Low 0.957 0.038*

*Medium 1.188 0.047*

*High 1.553 0.062*

*Baht $*

*Note: The base case assumption include a 10% interest rate and a 20% return for the equity portion of the investment. No use of cane tops or leaves is assumed and the heat rate for the boiler is assumed to be 16,000 BTU/kWh at all times and on either bagasse or fuel oil.*

*Option 4a*

*As with Option 3, there is a marginal investment option for the large, stand-alone boiler. Option 4a considers only the extra costs that might be needed for a new sugar mill processing enough sugarcane to fuel a 25 MW boiler. As with Option 3a, this option includes only those investments that are additional in order that the mill can export power to the grid.*

*The tie line is relatively more expensive in this option than in 3a due to the higher cost of the 69 or 115 kV line and transformer (see Figure 4.2). In relative terms, the other interconnection costs are about the same as for Option 3a. On a per MW basis, the investment costs for this option are:*

*Mechanical ß209,000,000 ($8,200,000)*

*Electrical ß76,500,000 ($3,000,000)*

*The total marginal cost of the design, equipment, and modifications required to export 25 MW of power is ß285M ($11.1 M). Figure 4.4 shows how this cost computes to a median value of ß0.33/kWh. The high end of the range is ß0.43 while the lower range is ß0.29/kWh. Given the higher efficiency of such a unit, the fuel costs will be about ß0.16/kWh when bagasse is valued at ß100/tonne. The total power generation costs, which range from ß0.43-0.62/kWh, are shown in Figure 4.4. The reader should note that these costs are only for bagasse-fuelled generation. The large boilers will use #6 oil for part of year. The average annual cost for such combined fuel generation will depend on the proportion of the fuel supply that is oil. Other fuel options may exist which enable the mill to use relatively inexpensive fuel throughout the year. In particular, recent trials with collection and use of cane trash have shown that it may be possible to collect this trash and transport it to a mill in the off-season at prices that are competitive with fuel oil. The trash, consisting primarily of tops and leaves left in the field, has been baled and transported at prices of about $25/tonne (ß630) which compares very favorably with fuel oil on an energy equivalent basis.[(17)] Trials will continue to determine optimal collection, baling, and transporting modes for this potential fuel.*

***Figure 4.3. Generation and Interconnection Costs for Options 3 and 3a***

***Not Available in HTML***

### *4.2.2 Fuel Price Issues*

*It was a working assumption of this project that bagasse would be available to cogenerators in whatever volumes might be required. The reasoning behind this assumption is quite direct; the high cost of transporting bagasse limits the value of that fuel to customers at any significant*

*distance from the mill. The team obtained data from a number of mills and bagasse buyers which indicated that a typical sugar mill selling bagasse to board or paper plants could expect to receive ß50-100/tonne. The highest figure that the consultants encountered was ß120/tonne.*

*With transport costs running from ß50-150/tonne, the apparent value of the bagasse to board and pulp mills exceeds ß150/tonne. At the same time, those sugar mills that are located far from board mills are unlikely to find any market for their surplus bagasse. In most cases, bagasse has a value to the mill of less than ß100/tonne.[(18)] This figure was chosen as the baseline value for fuel when making comparisons among different generation investment options.*

*Instead of simply assuming some value for fuel, utilities often find it helpful to calculate what the fuel is worth to the power plant; in other words, what can the generator pay for fuel. This measure is called the fuel netback value, and is the maximum that a user can pay for fuel given the following data:*

*-- The cost of the capital investment*

*-- The frequency with which the equipment is used - i.e., dispatch[(19)]*

*-- The efficiency of the plant (BTU/kWh)*

*-- The price at which the power is purchased.*

*The fuel netback value is calculated as:*

*NB fuel = Electricity Price per kWh - (annual capital charge + annual O&M charge)*

*(kWh generated in year)*

*In other words, the netback value shows how much a generator can pay for fuel on a per kWh basis. Once we know the netback value of fuel on an output basis, it is an easy conversion to calculate the value of that fuel on an input (per tonne or per $10^6$ BTU) basis. In this report, the convention of expressing fuel netback values in tonnage or $10^6$ BTU terms is used.*

*For example, take the case of plant Option 3 (See Table 4.3). Suppose that the purchase price for 1 kWh = ß1.25. Suppose further that the capital and O & M cost of generation, based on dispatch of 5694 hours annually (i.e., 65%) is ß0.826/kWh. Using the netback formula given above, we get:*

