GASIFICATION OF RICE HULLS

Development of a Five-Horsepower Gasoline Engine Rice Hull Gas Producer System

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INTRODUCTION

Beagle estimated in a 1976 publication that one-half of the approximately 60 million tons of rice hulls from the annual world rice production was used for energy or other purposes. He stated that India uses 40 percent of its annual rice hull production to produce steam for parboiling rice. The potential use for rice hulls as gas producer fuel to operate small diesel and gasoline engines is indicated by the number of small rice mills in Indonesia (20,000) and the Philippines (10,000) as reported by Goss and Creamer. Pumping water for flooded rice culture is an additional potential use. India is reported to have 8 million small tube wells pumped with engines or electric motors rated at about 5 horsepower. In the Philippines, the total market potential for small scale stationary gas producers was estimated to be 32,000 units. It was projected that the Gasifier and Equipment Manufacturing Corporation (GEMCOR), a Philippine Government Agency, would produce 28,800 gasifiers for small engines between 1983 and 1989. This projection will not be achieved because of the difficulties encountered with the biomass gasification effort in the Philippines.

OVERVIEW OF RICE HULL GASIFICATION AT U.C. DAVIS

The need for biomass-based energy supply for small engines in Developing Countries and the availability of rice hulls in these countries, as noted above, was the basis for initiating research to meet this need in 1981 with support from the Briggs and Stratton Corporation and the U.S.A.I.D. Office of Science and Technology during 1983-1985. In 1983, Kaupp completed an extensive study of the physical and chemical properties of rice hulls which resulted in his development of a unique, down-draft type gas producer to gasify rice hulls (Albrecht Kaupp: Fig. 10-34). A worldwide survey conducted by Goss and Stephenson in 1983 revealed the complete lack of commercial or successful operating, small-scale research gas producers fueled with rice hulls.

In 1986, Creamer documented the performance of a 5 hp. single cylinder, gasoline engine* operated with producer gas generated from rice hulls in an improved model of the system developed by Kaupp (Kurt S. Creamer, et al.: Figs. 12 and 14). Since the batch-fed, rice hull gasifier required refueling at intervals of 1 1/2 to 2 hours of engine operation there was a need to develop a system for continuous operation. In 1986, Tiangco reported the development and testing of such a design, accumulating 134 hours of engine operation (Valentino M. Tiangco, et al: Fig. 4). The reactor built by Kaupp for his studies was used by Creamer and Tiangco. These three researchers are estimated to have operated the initial reactor for more than 200 hours without any deterioration of the reactor components. Creamer found the optimum spark advance to be 23 degrees before top-dead-center. Both Creamer and Tiangco found the engine to develop 40 to 45 percent of the rated engine power at 3600 rpm when fueled with producer gas generated from rice hulls. The engine brake thermal efficiency ranged from 16 to 20 percent. Because the gas producer-gas clean-up system had a low pressure drop (around 25 mm of water) and cooled the gas to about 5 to 7°C above ambient temperature, equipping the engine with compression ratios greater than the normal value of 6.2 to 1 was the next logical step to improve overall system performance.

INFLUENCE OF COMPRESSION RATIO ON ENGINE PERFORMANCE

The principal reasons for increasing engine compression ratio are to improve brake thermal efficiency and brake mean effective pressure (hence, brake power). Brake mean effective pressure (bmep) is expected to increase with increasing compression ratio, at least within the knock limited region for most spark ignited engines, as shown by considering the influence of compression ratio on indicated mean effective pressure (imep) and friction mean effective pressure (fmep). Both imep and fmep will tend to increase

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* Briggs and Stratton 5 hp Gasoline Engine Specifications

Model	132432
Type	0111-01
Rated HP	3.7 kW (5 hp) @ 3600 rpm
Displacement	206 cc (12.571 in^3)
Bore	61.0875 mm (2.5625 in)
Stroke	61.9125 mm (2.4375 in)
Compression Ratio	6.2 to 1
Connecting Rod	98.4250 mm (3.8750 in)

with increasing compression ratio. At lower compression ratios, improvements in imep will dominate, while at higher compression ratios, the fmep begins to offset gains in imep. Increasing compression ratio also serves to reduce clearance volume, thereby increasing the heat addition to the cycle for any fixed cylinder displacement. Taylor indicates that compression ratio can also have an influence on volumetric efficiency by causing an increase in volumetric efficiency with increased compression ratio when the exhaust pressure is higher than the intake pressure.

ENGINE TEST RESULTS FOR THREE COMPRESSION RATIOS

In 1987 Camacho completed a study of the influence of compression ratio on engine performance.

A new 5 hp. engine with the standard 6.2 compression ratio head was first "run-in" for about 10 hours on gasoline at 1/4, 1/2 and rated power. The producer gas compression ratio tests added another 54 hours of engine operation. The engine was modified for the 7.3 and 8.2 compression ratio tests by machining two production-line cylinder heads that had not been milled for the standard 6.2 compression ratio.

The engine performed best at the 7.3 compression ratio in that for all test loads, very small and infrequent load or combustion air adjustments were needed to maintain a constant speed (Inigo R. Camacho, et al.: Fig. 7). For the 6.2 and 8.2 compression ratio, these adjustments were made frequently to control the engine speed. For most of the tests, the amount of CO in the engine exhaust gas ranged from 0.35 to 0.55% while the hydrocarbons ranged from 0.15 to 0.50 ppm. The combustion chamber and spark plug showed very little carbon deposit at the end of the tests. The spark plug closely resembled that of an engine fueled with LP or natural gas. Rice hull char was the filter material in the packed bed filter (See Tiangco, Fig. 4).

The lower heating value of the producer gas induced by the engine averaged 3801 kJ/m^3 (102 Btu/ft^3) and ranged from 3652 to 3877 kJ/m^3 (98 to 104 Btu/ft^3). Lower quality gas was produced with the 6.2 compression ratio and improved at the higher compression ratios. The best quality gas (3877 kJ/m^3, 104 Btu/ft^3) was for one of the 7.3 compression ratio tests when one reactor of fuel was used for the speed range starting at 3600 rpm and ending at 2400 rpm in 200 rpm steps. The molecular weight of the gas changed very little. However, a small change in the hydrocarbon concentration has a large effect on the lower heating value of the producer gas. The 7.3 compression ratio increased the brake power over the standard 6.2 compression ratio by 13.5% at 2600 rpm and nearly 19% at 3600 rpm. Similarly, the increase for the 8.2 compression ratio ranged from 8% at 2600 rpm to 11.6 percent at 3200 rpm and then dropped to 9.3% at 3600 rpm. This result is not expected from a theoretical standpoint and likely indicates deficiencies in combustion chamber and valve configuration.

CONCLUSIONS

1. A specialized, downdraft-type gas producer system has been developed and extensively tested with rice hulls for fueling small gasoline engines. The system is made from standard steel stock components, requires no auxiliary power to operate and can provide gas fuel for continuous engine operation.

2. Standard gasoline engines will be derated 55 to 60 percent. The required spark advance for optimum power from rice hull generated producer gas is 23 degrees before top-dead-center.

3. An increase of around 20% in the brake power was achieved with the 7.3 compression ratio in comparison to the standard 6.3 compression ratio for the 5 hp Briggs and Stratton engine. This compression ratio gave the best engine-gas producer performance in terms of speed stability at each of the fixed loads.

4. Combustion chamber deposits from producer gas fueling were similar to those for gasoline fueling, indicating that the gas clean-up system provided clean gas.

REFERENCES

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Kaupp, A. 1984. Gasification of Rice Hulls, Theory and Praxis, a publication of GATE, Vieweg & Sohn, Federal Republic of Germany.

Tiangco, V. M., B. M. Jenkins, J. R. Goss and W. J. Chancellor. 1986. Design and Development of a Continuous Small-Scale Rice Hull Gas Producer, for presentation at the 1986 Summer Meeting, American Society of Agricultural Engineers, ASAE Paper #86-3070.

