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BIOMASS EQUIPMENT SUPPLIERS & TECHNOLOGICAL POTENTIAL IN SELECTED PHILIPPINE AGRO-BASED INDUSTRIES

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ABSTRACT

This paper gives an overview of the technical and financial viability of using agricultural residues to generate heat and/or electricity. The government's policy toward cogeneration and private sector power generation is discussed. The paper identifies the key factors that boost the potential of cogeneration, particularly when available biomass residues such as bagasse, rice husk and coconut shells/husks are used. It also looks at the technical, economic/financial and institutional issues that confront projects of this nature. The paper discusses the status of domestic manufacturing capability and the end-user interest in cogeneration projects. Finally, it gives a profile of three sectors (namely sugar, rice and coconut) with potential for the application of cogeneration projects using biomass residues.

INTRODUCTION

There has been a long standing interest in heat and/or power generation from agricultural wastes ("agriwastes") in the Philippines. Popular wisdom has held the notion that since these waste materials are free, then they must be viable commercial sources of energy. However, as many have found out, it is not enough that substantial quantities of agriwastes are accessible. The means to gather and deliver them at the plant location, the technology to convert them to useful forms of heat and the expertise to operate and maintain the equipment are only some of the factors that must be reviewed. Only a detailed assessment of particular applications using specific technologies in actual sites can establish the overall feasibility of these projects.

In relation to the foregoing, the European Community (EC) has initiated an ASEAN-wide Cogeneration Programme in the field of heat and/or power generation using agro- and wood wastes. The Cogen Programme will undertake activities that will identify areas for cooperative endeavors between ASEAN and EC entities and examine joint venture opportunities. The ASEAN-EC Cogen Programme wishes to facilitate such joint ventures by providing a venue for evaluation and discussion of possible projects and by making available the necessary financial and technical support.

There is no comprehensive national assessment of industrial cogeneration potential using agriwastes. No in-depth analysis has been undertaken to show the size of the market, the needs for technological development and the likely viability of particular technologies in various applications. This study does not claim to be comprehensive in scope nor detailed in its investigation. It is intended to provide indicative numbers for a set of target user sectors and to point the directions for more detailed subsequent activities that may be undertaken by the Philippine Cogen Team. It will use as much information as possible from existing studies undertaken by the government and the private sector.

The study also looks at the status of domestic manufacturing capability and the end-user interest to better identify the appropriate technology for the local market and to determine the level of effort needed to sell the concept of cogeneration to specific companies or target user groups.

COGENERATION AND PRIVATE POWER INITIATIVES

Cogeneration, i.e. the sequential production of heat and mechanical power from one fuel source, is the preferred power generation alternative for several industries. Onsite power generation has proven to be a most reliable power source in many companies both locally and in other countries. Cogeneration optimizes energy efficiency and may be viable in several applications particularly where there is abundant supply of organic residues.

The cogeneration approach is consistent with the Philippine government's energy efficiency objective embodied in the Medium-Term Energy Development Program and in the Rules and Regulations Implementing Executive Order No. 215 which encourages private sector participation in power generation.

At the start of the present administration, private power in the Philippines was encouraged for the following reasons. Firstly, there was a recognition that the generation of electricity, unlike the transmission and distribution of electricity is not a natural monopoly and can be undertaken economically by more than one entity. The presence of alternative bulk electricity producers may even foster efficiency in the sector.

Secondly, the Philippine government as a matter of policy wanted to encourage the private sector to participate in economic development and to disengage from areas where the private sector has shown interest and capability.

Thirdly, the government would like to reserve public funds for areas such as social services which normally do not attract private investment.

The foregoing reasons were cited when the government promulgated Executive Order No. 215 in mid-1986. Power supply was sufficient at the time, the country having gone through two previous years of economic contraction. However, the rapid economic growth experienced between 1986 and 1989 consequently raised power demand beyond available capacities. The situation was aggravated when no new baseload power plants were commissioned during the period.

Lately, the National Power Corporation (NAPOCOR), the state power utility, has been having financial, operational and project implementation difficulties. The power supply remains unreliable and the cost of power is likely to rise significantly in the near term.

KEY FACTORS FOR COGENERATION

From the private sector's viewpoint, several key factors collaborate to boost cogeneration and private power potential in the Philippines. The following factors apply to all industries throughout the country.

1. *Unreliable power supply is seen to prevail for the next five years.* The government has not been able to install new baseload power plants since 1985. All current plans to install new capacity are contingent on actions outside the control of NAPOCOR itself. These include the granting of Environmental Compliance Certificates (ECC) to large coal and geothermal projects and the acceptance and endorsement of local communities of the same projects.

   Specifically, the programmed coal thermal plants in Luzon; namely: Calaca II (300 MW by March 1994), Masinloc I (300 MW by May 1995), Masinloc II (300 MW by January 1996); and, the Mt. Apo geothermal plants (a total of 240 MW with the first 60 MW units commissioned starting January 1990) in Mindanao have not been given ECCs by the Department of Environment and Natural Resources. The ECCs are not based solely on technical grounds but also on socioeconomic and political factors. The lack of clear requirements and procedures can potentially deter the implementation of the above projects.

