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POTENTIAL FOR PRIVATE INVESTMENT IN RICE RESIDUE POWER GENERATION

INDONESIA 1987

PRELIMINARY ANALYSIS

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POTENTIAL FOR PRIVATE INVESTMENT
IN RICE RESIDUE POWER GENERATION

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ABBREVIATIONS

ADB	Asian Development Bank
BAPPENAS	National Development Planning Board
BKPM	Investment Coordinating Board for Indonesia
BPS	Biro Pusat Statistik (Central Bureau of Statistics), Indonesia
BRI	Bank Rakyat Indonesia
BST	Bioenergy Systems and Technology Project, USAID
BULOG	National Logistics Agency
E/DI	Energy/Development International, U.S.
GOI	Government of Indonesia
IRRI	International Rice Research Institute
KUD	Village Cooperative Unit
NRECA	National Rural Electric Cooperative Association (U.S.)
MOA	Indonesia's Ministry of Agriculture
MOC	Ministry of Cooperatives
MOI	Ministry of Industries
MME	Indonesia's Ministry of Mines, Minerals, and Energy
PLN	(National Electric Authority) for Indonesia
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

CHAPTER ONE

EXECUTIVE SUMMARY

Summary: The Opportunity

Rice residue electric power systems can either be associated with a rice mill, utilizing the mill's captive feedstock, or stand alone as power plants that purchase part or most of their feedstock from farmers or mill owners in the surrounding area. This study analyzes the potential for both models in Indonesia, in terms of resource availability, costs, and policy impacts.

Commercially proven rice husk electric power systems in the U.S. depend primarily on captive feedstocks of 83,000-112,000 M.T./year*. With the exception of the few large mills on Java, the current average size of rice mills (1 ton paddy [gabah]/hr) in Indonesia does not allow for sufficient accumulation of captive rice husk feedstock for these mills to depend exclusively on their own feedstock for power systems of even 600 kW to 1.5 MW. Adequate surplus husk and straw, however, are available in enough rice growing/milling areas (even at a twenty-five percent availability rate) to suggest that collection-based systems are an option.

Preliminary financial and economic models of two types of systems with possible application in Indonesia have been developed. An engineering analysis of these systems appears in this report as Chapter Five.

The analyses included in this study suggest that rice residue power systems which incorporate efficient** technology and use collected husk or straw (though not necessarily as mixed fuel) may be profitable over a wide range of feedstock costs - up to three times current market prices - given 1) dependable electricity sale prices of 90 Rp or more per kWh, 2) high load factors (over 75%) at the power plants, and 3) guaranteed ash markets. Private investment in collection-based residue power systems can be a viable commercial option particularly for less capital-intensive systems but will depend upon residue collection systems designed for and proven cost-effective at a particular site.

*The use of "M.T." refers to metric tonnes. Where data provided is in English tons, the designation used is "tons".

**"Efficient" in the context of this report refers to higher ratio of kcal-in: kcal-out of the newly demonstrated commercially proven rice husk energy system.

As shown in this prefeasibility analysis, potential benefits of rice residue power systems to the agricultural sector include waste utilization and ash sales, reliable rural electricity, additional farm and off-farm jobs, and increased "value-added" to the rural economy of Indonesia. Balanced against these economic incentives is the current high risk for investors in private power systems due to the lack of clear legal guidelines and institutional support in Indonesia.

Purpose of the Study

In response to an invitation from the Indonesian Ministry of Mines and Energy and the Ministry of Cooperatives, this study assesses the potential for private power generation from rice processing residue in the Indonesian context.

Major rice-producing countries such as Indonesia recognize that rice processing residue represents a significant agricultural commodity which currently earns little income for either rice farmers or the national economy. At the same time, pressures for increased supply of electricity, particularly in rural areas, are growing while the government's ability to invest capital in electricity generation and distribution is shrinking.

Recent success at one private rice mill in the United States in converting rice husks to electricity (10.6 MW installed capacity) with net annual profits of over $2 million has encouraged Indonesia to look at whether its rice residue resource base can sustain similar systems and, if so, under what conditions.

The task of this study is to determine whether the rice husk and straw resource base in Indonesia can be matched with the feedstock requirements of commercially proven rice residue power systems in configurations attractive to private investors.

The Resource Base

In 1986 milled rice production in Indonesia was 26,129,000 tons (USDA, June 1987). Milling of that rice also produced over 6.5 million tons of rice husk. (Husk is figured at 20% of unmilled paddy weight. This percentage is used by the International Rice Research Institute (IRRI), commercial millers, and government statistics). Mobilization of 25% of this husk (1.8 million tons) and a similar amount of available straw would yield a net energy feedstock of 3.6 million tons. (Estimates of straw-to-husk available range from 4:1 to 1:1). Based on feedstock requirements for the two systems currently operating commercially in the U.S., this amount of husks and straw could produce either 155 or 300 MW of electric capacity depending on the amount of capital invested in the facility. The more expensive system requires approximately 10,900 tons per year per MW of electric capacity while the less expensive system requires approximately 23,200 tons per year per MW of electric capacity.

The ability to convert available rice residues into energy and other products depends on developing a system that can provide a steady supply of feedstock to a conversion facility. Few if any rice mills in Indonesia can provide sufficient captive feedstock due to:

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- seasonality of feedstock production;
- sporadic nature of rice flow from farmer to mill;
- predominance of small mills, short annual operation year, seasonality of milling that corresponds to harvests;
- significant regional and sub-regional differences in harvest/milling patterns;
- Consequently, a reliable supply of feedstock will require collection and storage of rice residues.

Energy System Characteristics and Sensitivities

Government of Indonesia activity designed to encourage use of rice processing residue to meet rural energy demand will need to account for the following dimensions of rice residue energy systems:

- The vast majority of successful biomass energy systems, whether using wood wastes, urban solid wastes, or agricultural processing wastes, are predicated on the availability of "captive" feedstock. Usually the existence of the captive feedstock permits construction of the energy conversion system on-site at the processing plant incurring minimal additional feedstock transport and handling costs. In addition, what is called feedstock by energy producers is generally considered to be waste material by the agricultural processor and can constitute a considerable disposal and environmental problem. Successful implementation of rice residue energy systems, both in terms of plant owner motivation and the ability to attract financing, is directly related to the availability of captive feedstock. In Indonesia, given the small mill size, it is difficult if not impossible to have energy systems supplied solely by on-site wastes. Even a 600 kW (250 psig) system requires a minimum of 12,500 M.T. of husk/year. Collection systems required for additional husk or straw will increase fuel costs and could decrease system reliability. Resource mobilization must be addressed by any proposed scheme.

- The economics of rice residue energy systems are extraordinarily sensitive to location, economies of scale in feedstock collection and power plant design, and electricity sales throughout the year. Analysis preceding each plant siting must be site specific.

- The two rice residue energy systems currently in commercial use have taken different design approaches. One system uses a low pressure boiler which is easy to operate and relatively inexpensive. The other uses a high pressure boiler with automatic controls and higher capital costs. The less expensive system could probably be produced in-country. However, these lower foreign exchange costs, lower capital risks, and shorter payback periods must be balanced against lower rates of electricity production per ton of feedstock.

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For this study, performance factors for two alternative rice husk energy conversion systems were analyzed and compared. Use of feedwater heaters, superheaters, and/or condensing turbines and their effects on heat rates and capital costs are discussed in Chapter 5. For a low pressure 600 kW system, fuel consumption was estimated at 2 tons of rice husk per hour (8% overall efficiency). For a higher pressure 1500 kW system, fuel consumption was estimated at 2.95 tons of rice husk per hour (14% overall efficiency).

Of course, these figures depend upon the degree of sophistication of the thermal system and the characteristics of various system components. Generally as the size of the system increases, use of higher efficiency components becomes more attractive because higher system costs can be offset by reduced fuel costs.

Electricity Sector In Indonesia

Despite strong commitment by the government, the provision of electricity in Indonesia is severely hampered by the significant investment needs of the sector. Projected economic and population growth puts continued pressure on the sector to meet ever increasing industrial and residential demand for electricity. Earlier plans to replace inefficient captive power generation by the end of the decade and expand rural electrification to 23% of all households are becoming unattainable as budget expenditures over the last two years fell to 50% of planned levels.

A recent (1985) change in the law allowing the sale of electricity by private firms establishes a legal framework for encouraging private power generation. Such generation can help to defer public sector electricity investments while also making use of the excess capacity to produce electricity that exists in a number of industries. If widely encouraged, it also may increase the reliability and efficiency of power in rural areas where the national utility cannot serve cost-effectively. Utilization of rice residue at mills for electricity production could be a source of power for rural industries, aibeit limited vis-à-vis total energy demand.

Economics of Rice Residue Energy Systems In Indonesia

For the 600 kW system considered in this report, rice residue energy production is currently attractive over a range of reasonable electricity prices provided the system can operate a sufficient number of hours with an acceptable load factor, can obtain a steady supply of residues, and can find a reliable market for ash. Unit costs appear competitive even against current utility tariffs (103 RP/kWh). The 1.5 MW system, in contrast, becomes competitive only if PLN's purchase price reflects the high electricity costs experienced Off-Java.

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The economics of both systems depend upon five key factors: Feedstock cost, system load factor, PLN purchase price, ash price, and system conversion efficiency. Feedstock cost has less effect on the viability of the system than the other factors. In order to finance debt associated with installation of these systems, an established rice processing company will need to have firm contracts for purchase of electricity and ash.

At the macroeconomic level, production of electricity and other products from rice residues will strengthen rural economies by creating jobs, reducing energy imports to rural areas, and increasing revenues associated with production and processing of rice. It could also attract new investment to rural areas.

Policy Implications

Within the umbrella of general government policy in Indonesia that strongly supports the rice industry, specific sub-policies may need reconsidering if and when a decision is made to create optimum conditions for rice residue utilization. Some current policies work against successful residue energy systems and should be reviewed vis-à-vis the full set of government intentions.

Successful rice residue energy systems are essentially the companions of modernized milling. Government policy to encourage modernization of mills implies some degree of centralization of milling and will probably require some incentives such as concessionary rate financing, reduction of constraints on foreign investment, stimulation of the luxury rice market, elimination of investment tax or other techniques to encourage equity financing, etc.

In addition to modernization of mills, providing predictable feedstock for rice residue energy systems will require adjustments to the overall transport and storage system for paddy. Because most mills are small and decentralized, current movement of rice to mills seems mostly dependent upon price variations and/or the farmers' need at a given moment to sell rice to meet cash needs. Mills do not normally store paddy in order to ensure sufficient supplies to keep equipment running.

Modernization of milling contradicts current policy in Indonesia that emphasizes decentralized milling for specific economic and social reasons. The government will need to balance these reasons against the potential benefits of modern mills including: Higher rice quality, more efficient milling rates (+5%) yielding more marketable rice with no additional field inputs, ability to produce by-products such as bran and the concomitant earnings from these by-products, and more efficient use of capital especially if mills are privately run.

To attract foreign investment for rice residue energy systems, the government will probably need to guarantee the sanctity of contracts for purchase of electricity. In addition, investors will need to be convinced that contracts with suppliers of feedstocks will be upheld in the courts.

The following chart summarizes constraints associated with rice husk energy systems in Indonesia.

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SUMMARY

SITUATION/CONSTRAINT	OPTIONS
RESOURCE BASE	
Adequate husk available in several areas for small (600 kW to 1.5 MW) power plants but lack of adequate husk supply at most individual mills given decentralized milling capacity. Collection/ transport of husk would be necessary to supply even small-scale plants.	Due to lack of alternative uses for husk and straw, energy systems could buy the residues but must create a reliable, low-cost residue collection and transport system. Seasonal and geographic production differences and logistics must be considered in plant location. Optimal initial sites may be on-Java.
Straw also in sufficient volume but like husks it is dispersed and would require a collection/ transport system that does not exist in most regions.	
Given lower melting point of rice straw systems should not presume mixed fuel possibility.	
TECHNOLOGICAL	
Due to small mill capacity, the current size of commercial rice residue power systems is too large for Indonesia.	Downsizing of commercial power systems is needed, and is underway by some foreign firms. New smaller systems will still require commercial demonstration.
ECONOMIC	
Analysis of smaller model systems show positive returns over a range of feedstock prices and electricity purchase prices provided that there exists a reliable residue transport system, high load factors and by-product (ash) sales. World markets for ash appear strong. Actual feedstock costs, while a small percentage of total costs, are highly uncertain.	Power plant owners would need to ensure a husk transport network by guaranteeing prices for the feedstock. Firm power contracts for electricity prices must be negotiated and enforceable. Government must guarantee contracts.
FINANCIAL	
Local investors require extremely short (1 yr) payback periods and high returns (35-45%) due to past instability and current conditions for alternative investments. Although firms invest in on-site captive energy use, most feel power generation has high risks due to tax and legal policies that discourage foreign and local ventures.	Provide incentives for private energy investment on a selective basis.
POLICY	
Rice Current government policy is to encourage small mills (1T/hr) because of employment and income benefits and food supply stability.	Production of rice residue power will require either large mills or substantial residue collection system.
Electricity New 1985 electricity law allows sale of electricity by private producer, but few cases of private power generation for sale currently exist. Private sector is uncertain of legal and government support.	Further laws or guidelines must be established to ensure both electricity sales and prices are guaranteed. Ongoing successes need to be publicized.

CHAPTER TWO

ORIGIN AND ORIENTATION OF THE STUDY

Programmatic Activity of The U.S. Agency For International Development

Origins

As a result of the the 1973 oil embargo, world-wide interest in "renewable energy options" increased. For many non-oil producing countries, the need to develop indigenous energy feedstocks became of crucial importance. Donor agencies, including the U.S. Agency for International Development (A.I.D.), assisted developing countries by exploring the potential of various renewable energy systems including solar cells, wind machines, mini-hydroelectric plants, and biomass based energy conversion technologies.

A New Focus

In 1979, recognizing that biomass systems were quite different from other renewables in up-front capital investment, systems and feedstock management requirements, and in the scope of ultimate benefits, the Office of Energy, Directorate for Energy and Natural Resources of A.I.D., created a specific project to evaluate and encourage the implementation of Bioenergy Systems and Technology (BST).

Over the past eight years, the BST Project's understanding of ways to encourage bioenergy systems has evolved. In 1983 a rationale developed to focus on food processing industries which produce vast amounts of biomass waste residues having little or no current market value. These residues represent "captive" feedstock for bioenergy systems. An analysis by BST of the revenue and job producing agricultural commodity sectors of A.I.D.-assisted countries indicated that the two most significant were sugar cane and rice. Particularly in Asia, a vast majority of rural people depend on these commodities for their employment. Revenue from sale of these commodities also accounts for the largest portion of agricultural earnings - whether for domestic or export use - in A.I.D. assisted countries.

Initial BST program efforts were on the cane industry, followed in 1985 by a look at the rice sector. Rice residue - husk and straw - is created in vast amounts during the growing and milling processes. Rice husk represents 20% of the harvested paddy (called "gabah" in Indonesia) and creates a massive disposal problem at milling sites. Minor uses for rice husk have developed throughout history: dishware packing material, cleaning material, filler and fuel for brick making, compost, chicken litter, etc. As mill size increases, however, disposal problems including the dangers

of open pile spontaneous combustion also increase. In the United States rice mills pay $7.00/ton disposal fee to rid themselves of this biomass waste (landfill tipping fee). Rice straw, while not a captive feedstock in the United States, is collected by farmers in some developing countries and represents an additional, potential energy resource.

Role of the Private Sector

Another BST activity was monitoring worldwide research and development efforts to efficiently use rice husk as a combustion or gasification fuel. Some laboratory projects were successful technologically, but it was 1985 before BST identified commercially successful rice husk energy systems. Two such systems, developed by U.S. rice mills, convert rice husk to steam/heat/electricity used to power adjacent rice mills. In one case, excess electricity is sold to the local power utility. Rice husk ash from each of these systems earns over $1 million/year in sales to the steel industry for use as a lading cover and to the toxic waste cleanup industry for use as an absorbant (communications from private companies).

In each case, successful rice husk power systems were developed by the private sector initially as a financially sound waste disposal method. Initial capital investment is rated at $1 million/MW or MW equivalent for the currently in-place systems (10.6 MW). Fuel substitution savings of over $1 million/year coupled with by-product sales of over $1 million/year result in pay-back periods for capital investment in the range of 2-5 years depending on the size of the plant. Both U.S. rice mills have now developed energy subsidiary companies to market their rice husk energy systems in rice-growing developing countries. If they are successful, several interesting accomplishments can be demonstrated:

- implementation of efficient energy conversion systems based on rice residue and producing power in countries that need both new, diversified markets for their agricultural by-products and new power generation in rural areas to fuel rural economic development;
- development of new, diversified agricultural markets;
- establishment of new trade markets and joint ventures for transfer of U.S. goods and services to developing markets;
- identification of financial instruments to support both the local agricultural processing industries in developing countries and the small but dynamic sector of U.S. private interests that have technology and systems relevant to developing country needs;
- creation of new rural jobs and income - both in A.I.D.-assisted countries and in the U.S.;
- improved balance of payments both for the U.S. (selling goods and services abroad) and for developing countries (in reduced oil imports); and
- better resource management through by-product utilization (see Figure 2.1).

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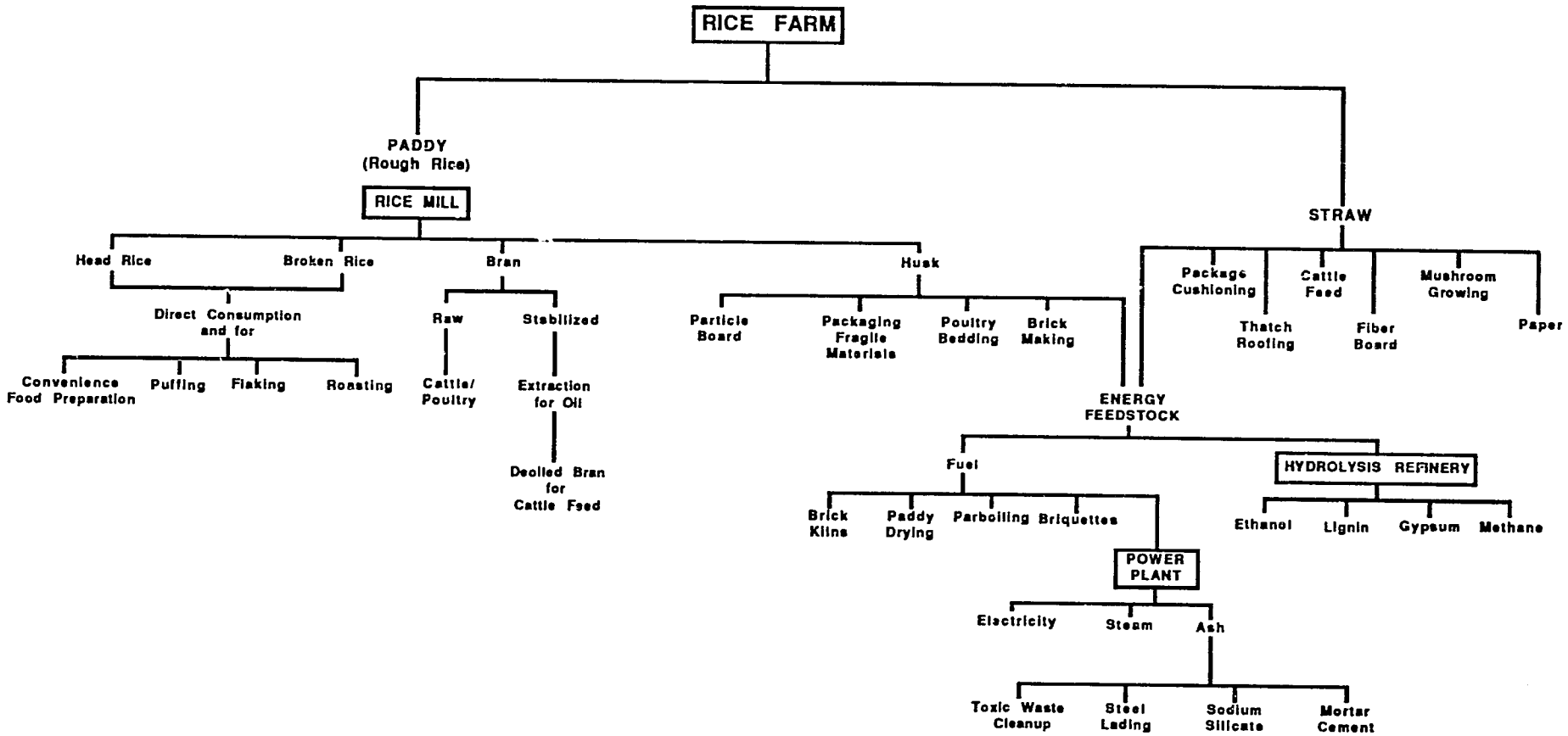
FIG. 2.1 Rice Residue and By-Product Utilization
Schematic Perspective



The Study

Initial BST efforts to evaluate the possibilities for rice residue power systems focus on Asia, specifically on Indonesia and the Philippines. A variety of activities conducted in 1986-1987 have stimulated interest in these countries, both in government and in the local private sector. In separate but related efforts sponsored by the Asia/Near East Bureau of A.I.D., increased interest in the overall concept of private power generation resulted in a request from the Indonesian Ministry of Mines and Energy for A.I.D. to undertake a specific look at "The Potential for Private Power Generation in Indonesia." Given the annual availability of over six million tons of rice husk in Indonesia, BST was invited to contribute to this study effort by providing three team members who would look specifically at the potential from rice residues. The rice residue study team worked together with the other four members of the private power generation evaluation team and its conclusions herein presented are also incorporated in the overall study as titled above.

Energy Potential of Rice Residues

Proven System Potential

Although rice husk has been combusted for many years in simple boilers and used as fuel in rural brick kilns, efficient systems capitalizing on the full BTU potential (6200-6400 BTU/lb) of this large fuel resource are a recent phenomenon. The high silica content of rice husk and rice husk ash produces serious handling problems. Inability to control burning temperatures often results in slagging. The new systems have conquered these old problems and produce energy in the following efficiencies:

A: 3500 lbs. husk per hour produces 15,000 lbs. of 125 psig steam per hour for a rice parboiling process plus 5,000 lbs. per hour producing a 2200°F hot gas stream used in a rice dryer.

B: 250-300 tons husk per day produces 112,00 lbs. per hour of 650 psig steam which runs a generator producing 10.6 MW of electricity.

A 10.6 MW power plant could provide electricity for a community of 20-40,000 people in a developing country. A power plant producing 360,000 lbs. of 125 psig steam per day could drive processing activities in key sectors of developing countries.

Potential and Problems of Rice Residue as Fuel

In 1982, net installed electricity capacity for the nine Asian rice-producing countries assisted by USAID was 60,584 MW (U.N., 1982). The projected required installed capacity in the year 2000 with no per capita increase is 85,455 MW - a 41% increase. Total rice husk available from the 1984 rice harvest in these same countries was 43,877,000 tons (USDA). A conservative doubling of this to include

some portion of rice straw would yield rice residue availability of 87,754,000 tons. Based on conversion rates of the high pressure U.S. system which uses 10,904 tons per MW per year, the gross potential is over 8,000 MW.

The problems of mobilizing this resource at the scale of the proven systems (109,040 tons/year for a 10 MW high pressure plant) are significant. To begin with, to presuppose a captive feedstock of rice husks at 109,040 tons/year, implies a rice mill with a milling capacity of 545,200 tons/year. In Asia, there are very few rice mills of this capacity; in the Philippines and Indonesia, none. The vast majority of mills are in the 1-3 tons/day category, (Ministry of Industries data, GOI) or 300-1000 tons/year range. (Few of these mills operate 365 days/year.) Mobilizing the largest ones to produce 10 MW would require the accumulation of husk from over 500 mills and introduce the difficulties associated with transporting biomass feedstock. A 1.5 MW size power plant would require husk from 80 mills, still a formidable transportation exercise.

Scale-down to one MW or less would greatly expand the market in Indonesia for rice husk power systems. The cost/economics of a one megawatt high pressure system would, however, suffer in a scale-down from $1 million/MW (4-12 MW scale) to $2-3 million/MW (one MW scale) and in any case has not yet been demonstrated in a commercial setting. Capital costs for low pressure systems of one MW or less may remain manageable but the feedstock requirements (18,000 tons/yr/MW) could prove unwieldy and increase system risks.

Commercially proven systems exist at high power outputs (11-12 MW) in the U.S. Rice residue is a vast and under exploited resource for power generation in the rural developing world. Electricity demands are great and will increase exponentially over the next 25 years in rice-growing countries. Even in Indonesia which is an oil-exporting country it will be difficult to meet domestic requirements for electricity without mobilization of biomass resources and electricity production by private generators. The real question is the match between cost-efficient systems and the resource. This study is a first step in gathering information to inform increasingly specific decisions: what size systems make sense both in terms of resource availability at reasonable cost and of electricity demand; which locations if any can sustain rice residue systems and under what scenarios; who can benefit from rice residue systems and what are they willing to contribute to project definition; what role can and would government play; do existing conditions favor integrated rice residue systems and/or stand-alone residue power plants (See Figure 2.2)? Use of waste heat and/or process steam from these power plants can improve economics considerably but requires plant siting in proximity to steam/heat customers.

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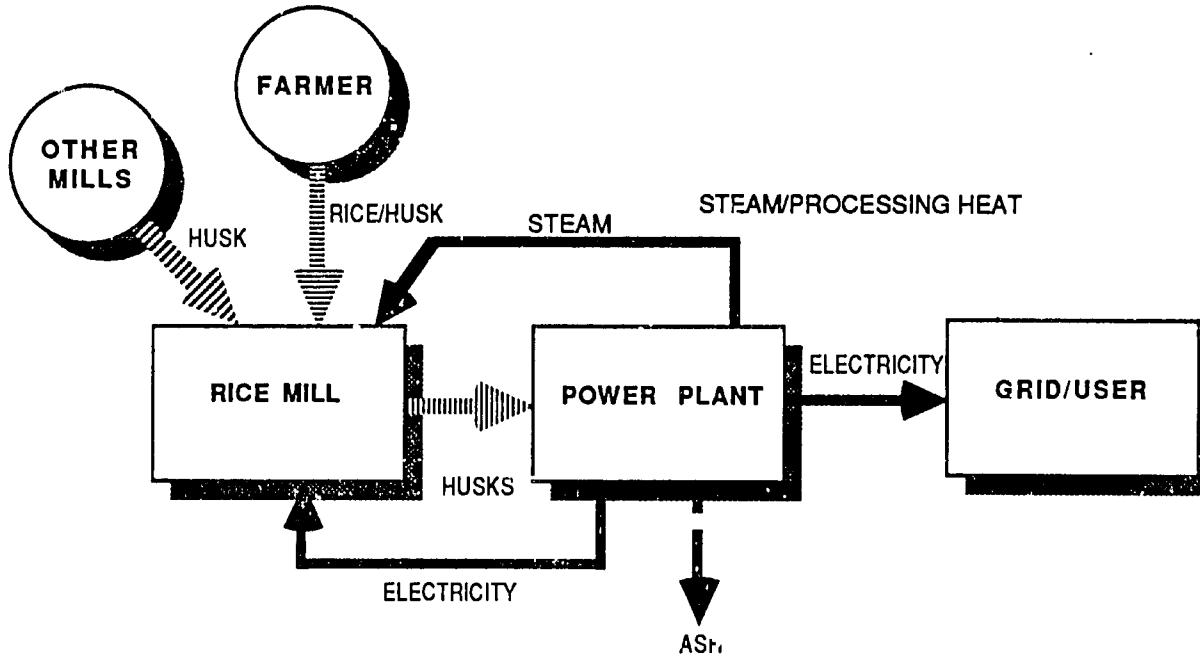


FIG. 2.2A Integrated Rice Mill-Power Plant System

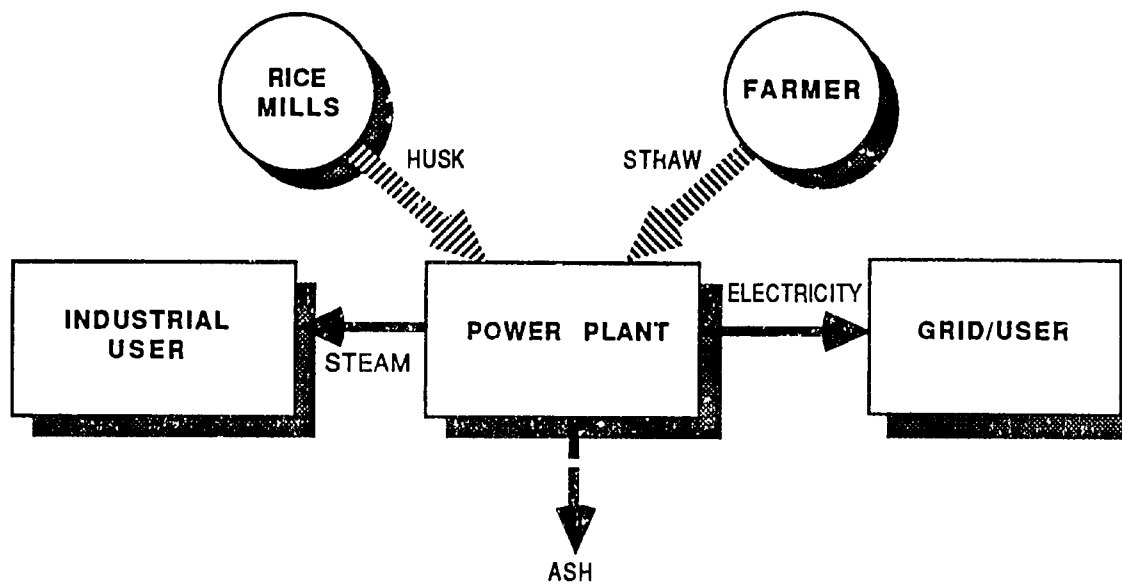
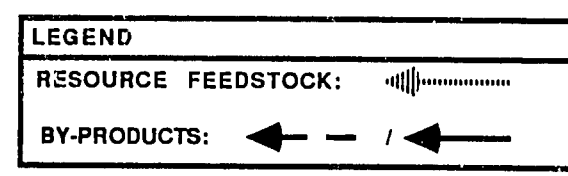


FIG. 2.2B Stand-Alone Rice Residue Power System



Indonesian Interest

For some years Indonesian scientists at the Institute of Technology at Bandung (IT Bandung) have worked with colleagues from Twente University in the Netherlands to develop a rice husk gasifier. The prototype of this gasifier fueled a 10-20 horsepower engine, using 20-25 kg of rice husk per hour and producing 33 cubic meters of gas per hour. In 1985 a 30 kW(e) version was developed for demonstration at IT Bandung. One such unit is now installed at a rice mill in Majalengka, near Bandung; a second unit has been given to an Indonesian private firm for commercial replication (BSR, April 1986). This system, however, has not demonstrated commercial viability.