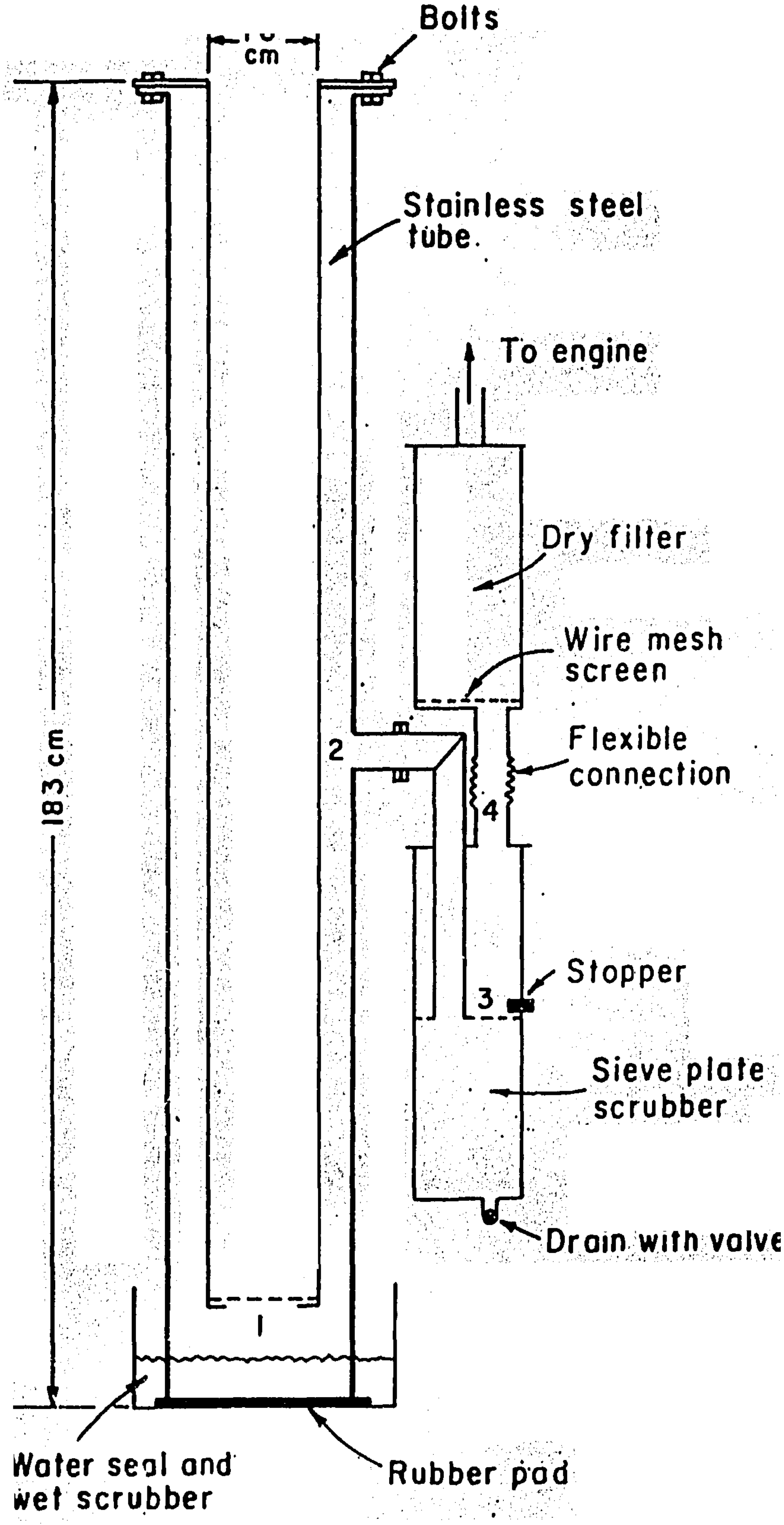

Figure 10-34. Batch fed gas producer without ash removal 1, 2, 3, 4 location of thermocouples.

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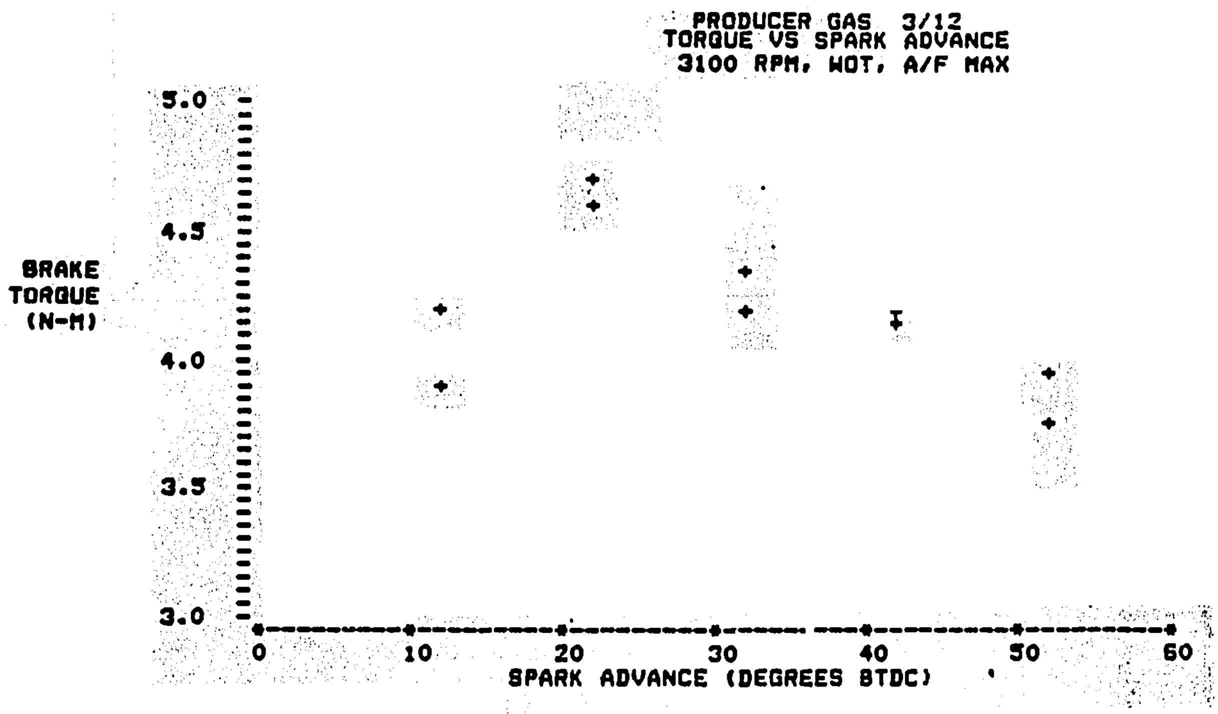


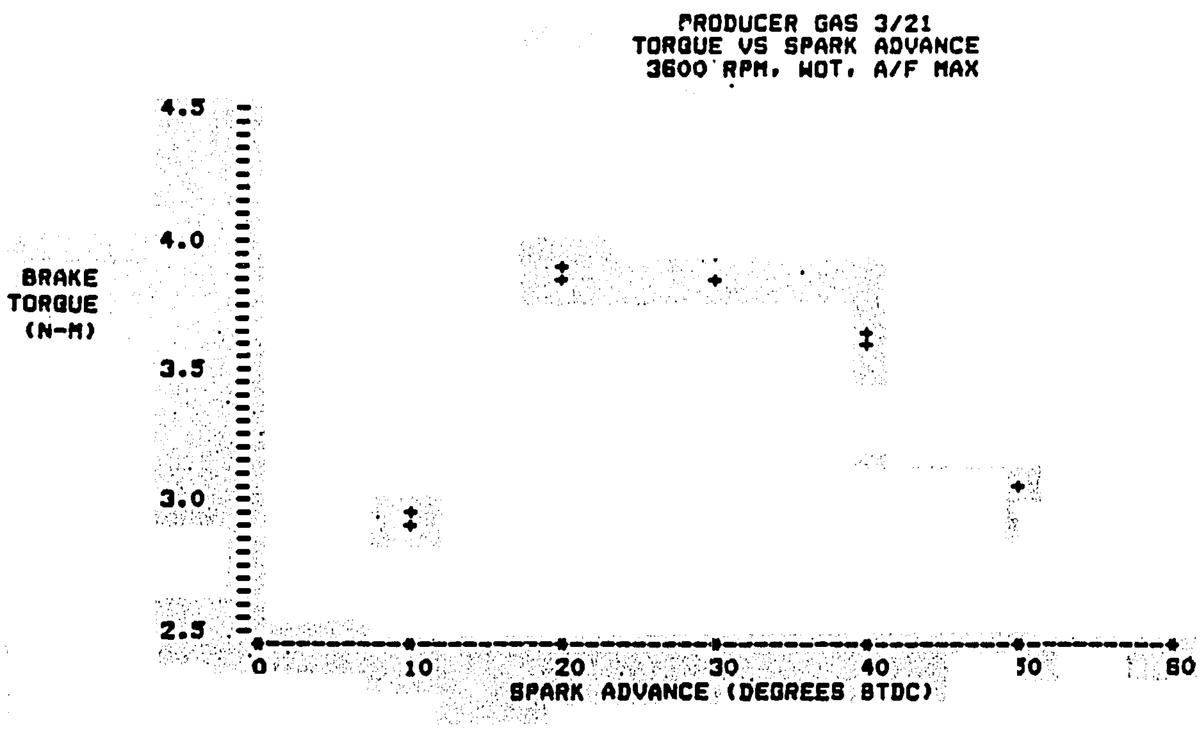


Fig. 12 Torque vs. spark advance at 3100 and 3600 RPM on producer gas.