   The delays that are expected would push the commissioning of major power projects to 1997 and beyond. Therefore, the earliest time when power supply can be expected to be adequate is 1997 when the geothermal power plants in Leyte[1] would be able to export power to Luzon[2] via DC submarine cables.

2. *High electricity costs.* NAPOCOR has installed over four hundred megawatts of diesel-fired simple cycle gas turbines to augment power capacities in Luzon and the Visayan islands. These peaking units are being operated practically as baseload power plants. Their very high running costs[3] has exacerbated NAPOCOR's financial problems. The power tariff increases that shall eventually be required to recover these costs will give forceful incentives to end-users to practice energy management.

   The NAPOCOR has announced a 22.5 centavos per KWH rate hike starting 1992. The burden of the increase has been dampened for residential customers consuming less than 300 KWH a month. Thus, the industrial and commercial sectors will likely shoulder the majority of the increase.

   Cogeneration may offer both a supply side alternative while at the same time offering a means to restrain fuel consumption. Initial price scenarios from NAPOCOR show that directly connected industries and Cogeneration may offer both a supply side alternative while at the same time offering a means to restrain fuel consumption.

The scheduled restructuring of NAPOCOR power tariffs towards long-run marginal cost will also provide further incentives for companies to practice energy management. Initial price scenarios from NAPOCOR show that directly connected industries would be charged higher effective tariffs. Thus, the economics of alternative power supply would improve once the new rate structure is implemented.

3. *Proven technology*. Cogeneration has been practice for more than hundred years in some countries[4]. The domestic sugar industry for example has been cogenerating since inception. The renewal of interest in cogeneration did not come chiefly from technological developments but rather from the new perspectives taken by utilities in sourcing their power supply from outside suppliers.

   Private power generation in the industrial setting has been proven to be reliable in several applications. Onsite generation also ensures that power supply is present at the time the operations require.

4. *Possible favorable environmental impacts*[5]. Recent attention has been focused on the excessive release of carbon dioxide to the atmosphere from fossil fuel combustion and clearing tropical forests. Scientists are increasingly in agreement that the increase of carbon dioxide and methane in the atmosphere will lead to global and climate change.

   Use of sustainable biomass feedstocks to produce electricity and liquid fuels can increase the energy available for economic development without increasing carbon dioxide emissions. Carbon dioxide is removed from the atmosphere each year as part of the process of growing the next year's fuel. In addition, managed plantations offer a way to reduce the net carbon consumption of biomass for electricity or liquid fuels, biomass energy systems are part of a global solution.

   In the case of sugarcane, for example, data provided by the Hawaiian Sugar Producers' Association shows that the net carbon dioxide absorption by one acre of sugar is 81 tons over tow-year period (the harvest cycle for sugar cane tops and leaves to produce energy as opposed to allowing the fixed carbon to return to the atmosphere as carbon dioxide after being left in the field, landfilled or dumped in the ocean. In other words, using biomass for energy is only an intervention on the inevitable road to the same carbon dioxide release.

   In the local scene, some Philippine companies located near urban centers have been advised by the Department of Environment and Natural Resources (DENR) to upgrade their facilities to reduce emission of pollutants. In such cases, there is a good chance that cogeneration alternatives may blend well with environmental objectives. For example, recovering heat from process fluids discharged to the environment may be a source of energy while lowering the fluid discharge temperature to acceptable levels.

The particular sectors with access to agricultural and/or byproduct wastes have the following additional motivating factors.

1. *Abundant agriwaste fuel.* The industrial sectors (sugar, rice and coconut) considered in this report all have access to agriwastes which are in most cases by-products of their production processes. These agriwastes have practically no cost. In fact companies consider them a nuisance and may even pay extra to dispose of them. In several cases including the sugar and rice sectors, the energy content of by-product agriwastes are enough to fully supply the steam and electricity requirements of the mills when using appropriate technology.

2. *Old equipment stock.* Many local applications of cogeneration and agriwastes utilization do not begin to approach the efficiencies available from late model equipment. The domestic sugar industry, for example, has an average equipment age of 34 years for its boilers. Several sugar mills have steam generating equipment with over 70 years of service. These pieces of equipment are ready for replacement as they are being operated beyond their normal economic lives.

3. *Employment generation.* Some industries are tied closely with the community where it operates. It sees itself not only as a business operation but also a source of social amelioration for the community. Social objectives like employment generation therefore affect business decisions.

   In a local sugar estate[6], the company initiated a field trash collection program to help members of the community earn extra income. The company paid for field trash brought into its baling area at a price equivalent to fuel oil on an energy basis. This had several benefits. Aside from providing the community an additional income opportunity, it discouraged the practice of burning the sugarcane in the fields to make them easier to harvest. Burnt cane loses sucrose content very quickly and therefore had to be processed soon after being brought into the mill. The company improved the system of collecting and baling of field trash and the combustion of field trash bales so that it is now fully self-reliant in its energy needs. Last year, it reported savings of about US$ 1 Million in foregone fuel oil purchases.

TECHNICAL, ECONOMIC/FINANCIAL AND INSTITUTIONAL ISSUES

Several issues conspire to impede the implementation of cogeneration projects in the country. While these are not impossible to hurdle, they may sufficiently frustrate efforts of project developers not familiar with the local environment.