Under the auspices of the Ministry of Cooperatives (Koperasi), the Indonesian Government is committed to the development of rural electrical cooperatives. Four categories of electric cooperatives are being created: 1) electric bill collection cooperatives; 2) cooperatives that collect bills and make house installations; 3) cooperatives that sell electricity purchased from PLN; and 4) cooperatives that generate their own electricity and provide O&M for the system. Since 1985, cooperatives generating electricity are under the supervision of the Ministry of Mines and Energy. To date, three electric cooperatives of the fourth type have been developed in Luwu, Lampung, and Lombok. Given the possibility that the national grid may not reach outlying rural areas as quickly as initially planned, Koperasi is interested in other sources of power, such as auto-generation using biomass resources or electricity purchased from private generators. Intrigued by the commercial success of U.S. rice husk power systems, the Koperasi encouraged A.I.D. assessment of the possibilities of scale-down to meet local Indonesian electricity demands with locally available rice residue. A.I.D. is encouraging consideration of site-specific feasibility studies by the private sector to define these opportunities and has commissioned this study to provide pre-feasibility information of value to both Indonesian government planners and to U.S. and Indonesian private sector interests considering implementation possibilities.

A workshop in Jakarta sponsored by the Ministry of Mines and Energy for the benefit of government officials will consider the study findings on "The Potential for Private Power Generation in Indonesia." Various branches of GOI are interested in expanding the electricity delivery system; regularizing, regulating, and expanding the contribution to this system by the private power sector; and mobilizing biomass resources for greater contribution to the national economy. The workshop will provide a stage for evaluation of overall potential and implementation alternatives.

CHAPTER THREE

THE RESOURCE BASE

The Importance of Rice in Indonesia

In Indonesia small farmers contribute 60% of the agricultural GDP and employ 54% of the labor force of the country [1]. A majority of these are rice farmers responsible for rice cultivation on more than nine million hectares of land and for rice production of over 26 million tons (1985-1987, milled basis) [1]. Rice is the mainstay of the Indonesian diet and as such, has received major dedication of national resources in the form of techniques to maximize productivity and to maintain local availability of rice to consumers [1].

The government commitment to rice resulted in an astoundingly successful intensification program which carried Indonesia from the status of major rice importer to the attainment of self-sufficiency in 1984-85 with 3.4 million tons of rice in Government stocks [1]. The annual production rate has decreased since 1985 partly because of the brown plant hopper infestation and partly due to a slight decline in rice area. The current Indonesian 5-year plan, Repelita IV (1984-1989), seeks to maintain rice self-sufficiency which, given expected population increases, requires a new super-intensification program to include provision of new seed, fertilizer, and pesticides to producers at preferential prices [1]. The Repelita IV target for rice production is 29.4 million tons, a 13% increase over the actual 1986 production of 26.1 tons.

Beyond its value as the most prominent source of calories for Indonesians, the rice industry is also important to the economy for the number of jobs provided. In addition to being a major employer of rural people in rice growing areas, the transportation, processing, and marketing of rice create many additional jobs [2].

Increased rice consumption in Indonesia is directly correlated with increased annual per capita income, both showing a 2.1% average annual growth rate between 1969 and 1985 [3]. The fact that the urban population is growing faster than the general population also implies expected future need for intensified production, (See Table A1.1). Maintaining the health of the rice sector is a keystone to economic growth in Indonesia.

Rice Production: Patterns and Policies

Traditional Production

Traditional rice production in Indonesia met farm or village consumption needs first with small surpluses entering milling and marketing systems and ultimately supplying population centers within the country. Prior to the late 1960's, practically all rice varieties grown in Indonesia were local strains trusted by farmers - despite relatively low yields - because of their reliability in producing food and their acceptability to consumers [4].

During the late 1960's, modern, more productive varieties were introduced, largely with assistance from the International Rice Research Institute. Introduction of these improved plant varieties was accompanied by a support package that included new farming practices, lines of credit, and marketing incentives. Various aspects of this government activity were implemented by the BIMAS, INSUS, and OPSUS programs (mass guidance and intensification) as well as by the Cooperative Village Units (KUDs) and the Peoples' Bank (BRI) [1] [4]. The success of this program (illustrated by Table A1.2) greatly increased supplies of rice. Marketing requirements associated with the new surpluses also affected traditional systems for processing, transporting, and selling rice. The National Logistics Agency (BULOG) assisted by providing floor prices for gabah (paddy a.k.a. rough rice a.k.a. unmilled rice).

Traditional Indonesian rice was of tall, lodging susceptible varieties harvested one panicle at a time by a hand-held instrument. Farmers tied the panicles together and stored them in raised, well-protected structures in the village. Panicle bundles were removed from storage as needed, threshed, and then milled with a mortar and pestle. Some rice husk was used within the village for animal litter, fuel, or for the cleaning of pots and pans. Any rice bran removed from the gabah was mixed with husk for use as animal feed; bran had no value as a separate by-product of the hand milling process [4].

Technological Advances

As a result of the government supported rice intensification program, rice yields increased steadily during the 1970's and 1980's, at an annual rate of 5.6% (1977-1986). Cultivated rice area also expanded annually at 1.9% [1]. Table A1.3 shows the nation-wide production trends by area during the period 1980 through 1985 [5]. The only recorded decreases are in isolated areas for isolated causes, such as the brown hopper attack or vagrant weather patterns. The fact that in 1986 98% of rice grown in Indonesia was of the high yielding variety (HYV) indicates the degree of acceptance by farmers of the new rice technology and support mechanisms. Future such increases, more on the order of 2.0-2.5%/yr, will be dependent upon even newer improved rice varieties, and new and different inputs to the land (such as trace elements and application timing variations) [6]. Increases in total available rice may also come from new rice handling, processing, and storage techniques to reduce post-harvest losses.

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Status of Competing Food Crops

Major food imports to Indonesia are wheat and soy beans (Table A1.4). Neither of these commodities were imported in significant quantity until the late 1970's. Wheat imports doubled (from 753,000 to 1,444,000 MT/yr) between 1977 and 1980 while soy bean imports increased six-fold during the same period. Rice imports were also increasing during this period to a peak of 2,026,000 MT in 1980. Given that wheat trades on world markets for about one half the cost of rice on a calorie/calorie basis, wheat has served and can serve again to make up for needed food imports when domestic rice shortages prevail. The introduction of wheat in the late 1970's has resulted in the development of some markets in Indonesia and trends world-wide indicate that wheat consumption increases with per capita income. Wheat production in Indonesia, however, is not likely to replace rice in areas where rice can be grown. Imports of wheat and other food commodities will supplement rice production, not compete with it.

Rice Husk and Straw

Rice Milling and Rice Husk Availability

Table A1.5 shows the primary rice production periods in Indonesia for 1985 and includes estimates of total available rice husk and straw [5], almost 8 million M.T. of husk and 20 million M.T. of straw.. The amounts of husk are those produced from all sources. Village and transient mills do not lend themselves to the accumulation of husk and should be excluded from estimates of husk available for rice residue energy systems.

There are four basic types of stationary rice mills primarily in use in Indonesia: [4]

1) huller mills with sieve cleaners and whitening machines which produce rice and a ground mixture of bran and husk used, where needed, as animal feed, at a rice recovery rate of 60-63%;

2) unipass mills with sieve cleaners, sheller and whitening machine in one housing, which produce rice, husk, and bran at a rice recovery rate of 61-64%;

3) multi-machine mills similar to unipass mills with the same recovery rate and separate sheller and whitening machines;

4) unit (modern) mills composed of separate machines for cleaning, milling, and separation of gabah components at a rice recovery rate of about 70% from clean, good quality gabah.

A general rule is that modern mills can recover 5% more rice than the smaller, less efficient systems. (Wimberly cites post-harvest losses that range from 7-26%). [7]

As shown in Table A1.6, 50% of Indonesian rice mills mill at approximately one M.T./hour with only 1.0% of mills exceeding this rate and 49% milling at far lower rates [8]. The average milling time per year is 1,400 hours/year whereas the standard for operational efficiency of rice mills should be in the vicinity of 6,000 hours/year [9]. This difference is partly explained by the dominant management procedure of Indonesian mills under which the mill owner usually oversees the purchasing, milling, transport, and sales operations. Apparently only rarely do any of these functions occur simultaneously which means that most often milling does not take place while the mill owner is busy at the other tasks [10]. Indonesian milling capacity, therefore, is far greater than the milled output would indicate.

Installed milling capacity based on the data in Table A1.6 is 25.7 million M.T. of rice per year. For the same year, total paddy production was 34.3 million M.T. implying a processing gap of 8.7 million which is presumably handled at the village level and/or by transient mills.

Table A1.6 also shows the number of installed mills by major region, breakdown of mill sizes, and estimates of potentially available husk residue from these installed mills by island. The gross amount of husk produced by stationary mills is on the order of five million M.T. per year [11]. Of this, a maximum of 10% is currently used for economically productive purposes, such as brick kiln fuel and brick filler, animal litter, mushroom growing medium, etc. The Agro-Industrial Technology Department of Bogor Agricultural University has developed a program to encourage possible uses for the large amounts of wasted rice husk. Products from rice husk being considered for agro-industrial activity are: particle board, furfural, paper pulp, charcoal, growth medium for high-value vegetables, fuel for combustion or gasification.

Most rice husk in Indonesia is considered a waste material of the milling process and is given away at zero or minimal costs to anyone who will remove it from the milling site. The best estimate on costs for transporting rice husk was provided by the faculty of Bogor Agricultural University as 200 Rp/M.T./kilometer in two-ton loads with a haul distance of five kilometers. Under current conditions rice husk can be obtained from mills for the cost of labor and transport [12]. If the demand for rice husk should increase as a result of the construction of rice residue energy systems, however, available rice husk could take on higher economic value requiring power producers to purchase it from millers.

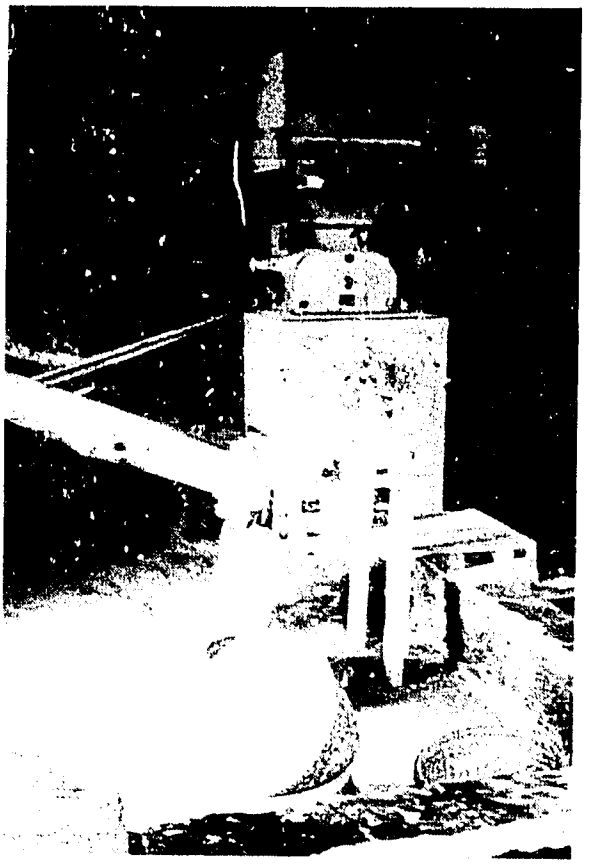
Given current per hectare paddy production rates in Indonesia and given that approximately 20% of paddy by weight is husk, 1.3 hectares of rice land are needed to produce each M.T. of husk (team estimates). A 1.5 MW (net) high pressure system (650 psig) requires at least 18,792 M.T./year of husk [13] or all the husk produced on 24,429 hectares. A 600 kW (net) low pressure system (250 psig) requires 12,528 tons/year of husk [13] or the husk production of 16,286 hectares of rice land. Moreover, the sites at which this paddy is milled should have a rice milling capacity of between 93,960 M.T./year (1.5 MW system) and 62,640 M.T./year (600 kW system). A prudent rule is that a rice husk power system not be dependent on more than 25-30% of the husk supply in any one market area.

Gabah waiting to be milled at 1 T/hr Mill.

Bagged husk waiting to be picked up by buyer.

Rice drying in front of houses.

Typical 1 T/hr Indonesian Rice Mill.



Husked rice sorting into baskets.

Rice Milling Policy Implications for Husk Availability

Current rice milling policy of the Government of Indonesia supports the concept of maintaining and encouraging a system of decentralized, small scale mills. Because a nation-wide system of smaller mills generally provides more rural jobs than a fewer number of larger more modern mills, this policy has been integral to the national goals of increasing rural employment and ensuring availability of rice to consumers throughout the archipelago [14].

As mentioned earlier, small mills are generally 5% less efficient than modern mills. Total rice output to gabah input is less because small mill equipment uses more pressure resulting in more broken rice. This portion of edible rice exits the machinery mixed with either husk or bran and can be reclaimed by hand screens that are marginally effective. Small mills, also, do not produce sufficient captive feedstock to power commercial systems. As Table A1.7 shows, there are only nine Kabupaten (districts) throughout Indonesia having more than 25 mills of 1T/hr. milling capacity size. In seven of these Kabupaten, 20% or more of the total potentially available husk comes from these largest mills: Pidie, Aceh Utara, Langkat, Deliserdang, and Labuhanbatu on Sumatra; Lumajang and Banyuwangi on Java Timur [15].

In the metropolitan Jakarta district there are three mills with milling capacity of over 10,000 M.T./year each. These three mills, if run at capacity, can mill 100,000 M.T. of rice/year yielding 20,000 M.T. of husk - an amount which could sustain a 1.5 MW version of a 650 psig power plant.

As shown in Table 3.1, feedstock requirements for various size power plants operating at their optimal levels range from 12,528 M.T./yr to 18,792 M.T./yr of husk. From Table A1.7, it is evident that sufficient husk potential exists in several districts to meet these needs if husk can be collected. Given that most mills operate on average for only 1,400 hours per year due to crop seasonality, Table 3.1 also shows (in the last two columns) that few mills actually would produce sufficient on-site, captive feedstock to run these plants at their optimal rates. Some mills, reportedly in W. Java, might run far beyond these average rates, but most apparently do not. It appears from Table A1.7 and 3.1 that in Indonesia the best model for rice residue energy systems is the stand-alone rather than the integrated mill-power plant system due to the predominant feedstock availability conditions. A rice extension specialist in the Indonesia Ministry of Agriculture has identified seven regions where rice mill size, transport system, and energy need converge to recommend more specific prefeasibility analysis of rice husk power system potential. Figure 3.1 displays these areas on a map of Indonesia.

The people of Indonesia have benefited from the decentralization milling policy, but there are associated costs. If rice residue energy systems are viewed as important to the improved management of rural natural resources <u>and</u> as a way to provide indigenous electricity to fuel rural economic development, a move toward some centralized milling would be required. This policy change would have other benefits which deserve mention. With an improved efficiency of 5% nationwide an additional 2,000,000 tons of rice with an additional value of $600 million (at U.S. $300/ton)

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would result from the same paddy input (based on 1985 paddy production). The quality of this rice would also improve which could increase that value further. The mill would run on its own electricity yielding further benefits in fuel displacement costs. The more modern mill would allow for bran separation and sale to a higher value market. Ash sales from the power plant would also accrue to the mill. Both production and capital efficiency would increase.

Table 3.1
Estimated Feedstock Requirements for
Power Plants

Power Plant Size	Feedstock Requirements Husk (MT/Hr)	Husk (MT/yr*)	Husk (t/hr)	Husk (t/yr*)	Average Actual Indonesian Husk Production (MT/yr**)	(t/yr**)
600 kW net at 250 psig	1.8	12,528	2.0	13,920	392	432
1.5 MW net at 650 psig	2.7	18,792	2.95	20,532	392	432

*Assumes: 6,960 operating hours or 290 operating days per year for maximum system utilization.

** Assumes: 1,400 operating hours per year based on average mill hours and above M.T./hr production in Indonesia at a 1.4 M.T./hr capacity rice mill.

MT = metric tons; t = short tons
Gabah/husk ratio = 0.20

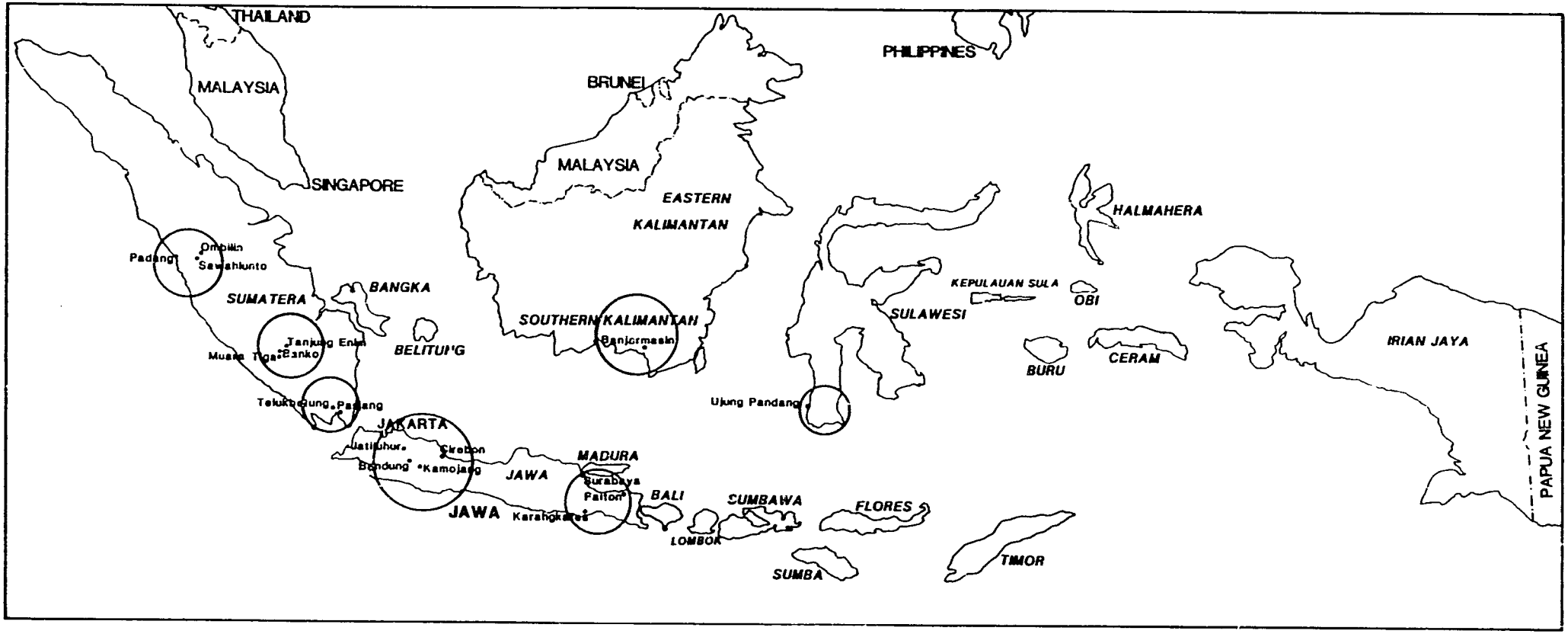

FIGURE 3.1

AREAS OF SURPLUS RICE RESIDUE PRODUCTION AND ADEQUATE ROADS IN INDONESIA

Rice Straw Availability

Rice straw can be a power system fuel when rice husk is in short supply or when price advantages exist for the use of straw. Some systems might be adjusted to burn husk for a portion of the year and straw for the rest. This as yet is not proven technically, however. Collection, storage, drying and sizing of straw for combustion systems may also incur unacceptable costs.

Currently rice straw is of little practical use or value to most farmers. Some straw is used in paper making, as packaging material, and in limited cases as brick kiln fuel. The Indonesian extension service recommends that farmers return straw to the soil to improve tilth and organic matter levels. Current harvest technique in West Java, however, results in most of the straw being raked into piles at the threshing site. Most farmers then burn the straw creating air pollution. Where managed in this manner, rice straw contributes little to soil quality improvement.

Quantities of straw produced can be determined by a 1:1 ratio with rough rice. Using this figure, about four to five metric tons per hectare per crop should be produced. Leaving half in the field, two tons per hectare can be removed with no serious nutrient loss to the land. Four thousand hectares of rice land could then provide 8,000 tons of straw. Table A1.8 displays the anticipated total straw production for 1984 as it appeared in Repelita IV (182 million M.T.) [16].

Rice Marketing and Transportation

The primary purpose (and consequently the governing activity) of BULOG is to assist in maintaining "self sufficiency" in rice. BULOG, through a rice procurement and regulated sales program, maintains floor prices for paddy [17].

Procurement by BULOG provides a mechanism for price supports of paddy and also assures supplies of rice for the military and certain other government personnel. Procurement of paddy is done largely at the village level primarily with the help of the KUDs (Cooperative Village Units). BULOG began enlisting KUDs to assist in procurement in 1983, and provides a margin over the floor price for paddy to KUDs in order to make them competitive and able to pay for services. In situations where paddy is scarce, BULOG will purchase from private traders above the floor level but below the price paid to KUDs which gives a competitive advantage to the KUD. BULOG may purchase any amount of rice necessary to keep market prices above the floor level, and can extend credit to any KUD that has had no outstanding credit for three years. Prices paid for paddy are based on standard quality and are adjusted to compensate for deviations below that standard. The KUD must process and condition the grain to meet standard quality prior to the sale to BULOG. KUDs have drying floors, warehouses, and other facilities for the purpose of this post-harvest conditioning. Once sold to BULOG, the grain is stored in bags in warehouses owned by or controlled by BULOG. Through conversation with BULOG and other government officials, it was learned that rice is milled for BULOG in small mills under a toll arrangement. BULOG has no limit on the amount of grain it procures and no limit on credit. BULOG is responsible to the President/Cabinet under the order of Presidential Decree 1/1968.

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In recent years, BULOG set a target of about 1.5 million metric tons of paddy to be procured and distributed about 10% of total rice marketed. BULOG reports, however, that during 1986, about 4 million tons were procured which created pressure on handling and storage facilities. Total rice husk available from such a procurement is potentially 300,000 to 800,000 tons, but retained in highly dispersed not centralized locations.

BULOG activity is in support of a government policy which encourages small rice mills. BULOG has made significant contributions to improving the food situation in Indonesia and apparently has fulfilled its primary obligations. Should BULOG decide to install larger rice mills for processing its own rice, the associated husk production at such mills could conceivably be adequate to fuel small generators. Not only would this new development provide a centralized husk accumulation point, it would also improve the production and economic efficiency of the milling process.

There are many very good primary roadways in Indonesia that can facilitate supply of fuel products to a residue power station. Despite extensive government investment in improving the secondary road network particularly in rice areas, further development in some areas may be required if collection of straw or other field products is necessary for residue energy systems [18].

The best estimate of cost for hauling bulk loads on primary roads is 2,000 Rp for a two-M.T. load and haul distance within five kilometers [18]. This then equates to 200 Rp per M.T.-kilometer for haul distances up to five km. This figure is about US $0.20 per M.T.-mile which may be fairly accurate under Indonesian conditions.

Only very careful economic analysis could establish the cost of moving straw to a primary road. Considering an average haul distance to be one kilometer it would probably require on the order of three person days to move each M.T. of straw to the road. If this is a reasonable estimate, the cost may be prohibitive. The labor costs per day indicate that Rps 1,500 (US $0.91) to Rps 3,000 (US $1.82) are the going rates in rice producing regions. From above data, road transport costs would be on the order of about Rps 1,000 (US $0.61) per M.T. for the average haul distance of five kilometers. If these are reasonable assumptions of total field to use point costs, the total cost for accumulation of straw would be between Rps 2,500 (US $1.52) and Rps 4,000 (US $2.43) per M.T. for a five km haul.

In Indonesia, farmers sell about 30-50% of the paddy they produce depending on yields and production retaining the rest for their own consumption. They do not sell all of their surplus at one time [19]. Paddy may be marketed in one bag lots. Generally, paddy is transported to a nearby market and/or rice mill, both destinations being on a good road. Little more than a bicycle is required in the way of transport from farm to first market. Once the paddy is on a good road, it may be milled at the point of sale or moved by truck in larger accumulations to the next large market or processing center, along primary roadways. Under present conditions, this system meets rice transport needs even though much of Indonesian

rice is harvested during the short period of January through April. Given the scale of this currently existing transport system and the above noted costs of moving rice straw, initial efforts to mobilize rice residue should concentrate on rice husk accumulation from mills rather than on the collection of straw.

Resource Management

There are very few long-term commitments of rice husk or straw to any industry. Husk and straw are now considered as waste. Some minor uses exist but reportly are not significant when considered against the total production of the country.

As long as no more than 25% of the husk available in a given market area is required to fuel a system, collection costs may be the only costs to procure the product. Above 25%, given the logistics, husk costs may include a scarcity value as the new demand places pressure on supply.

As part of an organized mobilization effort, rice mill waste can be collected and moved directly to the power station in movable collection vehicles. Light weight, relatively inexpensive trailers can be designed and placed in the husk discharge stream to collect husk for transfer to the power plant. If the policy decision is made to install a rice mill sufficiently large enough to supply fuel for a small plant, the husk can be collected into a surge system and used as needed.

Concern for air pollution is increasing in Indonesia, and rice residue power plants should conform to international standards which assure that the system burns cleanly with no excess ash or other discharge allowed into the air.

Rice straw is burned in farmers' fields and creates a great deal of smoke pollution in the air. Although removal of straw from fields and controlled burning at a power plant would be a desirable environmental consideration, it is probably not the best economic alternative given the inherent collection problems in comparison to the possibility of establishing a power system in a large paddy/rice market area.