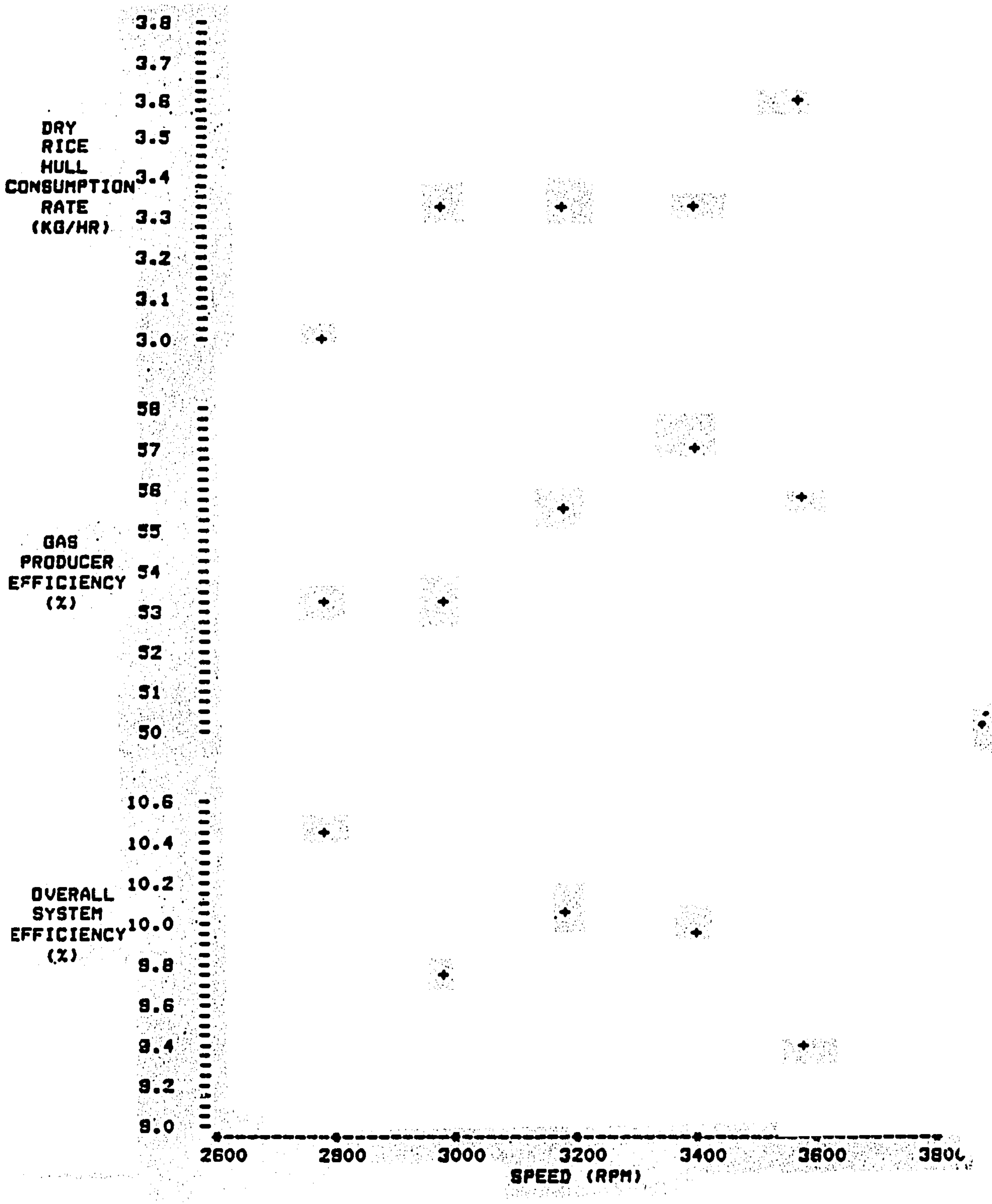
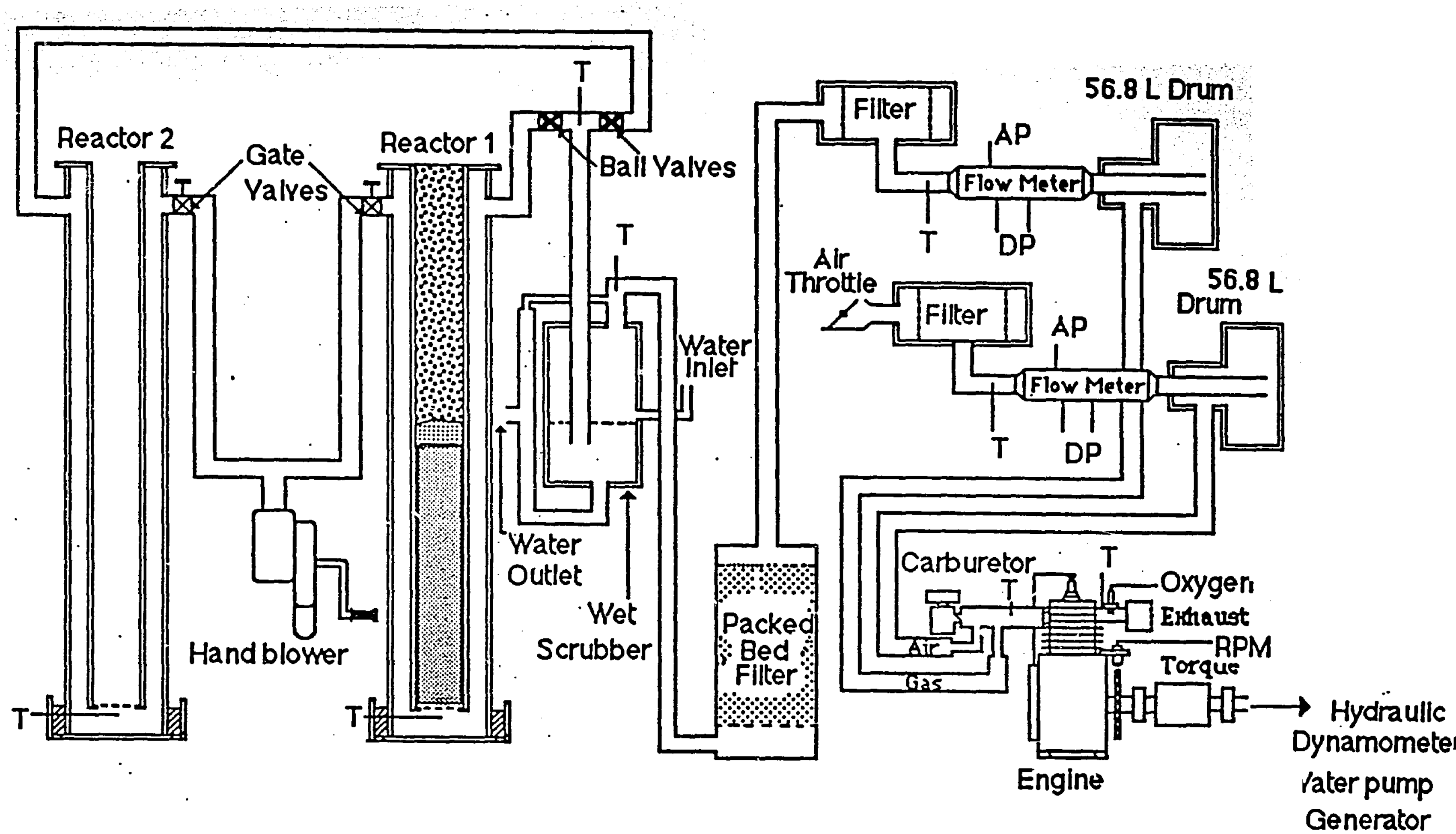


Fig. 14 Gas producer performance and overall system efficiency vs. engine speed.



Legend: T- Temperature measurement
DP-Differential pressure measurement
AP- Absolute pressure measurement

Fig. 4 Instrumentation and test set-up of dual reactor rice hull gas producer-engine system

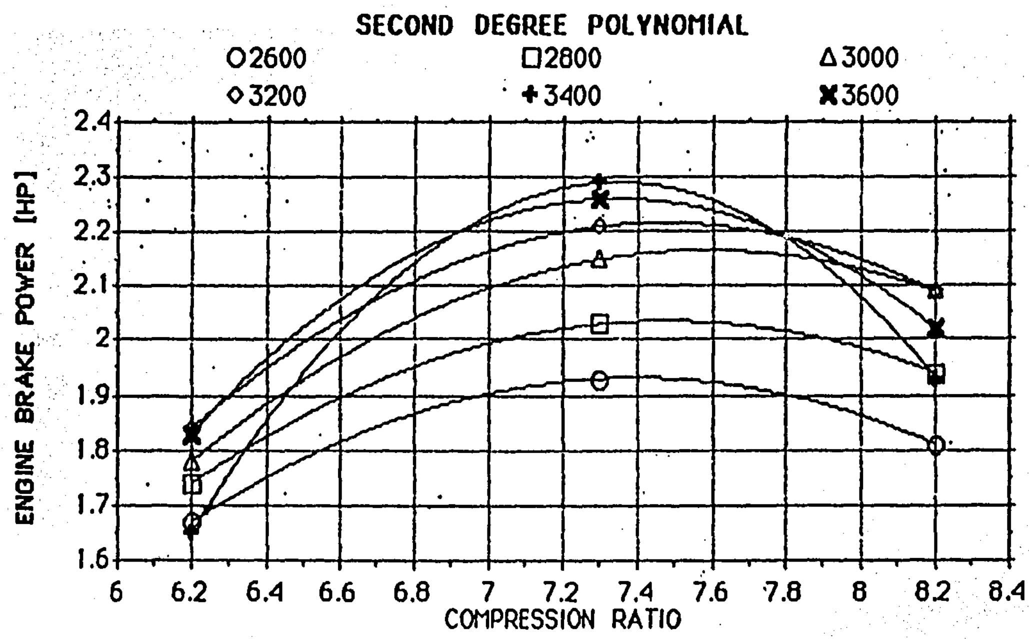


Fig. 7. Corrected engine brake power (hp). Data from Table 5 with compression ratios 7.3a and 7.3b deleted