Technical Issues

As mentioned earlier, cogeneration is well established in several industries. Moreover, the equipment required to implement such projects are not beyond the comprehension and competence of qualified engineers. However, the recent focus on greater energy efficiency has revealed a much larger cogeneration potential even in sectors which have not previously been involved in cogeneration. There is a need therefore to evaluate the wealth of new opportunities. In many cases, state of the art developments can only be followed by a few specialists. Further, the instrumentation needed to do an in-depth investigation of conservation potential through an energy audit may not be present in the industrial facility thus limiting the internal process of project identification and design.

The agro-based industrial sectors also may have a limited complement of qualified technical staff to oversee the additional operations arising from the installation of cogeneration projects. This problem is relevant particularly in industries such as rice milling which tends to be composed of many small scale millers. Therefore, although a project may be viable, the mill may not be inclined to implement it due to lack of technical expertise.

Economic/Financial Issues

The current levels of energy prices already provide sufficient motivation for companies to look at energy management opportunities. However, further adjustments are required to fully remove the subsidies present in the current price structure. Specifically, the relatively low price of diesel affects the financial viability of biomass-based energy utilization. The government also needs to restructure electric tariffs to give consumers appropriate cost signals that will encourage efficient consumption of electricity.

The major component that needs to be clarified is the transfer price between the private power developer and the electric utility which will purchase the excess electricity production. This task rests mainly on the state utility since in the context of the prevailing rules and regulations, the NAPOCOR is the buyer of last resort. However, it shall only purchase outside power at its "avoided cost". It is in the determination of avoided cost where the uncertainty lies. Private developers do not have the luxury of devoting much time and effort to negotiating with the state utility regarding the power purchase agreement.

The availability of financing is a crucial element in any cogeneration project. The equipment manufacturers we interviewed noted that availability of financing alone may be sufficient to convince several companies to undertake a cogeneration project.

Institutional Issues

The rules and regulations governing cogeneration and private power leave a lot of room for further enhancement. The overall thrust should be to limit the real and perceived risks of private developers by establishing clear and definitive procedures in place.

1. *Accreditation Procedure.* NAPOCOR has not finalized its internal accreditation procedure for cogeneration and private power proponents. Temporary accreditations have been given to certain projects pending the finalization of the accreditation procedures.

   However, the benefits of accredited facilities guaranteed by the current laws may not be enjoyed unless proper accreditations are made.

2. *Long-term power purchase contract.* Since even large cogeneration projects tend to be small by utility standards, most cogeneration projects would fall either under the category

of mini-PSGF (Private Sector Generating Facility) or those having excess capacities below one thousand watts.

It is to NAPOCOR's benefit to have a set of standard long-term contracts for mini-PSGFs in order to short-circuit the negotiation process and simplify connection of many small industrial facilities. In this manner, a significant amount of private capacity may be brought on line quickly and at only the cost of interconnection. Such standard contracts would present a clear business offer to private developers who can then undertake their own studies to see if they can present a viable project.

3. *Project financing.* The lack of a capital market and the high costs of financial resources in the country stifle the initiatives of private developers towards implementing otherwise viable projects. Aside from the EC, financial institutions like the Asian Development Bank (ADB) and the World Bank have expressed their support for cogeneration and private power projects. They have specific windows for private sector projects.

However, to enable the widespread access to these funds, the government may have to formulate and implement a specific program. In the Philippines, the Technology Transfer for Energy Management (TTEM) administered by the Office of Energy Affairs (OEA) has met with success in granting funds to energy management projects. Perhaps a similar and larger program tapping the various bilateral and multilateral donors can be initiated for cogeneration projects.

SUGAR INDUSTRY

The sugar industry is a vital component of the national economy. It remains a leading export commodity and is a major employer in areas where it operates. At the onset of the energy crisis in 1973, it helped prop up the economy in the face of discouraging performances of other traditional exports. That year, the United States, the principal sugar market of the country, registered a threefold increase in sugar prices as domestic sugar production expanded by nine percent. The foreign exchange earnings from the sugar sector in 1973 was the only bright spot in the nation's economic performance.

The following table will show that the export performance of the sugar sector has markedly improved for the past two years owing to favorable world sugar prices. Sugar exports accounted for an average of US$100 Million between 1989 and 1990. However, the prospects for further growth have to be tempered by the lower U.S. quota recently granted the country and additional competition from South African suppliers.

Principal Philippine Exports
(Million US Dollars)

	1986	1987	1988	1989	1990
Coconut Oil	333	381	408	377	36
Copper	90	109	216	237	207
Sugar	87	60	60	89	111
Lumber	103	155	157	136	20
Copra	18	32	28	25	20

Energy Requirements and Applications

Bagasse is the predominant fuel source of the sugar industry. It accounts for nearly 90 percent of total energy consumption of Philippine sugar mills. The sugar milling process produces a lot more bagasse than is required by the mill to produce electricity for its own use. The current operating practice is to ensure that bagasse does not unduly accumulate. Therefore, boiler efficiencies in burning bagasse are not as critical as when a purchased fuel such as bunker fuel is used.

Supplementary fuels are fired during boiler start-up. These include bunker fuel and agriwastes such as cane trash and wood. Wood and other residues are used during preheating stages of the boiler at the start of the milling season or when coming from a weekend shutdown. Bunker fuel serves the same purpose but is primarily employed to sustain steam generation during short breaks in operation.