Current methods for rice husk disposal also result in pollution. Frequently, husk is burned in piles that smolder for weeks. Husk also contributes to solid waste pollution. Collection of rice husk for use in well-designed combustion power plants would significantly reduce current levels of solid and smoke pollution.

Conclusions

The task of this study is to determine whether the rice husk and straw resource base in Indonesia can be matched with the feedstock requirements of commercially proven rice residue power systems in configurations attractive to private investors.

The main resource problem is that a captive feedstock volume sufficient for proven systems exists at very few if any rice mills in Indonesia due to:

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- seasonality of feedstock production;
- sporadic nature of rice flow from farmer to mill;
- predominance of small mills, short annual operation year, seasonality of milling that corresponds to harvests;
- significant regional and sub-regional differences in harvest/milling patterns; and
- resultant need for collection and storage of rice residue feedstock.

Description of conditions under which the proven rice residue power systems might be integrated with these constraints will focus on two implementation possibilities and will give the implications for private investment potential.

- An energy system integrated with one rice mill, running on that mill's husk and dependent upon significant extension of mill operation hours and storage for feedstock.
- A stand-alone power system fueled by husk from the surrounding area and selling electricity to the grid or to an industrial customer.

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CHAPTER FOUR

THE ELECTRICITY SECTOR IN INDONESIA

History of The Public Utility

Evolution of a National Electric Utility [1]

After a period of six years from 1953-1959 during which the GOI nationalized the private power companies of Indonesia, a State Electricity Company "Perusahaan Listrik Negara" (PLN) was formed in 1959 under the management of a Board of Directors. Between 1961 and 1985 various government regulations were enacted that affected the legal status and the scope of responsibilities of PLN:

1961: PLN became a corporate body with a Board of General Management.

1965: PLN became a separate entity within the Ministry of Public Works and Power.

1972: PLN status was converted to a public utility in the power sector and confirmed as a PERUM (Public Corporation). At this time PLN received exclusive rights and responsibilities for generation, transmission, and distribution of electric power throughout Indonesia. PLN also assumed the job of designing electric power policy for Indonesia.

1978: PLN came under the authority of the Ministry of Mines and Energy.

1979: A regulation reiterated PLN responsibility to provide electricity "for the welfare of the society" but acknowledged that limited investment funds for expanding the grid as quickly as needed necessitated allowing private enterprise and cooperatives to provide electricity, "especially" in areas where demand could not be met.

1981: The Directorate General of Electricity and New Energy assumed from PLN the general governing policy of the power sector which includes such responsibilities as issuing licenses for private and cooperative power systems.

1985: Act on Electricity promulgated to permit private agencies other than PLN to develop and sell electricity. PLN, however, retains authority for the overall national power plan.

Extent of PLN Service

PLN provides electricity to four categories of consumers in Indonesia (residential, commercial, industrial, and public) from Aceh on the far western tip of Sumatra to Irian Jaya in the east. Service is organized under 18 Operational Units, seven of these units being On-Java. Despite expansion of the grid between 1976-1986, estimates of total households with access to electricity range from 8-14%. Only 2-3% of all rural households are supplied by government/PLN rural electrification although additional electricity is available in many areas through private generation and use of batteries.

Total MWh sales to residential and industrial customers recorded by PLN for 1981 show that 78% of the total revenue is derived from Java although Java/Bali accounts for 64% of the total population. Table A2.1 (see Annex II) records installed capacity by PLN service unit for 1983/84 - a total of 3,783 MW. Captive power (generated and used internally by private industrial facilities) accounts during the same year for over 4,000 MW of installed capacity, more than the total installed capacity of PLN. Figure 4.1 displays the extent of PLN's transmission network on Java.

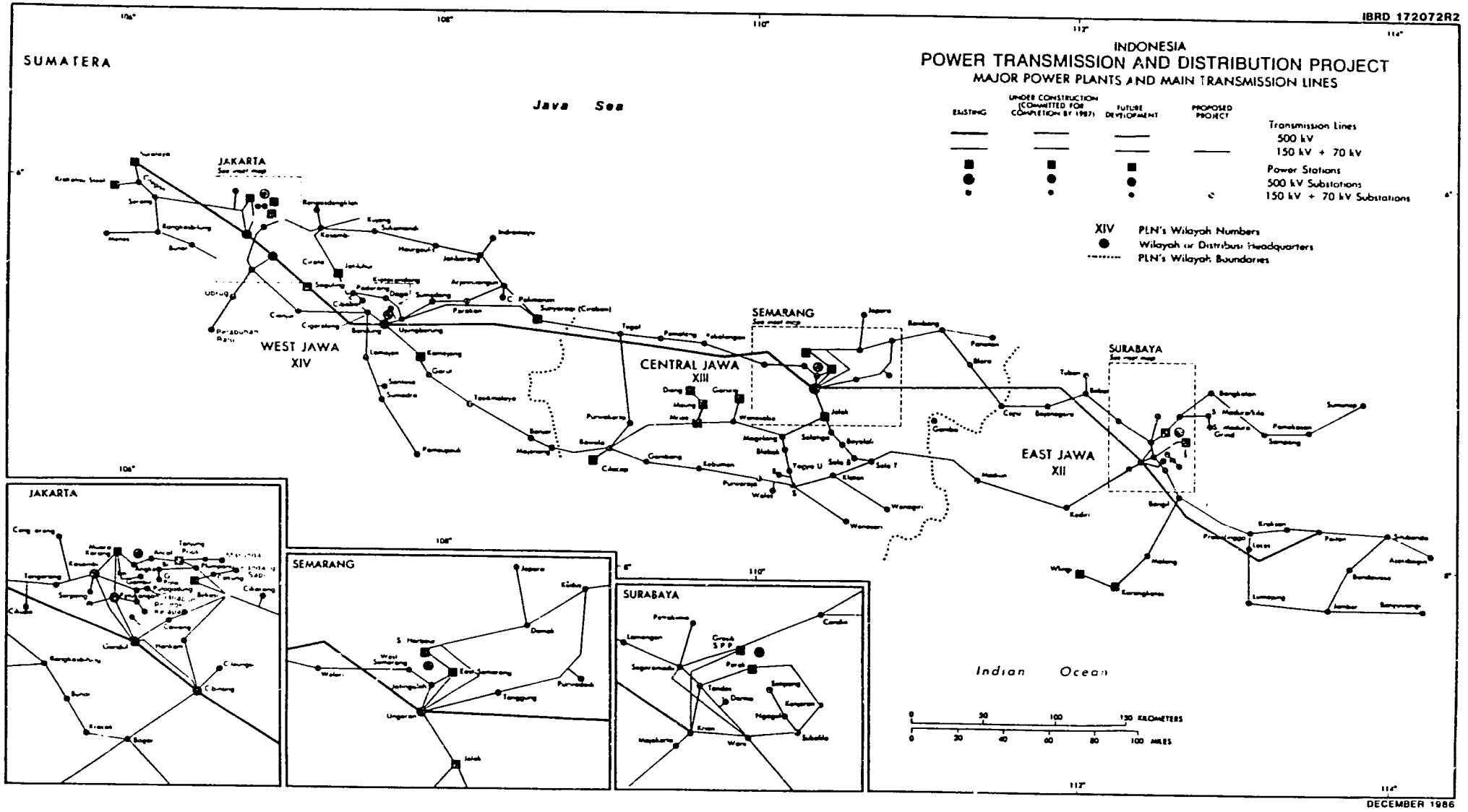
PLN Plans and Possibilities

Expansion of electricity generation capabilities in the country is a strong priority of the Government of Indonesia (GOI). For example, in the most recent five-year national plan (Repelita IV 1984-89), rural electrification was to receive 19% of PLN's budget, or 2% of total public investment funds. GOI has plans for rural electrification to expand from a targeted 14% (1985/86) to 21% of all households by 1994. Despite a strong past commitment and ambitious goals for future expansion, Indonesia is severely constrained in terms of generating (supply) capacity. Demand simply far outstrips supply capabilities, particularly for industrial and rural electrification. Both the infusion of government loans to PLN and expansion in private power generation are needed to meet its excess demand.

National Demand Potential and Supply Constraints

Over the past decade, Indonesian electricity consumption rose rapidly from 50 to 150 kWh per capita. With a heavy demand for industrial and residential electricity, PLN's annual sales reportedly grew by 12% per annum while total electricity consumption increased by twice this rate due to the expansion in private power generation [2]. Despite such rapid growth, disparities in consumption exist between regions and between Indonesia and its Asian counterparts. While there is some discrepancy between PLN and Agricultural Census data as to the exact number of electrified households, data provided by PLN suggest that at most only 14% of all households are electrified, with the ratio at 16% On-Java versus 11% Off-Java. In

Figure 4.1
PLN Power Transmission and Distribution Network Plan



1985/86, over 73% (3,841 MW) of PLN's total installed capacity (5,240 MW) was On-Java (Ministry of Mines and Energy). In addition, Indonesia at 150 kWh per capita fares poorly in per capita electricity consumption when compared to Thailand (350-400 kWh per capita), and ranks below the consumption levels of both India and Pakistan [1] [3]. However, given Indonesia's large, highly concentrated population and vast expanse (over 13,000 islands) with its inherent electrification problems, overall growth has been on par with other countries in the region.

Although important technical efficiency improvements in current and unused PLN capacity are possible, PLN's supply constraints are based fundamentally on economic rather than technical considerations. Supply expansion constraints have resulted from sluggish overall economic growth, limits on obtaining additional funding for capital investment from donors without changes in PLN's tariff structure and energy pricing, and delays in project implementation [2].

In response to the inability of PLN to meet existing and future demand, private power generation by industries and small electric cooperatives or entrepreneurs fills the gap. As noted above, over half (12%) of the growth in total electrical consumption in Indonesia (24% between 1982 to 1985) was possible because of private power generation. Captive power generation by industries for on-site use reportedly represented 50% of the installed capacity in 1974/75, and has continued to grow due to the addition of several new, large-scale industries installing their own facilities (e.g., Asahan, Krakatau Steel, and Cibinong Cement) [3].

In addition to significant captive power generation, rural electrification data from the Agriculture Census suggest that a substantial amount of residential electrification comes from private entrepreneurs. These data appear to indicate that PLN provides power to only 40% of the actual "electrified" villages, and that PLN data significantly underestimate the extent of private power generation. The provision of electricity by the private sector has resulted in a proliferation of models, and quality, of private power production. Many large industries rely on captive power due to their distance from the grid, their need for reliable energy, and the supply constraints of PLN.

Non-PLN residential/commercial electrical units are often run by local entrepreneurs with diesel generators that sell excess power to residents at varying, usually high, rates (209 Rp/kWh to 500 Rp/kWh) [4]. Such systems are believed to be unreliable, costly, and dangerous since they often do not meet PLN standards.

With this large excess demand, the capacity of PLN to absorb inefficient captive power producers, as planned in the early 1980's, as well as to significantly increase electricity delivery to new users is seriously limited in the near future. So far, with few exceptions, private power generation is used primarily for meeting on-site electricity demand [1] [4]. Few cases of sale to the grid exist. However, passage of the recent Act of The Republic of Indonesia, Number 15 Year 1985 on Electrification allows private power sale of electricity to the grid and may open the door for new, innovative mechanisms for PLN to increase its supply capabilities at marginal additional investment costs.

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Existing Non-PLN Power Systems

Captive Power

The 4000 MW of captive power in Indonesia are found primarily in three sectors: manufacturing industry, rural cooperatives, and privately owned village units. By contrast, a 1986 survey [4] of private small diesel systems indicates that total capacity of over 10,000 of these units is approximately 15 MW. Rural electrification was expected by the end of Repelita IV to contribute a total of 282 MW of captive power in rural areas, 232 MW of diesel capacity and 50 MW of mini-hydro. By far the largest segment of captive power resides in the larger manufacturing plants as follows [5]:

Larona Hydro Power Plant	165 MW
Krakatau Steel Steam Plant	400 MW
Asahan Hydro Power Plant	603 MW
Juanda Hydro Power Plant	150 MW
Aneka Tambang Diesel Power Plant	32 MW
Indocement Diesel Power Plant	90 MW
Total	1440 MW

The GOI predicts a continued growth of captive power at about 5% per year [1]. These plants are predominately in the mining and industrial sector, including textile, food, chemical, cement, paper, aluminum and steel industries. Of the 2671 MW captive power reported in 1983 (exclusive of Asahan, Juanda, Larona, Krakatau and Aneka), only 703.8 MW (26%) were connected to the PLN grid.

Cogeneration

A small number of plants have operating cogeneration systems. These include several fertilizer (urea) plants, two oil refineries, a textile plant, and a paper mill. Based on extremely limited data, it appears that the total capacity of existing cogeneration equipment is between 200 to 300 MW [1]. With the exception of the oil refineries, none of these plants appears to be interconnected with PLN. Some of these plants could generate surplus power at a very low cost and sell this power to PLN if an interconnection existed and PLN offered to buy the power.

Rural Electric Cooperatives

In 1978, a pilot program for development of rural electric cooperatives was launched by the Government of Indonesia with support from USAID. The program had two components: a group of electrification projects in Central Java tied to the PLN grid and three electrical cooperatives on other islands.

The rural electrical cooperatives are located at Lampung (southern Sumatra), Lombok (West Nusa Tenggara) and Luwu (South Sulawesi). Each cooperative owns and operates its own diesel generators. The purchase and installation of this equipment, along with distribution and house-wiring, were financed through a combination of USAID and government loans, and were supported by USAID-funded technical assistance [5].

Not surprisingly this somewhat innovative project experienced considerable delays in implementation. The original intent was to have the cooperatives in operation by 1983; when USAID project financing was ended at the end of December 1984, the combined projects were estimated to be only 35% complete [6].

These projects have been financed by a combination of Government of Indonesia and USAID soft loans with project support from other bilateral donors. The USAID portion - amounting to some $9.4 million - had a grace period of 10 years and an interest rate of 2.6%. The Indonesian loan (for about one half the amount of the USAID loan) originally had a grace period of six years and an interest rate of 6.6%. The average revenues per kWh received by the cooperatives range from 162 Rp/kWh in Lombok to 201 Rp/kWh in Luwu. Currently, even with concessional financing and tariffs considerably higher than PLN's, the cooperatives are not financially viable. In part this is due to a customer base much smaller than projected. The National Rural Electric Cooperative Association has analyzed the rates required to achieve financial break-even if the customer base continues to expand, increased financing is forthcoming from the Government, and the grace period on the Indonesian Loan is extended to 9 years [6]. Those rates are shown in Table 4.1.

Table 4.1
Cooperatives Revenue Requirement per kWh Sold
1989 Projections Average Tariffs, (Rp/kWh)

Cooperative	Residential	Total 1985	Total 1989
Lampung	181	163	171
Lombok	183	162	174
Luwu	244	201	230

The World Bank has suggested several other reasons for the inefficiency of the rural electrical cooperatives [2]:

- Complex budgetary and procurement procedures;
- Shortage of technical and managerial expertise; and
- Lack of baseload or industrial consumers.

Rural Private Systems

In addition to the official rural electrification program of PLN and the Ministry of Cooperatives, there are literally thousands of unregulated private electricity producers throughout Indonesia providing small amounts of power to villagers. By law, if operating at a power level below 5 kVa, a private producer needs no license and can set its own tariffs. According to surveys by Biro Pusat Statistik in 1982-1984, although there is a wide range of prices being charged by these "mini-power companies", their average rates in that period were roughly twice that charged by PLN to small residential customers [7].

Some of these private companies reportedly charge 5,000 Rp per month for a 50 watt connection (or 10,000 Rp for a 100 watt connection). These connections are presumably for lights and possibly a radio, conceivably a television set and battery charger. If the consumer uses this power for as much as 200 hours a month (about 7 hours a day) this would be equivalent to 500 Rp/kWh (30¢ US/kWh).

These costs are extreme examples, however, according to a recent survey by Biro Pusat Statistik [4] of some 10,000 non-PLN power producers throughout Indonesia. Companies sold an aggregate of 32,684 MWh in the three months in 1985 preceding the survey. Their revenues from these sales were 6,822 billion rupiah. This works out to 209 Rp/kWh. However, there was significant variation around this average both in terms of type of consumer and location. Table 4.2 indicates the average effective charges (actually revenues per kWh sold) for each type of customer for each region. The averages for each customer class were households 311 Rp/kWh (18¢ US/kWh) and industry 325 Rp/kWh (19¢ US/kWh).

The World Bank has characterized the quality of service provided by these mini-power companies as "generally far inferior to that of PLN" and states that on average "they are in a precarious financial condition" [2]. It has also been suggested that after some experience with such systems, the consumers are eager to accept PLN as a preferred alternative.

All of this not withstanding, the existence of these systems - and their continual growth in numbers - provides evidence both of widespread entrepreneurial skill on the part of the producers and of the willingness of villagers to pay more than PLN rates for at least small amounts of power.

Table 4.2

Average Characteristics of Private Producers

	Production (kWh)		Revenue RP (000's)		Unit Cost (Rps/kWh)		Ind/Household Ratio (kWh/kWh)
	Household	Industry	Household	Industry	Household	Industry	Ind/Hold
Daeran Istimewa Aceh	1,321,910	19,356	367,599	8,830	278.08	300.81	0.0222
Sumatera Utara	278,917	332	172,582	195	618.76	587.35	0.0012
Sumatera Rata	407,229	35,453	142,998	11,433	351.13	322.48	0.0871
Riau	886,303	44,873	318,942	14,368	360.67	320.19	0.0507
Jambi	639,378	18,241	172,166	9,000	273.55	493.39	0.0290
Sumatera Selatan	3,296,552	23,565	705,661	5,391	214.06	228.77	0.0071
Lampung	766,969	34,677	222,902	9,165	290.63	266.30	0.0452
Jawa Barat	665,600	10,378	191,662	2,673	287.92	257.56	0.0156
Jawa Tengah	3,294,627	110,590	487,330	14,746	147.92	133.36	0.0336
Di Yogyakarta	57,454	176	20,010	103	348.28	585.23	0.0031
Jawa Timur	4,761,463	383,751	1,500,390	70,245	315.11	183.05	0.0806
Nusa Tenggara Timur	130,446	3,123	27,934	933	214.14	298.75	0.0239
Kalimantan Barat	444,260	41,393	165,129	14,942	371.69	360.98	0.0932
Kalimantan Tengah	520,782	3,244	186,787	1,463	358.67	450.99	0.0062
Kalimantan Selatan	470,478	434	99,660	169	211.83	389.40	0.0009
Kalimantan Timur	1,058,197	30,701	266,233	9,802	251.59	319.27	0.0290
Sulawesi Utara	270,682	4,651	104,387	1,613	385.64	346.81	0.0172
Sulawesi Tengah	160,473	2,317	35,923	234	223.86	100.99	0.0144
Sulawesi Tenggara	186,378	109	89,216	41	483.88	376.15	0.0006
Sulawesi Selantan	1,088,757	12,675	246,586	2,087	226.48	164.65	0.0116
Total	20,692,855	790,037	5,524,075	177,433			
Average	1,036,643	39,502	276,204	8,872	310.70	324.22	0.0286
Standard Deviation					104.53	130.56	0.0281

Source: BPS, Reference 23

Economics of Electricity Generation

As is the case in many developing countries, expansion of the electricity sector in Indonesia requires heavy investment and subsidies, particularly for rural industrial or residential electrification. Electricity expansion in Indonesia currently is shackled by a set of economic constraints that include the temporary decline in government revenues, limited access of PLN to financing due to GOI's heavy debt burden, and substantial operating losses incurred by the systems from a negative tariff-production cost gap [3].

Given Indonesia's depressed economy, the government has had little choice but to curtail part of its ambitious expansion plans for the electricity sector. The substantial reduction in government revenues in the first two years of Repelita IV (ending March 1989) resulted in actual expenditures on electricity of only 75% of the planned levels, and 50% for 1985/6. This has caused major project implementation delays and cancellations [3]. Reflecting public sector constraints, a premium now exists on finding least-cost options for power generation in Indonesia.

The following summary of relative energy prices, tariff structures, government revenues, and investment needs in the Indonesian electricity sector highlights the key economic issues that limit electricity expansion. Potential new directions are suggested for making the electricity subsector more financially and economically attractive.

Energy Pricing Policies and Relative Fuel Costs

The Indonesian government has made a concerted effort since the seventies to realign its fuel prices to more accurately reflect their opportunity costs to the country [1] [3]. While price distortions still exist, particularly between transport and household fuels, such distortions have remained due to the explicit social objectives of the government. The impact of price distortions, through taxes or subsidies, on the relative prices for electricity production has received less attention due perhaps to the lack of quidelines on the appropriate economic criterion for determining the least-cost option in Indonesia. Such clarification is needed to provide a focus in the current high-level debate on optimal fuel use in Indonesia.

Since 1972 the basic principle of electricity pricing has been that sufficient revenue be earned by PLN to defray all costs, including proper maintenance and depreciation costs, payment of interest and taxes, as well as having reasonable surplus to finance part of the expansion work and debt repayment.

The present basic tariff is the Basic Tariff Schedule (Tarip Dasar Listrik) 1986, which has been effective since August 1986 following the local fuel price increases in July 1986 [1] [8].

The TDL's tariff structure was set with the objectives of subsidizing low income families, enhancing the growth of the industrial sector and coping with the PLN financial requirement in FY 1986/87 [1].

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The tariff comprises 17 consumer categories and 6 consumer groups as follows:

1.	Small Consumers and Social Institutions	(S1 and S2)
2.	Residential use	(R1, R2, R3, and R4)
3.	Commercial use	(U1, U2, U3, and U4)
4.	Industrial	(I1, I2, I3 and I4)
5.	Government Offices	(G1, and G2)
6.	Street lighting	(J)

The tariffs are shown in Table 4.3

The basic tariff is set in terms of a demand charge which relates to volt-amps (VA) connected and an energy charge which relates to kWh consumption, with the exception of S1 (Fixed VA connection) and J and U4 (Energy charge only) [8].

Industrial and large consumers (U3 and G2) are charged in terms of peak and off-peak tariffs. The peak rate is about 1.6 times of off-peak rate and the peak hours period is 4 hours (between 18.00 and 22.00).

Electricity prices have been raised by some 130 percent since 1981 to the current "average price" (revenue per kWh sold) of 96 Rp/kWh. Before the devaluation of September 1986 the World Bank estimated that the price was some 15 percent lower than long run marginal costs. The devaluation has increased that difference to over 20 percent.

Current policy development is leading to a system of financial requirements for PLN which differentiates between Java and Off-Java operations. The On-Java objective will be to attain an 8 percent annual rate of return. The Off-Java objective will be to produce total revenues at least equal to total operating expenses plus debt service less depreciation.

In 1985/86 PLN's operation On-Java was profitable showing a rate of return close to 5 percent. It is estimated that that has increased to over 6.5 percent in 1986/87. Thus the objective of an 8 percent return appears attainable with expected efficiency improvements and modest tariff increases. Off-Java, however, the situation is more difficult. In 1985/86 operating revenues were Rp 282 billion, and expenses Rp 386 billion, for a loss of Rp 104 billion. That loss increased to around Rp 160 billion in 1987 on estimated revenues of Rp 319 billion. Thus, simply to cover expenses Off-Java, rates Off-Java would have to be increased by 50 percent [1].

Table 4.3

Tariff Schedule 1986
(Effective August 1986)

No.	Code	Contracted Power	Demand Charge (Rp/kVA)	Energy Charge (Rp/kWh)
1.	S_1	to 200 VA	*	-
2.	S_2	250 VA to 200 kVA	2,100.00	43.50
3.	R_1	250 VA to 500 VA	2,100.00	70.50
4.	R_2	501 VA to 2,200 VA	2,100.00	84.50
5.	R_3	2.201 VA to 6,600 VA	3,680.00	126.50
6.	R_4	6.601 VA and over	3,680.00	158.00
7.	U_1	250 VA to 2.200 VA	3,680.00	134.00
8.	U_2	2,201 VA to 200 kVA	3,680.00	150.00
9.	U_3	201 kVA and over	2,300.00	P = 158.00 OP = 99.00
10.	U_4	450 VA and over	-	307.00
11.	I_1	to 99 kVA	2,300.00	P = 97.50 OP = 60.50
12.	I_2	100 kVA to 200 kVA	2,300.00	P = 92.50 OP = 57.50
13.	I_3	201 kVA and over	2,100.00	P = 90.50 OP = 56.00
14.	I_4	5,000 kVA and over	1,970.00	P = 77.00 OP = 48.50
15.	G_1	250 VA to 200 kVA	3,680.00	96.00
16.	G_2	201 kVA and over	1,970.00	P = 99.00 OP = 65.00
17.	J	-	-	76.50
			AVERAGE	

* = Tariffs$_1$
60 VA = Rp.1,550.00/month
75 VA = Rp.1,940.00/month
100 VA = Rp.2,510.00/month
125 VA = Rp.3,200.00/month
150 VA = Rp.3,765.00/month
175 VA = Rp.4,350.00/month
200 VA = Rp.5,025.00/month

Note: P = Peak Hours (18.00-22.00)
OP = Off Peak Hours (22.00-18.00)

Source: Ministry of Mines, Minerals and Energy

When comparing relative fuel costs, a consistant valuation technique or economic criterion, such as the financial costs of production versus long run marginal (social opportunity) costs, needs to be applied. In Indonesia, the debate regarding optimal fuel choice often appears to be comparison of costs and prices based on different valuation methods. Even the basic criterion of cost competitiveness, however, is not straight-forward. It is difficult to fully evaluate the methods used in existing economic analyses of alternative power fuels and technologies except to note wide differences of opinion on the values which immediately places the evaluation of private power on shaky ground. The following discussion attempts to better classify existing energy price data and identify charateristics that influence these values.

Serious on-going debate within the government focuses on the identification of the least-cost fuel for additional electricity production, with the debate narrowing down to coal, geothermal, natural gas, and nuclear [1]. Much of the wide variation that exists in costs of production between government and other studies can be attributed to five key factors: (1) the failure to include capital with operating and maintenance costs in some analyses, (2) the use of a financial versus an economic valuation method across different studies, (3) assessment based on grid versus non-grid connection, (4) disaggregation of costs by location, such as On-Java as compared to Off-Java, and (5) cost differences due to the size of demand, i.e., the user group.

First, some analyses neglect important cost components when reporting the "costs of production", such as the capital costs. This seriously alters the relative costs of electricity production from different fuels, often giving higher priority to capital intensive fuels. Second, some studies use financial prices (i.e., market prices with their inherent distortions) while other studies internalize important social costs based on an economic analysis. The effect on relative prices when costs of production are compared from a financial versus an economic perspective is readily apparent in Table 4.4. Total costs of production are used in a government study (Amarullah 1986), whereas World Bank (1987) and UNOCAL (1986) analyses internalize some social opportunity costs.

Inherent in the financial analysis in Table 4.4, but often overlooked, is the effect of price distortions due to inflated (taxed) prices for natural gas and the omission of air pollution externalities for coal. In fact, PLN's natural gas price (US$ 3.00/MMBTU) is higher as set by government pricing regulations than the price charged to other industries (US$ 1.00/MMBTU for fertilizer and $2.00/MMBTU for steel) or even the estimated LRMC for natural gas (US$ 1.80/MMBTU) reportedly due to the government's priority to earn foreign exchange from gas sales [1] [3]. In most analyses, pollution abatement equipment costs are often ignored for coal, with the exception of UNOCAL's study. The removal of such price distortions will change relative prices and fuel rankings in Table 4.4. While financial prices reflect current market realities, the government also needs to assess relative energy prices by their long run economic rather than financial costs. It may be that Indonesia's fuel choices do not change if the government wants to export natural gas for foreign exchange and insists on minimal coal pollution equipment, but such pricing considerations need overt recognition in the studies.