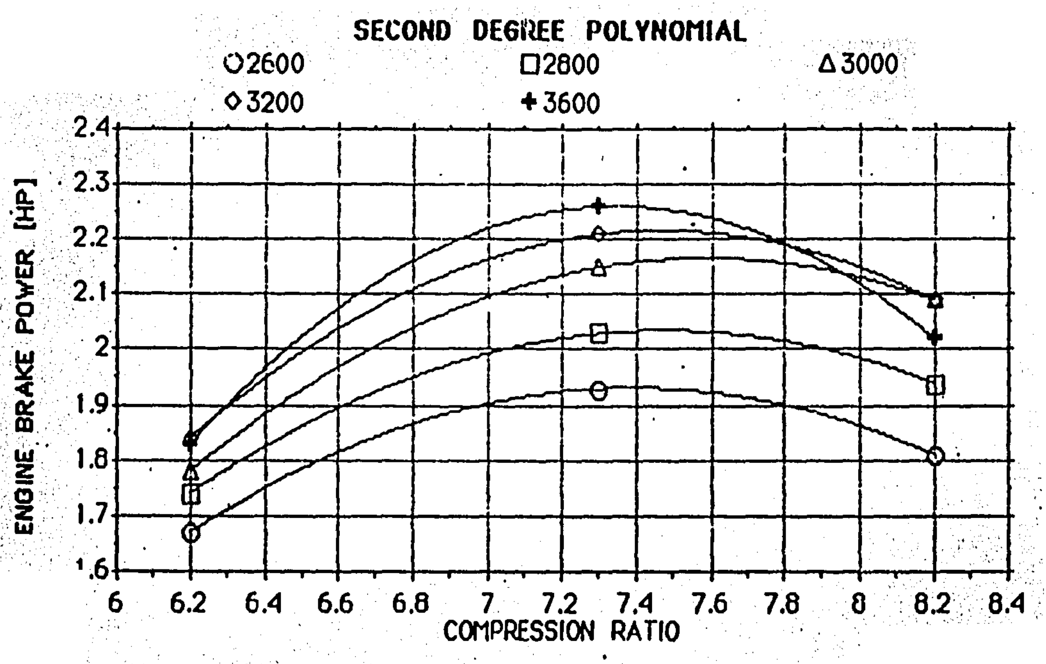


Fig. 8. Corrected engine brake power (hp). Data from Table 5 with compression ratios 7.3a and 7.3b and 3400 rpm deleted.

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GAS TURBINE COGENERATION WITH AGRICULTURAL RESIDUES

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Viewgraphs for presentation at the

Convocation on Rice Residue Utilization Technology
Market Prospects: U.S. and Overseas

Louisiana State University Agricultural Center
Baton Rouge, Louisiana
January 28-29, 1988

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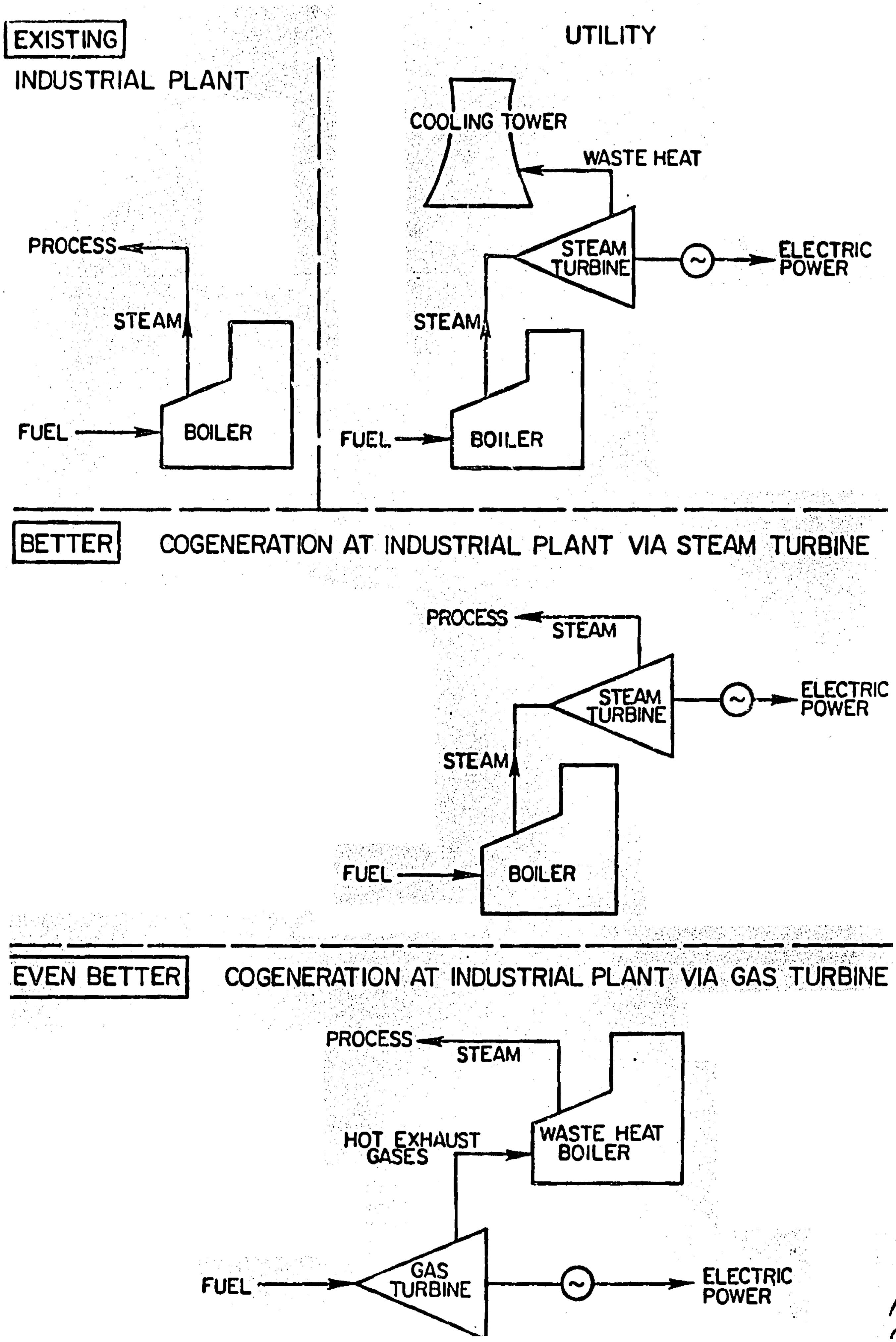
CEES APPROACH TO TECHNOLOGY ASSESSMENT

- o IDENTIFY PROMISING NEAR TERM TECHNOLOGIES WHICH
  - o ARE PRESENTLY UNEXPLOITED OR UNDEREXPLOITED
  - o COULD HAVE LARGE IMPACT IF SUCCESSFULLY DEVELOPED
- o CARRY OUT IN-DEPTH TECHNICAL, ECONOMIC, AND INSTITUTIONAL ANALYSIS
- o OUTREACH TO POTENTIAL PRODUCERS AND POTENTIAL USERS

CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES
TECHNOLOGY ASSESSMENT ACTIVITIES

- o STEAM-USING TECHNOLOGIES FOR SUGAR FACTORIES
- o NEW ELECTRIC MOTOR TECHNOLOGIES
- o NEW BUILDING COOLING TECHNOLOGIES
- o ENERGY EFFICIENT FUELWOOD COOKING STOVES
- o ADVANCED GAS TURBINES FOR
  - o CENTRAL-STATION BASELOAD POWER (GAS FIRED)
  - o CENTRAL-STATION BASELOAD POWER (COAL-FIRED)
  - o INDUSTRIAL COGENERATION (GAS FIRED)
  - —> o INDUSTRIAL COGENERATION (BIOMASS-FIRED)
  - o COMMERCIAL/RESIDENTIAL COGENERATION (GAS FIRED)


EXISTING
INDUSTRIAL PLANT
UTILITY
COOLING TOWER
WASTE HEAT
PROCESS
STEAM
STEAM TURBINE
ELECTRIC POWER
STEAM
STEAM
FUEL
BOILER
FUEL
BOILER
BETTER
COGENERATION AT INDUSTRIAL PLANT VIA STEAM TURBINE
PROCESS
STEAM
STEAM TURBINE
ELECTRIC POWER
STEAM
FUEL
BOILER
EVEN BETTER
COGENERATION AT INDUSTRIAL PLANT VIA GAS TURBINE
PROCESS
STEAM
HOT EXHAUST GASES
WASTE HEAT BOILER
FUEL
GAS TURBINE
ELECTRIC POWER

WHY GAS TURBINE COGENERATION ?