Electricity is used to drive motors and provide lighting and air-conditioning to the mill. Philippine sugar mills normally have three sources of electricity supply: (a) steam turbo-generators; (b) diesel engine generator sets; and, (c) grid connection.

Diesel gensets and grid connections supply power to shoulder some load from the turbo-generators when steam pressure drops; to provide sustained power to small motors which need not be shut off even on scheduled shutdown and for lighting, water pumping and other local requirements.

Grid connections are not normally considered when establishing new mills. Six mills however are reported to depend solely on grid connections for additional power[7]. At the same time, several mills have reported no grid connections at all.

Energy in the sugar industry is utilized primarily in process heating mainly in evaporation equipment (about 91%) and electric motors for mechanical power (about 6%)[8].

Delays, stoppages and shutdowns have adverse effects on sugar mill operations. These occur in the mill either as scheduled stoppages or unexpected delays. Power outages have increased fuel consumption and have necessitated more use of supplementary fuels such as bunker and wood.

During weekends, the mill is shut down for cleaning and maintenance. When the extraction plant stops, the boilers continue to operate to allow the boiling house to liquidate its process materials in preparation for the long stoppage. Depending on arrangements between Mill and Process, the sustained boiler operations last for 1-3 hours. It is during this time that excess bagasse (if any) and supplementary fuels are consumed of course, additional fuel is utilized when the mill resumes operations 16-24 hours later contingent on cane supply availability or completion of scheduled repairs and maintenance works.

The unscheduled stoppages might last for several minutes, hours, and even days depending on gravity of the cause. If remedial measures and economy dictate that the boilers continue to operate, supplementary fuels are employed. These operations have been known to deplete whatever excess bagasse the mill has accumulated and also compel most sugar mills to burn bunker oil during start-up.

Biomass Resource Base

There are 38 operating sugar mills in the country. The majority of the mills are located in Negros island where almost 58 percent of the national output in the last crop year was produced. The following tabulation shows the cane tonnage by major sugar areas. The production this crop year has been adversely affected by drought. A normal crop year will post at least a 10 percent increase.

Tonnage of Sugar Cane Milled
1989-1990 Crop Year

Area	Gross Tons	Percent
Luzon	4,237,698	22
Eastern Visayas	1,221,612	6
Panay	1,058,885	5
Negros	11,223,386	58
Mindanao	1,600,637	8
Total	19,342,218	100

The gross tonnage of sugar cane milled produced 5.7 metric tons of bagasse and a significant amount of field trash (tops and leaves) which can be collected also to serve as fuel. Field trash is normally burned in the fields. This is unfortunate since it is an even better source of fuel than bagasse due do its lower moisture content. The combination of bagasse and field trash has an energy content equivalent to about 8.6 Million barrels of fuel oil equivalent.

Cogen potential

The 38 operating sugar mills in the country average about 550,000 MT annual sugar cane throughput. The industry has a tradition of cogeneration which may be traced since its inception. All of the sugar mills appear to have the minimum size needed to undertake cogeneration projects although different technologies may be appropriate for the smallest capacity mills.

Based on comprehensive information from all operating sugar mills several important findings were found.

1. The equipment stock is very old. The simple average age of steam generating equipment was 34 years old. Victorias, the top raw sugar producer, has the oldest boilers (at 70 years old) but also the latest unit (2 years old) which has capacity equal to the aggregate capacity of the oldest units. The new unit has a much higher operating pressure (at 28 kg/cm^2) than the 70- year old units (9 and 18 kg/cm^2).

2. The operating steam pressures of the mills are merely 80 percent of their design pressures indicating reduced output and much lower efficiencies. It is also a reflection of the age of the equipment and/or the quality of its maintenance.

There are several implications here. Firstly, *companies may be starting to replace their old steam generating systems with new, more efficient and higher pressure units.* In evaluating the feasibility of a prospective cogen system for this case, the capital cost charged would just be the incremental cost of equipment needed for the cogen system itself (e.g. back pressure turbine and generator) plus the incremental cost between a low pressure boiler required by the milling process and a higher pressure boiler required if a cogen system is to be used. If the mills were using relatively new boilers, then the full cost of the steam generating system would have to be imputed.

Secondly, *the higher steam pressure from the new boilers installed by Victorias and some other mills appears tailor-made for a topping cycle cogen application.* High pressure steam may drive a straight back pressure turbine and exhaust directly to the milling process.

A preliminary analysis was made to see the viability of a cogen project on an average size sugar mill in the country. The Canlubang sugar mill was chosen on this basis. Coincidentally, since the company is looking at a cogen project, there was available information from an existing pre-feasibility study[9].

The base scenario was defined to have very conservative assumptions (Appendix 4). The NAPOCOR average industrial rate in Luzon used as proxy for power purchase price. The previous average of P1.69 per kilowatt-hour was increased by 22.5 centavos in accordance with the recently announce rate increase. Capacity is provided by 2 units of 10-MW modules consisting of steam generating equipment and a turbogenerator. *The full cost of the steam generating system was imputed.* Operation is limited to 60% capacity factor as this is the limit of bagasse availability from mill operations and field trash from an envisioned collection program. No sales of steam is imputed although there is a potential to sell 400,000 lb. of steam per hour to industrial customers in the vicinity during off milling season.