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Table 4.4
Cost of Production vs. Long Run Marginal Cost
(LRMC) Estimates by Fuel Source (1987 prices)

Fuel	Average Production Costs*		Economic Costs			
	PLN		LRMC** World Bank		UNOCAL***	
	(Rp/kWh)	(US¢/kWh)	(PR/kWh)	(US¢/kWh)	(Rp/kWh)	(US¢/kWh)
Diesel(IDO)	89	5.4	NA	NA	NA	NA
Diesel(HSD)	96	5.8	NA	NA	NA	NA
Gas turbine(HSD)	152	9.3				
Gas turbine (Nat.Gas)	80	4.9	37	2.2	NA	NA
Geothermal	74	4.5	72	4.4	72	4.4
Hydro	44	2.7	NA	NA	NA	NA
Nuclear	67	4.1	84	5.1	NA	NA
Steam -						
Coal -imported	61	3.7	45	2.7	93	5.6
-domestic	62	3.8	NA	NA	NA	NA
Nat.Gas	62	3.8	NA	NA	NA	NA
RESID	92	5.6	46	2.8	NA	NA

Assume: 1 US$ = 1,644 Rp (July 1987): CPI 1,157 (1984-1987) inflating factor for 1984 prices.
Revisions based on 1984 prices.
NA = Not Available

* Includes: Financial Cost valuation of capital, fuel, + operations & maintenance Costs; p. 413-424, February 1986. Amarullah, Munawar, ed. Analysis of Electricity Prices. National Development Planning Agency (BAPPENAS) Goverment of Indonesia.

** Confidential. World Bank Report. Indonesia Energy Options Review. Report No. 6583 IND. Energy Division. 1986.

*** UNOCAL unpublished report. 1986.

A third factor that differentiates electricity costs of production is grid versus off-grid connection. A comparison of on-grid to off-grid costs for rural electrification in Kalimantan (Table 4.5) and PLN versus non-PLN costs of production and long run marginal costs (Table 4.6) shows the importance of such differentiation. A fourth factor, location, further reinforces grid versus off-grid gaps. As implied in Table 4.7, the long run marginal costs are lower On-Java than Off-Java.

Finally, another major cost difference can be found between user groups, due in part to the effects of economies of scale, location, and connection to the grid (Table 4.7 and 4.8). Taken together, these five factors explain why Indonesia's costs of production vary significantly, for valid reasons, due to a variety of geographical and generation characteristics in the electricity sector.

The relevance of such price variations to a debate over private versus public power generation is that private must be less expensive than public power generation. The trouble, as suggested by the above data, is in choosing appropriate cost criterion.

Table 4.5
Cost of Production for Electrification
Alternatives in Kalimantan (1987 Prices)

Fuel Source	Unit Costs (Rp/kWh)	(US¢/kWh)
Off-Grid		
Diesel	132	8.1
Gasification (Rice)	176	10.7
Hydro	57	3.5
Steam		
- Coal	69	4.2
- Industry Wastes		
- on site uses	95	5.8
- utility uses	33	2.0
- Log (wood wastes)	78	4.7
Grid Extension*	156	9.5

Assumes: 1 US$ = 1,664 Rp; Production costs based on 1.11 CPI inflation factor for 1985 prices.

*PLN extension of grid

Source: Asian Development Bank, et.al. INDONESIA: Rural and Renewable Energy Development Study in Kalimantan. T.A. No. 524 - IND. Manila, Philippines. November 1985. p.7.

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Table 4.6
Costs of Operation or Production vs. Tariffs For
Non-PLN vs. PLN Electricity (1987 Prices)

Producers	Costs		Average Tariffs			
			All User's(Range)		Industrial	
	(Rp/kWh)	(US¢/kWh)	(Rp/kWh)	(US¢/kWh)	(Rp/kWh)	(US¢/kWh)
A. Non-PLN						
1. R.E. Cooperatives[1]						
Lampung	98	6.0	43-150	2.6-9.1	86	5.2
Lombok	85	5.2	43-125	2.6-76	125	7.6
Luwu	104	6.4	43-125	2.6-76	125	7.6
2. Captive Power[2]	N/A	N/A	311	1.9	324	19.7
3. KUD/PLD[2]	N/A	N/A	103	6.3	N/A	N/A
B. PLN						
1. RE/PLN values[3] (Original)	139	8.4	103	6.3	N/A	N/A
2. Diesel[3] (Off-Java & off grid)	174	10.6	103	6.3	N/A	N/A

Source: 1- Ministry of Cooperatives. Operations and Fuel Costs only.

2- Biro Statistik Pusat. Statistik Listrik Non-PLN 1985. Jakarta, Indonesia. No. 04140.86003. 1986.

3- Amarullah, Munawar, ed. Analysis of Electricity Pricing. National Development Planning Agency. (BAPPENAS). Government of Indonesia. February 1986. Total Production Costs.

Table 4.7
Comparison of Long-Run Marginal Costs
of Electricity Production (1987 Prices)

	LRMC (RP/kWh)	LRMC (US¢/kWh)
Indonesia		
Social	69-145	4.2- 8.8
Residential	157-260	9.6-16.0
Commercial (Sm to Lg)	136-240	8.3-15.0
Industrial	88-224	5.4-13.6
Government	146-209	8.9-12.7
Java		
Social	69-142	4.2- 8.7
Residential	116-263	7.1-16.0
Commercial (Sm to Lg)	138-243	8.4-14.8
Industrial	89-243	5.4-14.8
Government	147-207	8.9-12.6

*Includes demand and Energy changes.

Source: Amarullah, Munawar, ed. Analysis of Electricity Pricing. National Development Planning Agency (BAPPENAS). Government of Indonesia. Jakarta. February 1986. p.176 & 291.

Table 4.8
PLN's Estimated Long-Run Marginal Costs of Electricity
Production by Time of Day (1987 Prices)

User Level/ Category	Demand Charge (Rp/kWh/mo)	Demand Charge (US$/kWh/mo)	Energy Charge Peak (Rp/kWh)	Energy Charge Peak (US¢/kWh)	Energy Charge Off-Peak (Rp/kWh)	Energy Charge Off-Peak (US¢/kWh)
High Voltage	2,660	1.60	124	7.5	76	4.7
Medium Voltage	5,200	3.20	166	10.0	87	5.3
Low Voltage	10,900	6.60	248	15.0	110	6.7

Source: Amarullah, Munawar, ed. Analysis of Electricity Pricing. (BAPPENAS) National Development Planning Agency. Government of Indonesia. Jakarta. February 1986. p. 172.

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Costs of Production, Long-Run Marginal Costs, and Electricity Tariffs

The wide variation between costs of production, estimated long run marginal costs and actual tariffs (Tables 4.3, 4.4, 4.7) could lead to different economic criteria against which private power generation must compete. Most countries use the avoided cost method for judging the feasibility of private versus national power generation [3]. On-Java where excess generation capacity exists in some areas, avoided costs are the economic (not financial) energy (fuel plus operating) expenses saved by PLN by buying power from private energy producers. Off-Java and in some areas On-Java perhaps, full avoided costs that include economic energy plus capacity savings by PLN should be used.

The concept of avoided cost is simple in principle but complex in practice. There are two components to avoided cost. The first, the energy component, is relatively straight-forward and includes the utility's fuel and O & M expenses (which usually vary as a function of season or time of day).

More complex is the capacity cost component which accounts for the generation, transmission and distribution investment costs that are avoided by having the private producer on line. The value of that component depends on a number of factors including:

- The rate of growth of demand served by the utility
- The structure of demand
- The utility's current excess capacity, if any
- The utility's marginal cost of new capacity
- The reliability of the private producer and the ability of the utility to dispatch that particular facility
- Cost savings in line losses and interconnection costs
- The mix of private producers on the grid.

If long run marginal costs are an acceptable economic criterion for deciding avoided costs, then current tariff rates shown in the above tables substantially underestimate the value against which private power costs should compete. Yet such latter values are often given as the yardstick to determine PLN's purchase price. While it generally is accepted that rural electrification rarely pays for itself, PLN's subsidies due to operating losses, sometimes up to 40%, of its LRMC [1] for rural electrification Off-Java, strap it for investment funds. Concurrent with trying to reduce these losses through continued increases in its tariff structure, the government can encourage private power that is cheaper than the local alternative.

In summary, current economic constraints on the public electricity sector in Indonesia include limited access to additional investment funds, recurrent operating losses, and a sluggish economy. To meet the substantial pent-up demand On-Java and Off-Java, additional generation capacity is needed. Private power generation that competes favorably with the least-cost PLN option could provide additional capacity without adding new debt burden on the government. Given the wide range in real social costs to the government for electrification, one conclusion is that private power altenatives should be evaluated on a site-to-site and avoided costs basis.

Summary: Status of Power Generation

- Captive power provides over half the MW capacity of Indonesia; only approximately one-fourth of this is connected to the PLN grid.
- There also is a significant but unmeasured number of private power generation systems in Indonesia.
- Large industrial users of electricity do not depend on the PLN grid for reliability of service.
- Current law permits private power generation for sale to the grid.
- PLN official plans are to absorb captive power and to completely electrify the nation.
- Availability of public funds for capital investment in new generation and in grid extension is decreasing.
- High level excess demand is currently unmet by PLN yet expected to expand with increased economic development.
- No consistant economic criterion is used to compare energy costs when deciding optimal fuel choice.
- Current tariffs are below estimated long-run marginal costs and costs of production, particularly for Off-Java rural electrification. As a result, large operating losses are being incurred by PLN.
- Various government agencies with various sub-responsibilities for the provision of electricity are considering alternative private generation scenarios.

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CHAPTER FIVE

TECHNICAL CONSIDERATIONS OF RICE RESIDUE CONVERSION SYSTEMS

Introduction

As stated earlier in this report, rice residue is generally a problematic combustion fuel. In some larger systems in the United States, however, rice husk is used both effectively and with attractive financial returns. In one well-documented case, a 12 MW power plant has been continuously operating for three years with high capacity factors. At another installation, a gasification/combustion system is used to provide thermal energy for a rice drying application. Both systems realize attractive returns and are being marketed in the United States and overseas.

Large systems such as the 12 MW system cited above can take advantage of economy of scale with respect to energy efficient boiler and steam equipment, effectively reducing the specific fuel consumption rate. As the size of the installation decreases, efficiencies decline due to higher losses and to the inability of smaller systems to economically justify the use of more efficient equipment. Gains in efficiency and reduced recurring costs must therefore be balanced against higher initial costs when system designs are evaluated.

The upper limit of systems under consideration for this report is approximately 1.5 MW (net power output). It is also determined that 600 kW is the lower limit for economic operation of rice residue conversion systems in Indonesia, given commercially proven systems. In order to evaluate the service area required to provide fuel for systems of this size, several factors must be considered. As system size decreases from 12 MW to 1.5 MW (and lower), fuel consumption does not decrease at a proportional rate. Due to lower system efficiencies at the lower plant capacity, the fuel consumption per MW output will in fact increase. It is therefore necessary to proceed with a thorough analysis of a typical system operating under the design conditions chosen by the equipment manufacturer to arrive at an accurate estimate of the fuel consumption.

Chapter 5 outlines the methodology followed in determining first design efficiencies of the power plant, and then the actual fuel consumption rate. As these figures are dependent largely on a number of design considerations, a range of solutions will be presented to reflect the more relevant variations in operating conditions and equipment configurations. The results are summarized in tabular and graphical form with a descriptive methodology provided to allow the reader to verify results.

The following section will begin with a description of some of the factors affecting design of the systems. This will be followed by an evaluation of systems operating under various design parameters. It will conclude with a discussion of the risk factors affecting the successful use of rice residue energy conversion systems.

Design Considerations for Biomass Conversion Systems

Fuel Characteristics

Biomass resources have widely varying fuel characteristics. In most cases they are much more problematic fuels than conventional fossil fuels from the standpoint of equipment design and maintenance. Of the conventional fossil fuels in use for power generation, solid biomass fuels most closely resemble coal in terms of handling and combustion characteristics.

The characteristics of rice husks and straw typify some of the problems which are often encountered in utilization of biomass materials. Rice husks have a very low bulk density of approximately 10 kg/m^3 (6.23 lbs/ft^3) [1]. The highly abrasive nature of the material (due to high silica content) can cause many handling problems. The relatively high ash content of both straw and rice husk also requires continuous ash removal from the combustion or gasification zone in thermal conversion systems.

The higher heating value* of the husks has been measured at 16.14 MJ/kg (6938 Btu/lb); for rice straw, the reported value ranges from 14.56 to 16.28 MJ/kg (6259 to 6998 Btu/lb) [2]. The lower heating value of rice husks and straw are 15.27 MJ/kg and 13.76-15.34 MJ/kg respectively (6564 Btu/lb and 5915-6594 Btu/lb). This value represents the heating value of the fuel less the latent energy of vaporization of water present in the fuel. The later value more accurately represents the net available energy in the fuel for combustion applications. Table 5.1 summarizes the above data.

Table 5.1
Chemical Properties of Rice Husk and Straw

Biomass Carbon	Higher Heating Value (MJ/kg)	Lower Heating Value (MJ/kg)	Proximate Analysis (% by weight, dry basis) Volatile	Ash	Fixed
Rice Husk	16.14	15.25	65.47	17.66	16.67
Rice Straw (Fresh)	16.28	15.32	69.33	13.42	17.25
Rice Straw (Weathered)	14.56	13.74	62.31	24.36	13.33

Source: J. M. Ebling and B. M. Jenkins, "Physical and Chemical Properties of Biomass Fuels", Transactions of the ASAE 28 (1985), Table 1, p. 899.

*These values are for oven-dried samples. Field samples with residual moisture will vary from these values.

One concern related to biomass fuels is the melting point of the fuel. At temperatures exceeding the melting point, fusion of ash can occur eventually causing maintenance problems in the biomass conversion system. Fusion temperatures can be defined in several ways, but usually is taken as the temperature at which deformation occurs of an oven-dried sample heated in an inert (Nitrogen) atmosphere. As Table 5.2 indicates, rice straw has a much lower fusion temperature than does rice husk (1027°C as compared to 2676°C). If used in the same furnace concurrently, the combustion temperature would have to be reduced to prevent fusion of rice straw.

As mentioned above, a further consideration in use of biomass materials is the handling characteristics of the fuel and residue. Both rice husks and rice straw are very abrasive due to the relatively high silica content of the material. In systems using highly mechanized conveying equipment, equipment must be safeguarded from degradation due to the frictional characteristics of the feedstock and ash. As manufacturers of rice husk-fired boilers have experienced, the abrasive nature of the product can cause recurring equipment failures if not designed to minimize exposure to the fuel and ash.

Given the low density and relatively low heating value of the fuel, large volumetric quantities of rice husk/straw are needed to provide fuel requirements for power generation. To evaluate the financial, technical and institutional feasibility of investing in a rice husk-powered system, it is essential to determine how the fuel will be transported to the plant site, and from what distance the fuel must be transported to satisfy consumption requirements.

Table 5.2
Fusibility of Rice Husk and Straw

Type	Temperature°C			
	Initial Deformation	Softening	Hemispherical	Fluid
Rice Husk	1439	--	> 1650	--
Rice Straw	1060	--	1250	--
Rice Straw (Oxidizing)	1027	1421	--	> 1500
Rice Straw (Reducing)	1027	1410	--	> 1500

Source: B. M. Jenkins, "Physical Properties of Biomass", draft manuscript for Biomass Handbook, 1987.

Facilities and Equipment

There is a limited number of manufacturers both in the United States and abroad currently marketing rice husk/straw energy conversion systems. Several designs of rice husk boilers have been used in the past for small and intermediate scale systems. In very small rice mills (25-150 kW), surplus boilers salvaged from sugar mills or railroads are used with step grate furnaces retrofitted to the boilers. Steam engines are used to convert the steam output of the boiler to a mechanical form for driving the rice mill, and in some cases excess heat from the boiler was used for rice drying. These systems have proven to be very durable and relatively trouble free. They do, however, require constant maintenance (ash must be removed from the fire tubes on a regular basis), and they operate at less than 5 percent overall efficiency. Moreover, these systems are possible only in areas where a market for surplus equipment exists.

Requirements for additional maintenance go beyond that resulting from the abrasiveness of the feedstock. While the material handling equipment can be designed to minimize equipment failure, it must be kept in mind that in general maintenance costs will be higher for fuels which require processing prior to conversion. Grinding, crushing, separation and conveying systems all require maintenance in excess of that required for the boiler/genset. Ash removal system equipment will also require additional maintenance time not normally required for fossil fuel fired systems.

Equipment costs vary according to design complexity and overall system capacity. Systems of equivalent capacity but of dissimilar design may vary substantially in cost. Systems operating at lower pressures normally will employ less expensive but also less efficient equipment. As system size increases, the volume of fuel required for operation may allow the use of more efficient, higher cost equipment. Furthermore, as system capacity is increased, economies of scale can become a factor in cost; downsizing therefore will not reflect a directly proportional reduction in system costs.

Many biomass fired systems in use in the United States employ supplemental fuels. This may be done for a variety of reasons, such as enhancing flame stability, increasing system capacity and simply to diversify fuel capabilities. Some systems are designed such that they have the capability of operating with a variety of biomass fuels, with the capability of using a gaseous or liquid conventional fuel as well. Any discontinuity in the biomass fuel supply can be compensated for by increasing use of the supplemental fuel. With this sort of versatility, system downtime can be minimized.

Evaluation of Commercially Available Systems

Only recently have rice husk energy conversion systems in excess of 1 MW been used on a commercially viable basis. While other biomass resources such as wood, coconut shells, and coffee grounds are common to several commercial users, rice husks have not enjoyed similar popularity.

The larger rice husk systems enjoying commercial success are quite large in comparison to what one might expect to use in a developing country such as Indonesia. As mentioned earlier, rice mills in Indonesia are much smaller than in the United States; subsequently, less rice husk is available on site to provide fuel for the biomass conversion system. One can expect much smaller systems with suitable lower feedstock requirements to be in higher demand in rural milling environments as a consequence.

By nature, as systems are reduced in size below a certain lower limit (perhaps 5 MW), suitably priced equipment yields lower efficiencies than one would expect from a larger system. The 12 MW system mentioned earlier, for example, operates at a system efficiency of approximately 26% [3]. Small commercial systems in Southeast Asia which utilize surplus boilers and steam engines operate at efficiencies in the range of 3 to 5 percent.

Most likely, a 1.5 MW system operating at 650 psig in the superheat range will operate with a system efficiency in the range of 12 to 17%, depending on the type of energy conservation equipment used and, of course, on boiler design. Efficiency is also dependent on the turbine selected and moreover on the carbon content of the ash (the degree of complete combustion attained in the boiler). The following section provides an outline of how one can determine the expected efficiency of a rice husk conversion system, given a set of operating parameters and making a few generalized assumptions regarding boiler and turbine performance. A sensitivity analysis is provided to illustrate the range of expected fuel consumption rates. System performance characteristics have been verified with equipment manufacturers to insure the assumptions presented are valid.

Combustion Analysis

Depending upon the type of equipment used, operating efficiencies can be expected to range anywhere from 5 to 17% (for systems below 2 MW). This wide range indicates that fuel consumption can vary by over a factor of three depending upon system configuration.

Obviously, a prospective purchaser will want to know how much fuel will be needed to run the system. For this reason, an analysis was performed to provide user information for systems operating under various conditions. Prior to presenting the results of this analysis, the methodology employed in determining the respective figures is presented to enable the reader to verify the findings.

Methodology

The method used in this analysis to determine fuel consumption rates was a cycle analysis. Each system configuration was diagramed to designate the various state points and conditions coinciding with respective changes in steam conditions associated with each process around the steam cycle. These processes include:

- compression of boiler feedwater
- feedwater heating (optional)
- heat addition through boiler
- expansion of steam through turbine (power out to generator)
- condensation of steam in condensate recovery system.

This is a simplication of most systems which may have multi-staged feedwater pumps, turbines, and feedwater heaters. Larger systems may also employ economizers and other energy conservation equipment when financially feasible. However, for this analysis, the above five processes were included in the analysis as an example of a typical system configuration for illustrative purposes only.

For a typical system, then, the following assumptions were made:

- operating pressure: 650 psig
- boiler temperature: 750°F (superheat)
- feedwater temperature: 250°F
- turbine exhaust pressure: 26" Hg
- boiler efficiency: 80%

Using these assumptions, a detailed analysis of the above described system was performed (see Annex III).

This procedure can be repeated for similar systems with a variety of system configurations to provide an appreciation of the sensitivity of the efficiency (and ultimately, the fuel feed requirements) to factors such as turbine and boiler efficiencies. The following table provides a summary of the results for calculations made for several different systems. Assumptions and other relevant data are provided to allow for verification.

As Table 5.3 shows, fuel consumption of a steam driven generator can vary dramatically depending upon the type of equipment selected, the pressure at which steam is raised, and the quality of the fuel (e.g., moisture content of the fuel). Note that the table indicates that for lower pressure systems (i.e., 250 psi), one would normally expect a system efficiency of 10% for a larger 1.5 MW output, and a lower system efficiency of approximately 8% for a system generating less power (650 kW). This is due partly to the greater losses incurred when the turbine size is reduced, and also to economies of scale of which one can take advantage of when using larger equipment. The greater benefit of producing more power may off-set higher component costs. Feedwater heaters, multi-staged turbines, and other heat

recovery and energy conservation equipment may not present high enough gains to justify their use in smaller systems. This is strictly a matter which must be analyzed with each respective installation, or with modular systems, for each successive increment in size for the modular design.

An analysis was also performed to demonstrate the effect of turbine efficiency on smaller, lower pressure systems. Turbines can be purchased for a variety of applications, depending on user requirements and limitations on investment capital. If, for example, process low pressure steam is needed to drive a particular industrial process, the steam may be drawn off the turbine at a pressure slightly higher than atmospheric pressure for the particular application. However, if the steam is used for electricity production only, it might be much more effective to use a much lower exhaust pressure on the turbine, which has the effect of increasing the overall system efficiency. The equipment costs are higher for this type of turbine (as much as two or three times the cost of an extraction turbine) but the higher efficiency may very well justify the higher initial equipment cost. Figure 5.1 provides a summary of the expected fuel consumption (tons/h) for 150 and 250 psig systems.

Table 5.3
Efficiencies and Feed Rates
Tons/h of Rice Husk for
250 and 650 psig Steam Systems

	Overall Eff/Fuel Consumption[1]			
Steam Pressure	1.5 MW High	1.5 MW Low	650 kW High	650 kW Low
250 psig	10% 4.0[2]	8% 5.04	10% 1.67	8% 2.0[3]
650 psig	17% 2.35	14% 2.95[4]	N/A[5]	

Source: Calculations made by the author. Turbine efficiencies provided by Turbodyne, Inc.

1 - Figures represent both high and low efficiency figures for each respective system.
2 - More probable efficiency and consumption at 1.5 MW capacity. Assumes turbine efficiency of 55%; boiler efficiency of 60%.
3 - More probable efficiency and consumption of 600 kW capacity. Assumes turbine efficiency of 50%; boiler efficiency of 60%.
4 - Represents fuel feed rate using lower boiler efficiency (65%) based either on increased moisture content of fuel or lower other factors which may decrease system efficiency.
5 - Systems of this size would normally employ lower pressure steam systems, in the range of 100-250 psi saturated steam.

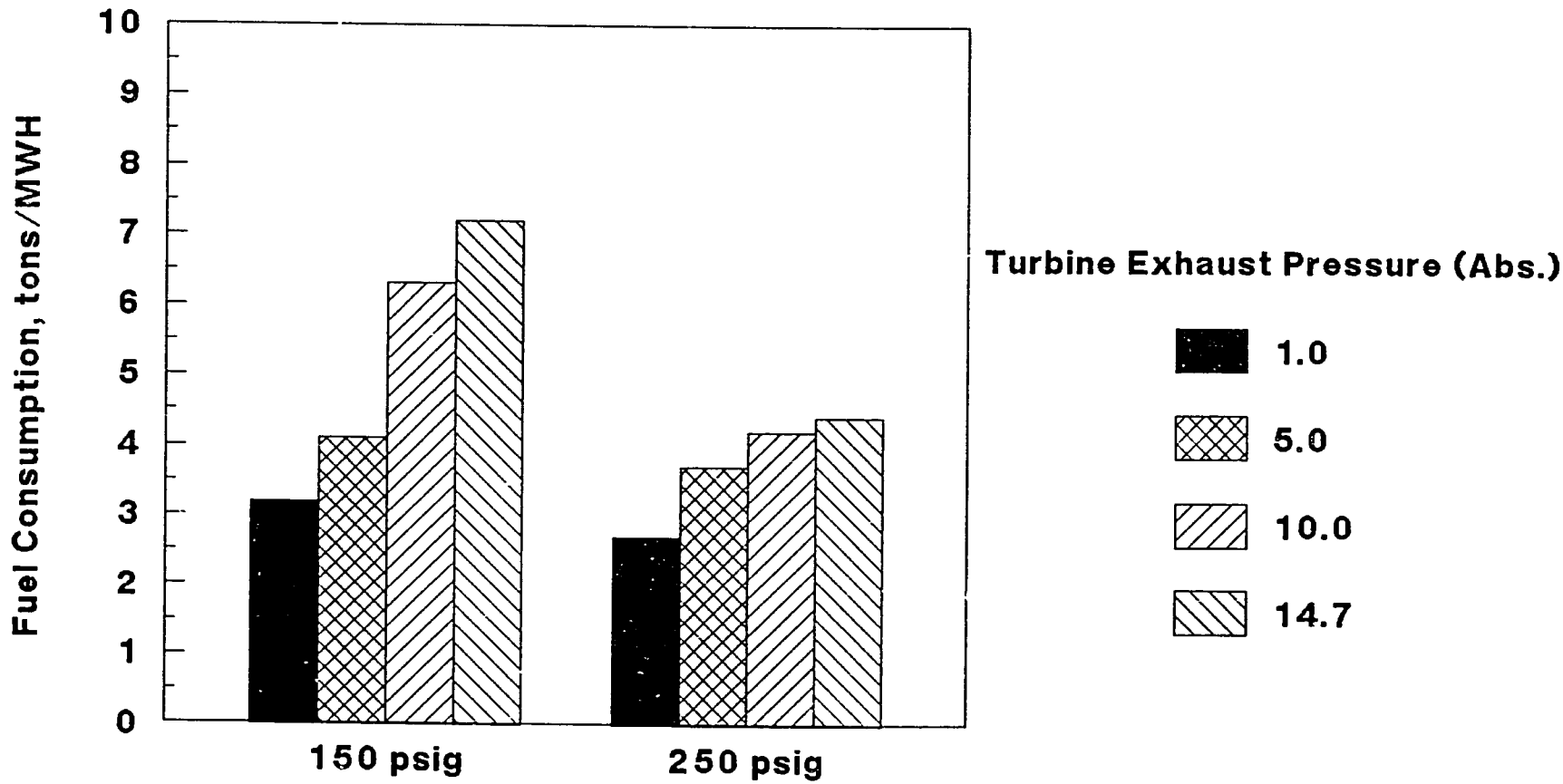


Figure 5.1 : Summary of expected Fuel Consumption (tons/MWh) for 150 and 250 psi Systems.

Risk Factors Affecting Successful Implementation

The above methodology can assist prospective users to determine amount of fuel required for a rice husk energy system for a number of various system configurations. Specifically, it provides a range of fuel fed requirements for two system sizes (1.5 MW and 650 kW) for both high and lower efficiency systems. Using this data, and with knowledge of fuel transportation costs, a buyer could then determine the direct costs and benefits of employing rice husk to generate electricity.

Managing System Risks

Ash Sales

Perhaps the single most important technical and economic factor that has assured success at the two large-scale installations in the United States has been the identification of income streams from the sale of ash from the rice husk combustion systems. By producing a high quality ash product that is attractive to steel producers, operators of both the U.S. systems have enjoyed the benefits of energy generation and product sales, one complementing the other. In the absence of ash sales, it is doubtful whether either of the two systems would be attractive as an investment opportunity. Rice power plants will need to insure that their ash by-product maintains the appropriate technical qualifications to meet end-users' specifications. Small producers could have difficulty maintaining the ash quality and establishing profitable market networks.

High Capacity

Both installations have also enjoyed high capacity factors. By the nature of a solid fuel combustion system, these systems cannot respond quickly or easily to variations in loading, and are operated most effectively (and economically) if they are base-loaded. Intermittent interruptions in demand are difficult to service, and make fuel management very difficult. This may not be a very important issue in countries with well established grid systems enjoying high system reliability, but in countries with less reliable transmission and distribution systems, grid system interruptions can cause power plant downtime when demand decreases. Such a risk can be very costly and prove to be very difficult if not impossible to control.