====> LOWER UNIT CAPITAL COSTS
THAN STEAM TURBINES

====> WEAKER SCALE ECONOMIES
THAN STEAM TURBINES

====> HIGHER THERMODYNAMIC EFFICIENCY
THAN STEAM TURBINES

====> UNDER ACTIVE DEVELOPMENT FOR
FIRING WITH SOLID FUELS

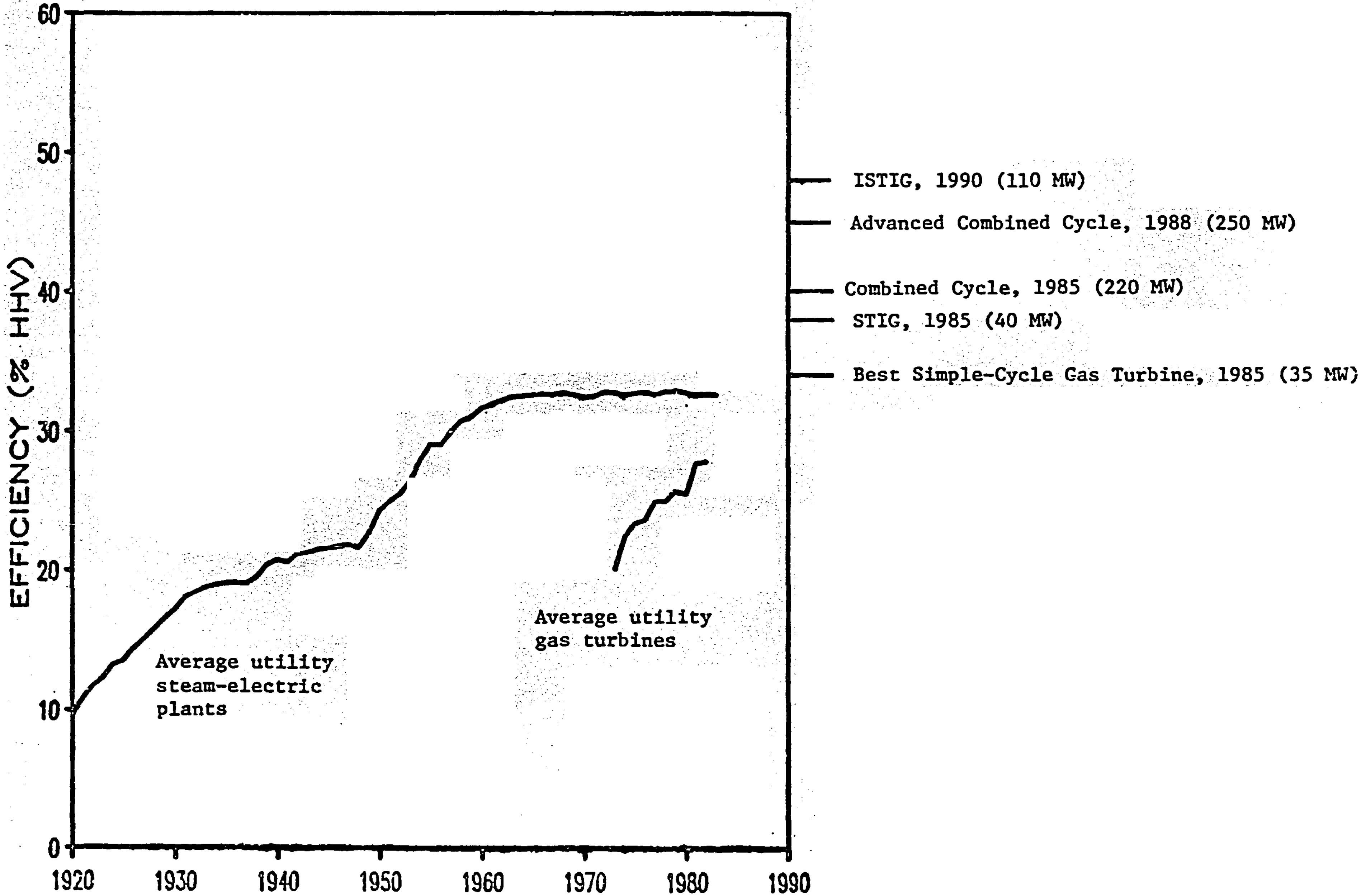
====> ONGOING TECHNOLOGICAL REVOLUTION DUE TO:

===> $400 MILLION/YR DoD R&D INVESTMENTS

===> MARKET DEMANDS OF COMMERCIAL AIRLINES

===> PURPA AND THE COGENERATION BOOM

CENTRAL-STATION
ELECTRICITY GENERATION IN THE US



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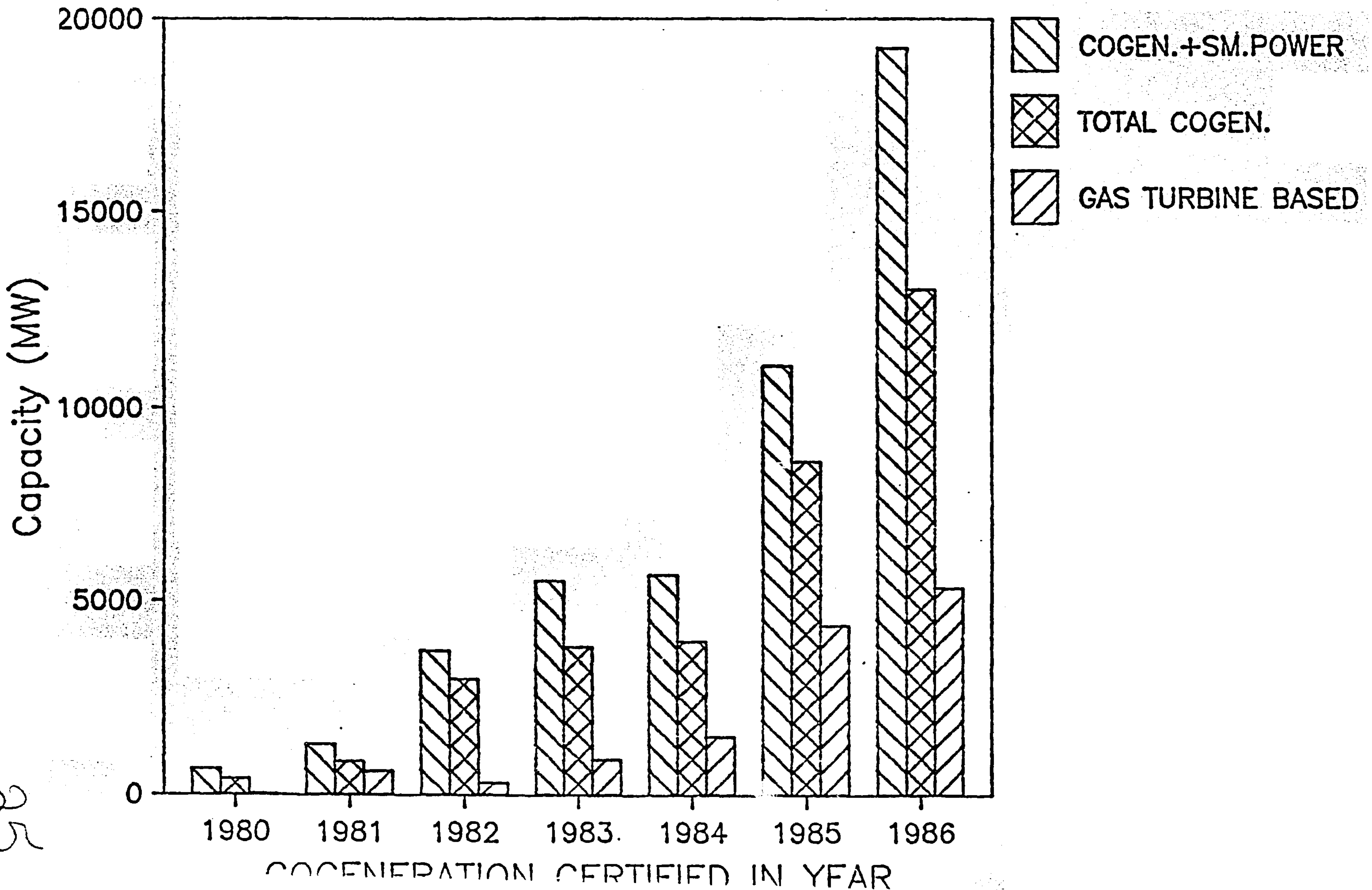
CERTIFIED COGENERATION IN THE U.S.