*NB = ß1.25-ß0.826*

*= ß0.420*

*In other words, the generator can pay ß0.42 in fuel charges to generate*

*1 kWh of electricity. Since the heat rate of the plant is 20,000 BTU/kWh, we calculate that ß0.42 is the value of 20,000 BTU. This figure is equivalent to a value of ß21.2 per $10^6$ BTU ($0.84) or $4.70 (ß118.7) per barrel of oil equivalent, far below current market prices for fuel oil. In other words, given the prices, costs and efficiencies of the equipment, along with the frequency of use (dispatch), the plant cannot afford to pay more than ß210 per tonne of bagasse at 10.9 x $10^6$ BTU per tonne of bagasse. If dispatch goes up, then the fuel netback value will rise as well. Conversely, if dispatch goes down, then the price that a mill can pay for fuel will fall as well. In a similar way, each of the four factors listed above directly affects the value of fuel to the plant. If*

*dispatch, for example, rose to 75% or 6570 hours annually, the netback value of fuel would rise as follows, assuming the other parameters remained constant:*

*NB = ß1.25-ß0.739*

*= ß0.511*

*With such a netback value per kWh (20,000 BTU), the value of $10^6$ BTU rises to ß25.55 ($1.01). This figure is equivalent to ß278.5/tonne of bagasse ($11) or ß143/boe ($5.66).*

*When a netback value exceeds the cost of acquiring the fuel, then the mill can justify the investment. However, if the fuel netback value is low or negative, this usually indicates that the capital is too expensive, the power purchase price too low, or the boiler too inefficient. Using a range of potential power purchase prices, the team calculated the fuel netback value for each of the plants. Three purchase prices for electricity were used to calculate the fuel netback values. These purchase prices are shown in Table 4.5, and are the ones agreed upon by the Thai National Energy Policy Council for cogenerators. They are converted from composite measures of capacity and energy and time of day to an average price per kWh based on 24 hours/day generation. The prices used to calculate fuel netback values are: ß0.63, 0.85, and 0.92 per kWh. The purchase prices used in Table 4.5 are equivalent to the non-firm, 11-16 year, and 21-25 year contracts, respectively (See Annex 2 for further details on the rates of return and other economic calculations from these purchase prices). With an assumed opportunity cost of bagasse of ß100/tonne, $0.50 per million BTU, Table 4.5 shows that the non-firm price of ß0.63/kWh is insufficient to compete with other uses of the bagasse for Options 1, 3, and 4.[(20)] On the other hand, the more cost-effective options, 2, 3a, and 4a, can all pay more for bagasse than can other uses, even at non-firm power purchase prices. The medium-term purchase price, ß0.85/kWh, for 11-15 year firm power contracts, permits all of the plants except 3 and 4 to pay well above other competing uses for the bagasse supplies that they need for fuel. The longest term purchase price, ß0.92 per kWh for 21-25 year firm power contracts, permits all options except the two biggest investments, 3 and 4, to pay well above the values of bagasse in virtually any other end uses.*

*For the higher-cost investment options, 3 and 4, power prices in excess of ß1.25/kWh would be required for the mill to impart a value to bagasse that is greater than what its competing uses can command. However, both of the marginal options, 3a and 4a, impart more value to the bagasse than either of the low cost immediate term options. This result would hold for any fuel. What it means is that the high capacity, high efficiency mills could afford to pay more for their fuel than can the lower efficiency ones. Indeed, such mills could probably afford to pay farmers enough to supply cane residues whereas less efficient mills might not be able to do so.*

***Table 4.5. Netback Values For Bagasse (ß/tonne)and Oil ($/bbl)***

| Power | Bagasse (ß/tonne) | | | | | | Fuel oil ($/bbl) | |
|---|---|---|---|---|---|---|---|---|
| purchase price (ß/kWh) | Option 1 | Option 2 | Option 3 | Option 3a | Option 4 | Option 4a | Option 3a | Option 4a |
| 0.63 | 23.03 | 51.23 | -106.82 | 145.23 | -219.09 | 147.13 | 5.64 | 5.71 |
| 0.85 | 53 | 91.2 | 13.08 | 247.37 | -99.19 | 257.13 | 9.61 | 9.99 |
| 0.92 | 62.91 | 104.4 | 52.7 | 281.13 | -59.57 | 293.48 | 10.92 | 11.40 |