The results of the analysis show that a *16.6 percent return on investment (ROI)* can be attained under this base scenario. The investment can be recovered in six years. Sensitivity analyses were undertaken to determine the effects of more rate increases by the NAPOCOR. A 20 percent increase in NAPOCOR grid rate would push the ROI to about 20.5 percent with a payback period of less than five years. This 20 percent increase is realistic since NAPOCOR's long run marginal cost is about this level.

The economics shoot up when steam sales to industries nearby is factored in. In this case, a 29 percent ROI is estimated. Payback period is 3.4 years. Canlubang also has an alcohol distillery. The cogen system can therefore provide for some of its steam and power requirements. Other sugar mills have auxiliary and/or integrated processes that are natural prospects for similar configurations. Eight sugar mills have distilleries while six have sugar refineries. These integrated plants can best make use of the excess steam and power output of cogen systems which will enhance overall feasibility of the cogen project.

Other opportunities exist in the Canlubang site. There are coconut and wood wastes in the locale which can be used to supplement bagasse and field trash. The greater fuel availability will help the mill realize much higher capacity factors which will add to the project viability.

The bottom line for sugar mills in general appears very favorable. Extrapolating from the preceding analysis, a total generation capacity of about 760 MW may be sourced from cogeneration of all operating sugar mills. The cogen system economics can be drastically improved by closer examination of steam and power requirements of associated industrial processes such as sugar refinery.

RICE INDUSTRY

Rice is the staple food of most Filipinos. According to the International Rice Research Institute (IRRI), rice provides 41 percent[10] of total calorie supply from food intake in the Philippines. Undoubtedly, it is also a means of employment and livelihood for millions of Filipinos.

Energy Requirements and Applications

Rice milling in the Philippines produces white polished rice. Parboiled rice popular in South Asia and Thailand is not produced locally. Therefore, the energy requirement of Philippine rice mills is entirely for electricity to run motors, other electric process equipment and lighting. No demand for steam exists as rough rice is delivered by farmers to the mills after solar drying.

The power requirement of rice mills are modest. A mill with a capacity of 250 cavans of white rice per day or about 1.5 metric tons of paddy per hour will have a peak demand of 70 KW and will consume about 16,700 KWH each month. The monthly electric bill will be around P60,000.

It has also been observed at the field surveys that most millers rely more than grid power rather than on diesel and gasoline engines as their power source. Aside from being much less convenient to use, millers report that diesel or gasoline generators complicate the production process and make it "dirty". Some reported that they retired their old generator sets for these reasons. However, the unreliable power situation throughout the country may compel them to reconsider their present dependence on grid power.

Biomass Resource Base

The country harvests nearly 10 Million metric tons of rough rice or paddy annually. Most of the residues from this output are burned in the fields although a small portion of the rice husks is used as cooking fuel in rural areas.

Table 1 shows the fuel potential of rice husks produced from the paddy. There is a potential of 5,800 Million barrels of fuel oil equivalent from rice husks alone.

The qualities of rice husks however do not make it easy to fully tap this potential. Bulk density of rice husks is low. Moreover, much of the carbon is trapped in the rigid ash skeleton of the husks and is not convertible to energy in most thermal conversion systems[11]. The high ash content also affects handling and burning equipment because of its abrasive property. A combustion system using rice husks requires more expensive and extensive ash removal equipment. The large volume of ash can cause problems of ash fouling.

Cogen Potential

There are thousands of rice mills registered with the National Food Authority (NFA). However, most of these are small operations. The private mills tend to be smaller than the NFA rice mills.

Table 2 shows the information on the 51 NFA rice mills as of end 1990. The average mill size is 1.48 metric tons of paddy per hour. Large NFA rice mills[12] are estimated to have a total capacity of about 3,116 bags or 155 metric tons of paddy per day. It is this scale of rice mills that can feasibly generate power from rice husks. Collectively, these NFA mills alone may add nearly four megawatts to grid capacity.

To estimate the viability of a cogen project using rice husks, information on new rice husk technologies were perused having in mind the qualities of rice husks that impact on operational continuity and performance.

A new firm, Energeo, Inc.[13], has been established to manufacture and market "Brayton cycle" systems through joint ventures in Asia. The system uses a fluid bed combustor with a radiant heat exchanger (to minimize erosion of exchanger tubes since rice husk flue gases do not pass through them), a convective heat exchanger and a small gas turbine set.

Fluidizing and overfire air are preheated by flue gases. Rice husks are fed into the combustor by a screw conveyor. All ash is entrained in the flues gases and ultimately removed in a cyclone. Heat from the flue gases is radiated to the stainless steel tubes of the radiant heat exchanger. The radiant heat exchanger transfers heat from combustion gases to clean air which has been preheated in a recuperator by turbine exhaust air and in a convective heat exchanger by flue gases from the combustor. The hot gas is fed into a somewhat modified gas turbine generator set originally designed for use in a system burning kerosene or diesel. Commercial sizes are 80 KW, 100 KW and 200 KW.

Energoe's system was used in the financial evaluation. The assumptions are listed in Table 3. It should be pointed out that the evaluation would be valid for all other technologies that have similar costs and operating parameters.