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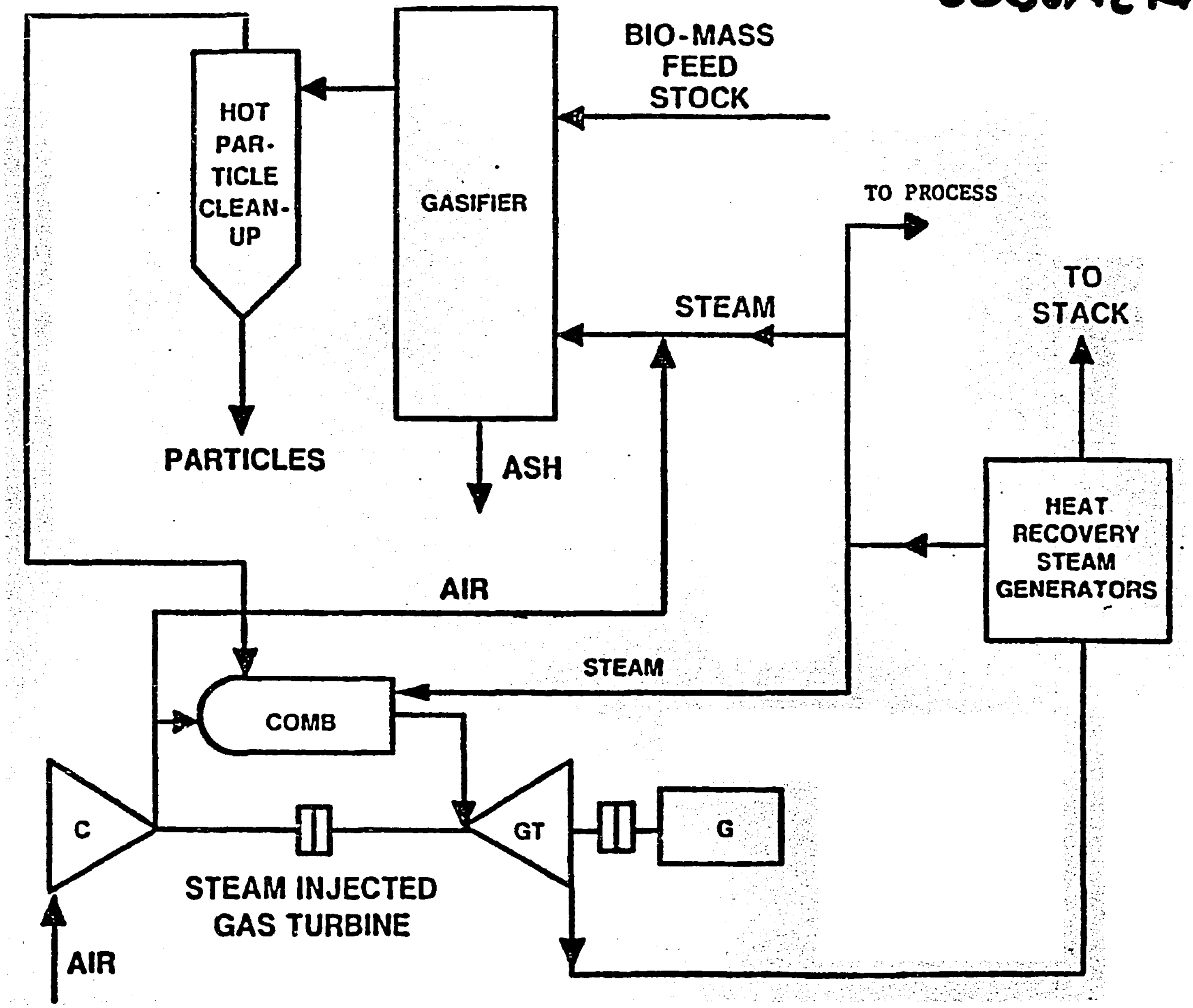
BIOMASS-GASIFIER STEAM-INJECTED GAS TURBINE COGENERATION



DRAFT

POTENTIAL FOR PRIVATE INVESTMENT IN RICE RESIDUE POWER GENERATION

INDONESIA 1987

PRELIMINARY ANALYSIS

Betsy Amin-Arsala, Project Leader
Dr. Marcia M. Gowen
Dr. Macon D. Faulkner

prepared for

Bioenergy Systems and Technology
Office of Energy
Science and Technology Bureau
U. S. Agency for International Development

by

Tennessee Valleu Authority Under RSSA: BST-5709-R-TV-2181

November 1987

ROLE OF A.I.D. S&T/EY

IN

PROJECT DEVELOPMENT

<u>Project Stages</u>

Pre-feasibility Analysis*

- Assess Potential/Risks
  - Resource
  - Technical
  - Economic/Financial
  - Institutional/Policy
  - Institutional/Policy
- Outline Options

Project Development/Risk Assumption

- Pre-Investment Analysis*

- Technical Feasibility Analysis
  - System Performance
  - System Scale
  - Feedstock Supply
  - By-product Sales

- Financing Package*
  - Captial Financing
  - Equity Financing
  - Insurance

- Policy Support Initiatives*
  - Contract Sanctity
  - Power Puchase Agreements
  - Power Distribution

Project Implementation
- Construction
- O&M
- Power Sales
- Loan Repayment

*Role for A.I.D.

PRE-FEASIBILITY ANALYSIS OF RICE RESIDUE ENERGY SYSTEMS IN INDONESIA

SUMMARY OF RISKS

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RESOURCE BASE

SITUATION

Husk

Small average mill capacity (1 T gabah/day) severely restricts on-site husk supply

Cumulative supply of unused husks in many districts is adequate to meet small (600 KW) to larger (1.5 MW) rice residue plant needs

Low competition for alternative uses (10-25 %)

Neglible husk collection network exists

Collection from mills by husk users (brickmakers, etc)

Straw

Adequate straw available in fields, even if 1/2 left on field

Existing cases of field collection extremely limited (pulp mills)

Conclusion:

Collection of husk or straw manditory for stand-alone systems (1.5 MW still likely for integrated systems (600 KW)

Given lower melting point of rice straw, systems should not presume mixed-fuel possibility.

RISKS

Establishment of husk collection and transport system

Collection may lower feedstock quality

Need consortia of mills or to identify large government mill to meet small (600 KW) or larger (1.5 MW) power plant husk demand

TECHNICAL

SITUATION

U.S. commercial rice residue power systems range from 10-24 MW, pilot systems of 600 KW for steam heat producton

Due to average mi' [illegible] of 1 T gabah/hr in Indonesia, current scale of U.S. rice residue pow[illegible] stems too large for most mills

Conclusion:

Downsizing of U.S.commercial power systems necessary

RISKS

New smaller systems will require commercial demonstration

U.S. manufacturers will need to explore local manufacturing

Quality of ash may change with dowscaling and husk collection

:CONOMIC

SITUATION

Models developed for 600 KW and 1.5 MW systems

Essential to financial feasibility are:

- Ash sales/market
- Operating days/load factor
- Electricity price
- Husk price
- Fincancing terms (interest rate, discount rate) and capital costs

Conclusion:

- Pre-feasibility models indicate smaller scale system (600 KW) has lower unit costs and greater competitive range than larger system (1.5 MW)
- Economics of the systems revolve arouna market ior asn, size oi plant, operating days and electricity price

RISKS

Ash market <u>must</u> be assured

Husk transport network must be feasibile

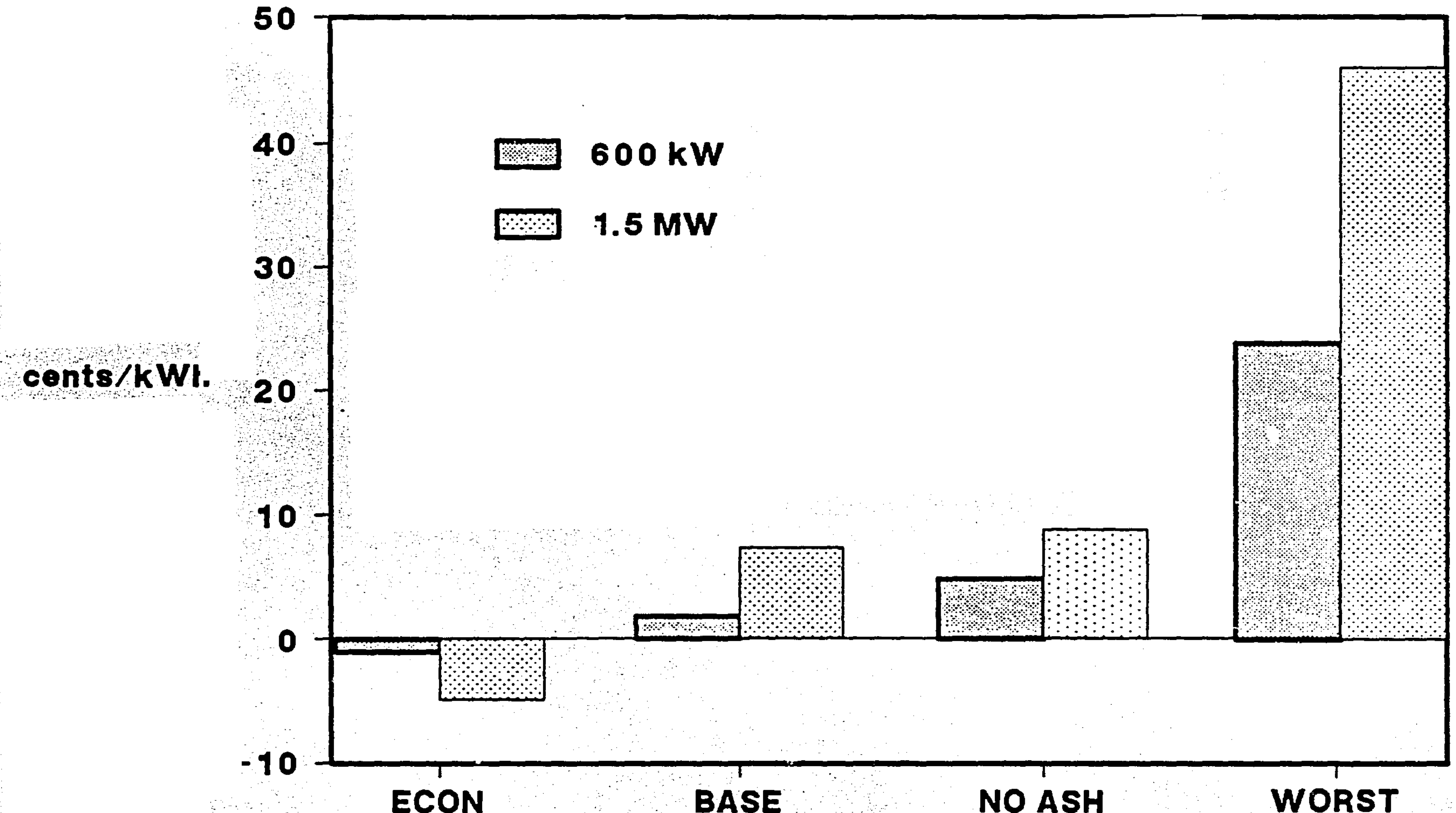
Guaranteed electricity prices- pay or take contract