*Another important point to remember is that the larger mills are more likely than are the smaller ones to sign long term contracts with EGAT. Under the proposed schedule of buyback prices, the longer term contracts will pay more per kWh than will spot sales contracts. This means that longer term contracts will impute more value to the fuel than will spot ones. For example, at a purchase price of ß0.92/kWh, a 3a-type mill could pay $1.22 per $10^6$ BTU for fuel, much more than the $0.38/$10^6$ BTU for a 2-type mill which is in turn far greater than the $0.23/$10^6$ BTU for the 1-type mill.*[21]

*Table 4.5 shows that burning fuel oil during part of the year would result in losses for the mills, even on the low cost 3a and 4a options. In each case, the maximum netback value for fuel oil is about $11/barrel of fuel oil, well below its price in Thailand or on world markets. The upside of this analysis is that mills will have great incentives to use bagasse in an efficient manner since resorting to fuel oil as a means of fulfilling a power purchase contract will result in losses for them.*

### *4.3 Power Purchase Price Issues*

*At the present time there is no final set of purchase price terms for cogenerators or independent power producers. As a result, the team's economist has used a tariff structure proposal that was recently released by the Government's Cogeneration Working Group. The proposed buyback tariffs are of two types, non-firm or spot sales and long term contracts. The spot sales tariff has three parts, for peak, shoulder, and baseload supply. They are ß0.87, 0.65, and 0.55, respectively. Based on the hours for which each of the non-firm tariffs is effective, the composite price that EGAT will pay for non-firm electricity is ß0.63/kWh.*

*In contrast, the firm supply contract terms include a ß0.69/kWh payment for energy*[22] *plus the following fixed charge schedule:*

*Contract Length Payment (ß/kW/month)*

*5 - 10 years 100*

*10 - 15 years 115*

*15 - 20 years 123*

*20 - 25 years 170*

*Clearly, these contract terms place a premium on the steady long term commitment by cogenerators. The proposed structure appears to be sound and the energy payment appeared to be sufficient for most fuel types unless there is a run up in fuel prices.*[23] *There may be some question about the particular periods that were chosen but this is a rather minor quibble in light of the overall soundness of the contract structure.*

*To assess the incentive effects of these proposed purchase terms, the team calculated the internal rates of return on investment implied by such prices. In addition, the net present value of production under each option was calculated. Selected results, for the medium cases, are shown below in Table 4.6 with a more complete listing in Annex 2.*

***Table 4.6. Rate of Return Analysis for Sugar Mills: Mid-range Case***

*Contract Regime*

*Firm Power: # years*

*Net Output Non-Firm*

*Mill Option (kWh/yr) (energy only)*

*5-10*

*11-15 16-20 21-25*

*Option 1 1,314,000*

*IRR -8.05% 1.46% 7.25% 9.50% 12.10%*

*NPV -2.842 -1.552 -0.7 -0.155 0.762*

*Option 2 10,950,000*

*IRR 11.17% 20.73% 23.91% 24.94% 27.48%*

*NPV 1.159 11.904 20.937 26.68 35.066*

*Option 3 56,940,000*

*IRR -2.69% 3.58% 8.70% 10.67% 12.70%*

*NPV 12.4 57.3*

*Option 3a 56,940,000*

*IRR 14.83% 23.73% 26.51% 27.39% 29.80%*

*NPV 26 82 132 164 209*

*Option 4 142,350,000*

*IRR -3.85% 1.72% 7.09% 9.20% 11.18%*

*NPV -400 -261 -127 -42.4 72.8*

*Option 4a 142,350,000*

*IRR 16.41% 24.95% 27.62% 28.46% 30.81%*

*NPV 88 229 362 447 562*

*Note: Net present value figures given in millions of baht.*

*For spot sales, the two immediate term options, 1 and 2 produced satisfactory results only if the plants were utilized well. In other words, low plant factors would almost certainly result in substantial losses for each of the mills. The mid-range case, shown in Table 4.6, indicates that at 15% capacity utilization, Mill option 1 can yield a modest positive return under a long term (>20 years) firm supply contract. A contract to supply non-firm energy results in substantial losses for the mill under virtually any reasonable rate of capacity utilization. In terms of present worth, the*