Contract provisions with local power companies can partially offset income losses incurred due to system failures. Such provisions can protect the interests of both parties. In the United States, it is often the case that independent power producers must maintain a minimum standard of reliability or suffer lower purchase rates by the utility. Conversely, if the utility is unable to accept the power generated by the independent power producer, compensation may be due to the generator to satisfy opportunity costs associated with the system failure.

Fuel Security

Security of fuel supply is another factor important in systems requiring importation of fuel from off-site sources. For systems which have a captive source of fuel on-site, this issue may not apply. However, for most of the systems under consideration for larger rice mills, rice husk will have to be imported to power the combustion units. If these systems are going to operate on an annual basis, it will be very important to insure that fuel will be available in sufficient quantity and quality throughout the year, not just during harvest season. In many cases, it may be necessary to provide a storage facility for the rice husks, which will add to system cost but could have the effect of reducing risk of fuel degradation.

Fuel Homogenity

Another factor which must be considered is homogenity of the fuel. Rice husk in developing countries can vary considerably from rice husk used in conversion systems in the United States in terms of foreign matter present in the fuel, the presence of "brewers" rice, and other inconsistencies. The result is that if the rice husk is not cleaned prior to introduction to the combustion zone, quite a different material could be fed into the furnace than expected. For suspension combustion systems, this can cause a variety of problems.

Combustion Characteristics

It is also necessary to insure that the fuel is of uniform combustion characteristics. Use of a mixture of dissimilar fuels, such as use of rice husk combined with rice straw under varying feed conditions can cause a variety of boiler control problems. The two materials have similar heating values, but rice straw has a much lower melting point. Furthermore, unless both materials are ground to similar particle size, the residence time for complete combustion will vary with the change in proportional mixing rate of the two materials. This may not be problem which will cause system failure, but it introduces a need for a higher level of system management than if a singular fuel source is used. The problems of using two dissimilar fuels should not be taken lightly and should not be underestimated, especially under field conditions in remote areas.

Other factors requiring management intervention include: maintenance capabilities, institutional cooperation (such as the necessity for one government agency to interact with another) and the need to change an existing mode of operation within a particular system or organization.

Any of these factors taken by itself can potentially cause severe problems with project success, both from technical and financial perspectives. Therefore, it is recommended that each factor be carefully considered in the pre-feasibility and feasibility analyses to define risk and determine its impact on the project. Fuel supply, fuel price projections, capacity factors, relationships with key government institutions and equipment reliability and maintenance concerns should all be very carefully considered in the analysis. When changes in traditional methods of fuel collection and distribution are required to assure adequate quantity of rice husk, the high risk associated with such an innovation must be recognized.

CHAPTER SIX

ECONOMICS OF RICE RESIDUE ENERGY SYSTEMS IN INDONESIA

Economics of Rice Production in Indonesia

Rice is the main staple in the diet of Indonesians; rice production is basic to the livelihood--jobs, income, and diet--of rural and urban people. The government's high priority program for the rice sector with its infusion of substantial subsidies for farm inputs such as fertilizer, credit, pesticides, and extension over the last decade has been extremely successful. Rice production grew by almost six percent annually between 1976-1985, shifting Indonesia from a status of rice importer to exporter in 1985 [1].

In 1983, the agricultural sector contributed over 30% of the value-added in the economy and about 30% of the GDP. Rice production represented over 50% of agriculture's value-added, meaning that rice production directly contributed 15% of the value-added to the economy [2]. Approximately 60% of Indonesians live in rural areas, with over 50% working directly in agriculture [3]. Given the importance of rice production to Indonesia's agriculture, it is fair to assume that rice production provides direct or seasonal employment to most of these agricultural workers [4]. Many of the imputed costs of rice production are attributed to family workers, which compose 50% of the labor value (see Annex IV Table A4.1) [4]. In addition to the direct value in the economy from rice production is the significant indirect income and employment related to the post-harvest processing sector.

By improving agricultural waste utilization with rice residue energy systems, additional off-farm incomes and jobs may be created while also increasing the value-added of the milling process through domestic sales of energy and export revenues from ash by-products. The energy and labor factor content in rice milling, relative to other Indonesian industries, is low (see Annex IV Table A4.2) [5]. Given the trend over the past decade towards less capital intensive, smaller mills, labor content probably increased. If rice mills produce higher quality rice, a shift towards larger plants means that the labor content per ton processed may fall over time and the mills will capture greater scale economies for product differentiation.

Economic Characteristics Affecting Rice Residue Energy Systems

The employment, income, and industry diversification opportunities of rice residue energy systems will be important to areas where systems can be commercialized in Indonesia. However, given the site specific economics of these energy systems and the particular size characteristics of the Indonesian rice industry, commercialization has yet to be proven and currently faces important barriers. Potential changes in the industry that are evolving--a tendency towards some

larger mills due to product specialization, the strong demand for rice in contrast to recent leveling of yield increases, and local investment restraints--will create a dynamic but countervailing market for rice residue utilization. Key factors to influence commercialization of rice power systems are the scale economies of the steam or power generation systems, costs of a transport network for hauling husk (or straw), availability of by-product (ash) markets for export, access to financing, and political commitment to private power generation.

Rice Milling Versus Electric Generation Scale Economies

To ensure all villagers had access to milling, to increase national marketing potential, and to raise employment and incomes in the rural areas, the GOI encouraged the milling industry to decentralize over the past decade through an emphasis on smaller milling equipment [4]. With over 61,000 mills, the average capacity of 50% of these mills is extremely small, 1-4 metric tons per day, as contrasted with the existence in Thailand of several 1,000 ton/day mills [5]. The present scale of rice milling in Indonesia makes it impossible for the vast majority of mills to supply enough husks from their own mills to meet the requirements of the commercially proven scale of residue power (not necessarily steam) systems. Unless husk can be economically collected, transported and used as a boiler feedstock such power systems can be viable only where clusters of mills or perhaps large associated mills operate.

The scale economy barrier may become less critical if product differentiation occurs in the domestic Indonesian rice market. With continual increases in rice yields, the Indonesian rice market is beginning to see product differentiation with the emergence of high priced (600-900 Rp/kg versus 300-400 Rp/kg), high quality rice [4]. It is possible that such product differentiation will gradually reverse the decentalization trend in some areas, since larger, more modern mills are needed to produce higher quality products. With a substantial projected excess demand, more rice will need to get to market. Greater pressure will be put on the Indonesian rice industry to continue increasing yields, centralize, and modernize its processing facilities. Current underutilization in milling, estimated to be 30% of capacity, could be readily absorbed, but eventually new mills will need to be built.

However, at least two factors may impede movement towards larger mills. First, a government analysis has shown that small millers receive higher net returns per ton milled than larger millers due primarily to the larger quantity per ton milled and high price of brokens at small mills. If such cost relationships are substantiated, financial discentives may act against increasing scale economies in milling unless higher product prices for high quality rice sufficiently off-set the loss in revenue from fewer brokens per ton milled at larger mills. Second, the domestic market for high quality rice is unknown and limited mostly to middle and high income urban consumers. An export market potential exists, but it is difficult to break into for high quality rice particularly with world prices having declined in real terms over

the eighties. Hence, only a limited quantity of larger mills probably will develop in the immediate future. Proposed rice energy systems would need to identify and locate near such larger mills, most likely close to urban centers.

Current and Potential Rice Residue Uses

The majority of rice husk and straw in the country is wasted or has low market value. Anywhere from usually 10%-40% is used depending upon highly variable local patterns. If sold commercially, farm gate prices for rice husk generally run 2-5 Rp/kilo bag (0.2 US¢/kilo bag) to be used by brickmakers (in villages it is often given "free" to the brickmaker [6]), sold at rural or urban markets as domestic cleaners or used as chicken feed (Table 6.1).

Similarly, rice straw has few but occasionally important competing uses. The primary value is for nutrient recycling by return of the straw to the fields. The actual monetary, nutrient value and importance in terms of fertilizer is unknown. Agronomists are skeptical given the limited nutrient content of rice straw and believe the uncut stub and root structure left in the field may satisfy this need. Minimal use for mushroom growing, cattle feed, and as filler at pulp mills is reported [7]. More information on pulp mill use of rice straw at Padalarang is needed by any one attempting to develop a transport system for straw.

Transport Network

To support its rice industry, the GOI greatly improved the transport sector in major rice producing regions to increase local access to markets and to facilitate movement from rice surplus to rice deficit regions [8]. Many rice producing regions On-Java reportedly have adequate secondary transport systems to support husk collection. Again, however, there is significant variation in transportation quality from region to region. Assessment of residue energy system feasibility will depend heavily on adequate evaluation of how the transport system will affect the quality of the delivered husk.

By-Product Markets

A fundamental theme in Indonesia's agricultural strategy is to increase the value added to raw commodities through encouragement of agricultural waste processing industries. Increasing mill production efficiencies and the number of by-products can raise net returns to the mill owner, and possibly rice farmers, provided that government pricing policies favor such improvements in the industry. Greater utilization of rice waste by-products--bran, husk, and ash--offers new markets.

Improved scale economies and installation of rice residue energy systems can offer important new sources of revenue to the rice industry through 1) energy sales and imported fuel displacement savings, 2) significant export revenues (hence, foreign exchange earnings) from the sale of the silica ash by-product produced from rice residue power plants; and 3) larger quantities of high grade rice due to more efficient milling technologies.

The national benefits include a new source of foreign exchange from ash sales ($45-200/ton), more total marketable rice, and foreign exchange savings as well as lower government expenditures for diesel subsidies (currently 50% of diesel costs) through fuel displacement. The world ash market appears to be fairly large due to the demand in the steel industry for lading materials. In-depth analysis of the market is important to the success of rice power systems. As long as the rice and export pricing structures favor increased mill efficiencies, these three factors can increase the value added to the industry and agricultural sector.

Diversifying into energy production also could catalyze rather than preclude utilization of other high value rice mill wastes such as bran. The Japanese are the farthest along in exploring alternative uses for stabilized bran although several U.S. companies are also marketing advanced stabilization technologies [9]. Plans to use husks or straw for other higher value products such as furfural or the paper industry appear to have long, rather than near, term potential. Rice residue energy use may offer the best intermediate solution to the industry due to its multiple-product advantages--energy and ash.

Table 6.1

Alternative Uses and Prices
of Rice Husk and Straw

Feedstock	Farm Price (Rp/kg)	Retail Price (Rp/kg)
Husk		
Brick Making	3-4	-
Feed	5	-
Cleaner	2-5	100-200*
Straw		
Pulp	3	-

*Range represents reported Bogor (100 Rp/kg) versus Jakarta (200 Rp/kg) prices.

Source: Team Estimates.

Mill Ownership

Most mills reportedly are owned by extended families who may also handle the transport-wholesale-retail chain. Organizing by cooperatives or attempting to form consortia of different rice mills to gain scale economies for energy systems may therefore be difficult unless such ventures build upon the existing ownership pattern in the region. Groups of interested private entrepreneurs or mills located near large government storage facilities may be the likeliest target groups to work with for installing initial rice energy systems.

Labor and Land

On-Java, with its extremely dense population, no shortages of labor would exist to prevent collection of rice husk or straw; in fact energy systems can provide some badly needed rural employment. No shortages also would exist Off-Java. Although unskilled workers' wages are about 60% higher than On-Java, no significant pressure would be put on wages if rice residue energy systems were introduced because of the few opportunities that exist to install such power plants. In fact, such systems would bring needed employment (3-4 jobs) at mills and additional farm and off-farm income to the rural areas for unskilled and relatively skilled workers. For some regions On-Java, land availibility is a problem because of population pressure and resulting high land rents. Off-Java, land acquisition for businesses should be less difficult.

Financial Climate

In interviews with the government and private banks, a general consensus developed that in general adequate private investment funds are available in Indonesia for financing new ventures. Compared to alternative private power investments, rice residue energy systems will require quite small (US$ 2-5 million) investments, and could be handled by regional or possibly cooperative banks.

However, the climate for making private investments in rice residue power systems is very risky for several reasons. First, Indonesian investors expect extremely short payback periods, 6 to 18 months, due to the recent devaluation and pressure on the economy from loss of oil revenues [10]. In the United States, commercial rice residue systems, albeit of much larger size than needed in Indonesia (12-25 MW vs. 1.5-4 MW), have payback periods of 2-3 years [11]. Second, local firms appear reluctant to finance or provide equity for some international joint investments. Given the high rates of return expected on investments, 25-35% in nominal terms [12], local hesitation is understandable. Third, investment insecurity is a major deterrent to private power generation investment in Indonesia. A strong commitment by the government to support private power contracts by assuring the sanctity of contracts with a public utility is needed to attract the private investor (see contractual requirements in Chapter Seven). Foreign entities (equipment manufacturers, donor agencies, or investment banks) also will require the necessary contractual, as well as technical, commitments to insure local and public participation.

Financial and Economic Assessment Models

Since no commercial systems for rice residue energy production currently exist in Indonesia, these analyses must be considered as only indicative, not definitive, of the economic potential. Biomass systems' economics are highly site specific. Before any investments can be seriously recommended, detailed site and technical analyses must be made on a proposed project.

Rice residue energy systems in Indonesia, like any new venture, carry particular economic uncertainties that must be identified and minimized to the extent possible before the systems can be seriously considered. The major cost uncertainties for rice residue energy systems include:

1) feedstock (husk or straw) costs due to unknown demand and price elasticities;

2) capital investment requirements due to the need to redesign the boilers to more closely fit Indonesia's milling scale economies;

3) unknown electricity buyback rates or purchase prices resulting from the absence of existing baseload or firm power contracts; and

4) potentially low capital utilization rates (i.e., operating days) in rural areas due to wide regional differences in load factors.

Each type of uncertainty is considered in the following generic models of stand-alone power systems by making sensitivity analyses on specific costs and benefits. These models are developed to highlight the key areas of financial and economic risk involved with rice residue power systems.

Model Assumptions

Due to the uncertainty of many variables that will impact the economics of rice residue power systems in Indonesia, several scenarios of the models are presented. The basic difference of the models is plant scale. Both 600 kW net (250 psig) and 1.5 MW net (650 psig) systems are developed since these sizes cover the technically appropriate range of rice residue power systems for Indonesia. For each scale plant, a variety of sensitivity analyses are made using different assumptions regarding the husk price, number of operating days, ash price, electricity purchase price, capital costs, and discount rates of the systems (see Annex V for a full description of the models and model assumptions).

Model Results

The results of the financial and economic assessments can be seen in Figures 6.1 to 6.6 and in Tables 6.2 to 6.11. In Figures 6.1 and 6.2, four basic scenarios for each plant size are presented for the 600 kW and 1.5 MW system, respectively:

67

Figure 6.1

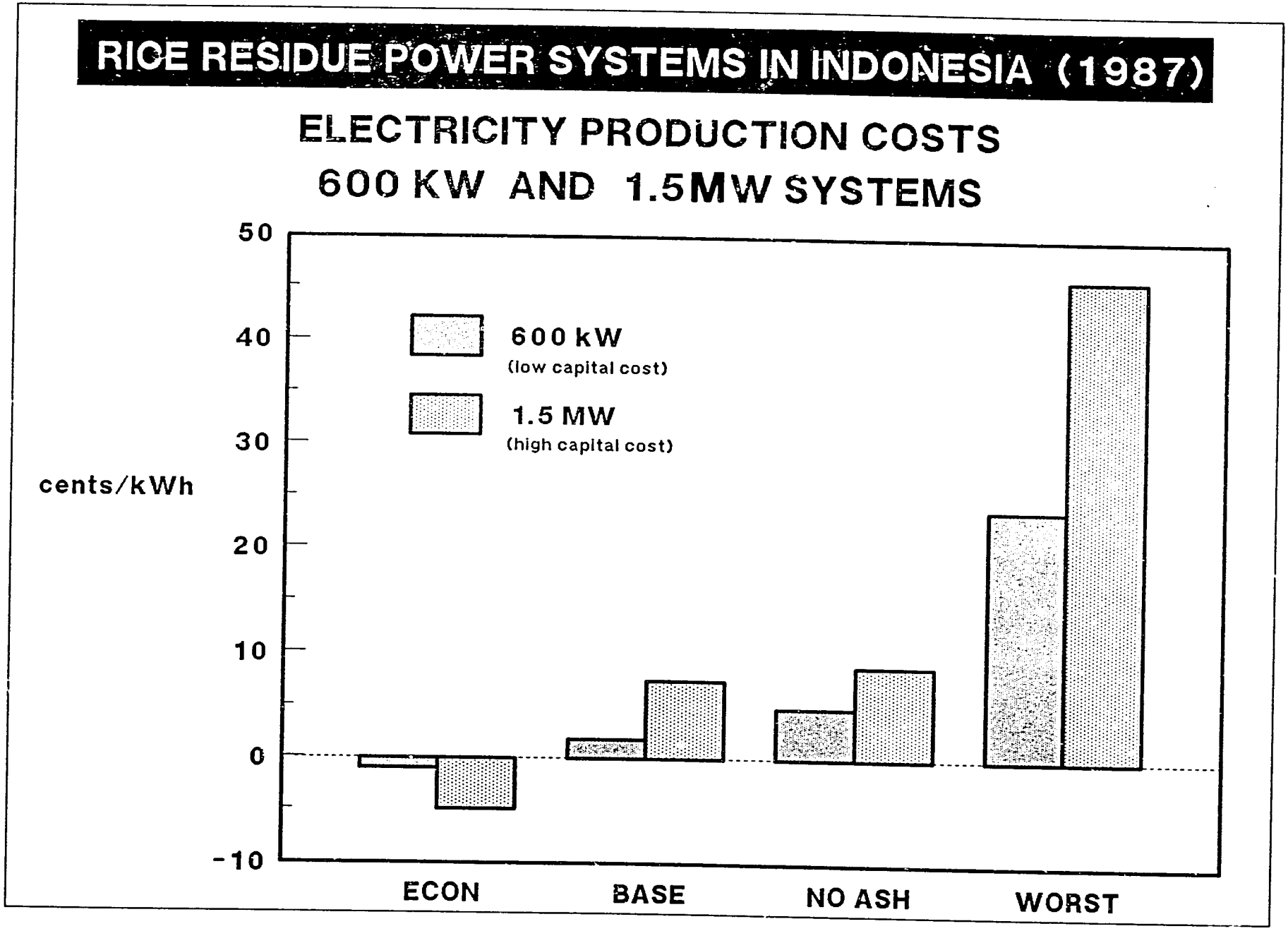
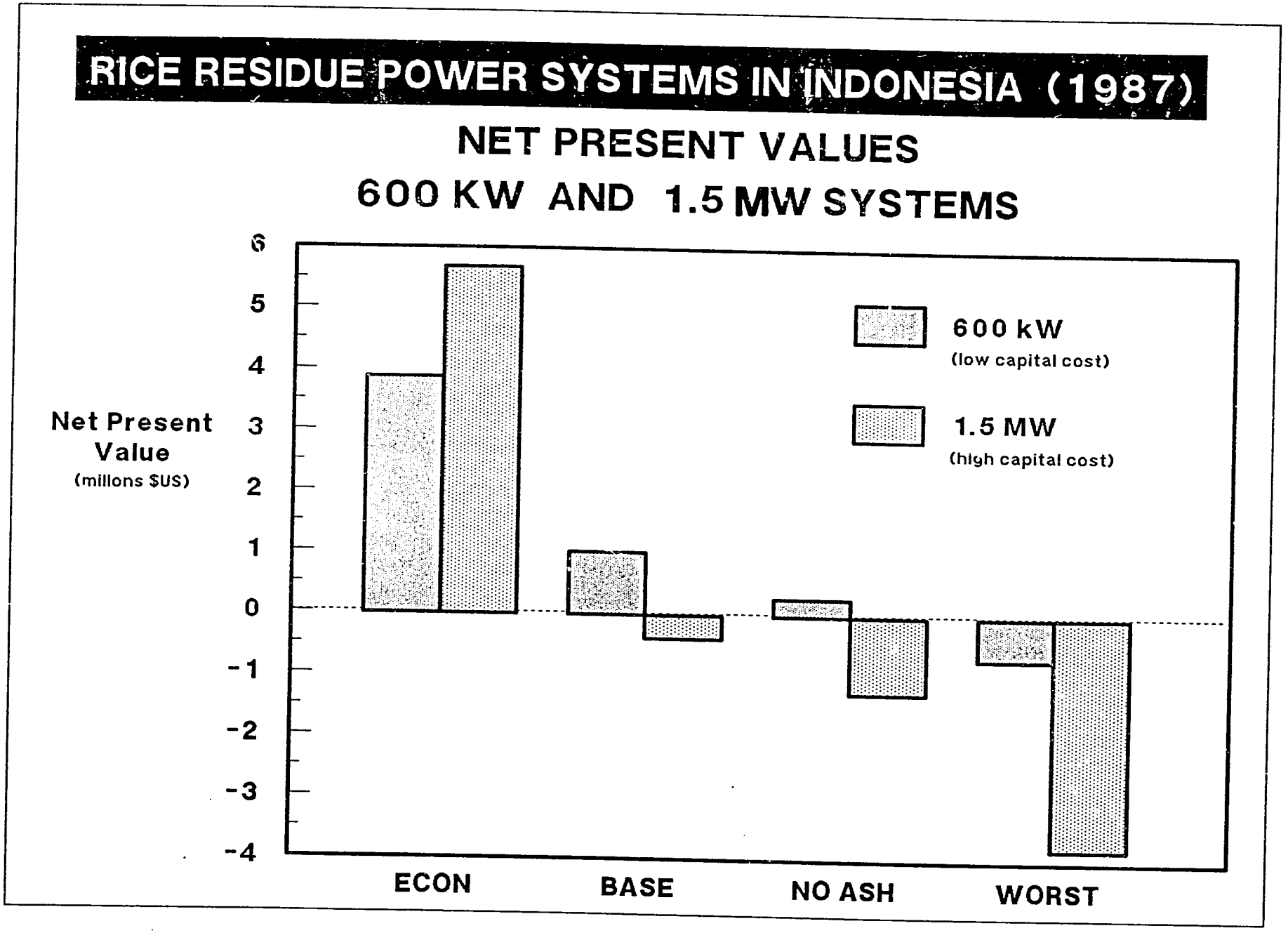

RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)
ELECTRICITY PRODUCTION COSTS
600 KW AND 1.5MW SYSTEMS
cents/kWh
50
40
30
20
10
0
-10
600 kW
(low capital cost)
1.5 MW
(high capital cost)
ECON
BASE
NO ASH
WORST

Figure 6.2


RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)
NET PRESENT VALUES
600 KW AND 1.5 MW SYSTEMS
Net Present Value
(millons $US)
6
5
4
3
2
1
0
-1
-2
-3
-4
600 kW
(low capital cost)
1.5 MW
(high capital cost)
ECON
BASE
NO ASH
WORST

1) a "base" or financial analysis case that uses the current or expected market prices for the systems' costs and benefits;

2) a "no ash" case, which is a variation of the base case but where no ash sales are included;

3) a "worse" case scenario where market prices are high for husk but electricity and operating days low and no ash sales exist; and

4) an "economic" case where higher feedstock and the full avoided costs of electricity are used in the models (see Annex V for prices).

As shown in Figures 6.1 and 6.2, these basic cases demonstrate the absolute importance of ash sales to the viability of rice power systems.

In Figures 6.3 to 6.6 and Tables 6.2 to 6.11, more detailed sensitivity analyses are presented on capital costs, husk price, ash price, operating days and electricity prices. The findings shown in these figures support the following general conclusions:

- The 600 kW (250 psig) systems are more financially and economically attractive than the 1.5 MW (650 psig) systems due to the formers' substantially lower capital costs*. These costs are lower for the 600 kW systems primarily because they are run at much lower psig than the 1.5 MW systems and require less costly feedstock preparation equipment and other hardware.

- Assured sale of the ash to a guaranteed market is absolutely essential to the viability of all systems, particularly 1.5 MW systems. This by-product market is the major factor that determines whether these systems are attractive investments.

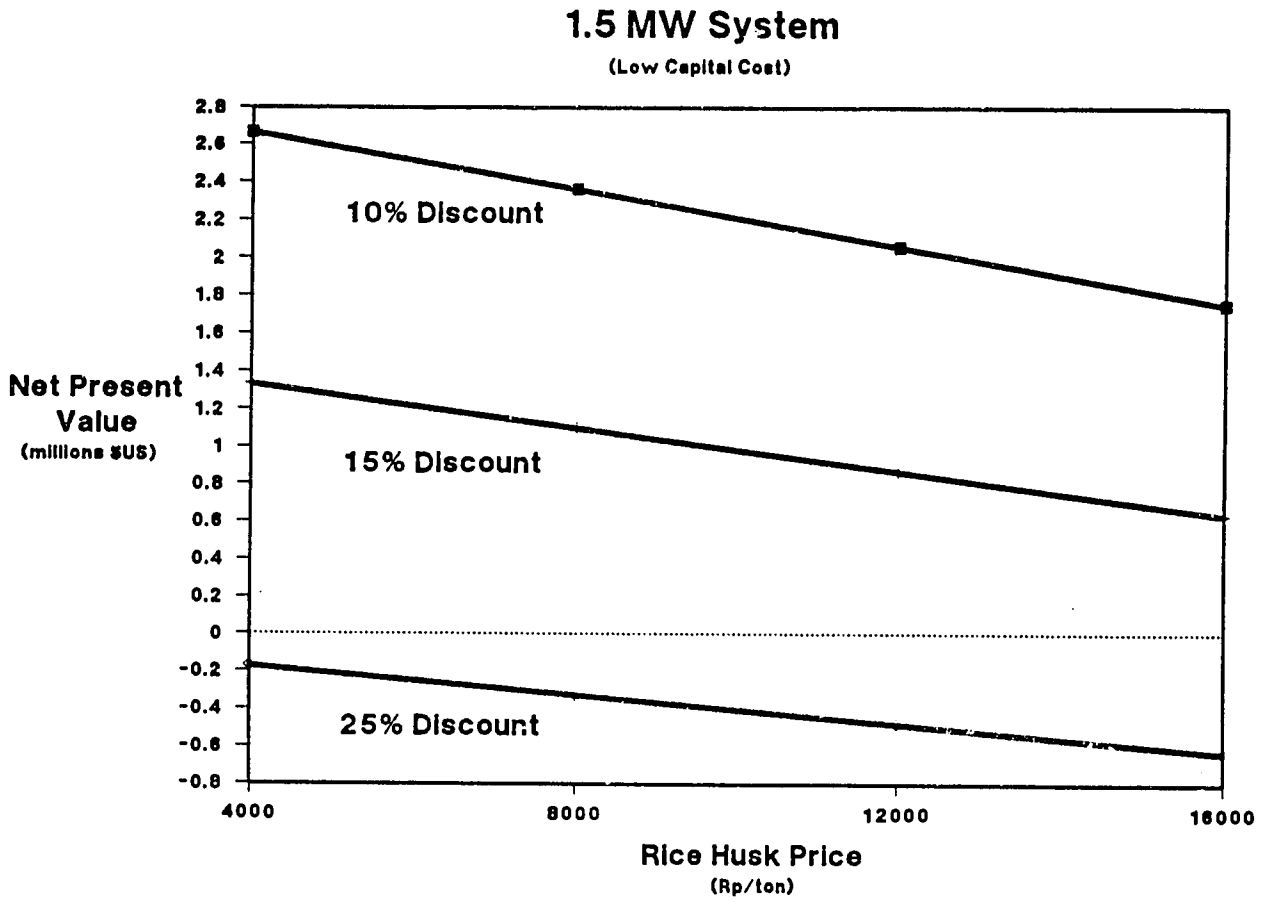
- Ability to achieve high load factors at a power plant is fundamental to the viability, financial or economic, of any system. It is particularly important to the larger system, which must be run close to a full operating schedule, near 290 days per year if high capital costs are assumed and 240 days if low capital costs are assumed. In contrast, 600 kW systems have far less stringent operating day requirements.

- The level of the PLN electricity purchase price is less important to the 600 kW than the 1.5 MW system. It can fall within a wider band for 600 kW systems to be financially and economically feasible but must be at or above the current tariff rates when low capital costs are assumed for the 1.5 MW system and at or near the full avoided costs for the larger 1.5 MW system when high capital costs are used.

* In contrast, one expects scale economies to favor 1.5 MW over 600 kW systems. However, as noted above these plants are very different technically.