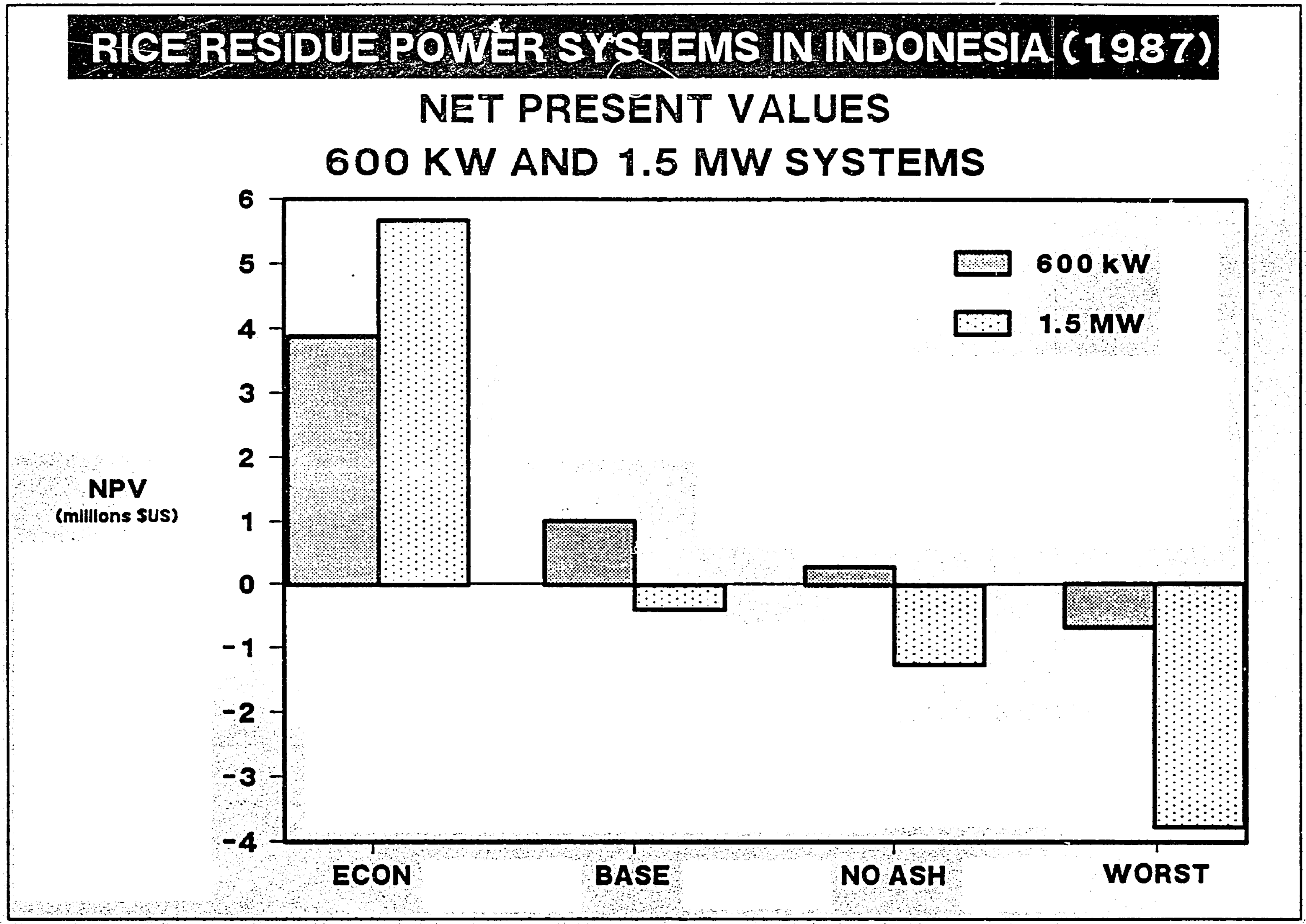
Financing terms must be reasonable, below average market rates for larger system

Demand must exist for adequate operating days

RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)

ELECTRICITY PRODUCTION COSTS
600 KW AND 1.5 MW SYSTEMS

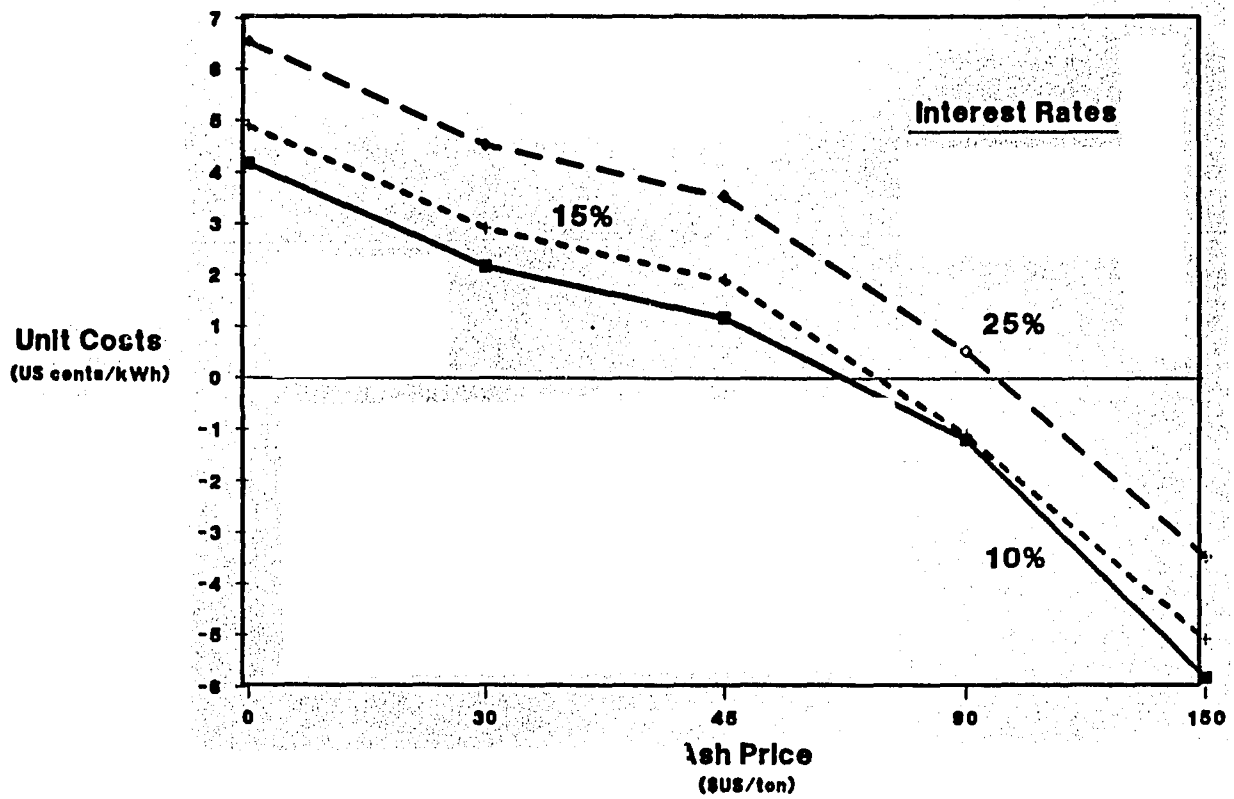



RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)
NET PRESENT VALUES
600 KW AND 1.5 MW SYSTEMS
NPV
(millions $US)
6
5
4
3
2
1
0
-1
-2
-3
-4
600 kW
1.5 MW
ECON
BASE
NO ASH
WORST