*mid-range results for Option 1 indicate that only the longest range contract option yields a positive value. In order to be an attractive investment, the mill would need to generate power at least 25% of the year and sell that power on a firm supply contract.*[(24)]

*Mill Option 2 shows attractive returns under virtually all of the contract régimes. Even spot sales give a modest positive return, 11.2%, with the mid-range capacity utilization rate of 25%. Firm power sales contracts for virtually any term show adequate returns in the mid-range case, exceeding 20% and with a present value worth well in excess of ß10 million. Firm contracts for terms exceeding 10 years have present worths that exceed the value of the initial investments by substantial margins.*

*For the two larger options, the initially heavy investment costs make a return based on energy sales alone a virtual impossibility. For both mills, the IRR for spot sales is negative in the mid-range case. The rates of return, and present values only move into acceptable ranges (above 10%) if the plants are used about 75% of the time, higher than the 65% assumed in the medium case and higher than EGAT's own averages.*

*The marginal options, 3a and 4a, both show attractive rates of return under all contract régimes. Indeed, the returns on investment exceed 20% for all contract options in the mid-range case. This means that a mill considering a new boiler or relocating may find it worth their while to make the additional investments necessary for power generation.*[(25)]

***Findings on Pricing Issues***

*Several conclusions emerge from the economic analysis that was performed for this project. On the subject of incentives for supply investments, the team found:*

*-- The proposed spot purchase prices are sufficient only for the Option 2 mill. Other sugar mills cannot make profits from the average price received for spot sales. Therefore, the immediate term incentive effect on power supplies is likely to be modest at best.*

*-- Several of the investment options, even the large investments, 3 and 4, appear to be attractive under the longer term contract prices.*

*-- In particular, Options 2, 3a, and 4a show promising rates of return for most contract terms, especially those of 10 years or more.*

*-- The present values of the marginal options are extremely attractive relative to virtually any other investments for those mills planning to install new boilers and generators.*

*With regard to fuel supply, it is apparent that mills which generate power for sale to the grid may occasionally need to purchase bagasse on the market, especially if the mill plans to generate year-round. In addition, the idea of using fuel oil in some newer mills has been discussed. The team found that:*

*-- Efficient mills which export more than 2.5 MW, should be able to pay enough for bagasse, i.e., more than ß100/tonne, to ensure a steady supply. The bagasse is more valuable to a sugar mill as a fuel for power generation than to that same mill if sold to a board or pulp plan.*

*-- The price that mills can pay for fuel is not sufficient to cover purchases of fuel oil except in extreme cases to avoid non-compliance penalties imposed by the EGAT contracts.*

*-- The larger mills will be able to augment their own supplies of fuel with cane tops and leaves that can be supplied at prices of around ß145/tonne. Fuel netback values will cover the costs of such purchases more readily than they will fuel oil or coal but at current prices they are not suficient to cover the projected cost of procuring cane trash.*

*1. [1] EGAT stands for Electric Generating Authority of Thailand, a state-owned generation and transmission monopoly. The PEA is the Provincial Electric Authority which distributes electricity outside of metropolitan Bangkok.*

*2. [2] "Biomass-Fueled Electric Power Survey" (Chemstar, Ltd., Bangkok, Thailand, 1989, unpublished).*

*3. [3] Biomass Systems and Technology Program, Electric Power from Cane Residues in Thailand, Office of Energy Report 89-03 (Washington, D.C.: U.S. Agency for International Development, 1988).*

*4. [4] In this report the large scale export options (5-25 MW) are cometimes referred to as "short term." This is because the period in which the investments can be made, 2-4 years, is the short term for an electric utility which normally has a 15-25 year planning cycle.*

*5. [1] It is estimated that current commercial-condominium construction now underway in Bangkok will place an additional peak demand of as much as 200 MW on the MEA system.*

*6. [2] Currently under construction or under contract are about 2,100 MW of lignite and gas-fired generating capacity. Timely completion of these projects should just about keep pace with expected increases in demand through 1993. However, this capacity is not expected to add to the systems reserves, leaving the possibility of low reserve margins through the mid-1990s. In early 1990, there was some load shedding in the EGAT system due to high peak demand in the hot season.*