6k

FIGURE 6.3


1.5 MW System
(Low Capital Cost)
Net Present Value
(millions $US)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
10% Discount
15% Discount
25% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

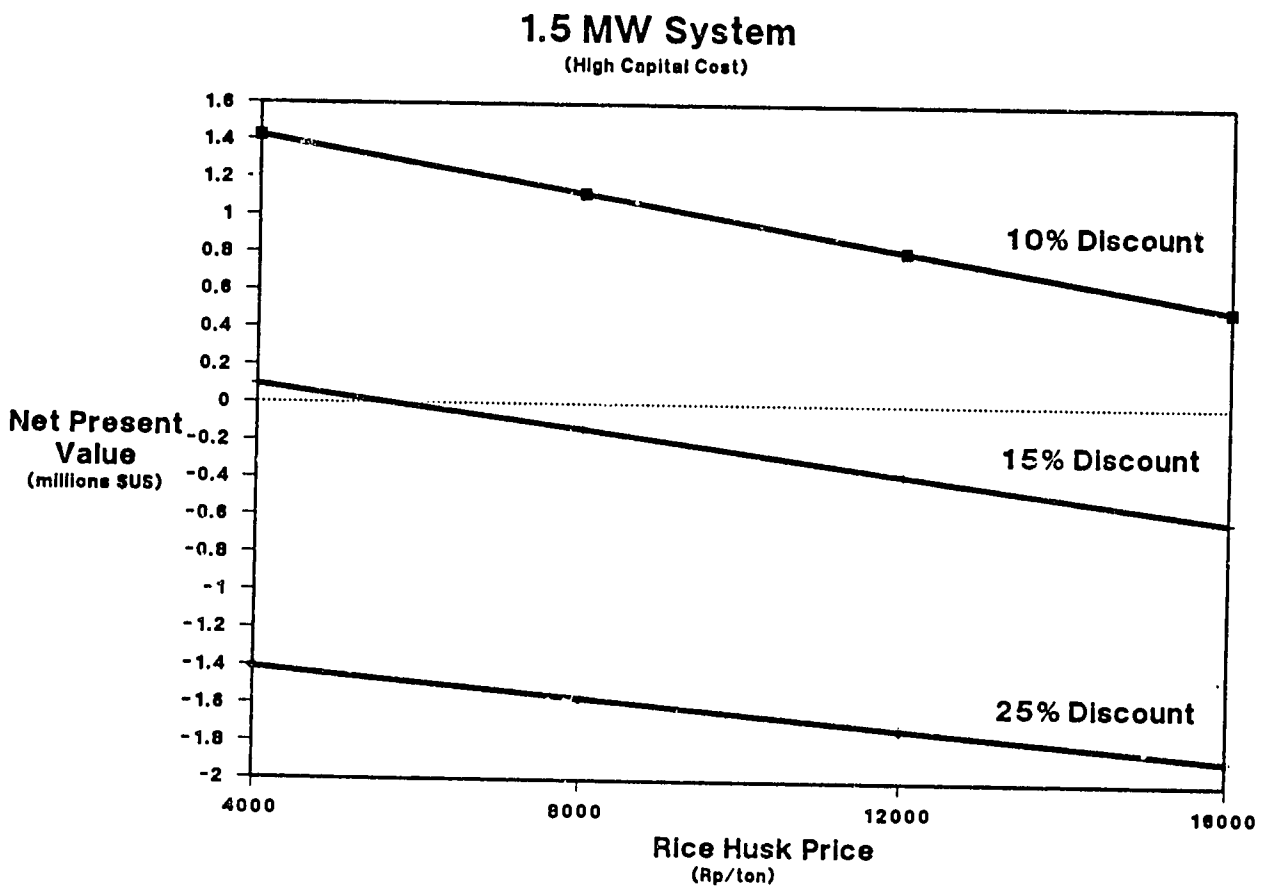
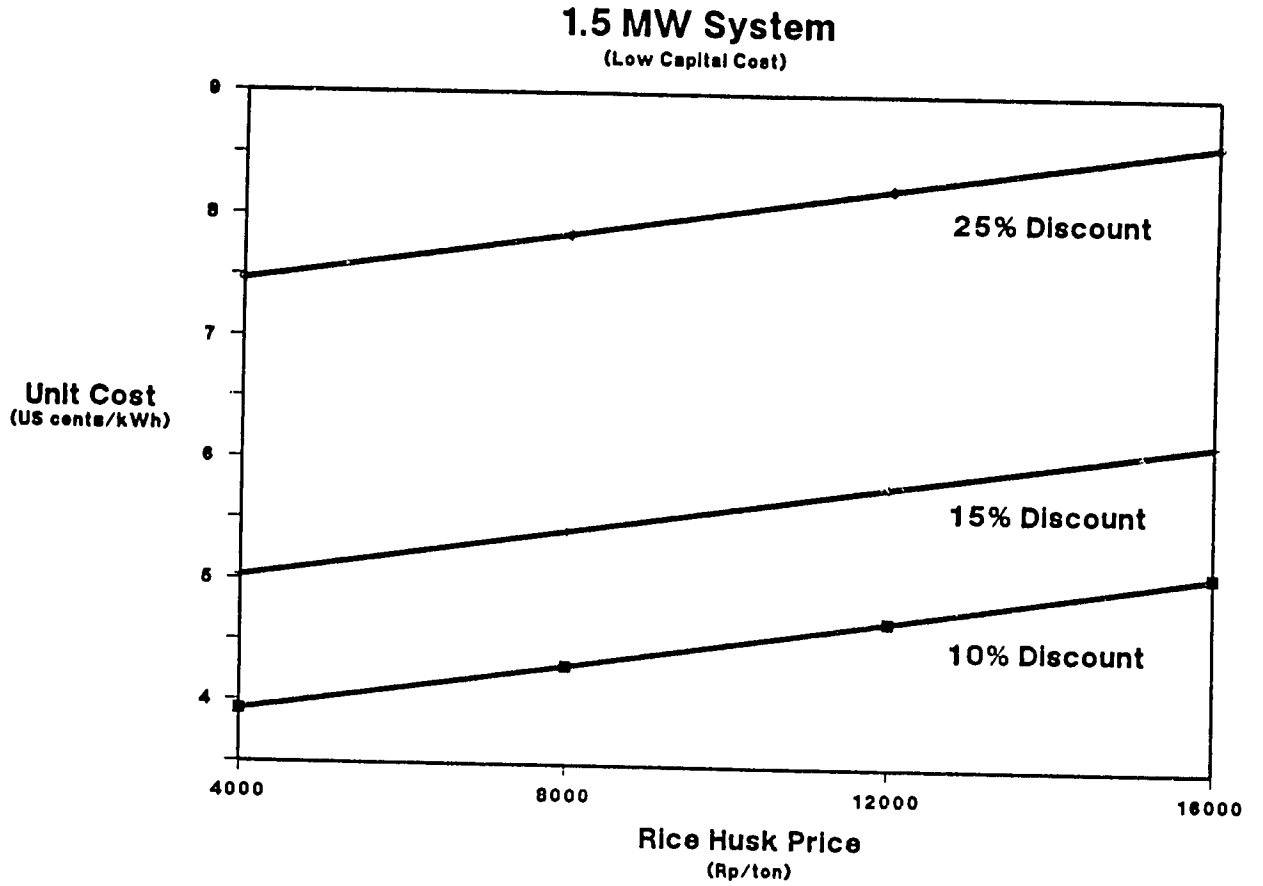

1.5 MW System
(High Capital Cost)
Net Present Value
(millions $US)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
10% Discount
15% Discount
25% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

FIGURE 6.4


1.5 MW System
(Low Capital Cost)
Unit Cost
(US cents/kWh)
9
8
7
6
5
4
25% Discount
15% Discount
10% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

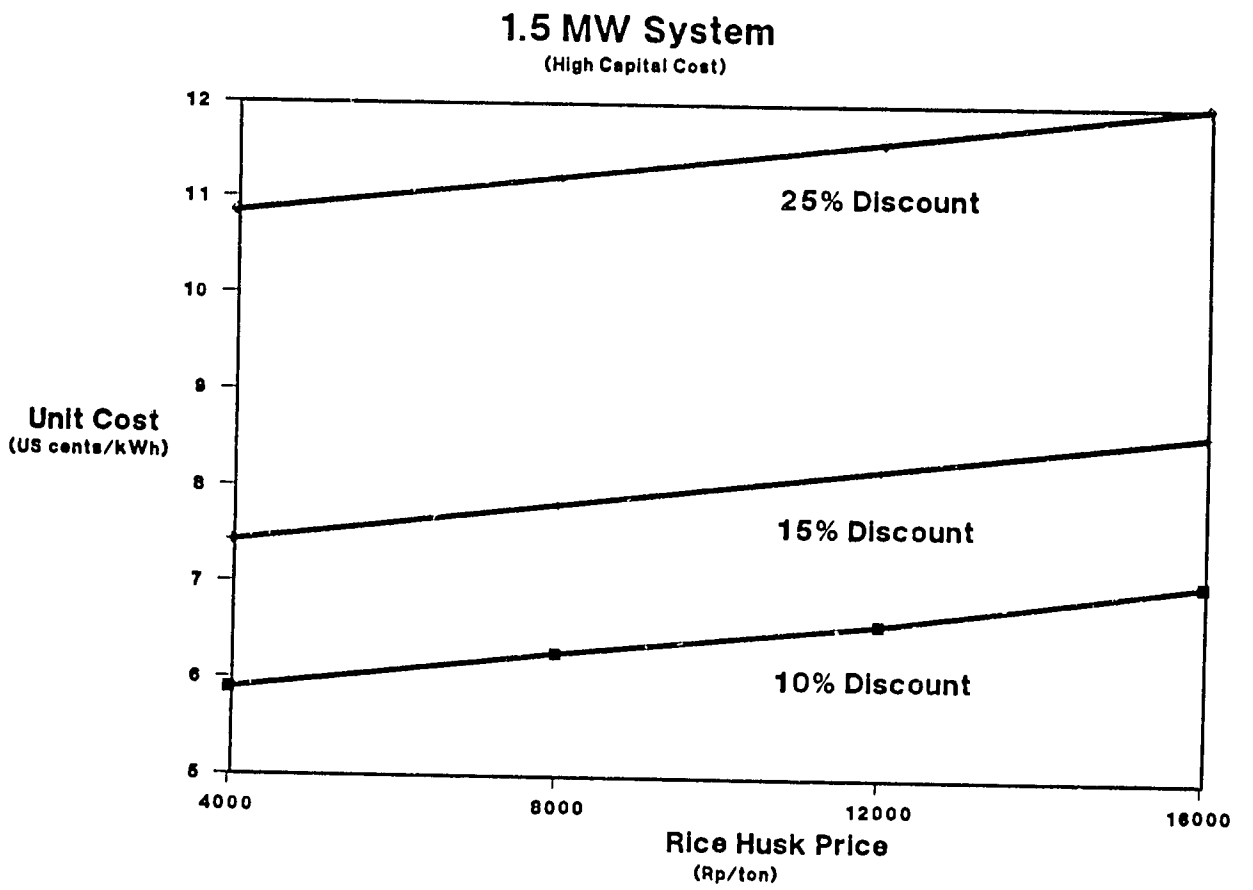
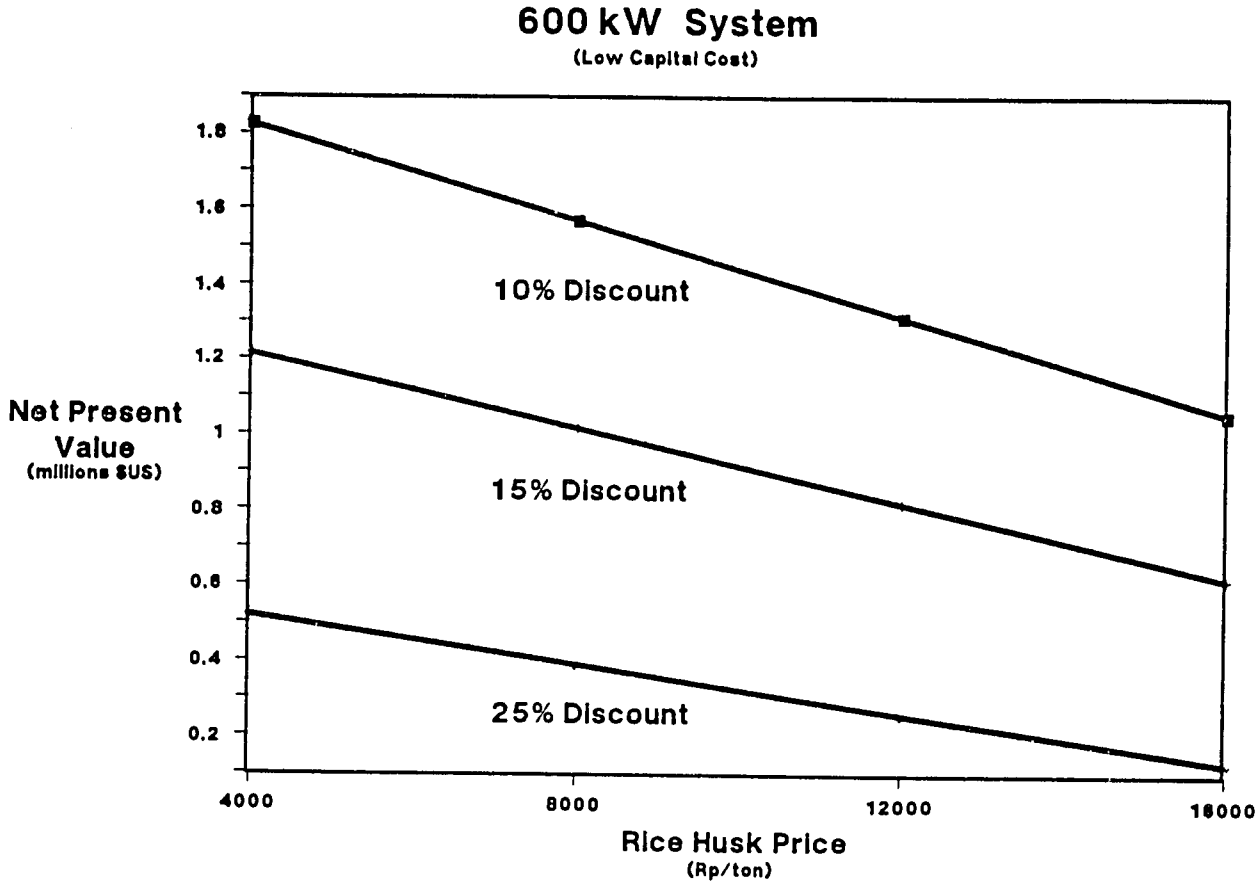

1.5 MW System
(High Capital Cost)
Unit Cost
(US cents/kWh)
12
11
10
9
8
7
6
5
25% Discount
15% Discount
10% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

FIGURE 6.5


600 kW System
(Low Capital Cost)
Net Present Value
(millions $US)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
10% Discount
15% Discount
25% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

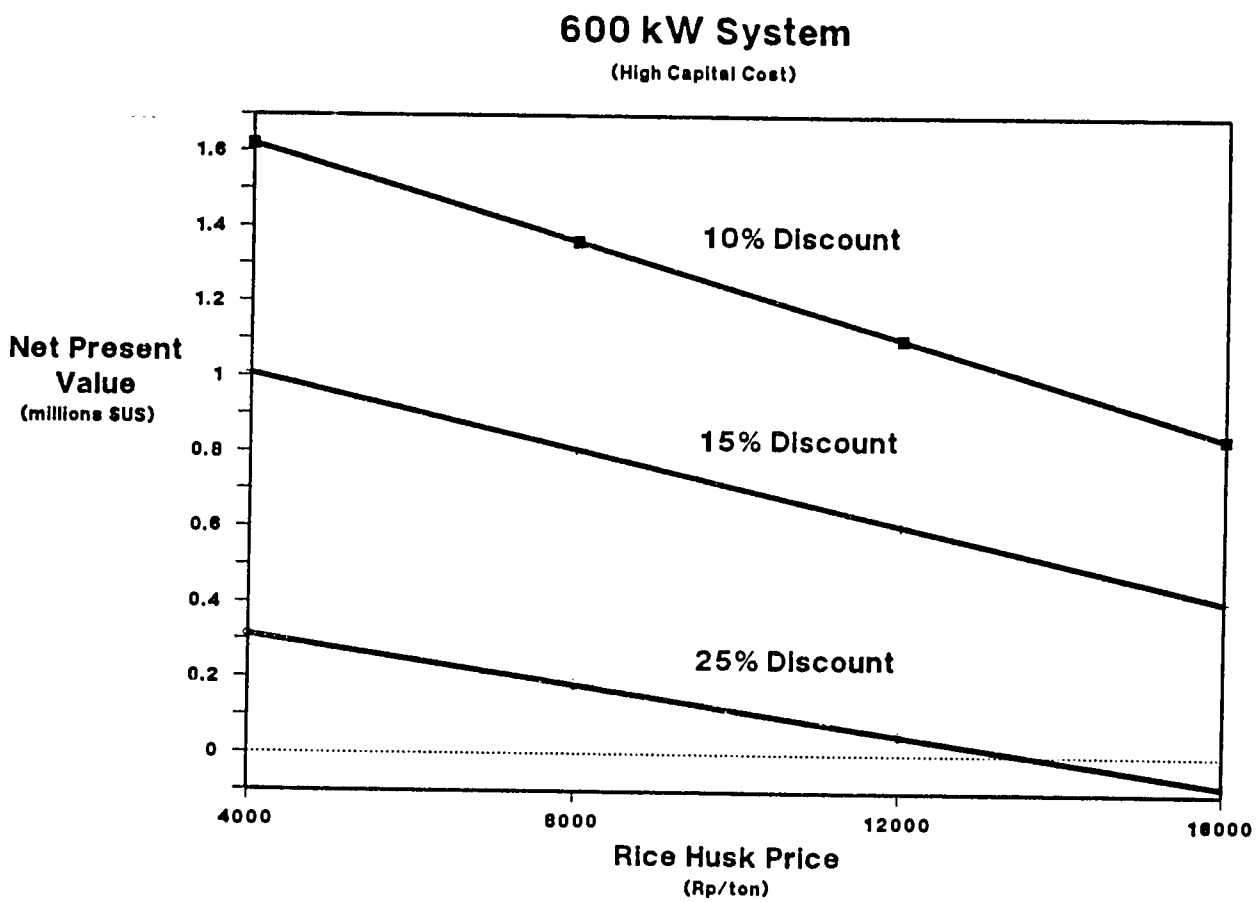
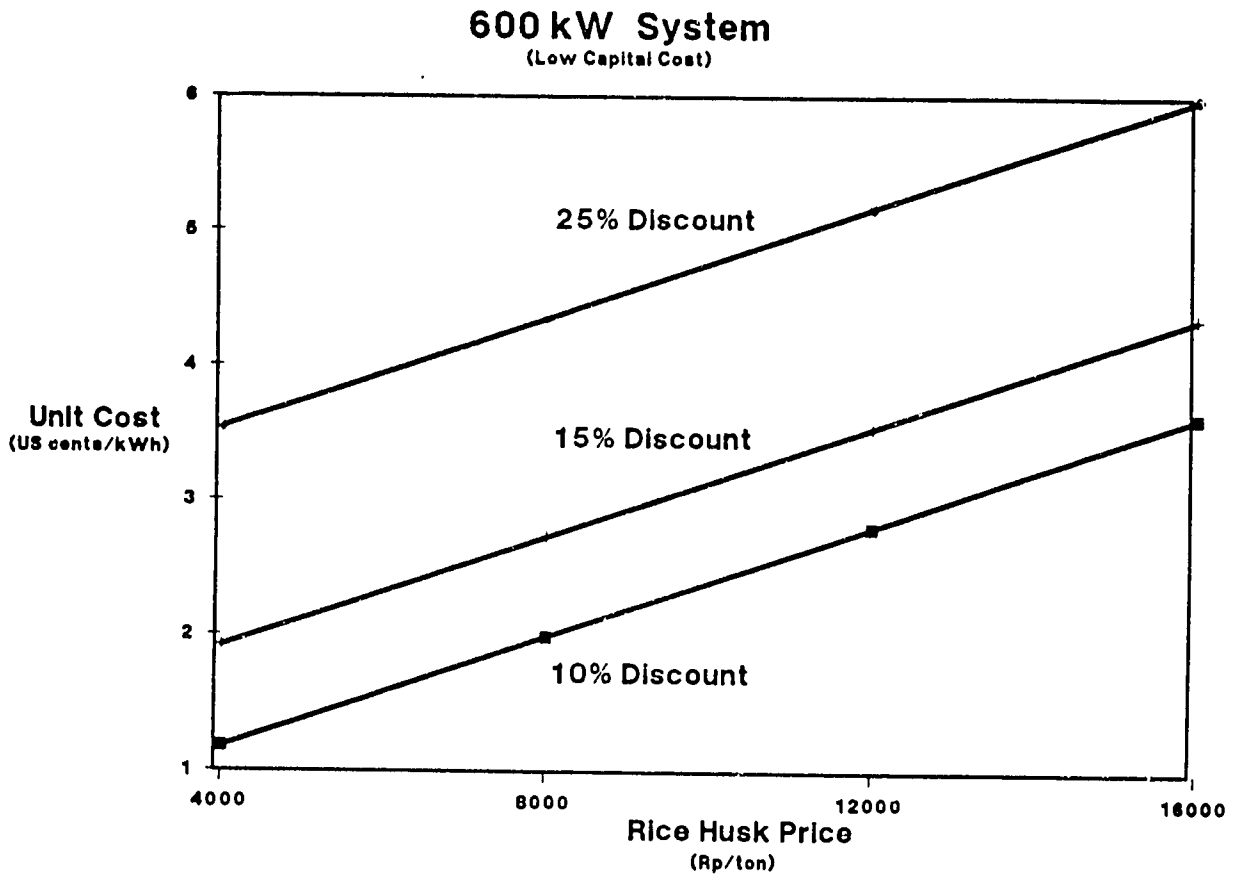

600 kW System
(High Capital Cost)
Net Present Value
(millions $US)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10% Discount
15% Discount
25% Discount
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

FIGURE 6.6


600 kW System
(Low Capital Cost)
Unit Cost
(US cents/kWh)
25% Discount
15% Discount
10% Discount
1
2
3
4
5
6
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

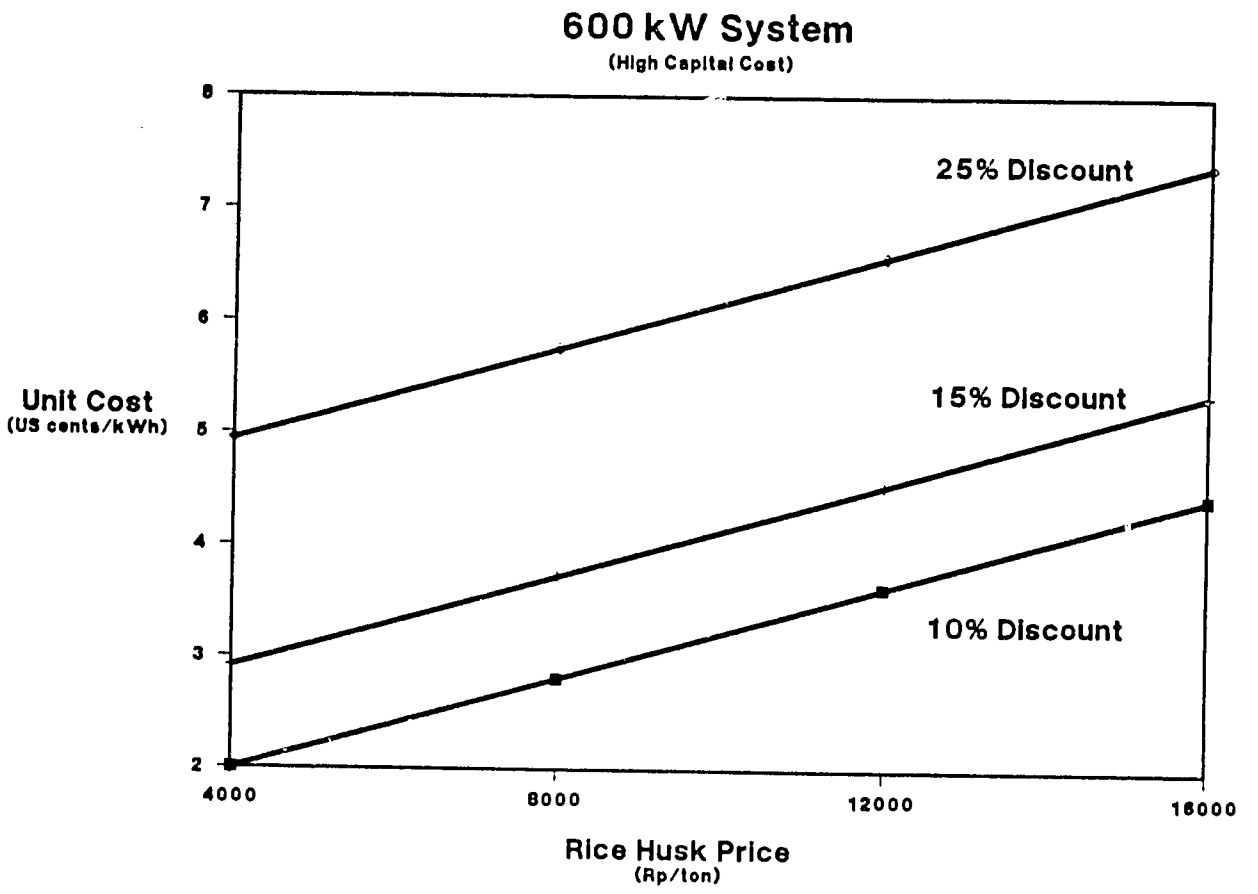

600 kW System
(High Capital Cost)
Unit Cost
(US cents/kWh)
25% Discount
15% Discount
10% Discount
2
3
4
5
6
7
8
4000
8000
12000
16000
Rice Husk Price
(Rp/ton)

Table 6.2
1.5 MW System

Net Present Value
(US$ Thousands)

Electricity Purchase Price (Rp/kWh)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
75	1311	294	-858	70	-944	-2096
90	2038	852	-490	796	-386	-1728
103	2667	1336	-170	1426	98	-1408
174	6105	3979	1574	4864	2741	360

Table 6.3
1.5 MW System

Net Present Value
(US$ Thousands)

Ash Price (US$/ton)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
0	1547	476	-738	306	-763	-1977
30	2294	1049	-360	1053	-189	-1598
45	2667	1336	-170	1426	98	-1408
90	3787	2197	398	2546	959	-840
150	5279	3345	1155	4038	2106	-83

Table 6.4
1.5 MW System

Net Present Value
(US$ Thousands)

Annual Operating Days	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
140	-315	-956	-1683	-1556	-2195	-2922
200	878	-39	-1078	-363	-1278	-2316
245	1772	648	-624	531	-590	-1862
260	2070	878	-473	829	-361	-1711
275	2369	1107	-321	1128	-131	-1500
290	2667	1336	-170	1426	98	-1408

Table 6.5
1.5 MW System

Unit Cost
(US cents/kWh)

Ash Price (US$/ton)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
0	5.34	6.44	8.88	7.31	8.84	12.26
30	4.40	5.50	7.94	6.37	7.91	11.32
45	3.93	5.03	7.47	5.90	7.43	10.85
90	2.52	3.62	6.06	4.49	6.03	9.44
150	0.64	1.74	4.18	2.61	4.15	7.56

Table 6.6
1.5 MW System

Unit Cost
(US cents/kWh)

Annual Operating Days	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
140	9.20	11.48	16.53	13.26	16.46	23.52
200	6.14	7.74	11.27	8.99	11.23	16.18
245	4.83	6.14	9.02	7.16	8.99	13.02
260	4.50	5.73	8.45	6.69	8.41	12.22
275	4.20	5.36	7.93	6.27	7.90	11.50
290	3.93	5.03	7.47	5.90	7.43	10.85

Table 6.7
600 kW System

Net Present Value
(US$ Thousands)

Electricity Purchase Price (Rp/kWh)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
75	1284	797	246	1078	591	39
90	1575	1020	393	1368	814	187
103	1826	1214	521	1620	1008	314
174	3202	2271	1219	2995	2065	1012

Table 6.8
600 kW System

Net Present Value
(US$ Thousands)

Ash Price (US$/ton)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
0	874	281	37	667	275	-169
30	1509	970	360	1302	763	153
45	1826	1214	521	1620	1008	314
90	2779	1946	1004	2573	1740	798
150	4050	2923	1649	3843	2717	1443

Table 6.9
600 kW System

Net Present Value
(US$ Thousands)

Annual Operating Days	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
140	454	159	-176	248	-47	-382
200	1003	581	103	797	375	-103
245	1425	897	312	1208	691	106
260	1552	1003	382	1345	797	175
275	1689	1108	451	1483	902	245
290	1826	1214	521	1620	1008	314

Table 6.10
600 kW System

Unit Cost
(US cents/kWh)

Ash Price (US$/ton)	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
0	4.18	4.92	6.54	5.00	5.92	7.95
30	2.18	2.92	4.54	3.00	3.92	5.95
45	1.18	1.92	3.54	2.00	2.92	4.95
90	-1.18	-1.08	0.54	-1.00	-0.08	1.95
150	-5.82	-5.08	-3.46	-5.00	-4.08	-2.05

Table 6.11
600 kW System

Unit Cost
(US cents/kWh)

Annual Operating Days	Low Capital Cost Discount 10%	15%	25%	High Capital Cost Discount 10%	15%	25%
140	4.69	6.21	9.58	6.39	8.29	12.49
200	2.65	3.72	6.08	3.84	5.17	8.12
245	1.78	2.65	4.58	2.75	3.84	6.24
260	1.56	2.38	4.19	2.47	3.50	5.76
275	1.36	2.13	3.85	2.22	3.19	5.33
290	1.18	1.92	3.54	2.00	2.92	4.95

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- Feedstock costs have minimal impact on total costs and system feasibility for either system, since they represent a small percentage of total costs, and negatively affect only the viability of systems that are at the margin.