Since local rice mills do not have steam demand, the system considered would be used to generate electric power only. However, exhaust gases may offer potential heat recovery in possible future applications (e.g.. drying). Independent calculations were made for Luzon and

Visayas applications because project feasibility is highly dependent on current costs of electric utility service. Further, single- and 2-shift operations for the power plant was assumed since the rice mill produces much more husks than required for a single-shift operation. However, the 2-shift operation would need additional husks from possibly adjacent or nearby mills.

Table 4 shows the estimated annual profit and loss statement for Luzon and Visayas applications. ROIs range from 15 percent to 39 percent. Payback periods go from 6.6 years down to 2.6 years. The large improvements possible from incremental power generation beyond mill operations should provide enough incentives to operate the power plant as much as husk supply would allow.

Sensitivity analyses were made to see the combined effects of varying capital costs and NAPOCOR grid rates to payback period. The results are shown on Table 5. Even in a worst case scenario, a 2-shift operation would yield a payback period less than 4 years.

COCONUT INDUSTRY

The Philippines remains the world's leading exporter of coconut products. The export of coconut by-products such as coconut oil and copra account for around US$400 Million annually. (See table in the next page.) The country's largest market is Europe which imports coconut oil, copra meal, copra and dessicated coconut. The United States which imports coconut oil and dessicated coconut is the next largest market for Philippine coconut products.

The prices of coconut oil and copra have been volatile for the past five years. Copra prices varied from US$139/MT in 1986 up to US$349 in 1988 and fell to US$212/MT in 1990. Coconut oil prices exhibited the same trend: US$270/MT in 1986, US$514/MT in 1988 and US$318/MT in 1990. Obviously, this price fluctuation affects the viability of the industry and its capability to undertake capital investments.

Principal Philippine Exports
(Million US Dollars)

	1986	1987	1988	1989	1990
Coconut Oil	333	381	408	377	361
Copper	90	109	216	237	207
Sugar	87	60	60	89	111
Lumber	130	155	157	136	20
Copra	18	32	28	25	20

Energy Requirements and Applications

Coconut oil mills consume petroleum fuels for low to medium temperature process heating. This accounts for nearly 70 percent of the energy consumption of the mill. Electricity, which makes up the remainder of the mill's energy supply, is used to drive motors in the actual milling process. Minimal energy is utilized for transportation, air conditioning and lighting.

The main energy consuming equipment may be classified into two groups:

1. Copra Preparation

    a. Dryers to remove moisture from the copra load
    b. Cleaners to remove foreign materials from the copra load by vibrating metal screens
    c. Crushers to reduce the size of copra into powder with the use of mills and rollers

2. Oil Extraction - This may be done either by mechanical means or by immersing the copra in a solvent.

    a. *Mechanical Presses* - Electric motors are used to run hydraulic batch presses or continuous screw expellers.
    b. *Solvent Extraction* - Equipment consists basically of tanks and mixers where the input materials and the solvent are fed. The process uses steam to hasten the solvent activity.

Biomass Resource Base

There are 92 coconut oil mills in the Philippines with a total milling capacity of 16,876.5 metric tons of copra per day or an average capacity of about 183 metric tons per day. The biomass fuel potential of the coconut husks alone is about *9.5 Million barrels of fuel oil equivalent annually.*

Coconut shells are better energy sources than husks because they are denser and with more calorific value. However, these materials are being used to manufacture activated carbon and shell charcoal where prices are more attractive.

Unlike the sugar and rice sectors, where the by-product agriwastes can be found at the mill site, the coconut oil mills normally receive their raw material as copra, the husks being left to the coconut farmer. Household energy surveys conducted by the Office of Energy Affairs indicate that coconut husks are a significant source of fuel in rural areas. Thus, there is a problem of collection of coconut husks in the vicinity of the mill in order to pursue the cogeneration option.

There are reported cases where coconut mills have undertaken such biomass collection efforts, the most popular of which is the Procter & Gamble cogeneration facility in Tondo, Manila. Legaspi Oil Co., Inc. in Arimbay, Legaspi City has also indicated a program for using coconut shell charcoal as an alterntive fuel source.

Cogen potential

A premilinary analysis was made to examine the viability of a cogen system for the coconut industry. Since the process is somewhat similar in consumption level and pattern with that of the sugar industry, cost data from the sugar analysis were adopted to a coconut mill with a capacity of 270,000 tons per day. The assumptions are shown in Table 6.

Assuming a 67 percent capacity factor for the cogeneration system, the ROI and payback periods for the base scenario are computed to be 19.4 percent and 5.2 years respectively. In the case where NAPOCOR increases its power rate by 20 percent, the ROI will improve to 25.4 percent and the payback period will shorten to 3.9 years.

EQUIPMENT SUPPLIERS AND CAPABILITY

A key factor in the maintenance of cogen systems is the availability of competent operations personnel and the existence of capable equipment suppliers who can provide after purchase support. Domestic equipment suppliers may also joint venture with ASEAN-EC industrialists to serve the domestic market.

Local equipment suppliers are "job shops". They manufacture only per order and generally do not have an inventory of finished goods for sale. In addition to capability in making boilers and heat exchangers required by cogen systems, they normally manufacture ancillary equipment and/or have ties with foreign suppliers.

Visits were made to 2 manufacturing plants which are capable of making biomass boilers. Enertech Systems Industries, Inc. is a medium size company engaged in the design, fabrication and installation of boilers, heat exchangers and materials handling equipment among others.