*7. [1] The boiler for this plant can operate more efficiently on heavy fuel oil than on bagasse. The plant can burn oil for some parts of the year when bagasse or cane trash is unavailable. However, the fuel netback value analysis shows that use of fuel oil for extended periods in uneconomical.*

*8. [2] The boiler would be more efficient on fuel oil than bagasse, but as with Option 3, use of fuel oil for extended period is uneconomical.*

*9. [3] In other words, the plant can operate as a stand-alone facility.*

*10. [1] This subject is covered in greater detail in Section 5.*

*11. [2] Although reactive power (vars) is not directly related to energy (watt-hours), it is a component of total power (volt-amperes) relative to the current (amperes), and therefore has an effect on line losses, voltage regulation and generator capacity. The following equations make this clear:*

$$(\text{Volt-Amperes})^2 = (\text{Watts})^2 + (\text{Vars})^2$$

$$\text{Amperes} = (\text{Volt-Amperes})/3 \times (\text{Volts})_{L\text{-}N}$$

$$\text{Losses} = (\text{Amperes})^2 \times \text{Resistance}$$

*Voltage Drop = Amperes x Impedance*

*12. [1] This has to do with the economics of seasonal demands for various fuels and the responses of the refining system to those changes in demand. The availability, and therefore the price, of heavy fuel oil will vary from one season to another as a result of these refining changes.*

*13. [2] This issue may be locally important if a sugar mill is relatively isolated or if there are a number of competitors for the sugar mill's bagasse. These might include fiberboard or pulp mills.*

*14. [3]Another project, supported by USAID, has investigated the feasibility of gathering the cane trash and leaves to use as fuel for power generation. The project concluded that the costs of delivering cane trash to a sugar mill were competitive with coal and much less expensive than heavy fuel oil.*

*15. [4] This figure refers to the proportion of the total hours in a year that the plant is operating. Thus a 25% utilization rate means that the plant operates 2190 hours (i.e., 0.25 x 8760).*

*16. [5] For example, a new gas-fired combined cycle unit costs about $650 per installed kW (ß16.4 million), about half the cost of a new large bagasse boiler.*

*17. [6] The present cost of procuring the cane trash works out to $1.45/million BTU, about half the cost of heavy fuel oil delivered to such a site.*

*18. [7] A price of baht 100/tonne corresponds to baht 12.5 per million BTU. As a point of reference, the current world crude oil price, $28/bbl, is about $5.00 per million BTU or baht 125 per million BTU.*

*19. [8] This determines the number of kWh over which each unit of investment is amortized. As was shown in Section 5.2.1, infrequent use of the additional capital equipment affects unit capital costs adversely. Given equal performance, high unit capital costs in turn reduce the value of any given fuel to a generator.*

*20. [9] ß100 per tonne is the average opportunity cost for bagasse vis-a-vis its other users, as a feedstock for paper or fiberboard manufacture.*

*21. [10] Details of the netback pricing methodology are contained in Annex 2. However, the conversion from baht per kWh for fuel to $ per million BTU is simple and straightforward. The fuel netback value in baht/kWh represents the maximum fuel value for one kWh. This is the value of the input energy which is 80,000 BTU in the case of Option 1, in other words, the plant's heat rate in BTU/kWh. Therefore, a netback value of ß0.4617/kWh is multiplied by the number of BTU in one tonne of bagasse, 10.9 million, and divided by the plant's heat rate:*

*baht/tonne = fuel netback value x (heating value of one tonne of bagasse/plant heat rate)*

*= 0.4617 x (10,900,000/80,000)*

*= ß63/tonne*

*The uses of $/million BTU or baht/tonne are interchangeable, simply requiring the appropriate conversion factors for both money and energy.*

*22. [11] This payment includes maintenance, management, and fuel costs.*

*23. [12] If crude oil prices are in the $30/bbl range , an energy payment of ß0.85/kWh may be more appropriate. Using such a figure will change the rates of return substantially and improve the profitability of all investments for long term firm power supply.*

*24. [13] Under the proposed purchase regulations, EGAT would purchase only from connecting points in excess of 50 MW. Such a requirement suggests mills will sell to PEA rather than EGAT. For larger mills, selling to PEA may cause problems because of the size of PEA substations.*

*25. [14] In Annex 3, one of the case studies examines the export potential of one of the mills visited by the consultants, Thai Identity. This mill appears to have significant potential for export, particularly with additional investments in its boilers and turbogenerators.*