- Because of the significantly lower pressure and capital needs of the 600 kW systems, unit costs for the 600 kW system are almost always lower than the 1.5 MW systems despite the expectation that larger power systems would exhibit economies of scale.

In conclusion, these prefeasibility models, which represent generic plants, suggest that the smaller scale system (600 kW) can tolerate a wider range of variability than the larger 1.5 MW system in key cost and benefit streams over which it still remains competitive when compared to PLN grid electricity rates. The larger 1.5 MW system has a narrower band of values over which it is an attractive investment to the private sector. Critical factors for a 600 kW system are the sale of ash and capital costs, but it can be feasible over a range of operating days and certainly viable at a probable PLN purchase price of 90 Rp/kWh. Key to the success for a 1.5 MW power system is the absolute need for an ash market, high number of operating days, low capital costs, concessionary interest rates (10%), and high electricity purchase prices.

Summary and Implications

These models demonstrate that the financial and economic feasibility of rice power systems are highly dependent on five key factors, in descending order of priority:

1) ash sales/market;

2) operating days/load factor;

3) electricity purchase price, particularly for the 1.5 MW system,

4) financing terms (interest and discount rates) and capital costs, and

5) husk price.

If private firms or the government are to invest in rice residue power systems in Indonesia, they will need to adequately deal with the following risks to develop successful projects:

- the ash market must be assured;

- a husk transport network must be economically viable and technically reliable;

- guaranteed electricity prices need to be negotiated with the utility or industrial/residential user preferably on a take or pay contract basis;

- the financing terms must be reasonable, possibly below average market rates for a larger system in Indonesia; and
- a high demand must exist for the electricity to insure that there are adequate operating days to make the plants competitive.

While these economic results definitely favor the selection of smaller systems over a relatively larger system, it is important to keep in mind the appropriateness of both scales of plants. Small 600 kW systems fill a need for rural rice millers often located far from the grid that could produce locally their own internal power or preferably steam needs and who face very high off-grid prices (see Chapter 4). Sale of any excess electricity would probably be minimal from these systems and most likely be to off-grid users near the plant such as other small industries or households.

In contrast, due to their higher capital, feedstock, and electricity price requirements, the bigger systems would be stand-alone power plants that feed into the grid or serve remote areas where the full avoided costs of production are higher than current PLN tariff rates. Such systems need to be located near a large mill or cluster of large mills.

Given the current uncertainty regarding the PLN purchase price and low load factors in rural areas (25%), the results of these models underscore the need for close attention to and coordination of any proposed project with local electricity demand and institutional support. These systems can produce electricity at a profit while also producing significant foreign exchange revenues from ash sales only if the feedstock is assured, an ash market exists, adequate PLN purchase prices are guaranteed, and high load factors maintained.

Besides the private sector benefits of increasing net revenues to mill or power plant owners, such systems can provide important indirect benefits to an area and the country. Creation of a new market for feedstock--husk or straw--directly benefits farmers and mill owners. Farmers receive more income per hectare from their rice fields through waste utilization without any additional inputs or any changes in production practice. The addition of a new feedstock collection system will also create jobs in the transport and wholesale sector. Increasing off-farm employment is critical to rural industrialization in Indonesia. Meanwhile, if such systems are, as expected, partially built and serviced in Indonesia the manufacturing industry is also promoted. Finally, ash sales could represent important new sources of foreign exchange to the country.

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CHAPTER SEVEN

POLICY IMPLICATIONS: ACCESSING ENERGY POTENTIAL THROUGH RICE RESIDUE SYSTEMS

Cross-Policy Analysis and Meeting National Goals

Given the historically strong and extensive commitment of the Government of Indonesia to support all segments of the rice industry as highlighted in Chapters 3 and 6 above, GOI policy to encourage implementation of rice residue energy systems can be expected. There could be many benefits resulting to Indonesian people who depend upon rice for their livelihood: new jobs, value-added activity in rural areas, market value for currently wasted portions of the total rice plant crop, expanded electricity availability to spur economic development, and improved natural resource management and reduced pollution.

Within the umbrella of general supportive government policy, specific sub-policies may need reconsidering if and when a decision is made to create optimum conditions for rice residue utilization. For example, increasingly efficient energy systems require incrementally larger rice mills with adequate accumulation of captive rice husk feedstock. If the GOI envisions 100 MW of rice husk power, it will need to create conditions for the establishment of perhaps 10 large mills processing 1,000 tons of gabah/day (as is done in Thailand) or 500 mills of 20 ton/day capacity. Incentives for such a program could include: concessionary rate financing, tax holidays, reduction of constraints on foreign investment, stimulation of the luxury rice market, elimination of investment tax or introduction of taxes on savings accounts to encourage equity financing, etc. It can be seen that implementation of new policies in these areas or changes to existing policies may conflict with other national priorities and programs and must be carefully analyzed and evaluated by GOI to determine the best policy profile to meet national goals.

Rice Production, Milling, Consumption, and Marketing Policies

Production Policies

The Government's intention to mobilize rice processing wastes in support of energy systems would necessitate a look at possible production policy interventions. For example, the International Rice Research Institute (IRRI) at Los Banos now advocates concentrated effort to create markets for rice residues which are already being produced and which represent a significant portion of farm inputs such as labor, fertilizer, etc. (In other words, when you are growing rice, you are also

actually growing husk and straw and spending time and money to do it. If markets are created for these products, the net effect is to increase farm income without increasing farm inputs). A government policy which encouraged the harvest, collection, and resale of rice straw, for example, would stimulate the rural economy to recognize wastes as valuable agricultural commodities and would support energy systems at the same time.

Milling Policies

Long-term increase in the number of successful rice residue energy systems is predicated on recognition that these systems are the companions of modernized milling. Government policy to encourage modernization of mills implies some degree of centralization of milling. Such a policy contradicts current policy which emphasizes decentralized milling for very specific economic and social reasons in Indonesia. More modern mills are, therefore, associated with important costs. On the other hand, other stated goals of the GOI might be furthered by modernized milling: higher rice quality, more efficient milling rates yielding more marketable rice (+5%) for no additional field inputs, higher quality rice mill by-products such as bran and the concomitant additional earnings from these by-products, and more efficient use of capital.

Consumption and Marketing Policies

Government interest in improving rice resource mobilization for energy systems might also affect the movement of rice from the farmer to the consumer. Currently, rice in Indonesia is stored as both unmilled gabah and as milled rice by farmers, millers, middlemen, and government facilities. The movement of rice seems mostly dependent upon price variations and/or the farmers' need at a given moment to sell rice to meet cash needs. Owners of rice residue energy systems need a guaranteed feedstock - both in terms of volume and in terms of reliable availability. An intervention which puts a premium on timed rice sales by providing additional earnings for husk content could encourage regular entry of residue into the market and reduce the vagaries of the current flow. Again, however, such a policy would be in direct conflict with current policies which emphasize the retention of rice and rice milling at the village (desa) or district (kacamatan) level.

Current government policy in transportation assumes a high value on land in rice-growing areas and results in high quality main roads but few feeder roads throughout the rice production areas. Presumably this policy is based on the concept that a hectare of land growing rice has higher economic value than one hectare of road. If, however, the government were to place a new value on rice straw mobilization, the economics of the value of a hectare for paddy versus road might be altered and thus signify a need for differing transportation policy.

Policy trade-offs such as these deserve careful scrutiny by government agencies involved.

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POLICY IMPLICATIONS: ACCESSING ENERGY POTENTIAL THROUGH RICE RESIDUE SYSTEMS

Energy Pricing and Production Policies

The Government of Indonesia clearly has been revising its policies regarding energy pricing and production over the past decade, with an emphasis on moving towards fewer price distortions between fuels and more efficient energy production. Major decisions regarding the promotion of private power sales in Indonesia need to reflect the full opportunity costs and benefits to the economy from optimal fuel mix, production systems, and financing options. If deemed in the national interest, the GOI should identify and encourage those opportunities where the net social welfare gain from private power production is positive.

Government pricing policies are needed to provide decision rules when balancing the financial--private prices--against the actual economic costs of energy production in Indonesia. Assessment is required of the full economic costs, which include: the true costs of production without market subsidies or taxes; long-run marginal costs; externalities from future pollution and environmental risk; and incremental value to the economy of deferring additional public sector debt through private sector energy investment. Explicit pricing guidelines are needed to help determine purchase prices paid by the utility to private energy producers. Such guidelines should reflect the utility's actual avoided costs (either full energy plus capacity or partial energy), at the private power plant location. Recognition of locational price differences would increase cost effectiveness of production and, subsequently, reduce the current subsidies from low to high cost production areas. Because the costs of production for rice residue energy systems are apparently near or close to current PLN rural tariffs, clarity of government support for private power pricing agreements should readily facilitate the incorporation of such energy systems into Indonesia's energy network.

Policies such as the new 1985 law allowing the sale of private electricity will need further legal clarification to assure potential local and foreign investors of the government's commitment. If the GOI wants to encourage rice residue and other private power systems, it also will need to provide a more institutionally and financially supportive environment. PURPA forms of legislation would help to clearly define utility and private investor relationships and to establish institutional bodies for handling legal problems. Specific legal support to foster private power investment includes guarantees of contract sanctity and assurance of purchase price agreements. The utility must also commit to an infrastructural network for distribution of private power to end-users. At the macroeconomic level, a positive financial climate for encouraging foreign investors and joint venture relationships must be maintained due to the risk of private power investment in Indonesia.

If it commits to selective rice residue energy production, the GOI may consider locating the initial systems at mills associated with government institutions, e.g., BULOG, Ministry of Cooperatives, Ministry of Agriculture, or Ministry of Industries. This would reduce the private investor's risk due to government backing and take advantage of the Government's access to a large feedstock base. Policies

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to support rice residue energy systems at government facilities would demonstrate the Government's commitment to better agricultural waste utilization, increasing rural value-added products, cheaper electricity production, and the stimulation of rural jobs and incomes.

Financial Policies

If the GOI commits to the encouragement of residue energy systems, a variety of financial policies will be required to assist in identifying and reducing the scope of risk involved for owners and investors. Generally, the totality of risk must be divided into reasonable shares for all participants in a given project and incentives created to encourage participants to accept their fair share of such risk.

Several currently prevailing financial policies may benefit from review and analysis as to impact on encouragement of foreign and/or local investment in residue energy systems.

Banking Policies

The Central Bank makes investment loans at preferential rates for projects approved by the government only to local investors. The investor contributes 25% of the project cost; the Central Bank provides the rest.

Government commercial banks currently may not lend to foreign investors unless the share of foreign ownership is less than 40 percent.

Foreign banks in Indonesia are limited to lending local currency only in Jakarta and may not commit to a loan that exceeds one year. Loans in foreign currency outside Jakarta are permitted but current regulations prohibit hedging positions.

Institutional Investment Policies

The state owned mutual fund Danareska, created to broaden ownership of shares, currently owns 50% of all shares and 25-30% of all bonds listed on the stock exchange. Danareska is not permitted to sell certificates to foreigners.

Private insurance companies do not invest in capital markets perferring time deposits because of the latter's tax exempt status.

The Indonesian stock market, created to facilitate divestiture of foreign firms, remains small (fewer than 30 companies) and inactive (turn-over less than $10,000 per day). Temporary waivers to divestiture rules are relatively easy to get and most divested companies have been bought out by the local partners.

Development of an active bond market in Indonesia awaits several policy-related actions: leveling of taxation, investor acceptance of 4-5 year holding periods, and creation of a secondary market.

POLICY IMPLICATIONS: ACCESSING ENERGY POTENTIAL THROUGH RICE RESIDUE SYSTEMS

Private Investment Policies

Investors in Indonesia currently expect to receive, at a minimum, a ROI after taxes at least equivalent to the time deposit rate - 25-40% per year. The maximum investment horizon is four years.

The taxability of investment income and the non-taxability of bank deposit income is a serious disincentive to investment.

Foreign investors must have a joint venture with a local firm and Indonesian equity must be no less than 20% except when the project is in a remote area, produces 85% for export, or involves cost of over $10 million. After 15 years Indonesian share of equity must be increased to 51 percent. Minimum capital investment must be $1 million or more except in the service industry where cases are considered one-by-one.

Legal Policies

Encouragement to the private sector for investment in residue power plants must also rest in legal policies that guarantee the sanctity of contracts in the Indonesian environment. Given that a very sensitive economic balance between reliability of feedstock and earnings from electricity sales is the basis for successful loan repayment, power plant owners need the assurance of the government that contracts for the supply of husk/straw and contracts for the purchase of their electricity will be honored by contracting parties and that government will ensure they are honored.

Contractual Requirements for Successful Private Power Generation

For private power generation to be attractive as an investment to the private and public sectors, certain economic and contractual requirements are necessary to increase investor and public sector benefits. From the investor's perspective, they will need:

1) Guaranteed electricity prices: All parties must agree upon an electricity pricing formula to guarantee prices to the seller, e.g., electricity producers. This formula should account for various factors, such as system reliability, production costs to the private producer, avoided costs for alternative energy sources (e.g., oil, coal or natural gas) to the buyer, and generation capacity. If firm power is supplied by the producer, the full avoided costs (energy plus capacity costs) are part of the criterion for setting the electricity transfer price, which also is moderated by system reliability and capacity. From an economic perspective, avoided costs should reflect incremental or long run marginal costs of electricity production. These are the costs to the user for installing and operating the least-cost option. It is in the seller's interest to ensure that a floor price exists in the contract, to mitigate against the possibility of a transfer price that does not cover their production costs.

2) Payment guarantees: To maintain cash flow, private energy producers must be assured through the terms of their contract of prompt and full payment by the buyer(s). Besides guarantees of payment deadlines, establishing escrow accounts and regulations enforceable by a disinterested third party are mechanisms for dealing with possible late payment issues.

3) Investment security: While no investment can be fully secured, local and foreign private investors need guarantees that their investment into private power generation for sale to the public sector will not be at undue risk from the possibility of takeover or nationalization. Contracts could incorporate such guarantees by explicitly defining the terms of possible sale to the grid or user. For example, it may have the options as in a BOT (Build, Operate and Transfer) agreement.

4) System guarantees: Where transmission systems are either inadequate or do not exist, the private sector needs to have firm guarantees, and subsequent penalities, established in the terms of contract regarding the utility's commitment to provide the electricity distribution and transmission systems necessary for the firm to invest in power generation for public utility sales.

The purchaser of private power, whether the PLN or a consortium of industries, also has contractual reguirements that must be met to ensure delivery of the necessary amount and quality of energy to meet its demand. The purchaser's main needs are:

1) Firm power contracts: The electricity buyer(s) must have well defined power contracts stating the amount, reliability and length of time (i.e., months, downtime, and time of day) that the energy producer will supply electricity. Liabilities such as penalities for default on contracts are important to the purchaser vis-à-vis future expansion plans.

2) Regulatory policies: It is in all parties' interests to have clear guidelines and regulations for private power sales and generation and an institutional body, not connected with the national utility, established to insure that both public and private sector comply to the terms of a contract.

ANNEX I

THE RESOURCE BASE

Table A1.1
Growth in Rice Consumption, Population, Urbanization and Income (1969 to 1985)

Year	Annual Rice Consumed (kg/capita)	Total Population	Urban Population (millions)	% Urban Share	Real Annual Per capita Income (Rp.)
1969	98.8	114.4	17.0	14.9%	113,870
1970	103.8	116.9	20.5	17.5%	114,688
1971	102.2	119.2	22.8	19.1%	117,822
1972	101.3	122.0	24.6	20.1%	121,798
1973	110.4	124.8	26.1	20.9%	132,250
1974	106.8	127.7	27.4	21.4%	148,031
1975	104.3	130.7	28.5	21.8%	149,855
1976	111.9	133.7	29.5	22.1%	158,150
1977	114.4	136.8	30.4	22.3%	160,743
1978	115.3	140.0	31.3	22.4%	168,881
1979	123.5	143.2	32.1	22.4%	188,706
1980	122.1	146.5	32.8	22.4%	207,896
1981	127.6	149.9	34.9	23.3%	237,211
1982	128.9	153.4	37.0	24.1%	239,674
1983	145.1	156.9	39.0	24.9%	251,874
1984	131.8	160.5	41.1	25.6%	258,092
1985	137.2	164.2	43.0	26.2%	249,837
Average Annual Growth rate	2.1%	2.3%	6.0%	5.0%	2.1%

Source: Figures derived from Central Bureau of Statistics, Economic Statistics, (various issues).

Note: Income is defined as real private consumption expenditures taken from the National Accounts. Income is defined in 1985 terms using a private consumption expenditures deflator. Population values refer to mid-year population estimates. Urban population values are based on a double-log extrapolation of census values for 1970, 1980 and 1985. Per capita rice consumption refers to availability for human consumption derived from a food balance sheet.

Table A1.2
Variety Production as Percentage of Total Rice Production in Indonesia

Variety Type	Java	Off Java	All Indonesia
1. Local Varieties	1.6%	9.5%	4.6%
2. Smooth Tasting Varieties (HYV)	1.9%	1.7%	1.8%
3. Other (HYV)	0.3%	3.2%	1.4%
4. Smooth Tasting - Disease Resistant (HYV)	63.0%	17.2%	45.5%
5. Other Disease Resistant (HYV)	28.7%	59.3%	40.4%
6. HYV or Disease Resistant (HYV)	4.3%	9.1%	6.1%
7. Glutinous Rice	0.2%		0.1%

Source: Primary Data Tabulations from CBS Floor Price Monitoring Survey and Ministry of Agriculture, Production Statistics, 1986.

Table A1.3
Paddy Production Trends

Year of Production
Production in M.T. - Increase in Percent

Location	1980	To	1981	To	1982	To	1983	To	1984	To	1985
SUMATRA											
Wetland Crop	5,005,523		5,438,316		5,899,187		6,349,653		6,721,039		**
Dryland Crop	673,147		646,719		716,462		831,081		775,004		**
TOTAL	5,678,670	7.16	6,085,035	8.72	6,615,649	8.54	7,180,734	4.39	7,496,043	2.25	7,664,389
JAVA											
Wetland Crop	18,025,097		20,054,750		20,391,196		21,058,663		22,961,500		**
Dryland Crop	395,409		475,560		463,842		569,634		739,026		**
TOTAL	18,420,506	11.45	20,530,310	1.16	20,855,038	3.71	21,628,297	9.56	23,700,326	2.21	24,225,280
BALI & NUSA TENGGARA											
Wetland Crop	1,481,748		1,682,250		1,766,449		1,778,225		1,852,263		**
Dryland Crop	129,626		141,079		128,554		134,867		116,438		**
TOTAL	1,611,374	13.15	1,823,329	3.92	1,894,803	0.96	1,913,092	2..91	1,968,701	-0.69	1,955,033
KALIMANTAN											
Wetland Crop	1,330,288		1,456,722		1,431,452		1,393,826		1,452,584		**
Dryland Crop	297,511		340,494		347,867		302,627		327,331		**
TOTAL	1,627,799	10.41	1,797,216	-0.99	1,779,319	-4.66	1,696,453	4.92	1,779,915	3.23	1,837,443
SULAWESI											
Wetland Crop	2,146,754		2,352,929		2,282,547		2,707,644		3,024,439		**
Dryland Crop	139,012		153,964		138,206		153,312		142,609		**
TOTAL	2,285,766	9.67	2,506,893	-3.44	2,420,753	18.18	2,860,956	10.70	3,167,048	5.05	3,327,089
MALUKU & IRIANJAYA											
Wetland Crop	3,678		3,834		4,793		6,252		5,684		**
Dryland Crop	24,112		27,559		13,322		17,322		18,729		**
TOTAL	27,790	12.97	31,393	-42.30	18,115	30.14	23,574	-0.68	23,413	1.23	23,702
INDONESIA											
Wetland Crop	27,993,088		30,988,801		31,775,624		33,294,293		36,017,309		**
Dryland Crop	1,658,817		1,785,375		1,808,053		2,008,843		2,119,137		**
TOTAL	29,651,905	10.53	32,774,176	2.47	33,583,677	5.12	35,303,106	8.03	38,136,446	2.35	39,032,945

*Paddy = Dry Rough Rice
** Unavailable

Source: Statistical Yearbook of Indonesia, 1985, Biro Pusat Statistik, Jakarta

Table A1.4
Crop Import Volume
Indonesia
(1969 - 1986)

YEAR	RICE	WHEAT	SOYBEANS
	---(000 MT)---		
1969	604	n/a	0.00
1970	1,175	n/a	0.00
1971	565	n/a	0.00
1972	734	125	0.00
1973	1,706	663	0.00
1974	1,070	672	0.00
1975	674	717	18.00
1976	1,287	965	23.00
1977	1,964	753	32.00
1978	1,838	1,154	35.00
1979	1,929	1,210	107.00
1980	2,026	1,444	194.00
1981	525	1,366	361.00
1982	300	1,485	361.00
1983	1,154	1,713	391.00
1984	375	1,526	401.00
1985	33	1,317	302.00
1986	20	1,331	350.00
Average Annual Growth Rate		18.4%	31.0%

Source: Central Bureau of Statistics, Import/Export Statistics (various issues) and National Logistics Board, BULOG Statistics, 1987.

Table A1.5
Paddy Produced and Harvest Patterns
Indonesia
1985

Time - Area - Production (M.T.)

	January - April		% of	May - August		% of	September-December		% of	Totals	
	Ha. Harvested	Prod. M.T.	Total	Ha. Harvested	Prod. M.T.	Total	Ha. Harvested	Prod. M.T.	Total	Ha. Harvested	Prod. M.T.
SUMATRA	1,320,380	4,095,167		546,866	1,917,853		473,447	1,651,378		2,340,693	7,664,398
Husks Produced (M.T.)		819,033	53.43		383,570	25.02		330,275	21.55		1,532,877
Straw Produced (M.T.)	2,640,760		56.41	1,093,732		23.36	946,894		20.23	4,681,386	
JAVA	2,755,581	12,598,245		1,744,145	7,974,158		801,681	3,652,877		5,301,407	24,225,280
Husks Produced (M.T.)		2,519,649	52.00		1,594,831	32.92		730,575	15.08		4,845,056
Straw Produced (M.T.)	5,511,162		51.98	3,488,290		32.90	1,603,362		15.12	10,602,814	
BALI & NUSATENGGARA	250,010	869,672		207,006	772,680		74,809	312,681		531,825	1,955,033
Husks Produced (M.T.)		173,934	44.49		154,536	39.52		52,536	15.99		391,006
Straw Produced (M.T.)	500,020		47.01	414,012		38.92	149,618		14.07	1,063,650	
KALIMANTAN	402,276	820,509		246,546	596,613		162,444	420,321		811,266	1,837,443
Husks Produced (M.T.)		164,101	44.65		119,322	32.47		84,064	22.88		367,488
Straw Produced (M.T.)	804,552		49.59	493,092		30.39	324,888		20.02	1,622,532	
SULAWESI	285,844	1,132,062		371,279	1,318,790		243,274	876,237		900,379	3,327,089
Husks Produced (M.T.)		226,412	34.02		263,758	39.64		175,247	26.34		665,417
Straw Produced (M.T.)	571,688		31.74	742,558		41.24	486,548		27.02	1,800,758	
MALUKU & RIANJAYA	5,345	6,953		4,353	6,280		7,007	10,469		16,705	23,702
Husks Produced (M.T.)		1,390	29.34		1,256	26.50		2,093	44.16		4,740
Straw Produced (M.T.)	10,690		32.00	8,706		26.06	14,014		41.94	33,410	
INDONESIA	5,019,436	19,522,608		3,120,195	12,586,374		1,762,662	6,923,963		9,902,293	39,032,945
Husks Produced (M.T.)		3,904,521	50.01		2,517,274	32.25		1,384,792	17.74		7,806,589
Straw Produced (M.T.)	10,038,872		50.68	6,240,390		31.52	3,524,324		17.80	19,804,586	

Source: Composite of data provided by Biro Pusat Statistik, 1985.

Table A1.6
Rice Milling Capacity (M.T./HR) and Production by Area

Indonesia
1984

Mill Capacity M.T./YR*

	Over 1 TPH		Approximately 1 TPH		Less Than 1 TPH		Less Than 3.0 TPH (Huller)		Total Annual		Paddy Prod.**
	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity	M.T./YR
SUMATRA	314	317,263	2,663	1,002,210	5,067	1,955,035	9,387	2,558,076	17,431	5,832,584	6,560,024
Hull (20%)		63,452		200,442		391,007		511,615		1,166,516	1,312,004
JAVA	370	684,259	24,314	12,757,373	2,020	98,483	1,974	453,305	28,578	14,873,653	21,899,193
Hull (20%)		136,851		2551,474		196,096		90,700		2,974,730	4,379,838
KALIMANTAN	15	14,725	1,726	682,284	502	242,533	1,025	165,753	3,287	1,105,295	1,292,380
Hull (20%)		2,945		136,456		48,506		33,150		221,059	258,478
SULAWESI	37	43,520	909	302,760	3,807	1,457,720	3,577	587,905	8,330	2,391,915	2,137,758
Hull (20%)		8,704		60,552		291,544		117,581		478,383	627,551
IND. TIMUR	23	31,233	402	243,735	2,069	1,133,055	272	114,607	2,766	1,520,213	1,557,158
Hulls (20%)		6,246		48,747		226,611		22,921		304,042	311,431
INDONESIA (TOTAL)	759	1,091,009	30,014	14,988,362	13,455	5,765,826	16,234	3,875,463	60,462	25,723,660	34,353,533
Hulls (20%)										5,144,732	

*Based on 1,400 Hrs/Yr Average Milling.
**Paddy - Gobah = Rough Rice Does not include dry season production.

Source: Ministry of Industries, GOI.