Enertech is affiliated with European (English and German), American, Australian and Japanese companies for various products.

Enertech has a line of fire tube boilers ranging from 15 to 750 horsepower and operating pressures up to 200 psi. Models may be designed for petroleum or agriwastes at design thermal efficiencies of at least 80 percent and 60 percent respectively. It also has capability to manufacture water tube boilers. Enertech adheres to international (e.g.. ASME) and local standards. The clients it serves include large companies in the food processing, paper, wood and construction industries.

AG&P Honiron Division is one of the largest engineering companies for capabilities for design, fabrication and installation. AG&P fabricated and supplied more than 80 percent of the equipment of most sugar mills and refineries in the Philippines. Its heavy duty steel fabrication equipment is capable of rolling steel plates up to 6 inches thick. It claims the capability to fabricate water tube boilers with up to 1,400 pounds per square inch (psi) operating pressures although actual experience has been limited to 400 psi. The company is affiliated with several foreign manufacturers and holds certificates of accreditation from ASME for the fabrication and assembly of power boilers, pressure vessels and power boiler assemblies.

AG&P's has prioritized its operations in the sugar business to those specific critical process equipment where it can best utilize its capability. Its boiler segment of the business has expanded lately to take up the slack in the manufacture of crushing equipment. AG&P normally confines itself to the larger sizes of equipment and leaves other companies to serve the rest of the market.

Enertech and AG&P have expressed interest in cogeneration systems and possible joint ventures with ASEAN-EC companies particularly those offering appropriate technology. They both recognize the potential of cogeneration systems in the markets identified.

CONCLUSION

The combination of unreliable supply and its high cost when available will drive industrial and commercial establishments to look at alternatives. For a significant number and particularly for those with access to agricultural wastes, cogeneration may provide a viable alternative.

However, while cogeneration provides a welcome opportunity, it also demands a deeper commitment in terms of financial resources to purchase capital equipment and manpower resources for operation. In all three sectors considered in this report, there was a need to operate the cogeneration system beyond the normal business hours of the milling operation.

Table 1. Total Fuel Potential of Rice Husks

Year	Production		Fuel Oil
	Paddy ('000 MT)	Husks ('000 MT)	Equevalent ('000 Bbls.)
1981	8,122	2,152	4,932,422
1982	7,731	2,048	4,694,971
1983	7,841	2,077	4,761,773
1984	8,200	2,173	4,979,791
1985	9,097	2,410	5,524,532
1986	8,958	2,373	5,440,118
1987	8,540	2,263	5,186,270
1988	8,971	2,377	5,448,013
1989	9,657	2,559	5,864,615
1990	9,600	2,544	5,830,000

Table 2. National Food Authority (NFA)
Rice Mills as of 31 December 1990

REGION	# of Mills	Capacity (50-kg bags/day) Paddy	Husks	Average Size (MT per hour of Paddy)
LUZON				
Metro Manila	1	13	3	0.07
Ilocos Region	3	85	22	0.43
Cagayan Valley	5	715	189	3.58
Central Luzon	7	634	168	3.17
Southern Tagalog	5	144	38	0.72
Bicol Region	2	113	29	0.56
Sub-total/Ave.	23	1,704	451	1.42
VISAYAS				
Western Visayas	4	600	159	3.00
Central Visayas	2	33	8	0.17
Eastern Visayas	5	160	42	0.80
Sub-total/Ave.	11	793	210	1.32
MINDANAO				
Western Mindanao	7	109	28	0.55
Northern Mindanao	3	120	31	0.60
Southern Mindanao	3	407	107	2.04
Central Mindanao	4	760	201	3.80
Sub-total/Ave.	17	1,396	369	1.75
PHILIPPINES	51	3,893	1,031	1.48
LARGE RICE MILLS	23	3,116	825	3.12
Percent of Total	45.1%	80.0%	80.0%	

Yearly Fuel Potential of Large NFA Mills = 67 Thousand Barrels

Notes:

1. Husk capacity was calculated by multiplying paddy capacity by 0.265.
2. Average size refers to paddy throughput.
3. Mills operate at 10 hours daily.
4. Large rice mills are estimated from areas with greater than 2 MT per hour average capacity.

Table 3. Assumptions on Rice Analysis

RICE DATA		
Paddy	97% pure, dried to 14% moisture	
Husk	26.5	percent of paddy weight
Average heating value	6,250	BTU per lb
Mill capacity	1.5	MT per hour
Power load	75	KW at full production
Rice husk production	874	lb rice husk per hour
POWER PLANT DATA		
Plant capacity	200	KW
Capital cost	375,000	US$
Fuel requirements	560	lb rice husk per hour
Annual plant operation	4,685	hours
Annual power generation	937,000	KWH
Excess power for grid sale	737,000	KWH
NAPOCOR Luzon grid price	1.92	Pesos per KWH
NAPOCOR Visayas grid price	2.05	Pesos per KWH
Mill cost of power	3.06	Pesos per KWH

Table 4. Annual Profit and Loss, US$

	L U Z O N		V I S A Y A S	
	1 Shift	2 Shifts	1 Shift	2 Shifts
Revenues				
Sale of electric power	50,405	100,811	53,827	107,654
Savings on purchased power	21,885	43,711	21,885	43,771
Sale of Ash	18,000	36,000	18,000	36,000
Total Revenues	90,291	180,582	93,713	187,426
Costs				
Operation & maintenance	15,000	22,500	15,000	22,500
Depreciation	18,750	18,750	18,750	18,750
Fuel Cost	0	0	0	0
Total Cost	33,750	41,250	33,750	41,250
Net operating profit	56,541	139,332	59,963	146,176
Return on investment	15.1%	37.2%	16.0%	39.0%
Payback period	6.6	2.7	6.3	2.6

Table 5. Sensitivity of Payback Period to Capital Cost and Grid Rate

1 Shift

NAPOCOR grid rate, Luzon

Payback >		1.92	2.01	2.11	2.20	2.30	2.39
	300,000	4.7	4.5	4.0	3.4	2.8	2.2
Capital	337,500	5.6	5.3	4.7	4.0	3.3	2.6
cost ->	375,000	6.6	6.2	5.5	4.7	3.8	2.9
	412,500	7.8	7.3	6.4	5.4	4.3	3.3
	450,000	9.0	8.4	7.4	6.1	4.9	3.7

NAPOCOR grid rate, Visayas

Payback		2.05	2.15	2.25	2.35	2.45	2.56
	300,000	4.5	4.3	4.0	3.6	3.0	2.5
Capital	337,500	5.3	5.1	4.7	4.2	3.5	2.9
cost ->	375,000	6.3	6.0	5.5	4.8	4.1	3.3
	412,500	7.3	7.0	6.4	5.6	4.7	3.7
	450,000	8.5	8.0	7.3	6.3	5.3	4.2

2 Shifts

NAPOCOR grid rate, Luzon

Payback >		1.92	2.01	2.11	2.20	2.30	2.39
	300,000	2.0	1.9	1.8	1.5	1.3	1.0
Capital	337,500	2.4	2.2	2.0	1.8	1.5	1.2
cost ->	375,000	2.7	2.6	2.3	2.0	1.7	1.3
	412,500	3.1	2.9	2.6	2.3	1.9	1.5
	450,000	3.4	3.3	2.9	2.5	2.1	1.6

NAPOCOR grid rate, Visayas

Payback >		2.05	2.15	2.25	2.35	2.45	2.56
	300,000	1.9	1.9	1.8	1.6	1.4	1.1
Capital	337,500	2.2	2.2	2.0	1.8	1.6	1.3
cost ->	375,000	2.6	2.5	2.3	2.1	1.8	1.5
	412,500	2.9	2.8	2.6	2.3	2.0	1.7
	450,000	3.3	3.1	2.9	2.6	2.2	1.8

Table 6. Assumptions for a Typical Coconut Oil Mill

COCONUT MILL		
Size	270	Tons copra crushed per day
Milling Duration	300	Days per year
Power Requirements:		
Average Peak Demand	3	MW
Electric Energy Needs	10,716	BOE per year
Fuel Needs	26,536	BOE per year
Fuel Cost	20.00	$ per barrel
Total Energy Needs	37,252	BOE per year
Available Fuel		
Coconut Husk:	283	Tons coconut husks per day
Collection Efficiency	50%	of husks recovered
Heating Value	5,000	BTU/lb fuel
Cost of Coconut Husk	8.77	$/MT (Oil parity)
Energy Potential	53,180	BOE per year
COGENERATION SYSTEM		
Size	10	MW
Heat Rate	16,000	BTU/KWH
Power Production	58,400	MWH
Steam Production	200,000	lbs/hr @ 125 psig, 360 F
Fuel Needs	283	Tons coconut husk per day
Capital Cost	14.09	Million $
Annual 0 & M Cost (no fuel)	0.56	Million $
Power Plant Operation	67%	plant factor
Cogeneration Sales		
Sales of Power		
to MERALCO	51,970	MWH
Purchase Price:	1.92	P/KWH
Direct to Coconut Mill	6,430	MWH
Foregone Cost	2.87	P/KWH

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NOTES

1. An island south of Manila which has proven geothermal reserves of at least 44 megawatts. Further delineation is needed to prove an additional capacity of 440 megawatts for a total 880 megawatts.

2. The largest island in the Philippines and where Metro Manila is located. It accounts for over 75 percent of total electricity sales of the NAPOCOR.

3. Estimated at Ph/3.89/KWH by NAPOCOR in its 1991 Power Development Program.

4. See, for example, "Selected Case Studies of Implemented Cogeneration an d Private Power Projects: Industrial and Developer Perspective" by Walt P. Smith. Senior Executive Seminar on Cogeneration and Private Power. 9-11 November 1988, Hua Hin, Thailand.

5. Source : Office of Energy, United States Agency for International Development. "The A.I.D. Approach: Using Agricultural and Forestry Wastes for the Production of Energy in Support of Rural Development". Bioenergy Systems Report. April 1990.

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10. IRRI. World Rice Statistic 1990.

11. Source: Office of Energy, United States Agency for International Development. "Rice Husk Energy Systems". Bioenergy Systems Report. April 1986.

12. Those with greater than 2 metric tons per hour capacity.

13. Sources: (a) Winrock International, "Energy from Rice Residues", March 1990; and (b) personal communication with Richard Stevension of Energy Resources International, Inc.