Table A1.7

Selected District Rice
Milling Capacity, and Husk Production from Largest Capacity Mills
1984

Island	Province	District (Kabupatan)	Total Rice Prod	Total Milling Capacity	Total Husk Availability at 20% ('000 MT)	Total # of Mills	# of Mills IT/hr. or more	Capacity of Mills > IT/hr	Annual Husk Available from Mills > IT/hr (at 20%) ('000 MT)	% of Total Available Husk Coming from Mills > IT/hr milling Capacity
Sumatera			6,560,024	5,832,584	1,166,516	17,431	314	317,263	63,452	5.4%
	Aceh		650,200	654,064	130,8	1,390	105	112,483	22,496	17.2%
		Pidie	136,978	141,100	28,220	294	28	27,440	5,488	19.5%
		Aceh Utara	179,258	160,147	32,029	210	37	45,643	9,128	28.4%
	Sumatera Utara		1,843,080	1,982,120	396,424	4,934	176	184,800	36,960	10.1%
		Langkat	158,832	123,620	24,724	264	28	29,400	5,880	23.9%
		Deliserdang	467,015	292,320	58,464	638	55	57,750	11,550	19.8%
		Labuhainbutu	86,920	159,110	31,822	349	33	34,650	6,930	22.0%
Java			21,808,193	14,873,653	2,974,430	28,578	370	684,259	136,851	4.6%
	Java Barat		8,547,634	4,025,465	805,093	13,398	170	184,783	36,956	5.0%
		Karawarg	964,716	417,303	83,460	1,347	65	73,803	14,760	17.7%
		Cianjur	419,915	246,805	49,361	638	29	29,580	5,916	11.9%
	Java Timur		7,573,607	5,015,634	1,003,126	7,520	193	433,270	86,654	8.6%
		Lumajang	292,998	210,553	42,110	261	32	44,660	8,932	21.1%
		Banyuwang[1]	677,053	529,327	105,865	392	45	154,187	30,837	29.1%
	DKI Jakarta		34,661	88,260	17,652	79	3	54,000	10,800	4.2%
		Jakarta Timur	18,374	52,230	10,446	44	2	36,000	7,200	68.5%
		Jakarta Utara	8,520	23,665	4,733	20	1	10,000	2,000	42.6%

Source: Ministry of Industries data for 1984.

Table A1.8
Projected Paddy and Milling By-Products

No.	Province	Gagah	Husk	Rough	Fine	Other	Straw
1.	Jawa Barat	7.801.844	1.872.443	312.074	195.046	117.028	39.009.221
2.	Jawa Timur	7.303.551	1.752.852	292.142	182.589	109.553	36.517.757
3.	Jawa Tengah	6.196.707	1.487.210	247.868	154.918	92.951	30.983.537
4.	Sulawesi Selatan	2.212.193	530.926	88.488	55.305	33.183	11.060.963
5.	Sumatera Utara	2.114.669	507.521	84.587	52.867	31.720	10.573.346
6.	Sumatera Barat	1.285.219	308.453	51.409	32.130	19.278	6.426.096
7.	Sumatera Selatan	1.227.785	294.668	49.111	30.695	18.417	6.138.926
8.	Lampung	1.038.896	249.335	41.556	25.972	15.583	5.194.478
9.	Nusa Tenggara Barat	926.287	222.309	37.651	23.157	13.894	4.631.434
10.	DI. Aceh	924.638	221.913	36.986	23.116	13.870	4.623.191
11.	Kalimantan Selatan	908.125	217.950	36.325	22.703	13.622	4.540.625
12.	Bali	824.578	197.899	32.983	20.614	12.369	4.122.890
13.	Kalimantan Barat	630.594	151.343	25.224	15.765	9.459	3.152.971
14.	D.I. Yogyakarta	623.306	149.593	24.932	15.583	9.349	3.116.524
15.	Jambi	425.003	102.001	17.000	10.625	6.375	2.125.015
16.	Sulawesi Utara	370.515	88.924	14.821	9.263	5.558	1.852.574
17.	Nusa Tenggara Timur	308.762	74.103	12.350	7.719	4.631	1.543.809
18.	Riau	290.824	69.798	11.633	7.271	4.631	1.543.809
19.	Sulawesi Tengah	248.010	59.282	9.920	6.200	3.720	1.240.051
20.	Bengkulu	241.318	57.916	9.653	6.033	3.620	1.206.588
21.	Kalimantan Tengah	217.980	52.308	8.718	5.449	3.269	1.089.750
22.	Kalimantan Timur	94.444	22.667	3.778	2.361	1.417	472.221
23.	Sulawesi Tenggara	76.282	18.308	3.051	1.907	1.144	381.412
24.	D.K.I.Jakarta	32.440	7.786	1.298	811	487	162.199
25.	Maluku	25.428	6.103	1.017	636	381	127.140
26.	Irian Jaya	3.632	872	145	91	54	18.162
27.	Timor Timur	-	-	-	-	-	-
Total Produksi di Indonesia		36.323.000	8.874.483	1.454.720	908.826	545.294	181.764.998

Source: Department of Agriculture, Monografi Pertama Lembah Pertanian, Jakarta, 1985
Notes: Husk at 24% of GABAH, by weight
Rough Bran at 4% of GABAH
Fine Bran at 2.5%
Other Products, 1.5% of GABAH
Straw at 500% of GABAH

ANNEX II

THE ELECTRICITY SECTOR

Table A2.1
Installed Capacity, Electricity Produced and Distributed by State Electric Company (PLN) According to PLN Region and Province (1983/1984)

PLN REGION	Province	Installed Capacity (MW)	Electricity Produced (000 MH)	Electricity Sold (000 MH)
(1)	(2)	(3)	(4)	(5)
1. Region I	Daerah Istimewa Aceh	43	85	63
2. Region II	Sumatera Utara	218	716	503
3. Region III	Sumatera Barat; Riau	204	319	238
4. Region IV	Sumatera Selatan, Jambi Lampung and Bengkulu	145	384	291
5. Region V	Kalimantan Barat	35	105	78
6. Region VI	Kalimantan Selatan, Kalimantan Timur, Kalimantan Tengah	140	320	252
7. Region VII	Sulawesi Utara, Sulawesi Tengah	76	169	118
8. Region VIII	Sulawesi Selatan, Sulawesi Tenggara	114	299	217
9. Region IX	Maluku	28	52	37
10. Region X	Irian Jaya	28	61	48
11. Region XI	Bali, NTB, NTT	108	238	191
12. Region XII	Jawa Timur Tanpa Tuban, Lasem and Bojonegoro	20	50	1,943
13. Pemb. Jatim	Jawa Timur 1)	627	2,693	-
14. Region XIII	Jawa Tengah, D.I. Yogyakarta, Tuban, Lasem and Bojonegoro 1)	11	1,141	907
15. Pemb. Jawa Barat and DKI Jaya City	Jawa Barat and DKI Jakarta 1)	1,981	7,811	...
16. Distribution Jawa Barat Tanggerang Region	Jawa Barat Except Tanggerang 1)	5	22	1,578
17. Distribution DKI. Jakarta	DKI Jakarta and Tanggerang 1)	...	...	3,424
INDONESIA		3,783	14,466	9,888

Note: Interconnected system.
Source: Indonesian Statistical Yearbook for 1985.

ANNEX III

Annex III provides a detailed description of the calculations performed to analyze the thermodynamic characteristics of various steam systems. The data shown in Table 5.3 were generated from a similar set of analyses.

The analysis was begun by identifying the various components used in each respective system. In this illustrative example, the system consisted of:

- a single stage feedwater pump;
- a feedwater heater;
- a boiler to raise the feedwater from a subcooled liquid to saturated steam;
- a sugerheater to raise the steam from a saturated vapor to higher temperature (higher enthalpy) steam;
- a multi-stage turbine to convert the steam to mechanical energy; and
- a condenser to condense the steam mixture from a vapor state to a liquid state.

These components were configured as shown in Figure A3.1 below. The numbers appearing after each respective component are used to indicate state points around the steam cycle. The properties of the steam at each respective state point are summarized in the following table, which provides the enthalpy of the steam (or feedwater) at each point in the system.

Table A3.1

State	Pres (psia)	Temp (F)	Enthalpy (Btu/lb)	Entropy (F/Btu)	Cond
1	1	101	69.73		0
2	650		71.62		SCL
2f	650	250	220		SCL
3	650	750	1377	1.6	SHV
4i	1	101	893	1.6	.80
4r	1	101	1087		.98

Source: Enthalpy values were taken from 1967 ASME Steam Tables, American Society of Mechanical Engineers, 1967.

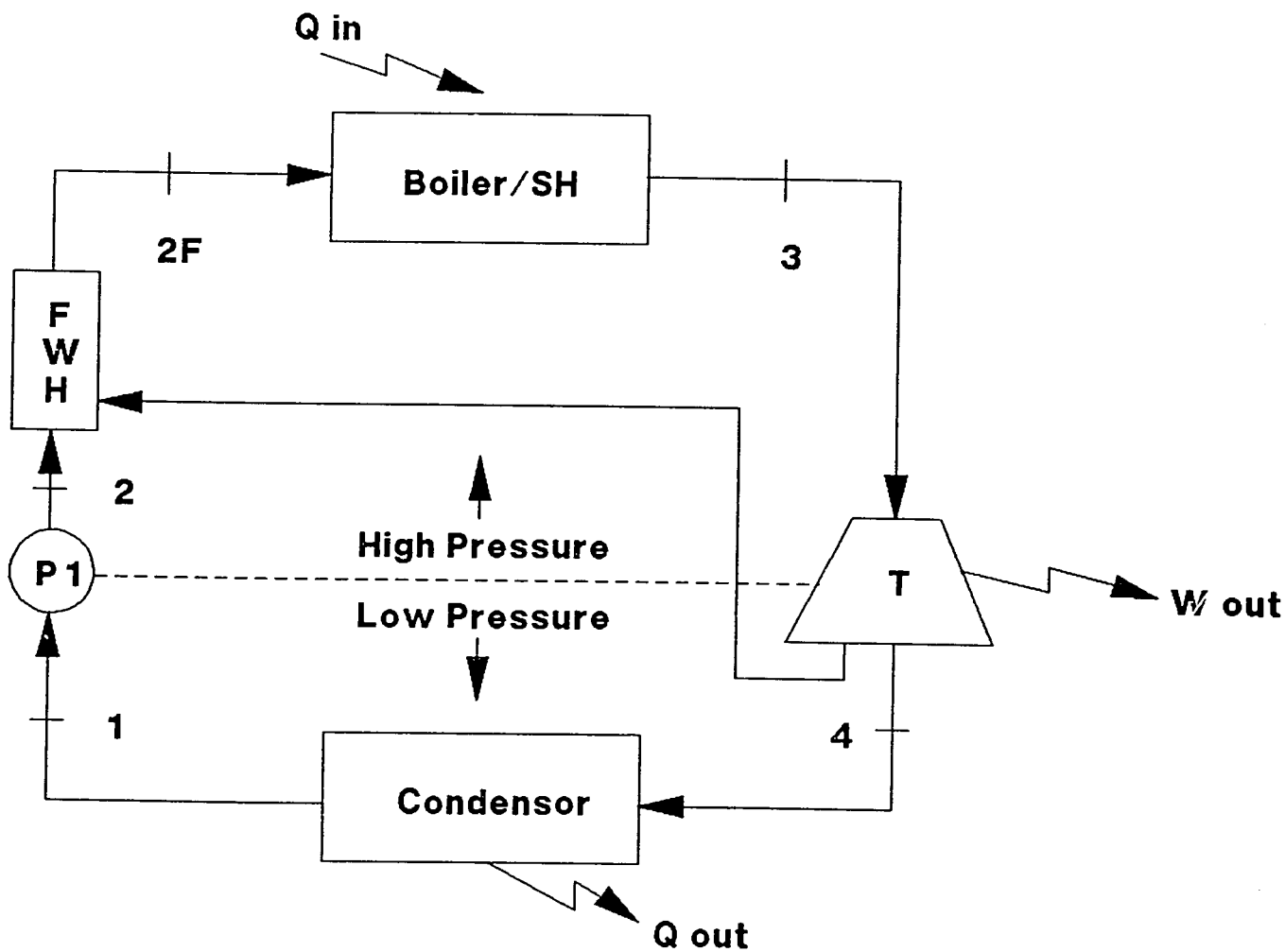

Figure A3.1 : Schematic diagram of Rankine cycle power system. This is a simplification of an actual system used for illustrative purposes.

State 1 indicates the point at which the condensate enters the feedwater pump. (Actually, more than one pump would be used in this arrangement, but for simplicity, only one is depicted here.) State 2 indicates the exhaust point of the feedwater pump. The feedwater then enters a feedwater heater, where temperature is raised to 250°F. This is indicated above as point 2f. The hot water then enters the boiler, where energy is added via the hot gases of combustion (from the furnace). The exit conditions of the steam are indicated above as point 3. The steam then expands through a turbine, which provides shaft power to a generator. The conditions of the steam leaving the turbine are indicated by point 4. The "wet steam" leaving the turbine is then condensed down to a saturated liquid state, passing through a condenser which exchanges the heat from the condensing steam with a cooling medium such as cool water or air. The exit conditions of the condensate correspond to the entrance conditions of the water entering the pump, as indicated by point one.

The enthalpy values are the values of greatest interest for this analysis. The enthalpy represents the gross energy content of the steam/water at each respective point in the system. From these values, one can determine the rate of heat addition to the steam, the rate of power extraction from the turbine, and given component efficiencies, the overall efficiency of the system.

Using the above figures, a fuel feed rate can be determined as follows:

$$h_2 = 69.7 \text{ Btu/lb} + 0.016 \text{ ft}^3\text{/lb} * (750-101) \text{ lb/in}_2 * 144 \text{ in}^2\text{/ft}^2 * 1 \text{ Btu/778 ft-lb}$$
$$= 71.62 \text{ Btu/lb}$$
$$t = 60\% \text{ (provided by turbine manufacturer)}$$

So, for the ideal case (isentropic expansion):

$$s_3 = s_{4i} === s_3 = 1.6$$
$$x_{4i} = (s_{4i} - s_f)/s_{fg} = (1.6 - .1326)/1.8455$$
$$= 0.80$$

Now:

$$h_{4i} = h_1 + x_{4i} * h_{fg}$$
$$= 69.73 \text{ Btu/lb} + 0.80 * 1036.1 \text{ Btu/lb}$$
$$= 893.56 \text{ Btu/lb}$$

And:

$$h_4 = h_3 - t * (h_3 - h_{4i})$$
$$= 1377 \text{ Btu/lb} - 0.6 * (1377 - 894) \text{ Btu/lb}$$
$$= 1087 \text{ Btu/lb}$$

$$x_{4r} = (1087 - 69.73)/1036 = .98$$

The specific heat addition from the fuel to the feedwater/steam is:

$$Q_{in} = h_3 - h_{2f} = 1377 - 220$$
$$= 1157 \text{ Btu/lb steam}$$

The specific turbine shaft work can also be calculated as follows:

$$W_{out} = h_3 - h_4 = 1377 - 1087$$
$$= 290 \text{ Btu/lb steam}$$

Estimating a gross generator output of 1.7 MW (for a net power output of 1.5 MW), the mass flow rate can be calculated as follows:

$$M = 1.7 \text{ MW} * 1000 \text{ kW/MW} * 3414 \text{ Btu/kWh} * 1 \text{ lb/290 Btu}$$
$$= 20{,}013.1 \text{ lbs/h}$$

Now,

$$Q_{in} = 1157 \text{ Btu/lb} * 20013 \text{ lb/h}$$
$$= 23{,}155{,}041 \text{ Btu/h}$$

This represents the amount of energy required to produce 20,013 lbs/h of 650 psig, 750°F steam. This is the energy transferred to the boiler feedwater by the furnace. Due to thermal and mechanical inefficiencies, a greater amount of energy must be supplied to the furnace in the form of boiler fuel. This can be calculated by dividing the above figure by the overall boiler efficiency:

$$Q_{in}(\text{net}) = Q_{in} * 1/\text{Boiler} = 23{,}155{,}041/.82$$
$$= 28{,}237{,}855 \text{ Btu/h}$$

In terms of rice husk with an average heating value of 6000 Btu/lb, this is:

$$M = 28{,}237{,}855 \text{ Btu/h} * 1 \text{ lb/6000 Btu} * 1 \text{ ton/2000 lb}$$
$$= 2.35 \text{ ton/h}$$

All other calculations performed followed the above procedure. However, in as much as each particular system used components with varying efficiencies and operating characteristics, the analytical procedure varied appropriately.

ANNEX IV

Table A4.1
Tiu Kulit: Wet Season Rice Production Costs and Returns:
Cash Costs and the Imputed Value of Family Labor

	Irrigated Sawah (N=8)			Rainfed Sawah (N=4)		
Costs/Return	Cash Costs	Imputed Fam. Labor Costs	Total Costs	Cash Costs	Imputed Fam.Labor Costs	Total Costs
A. Costs	27,287		27,287	17,147		17,147
•Pre-Harvest Labor						
Seedbed Prep.	2,500	1,625	4,125	3,500	2,250	5,750
Land Prep.	17,925	23,538	41,463	9,875	14,625	24,500
Transplant	58,519	6,350	64,868	56,813	5,875	62,688
Fert./Pest	-	2,156	2,156	-	2,062	2,062
Weed	-	3,219	3,219	-	375	375
Sub-Total	78,944	36,888	115,832	70,188	25,187	95,375
•Harvest Labor	54,150	27,212	81,862	58,150	17,500	75,650
•Total Labor	133,094	64,600	197,694	128,338	42,687	171,025
Total Costs	160,381		224,981	145,485		188,172
B. Total Returns	426,925		426,925	276,000		276,000
C. Net Returns	266,554		201,944	130,515		87,828

Source: Ministry of Agriculture, 1987. Unpublished data.

Table A4.2
Electricity Content of Various Products in Indonesia

Type of Product	Electricity Content		Labor Production	
Tin sheet (**)	3.07	%		NA
Rice Mill (*)	6.00	kWh/ton	20.9	ton/employee
Paper & Cardboard (*)	694.00	kWh/ton	4.2	ton/employee
Soap (*)	66.30	kWh/ton	15.5	ton/employee
Cement (*)	129.30	kWh/ton	182.0	ton/employee
Jute Bag (*)	0.667	kWh/ton	1070.0	bag/employee
Beer (*)	0.596	kWh/Litre		NA
Cigarette (*)	0.005	kWh/pack		NA
		0.41%		NA
Shoes (*)	0.80	kWh/pair		NA
		2.45%		NA
Coconut Oil (*)	35.40	kWh/ton		NA
		0.47%		NA
Remilling sheet (*)	60.06	kWh/ton		NA
		0.77%		NA
Shirt/mens wear (*)	0.0758	kWh/ton		NA
		1.01%		NA
Tea (*)	5.60	kWh/ton		NA
		4.52%		NA
Detergent chemicals(**)		4.37%		NA
	0.795	kWh/kg rod		NA
Grade Wire rod (**)		15.24%		NA

Note:
- % Shown is based on direct costs of production.
- (*) Based on Abdulkadir (1977) and 1986 prices.
- (**) Based on BKPM (1984) and TDL - 1984.

NA = Not Available

Source: Amarullah Munaswar. Analysis of Electricity Pricing. National Development Planning Agency (BAPPENAS). Government of Indonesia. Jakarta. February 1986, pg. 159.

ANNEX V

FINANCIAL AND ECONOMIC ASSESSMENT MODELS:

TECHNICAL AND COST ASSUMPTIONS

Financial and Economic Models

Economic Perspectives

A distinction employed in the basic case models and sensitivity analyses is the use of financial versus economic analysis. This difference is based on using monetary values that represent current private market prices regardless of market price distortions (a financial analysis) versus using values that reflect the estimated real costs to society after subsidies, taxes, and externalities are accounted for (an economic analysis). The economic analyses internalize (1) the social opportunity costs of electricity production based on the expected avoided costs and (2) higher feedstock costs. An avoided cost methodology is used in the economic analysis because the real costs to the country of incorporating private electricity generation will be the displacement in terms of fuel and operating expenses (energy costs) and possibly capacity costs to the utility[1]. Off-Java the avoided costs include both the energy plus capacity costs, whereas On-Java they are only energy costs where sufficient PLN capacity exists[2] [1]. Conducting sensitivity analyses on electricity prices demonstrates the importance of the purchase price criteria on the feasibility of the systems. Higher feedstock costs are also used because increased demand for husk or straw will likely drive up their prices.

Technical Design Characteristics

At present, two different system sizes are used, 600 net kW (250 psig) and 1.5 net MW (650 psig) systems, in the models. It is important to realize that plants of such small scale (600 kW to 1.5 MW) are only being planned for construction in several places but to-date plant cost estimates for these sizes, as discussed below, remain speculative.

The two systems have important technical and feedstock trade-offs, with divergent economic impacts, due basically to differences in thermal design efficiencies. Also, the potential economic advantages to Indonesia of these two systems differ. Many of the components of a low pressure (250 psig) 600 kW system can be manufactured locally, hence their domestic multiplier effect and servicability makes them more attractive at this time than an imported larger scale system to

---

1 See Table 4.6 for PLN tariffs and avoided cost rates on and Off-Java (Amarullah, 1986).

2 Assumes current market prices or feedstock in financial analyses, and higher prices (two to four times market) in the economic due to supply pressure, where market prices 4,000 RP/ton for 10 km hauls (Ministry of Agriculture).

Indonesia. Lower capital costs and local manufacturing also implies less drain on the economy in terms of foreign exchange needs. In contrast, a 1.5 MW system can produce more ash, which provides important foreign exchange earnings. Optimally each system wants to have the highest operating hours and load factor. Only a stand-alone system can expect to have high operating hours. Due to variability in load factors at the grid Off-Java, where rural industrialization is quite low, the load factor is often only 25 percent [1]. Sensitivity analyses on operating hours and load factors are made in these analyses. A conservative project life is assumed, 15 years, based upon the manufacturer's expected equipment life. The following sections outline the basic cost and benefit assumptions of the models.

A summary of the technical and project costs and benefit assumptions is given in Table A5.1. and described below.

Model Cost Assumptions

Feedstock Costs: A major constraint to commercialization of an integrated mill-power plant rice residue energy system is the lack of sufficient captive feedstock at most rice mills in Indonesia. Due to small mill sizes, it is inconceivable that most mills, even the "large" (8 ton/day gabah) mills, will have sufficient husk to power 600 kW to 1.5 MW systems. Thus, stand-alone power plants appear the likeliest option unless larger mills can be found or are encouraged by the government. Collection of husk or straw will entail a collection and resource cost as included in all models.

In the financial base case analysis, a low feedstock price based on a current market value of 4,000 Rp/ton (U.S. $2.44/ton) is used. Since new demand for husk (or straw) is bound to bid up husk prices, higher values perhaps even two to four times the market price, or 8,000 and 16,000 Rp/ton, are used in the economic base case and sensitivity analyses.

Power Plant Costs: Power plant costs include payments for capital, labor, and maintenance. Cost data used in these models rely upon manufacturer estimates [2]. The following cost assumptions are highly dependent on site factors that may not be fully accounted for in these estimates. Realistic but conservative assumptions are used below based upon the best projections for Indonesia. Like most new technologies, decreasing costs are expected over time with experience and local manufacturing of the systems.

- Capital: Capital costs are extremely sensitive to plant scale economies, with unit costs usually rising exponentially as size decreases. Given the 600 kW and 1.5 MW systems are extremely different technically, the unit costs of these two models do not follow the typical scale economies expected in power systems. The manufacturer's capital cost estimates used in the models are quite tentative, and may fall as local manufacturers are employed for supplying parts, and new methods developed to cut costs. In constrast, foreign firms often report 30% cost overruns in Indonesia. Loans for

Table A5.1
Summary of Model Assumptions for the
Stand-Alone Rice Residue Power Systems

TECHNICAL	
Power Output	
Large System	1.5 MW net output @ 650 psig
Small System	600 kW net output @ 250 psig
Operating Hours	
Base case:	290 days per year
Range:	140 to 290 days per year
Project Years	10, Discount rate 10%
COSTS	
Feedstock	
Husk Prices:	
Base Market Price	4,000 Rp/ton
Economic Prices	8,000-16,000 Rp/ton
Husk Quantities:	
1.5 MW net	16,356 short tons/yr
600 kW net	13,920 short tons/yr
Power Plant	
Capital	
1.5 MW net	
High (Base)	$4.2 million U.S.
Low	$3.0 million U.S.
600 kW net	
High	$1.0 million U.S.
Low (Base)	$800,000 U.S.
Interest Rates	
Range:	10, 15, 25 %
Loan Period	10 years
Labor	
Wages	
Unskilled	3,000 Rp/day
Skilled	5,000 Rp/day

Number of Workers	
High Operating Hours/Load Factor 6 unskilled, 2 skilled	
Low Operating Hours/Load Factor 2 unskilled, 1 skilled	
Maintenance (% Capital expenditures)	
5%	year 1
3%	years 2-3
2%	years 4-13
3%	years 14-15

BENEFITS

Electricity Sales	
Prices	
Financial (PLN Tariff)	103 Rp/kWh
Economic = Avoided Costs	
- Off-Java	174 Rp/kWh
- On-Java	90 Rp/kWh
Range:	75-174 Rp/kWh
Ash sales	
Base Price:	45 U.S. $/ton
Range:	0-150 U.S. $/ton

100% financing are assumed in the models with funding being procured at 10, 15 or 25% interest rates*. For simplicity, and because the results were not significantly changed by this assumption, no equity financing is assumed in these projects due to the high degree of project risk and aversion of local entrepreneurs to issuing equity shares [3].

- Labor: Models that assume 24-hour daily electricity production and high availability (over 80%) have 3 shifts per day with 2 unskilled workers per shift and 2 managers, models with lower load factors have only one shift per day with 2 unskilled workers and one manager. Wage rates for unskilled (3,000 Rp/day) and skilled (5,000 Rp/day) workers reflect current pay scales in Indonesia.

- Maintenance Costs: Due to the lack of commercialization of these systems, relatively high maintenance costs are assumed for year one at 5% of capital expenditures, but fall to 3% in years 2-3, then 2% in years 4-13, and rise again to 3% in later years.

* A 10% rate has been reported obtainable to U.S. cooperative-based manufacturing firms through Cooperative Banks in U.S. Sensitivity analyses (on terms of loan debt/equity ratios and grace periods) have only minimal effects on the system's feasibility.

Benefit Assumptions

Electricity Price: There is no established precedent for the purchase of firm power by PLN at present. Purchase price can only be estimated. To account for this uncertainty, a range of electricity prices is used in the models based upon current market (financial) prices--PLN tariffs--and the realistic economic prices (avoided costs) for electricity at different locations in Indonesia. These values are based on PLN's estimated costs shown in Table 4.4 for rural industries in Indonesia [4], [5].

In all financial analyses, the rate PLN has indicated it will pay, is appropriate (90 Rp/kWh or 5.5 U.S.¢/kWh), which is quite close to the PLN tariff rate (103 Rp/kWh or 6.3 U.S.¢/kWh) since these reflect market prices On and Off-Java. Recent conversations by rice residue energy system manufacturers with PLN suggest that PLN may be willing to buy at about 90 Rp/kWh for firm power contracts.

In an economic analysis for Off-Java, the full avoided costs to PLN for diesel-based electricity production (174 Rp/kWh or 10.6 U.S. ¢/kWh) are relevant, due to the lack of capacity in the utility or private power systems [4], [6]. These prices may be conservative since the price rural customers are willing to pay for captive power in Indonesia is estimated to be anywhere from 200 to over 300 Rp/kWh (Biro Statistik Pusat 1986). On-Java, a lower economic cost should be used (90 Rp/kWh or 5.5 U.S. ¢/kWh), which is the energy charge (fuel and operating costs) avoided by PLN by relying on private power generation [4].

Ash Sales: The sale of ash by U.S. rice energy producers represents a valuable by-product, yielding 50% of the energy systems' net profits for one firm [7]. The ash is sold to the steel industry in Europe for lading cover (insulation), used as cat litter in the U.S., or sold to the hazardous waste industry for environmental management at prices ranging from U.S. $90 to $200/ton [7]. An export market for the ash by-product is assumed in all models due to a high and lucrative demand for ash overseas. A more conservative base price for ash is assumed, U.S. $45/ton based on the offer by one rice residue energy system manufacturer to guarantee this price to mills that buys its equipment. However, a range is also used in the sensitivity analyses.

Sensitivity Analysis Assumptions

See Table A5.2 for the assumptions used in the sensitivity analysis models.

Table A5.2
Assumptions for Base Case
Sensitivity Analyses on Models

Cost/Benefit Values	Cases			
	Base	No Ash	Worse	Economic
Husk Price (Rp/ton)	4,000	4,000	16,000	12,000
Operating Hours (hr/yr)	290	290	140	290
Ash Price ($/ton)	45	0	0	90
Elect. Price (Rp/kwh)	90	90	75	174
Interest Rates (%)	15	15	25	10
Capital Costs ($M)				
600 kW	.8	.8	.8	.8
1.5 MW	4.2	4.2	4.2	4.2

ANNEX VI

LIST OF CONTACTS AND INTERESTED PARTIES

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