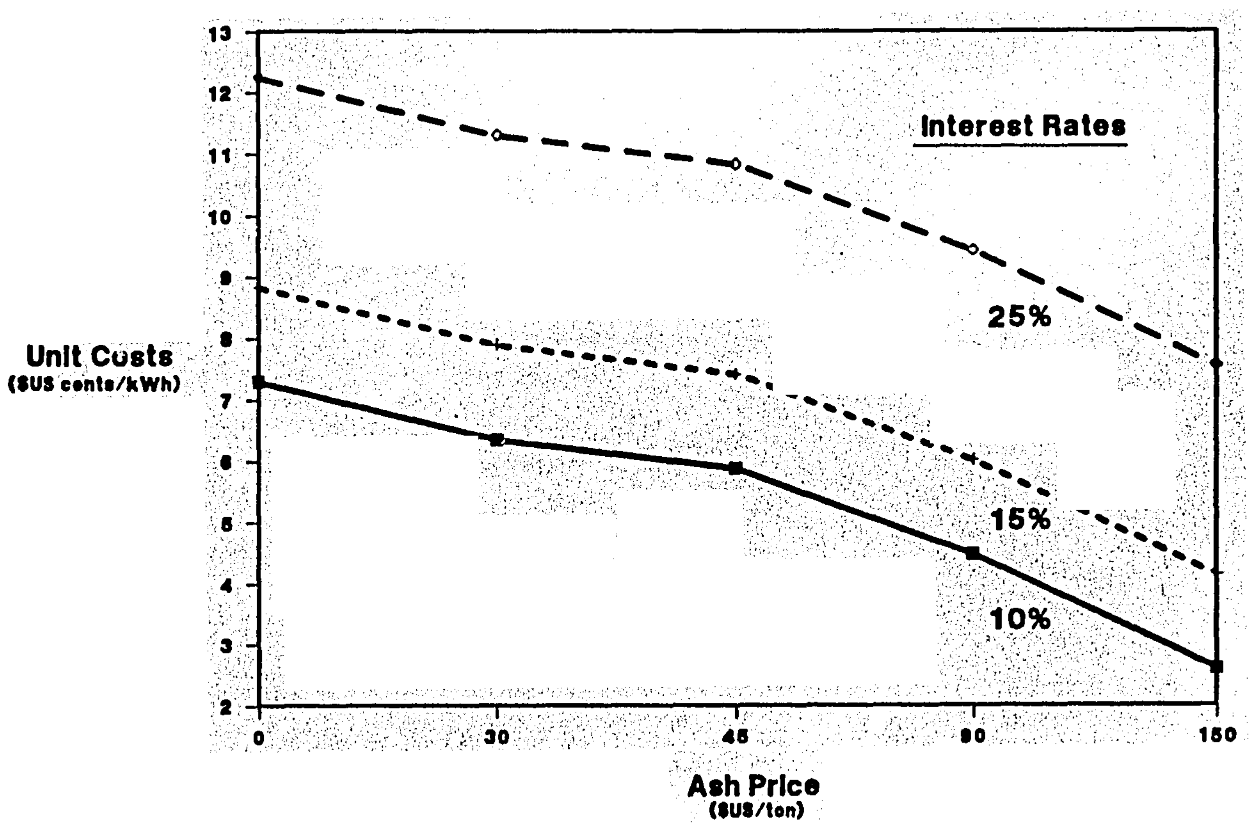
34

ELECTRICITY PRODUCTION COSTS BY ASH PRICE

600 KW SYSTEM

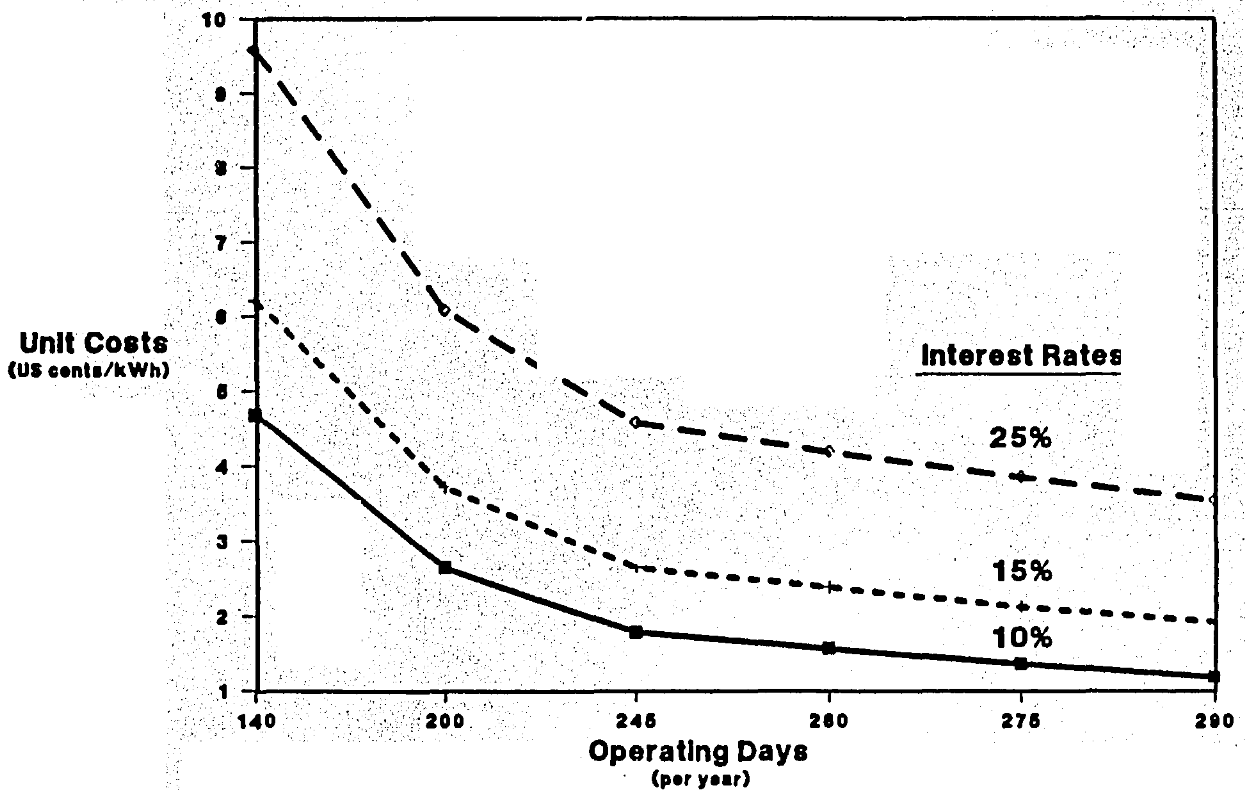


1.5 MW SYSTEM

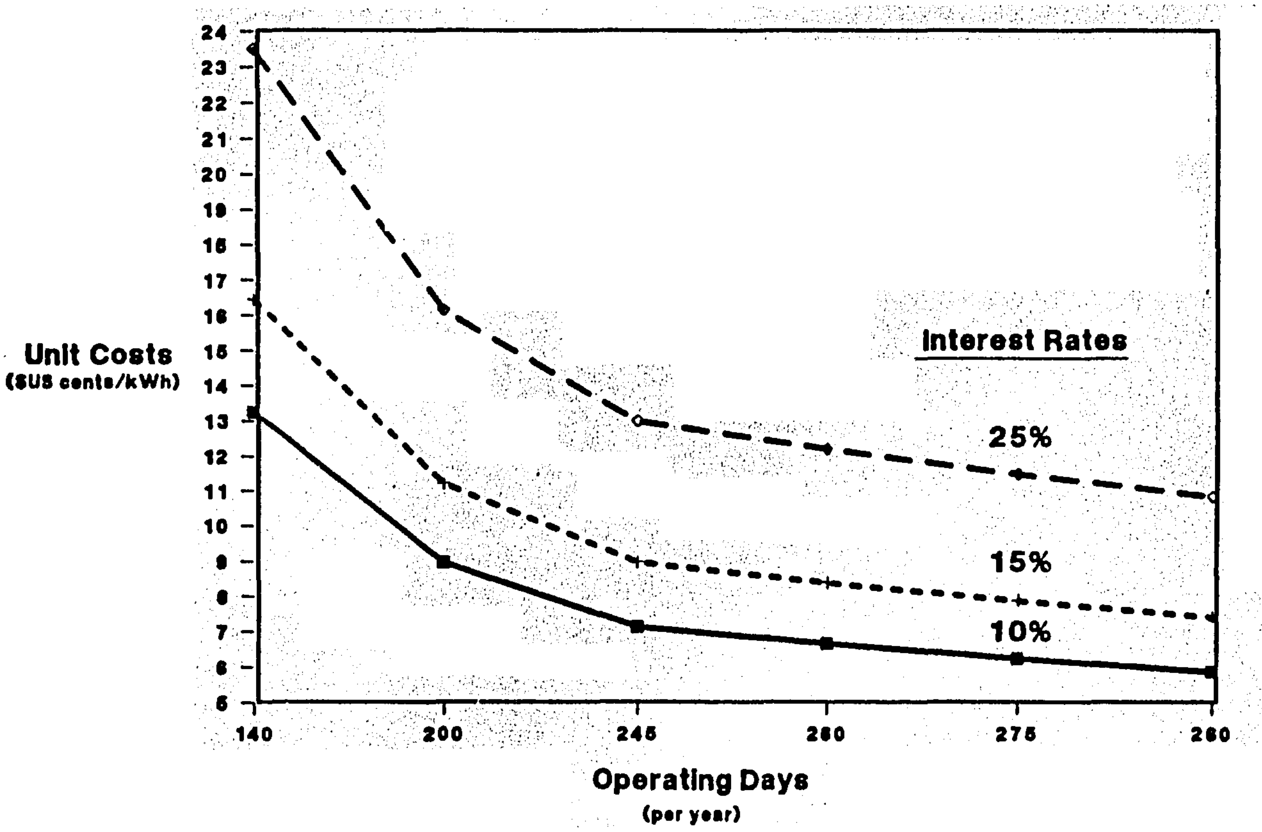


ELECTRICITY PRODUCTION COSTS BY ANNUAL OPERATING DAYS

600 KW SYSTEM

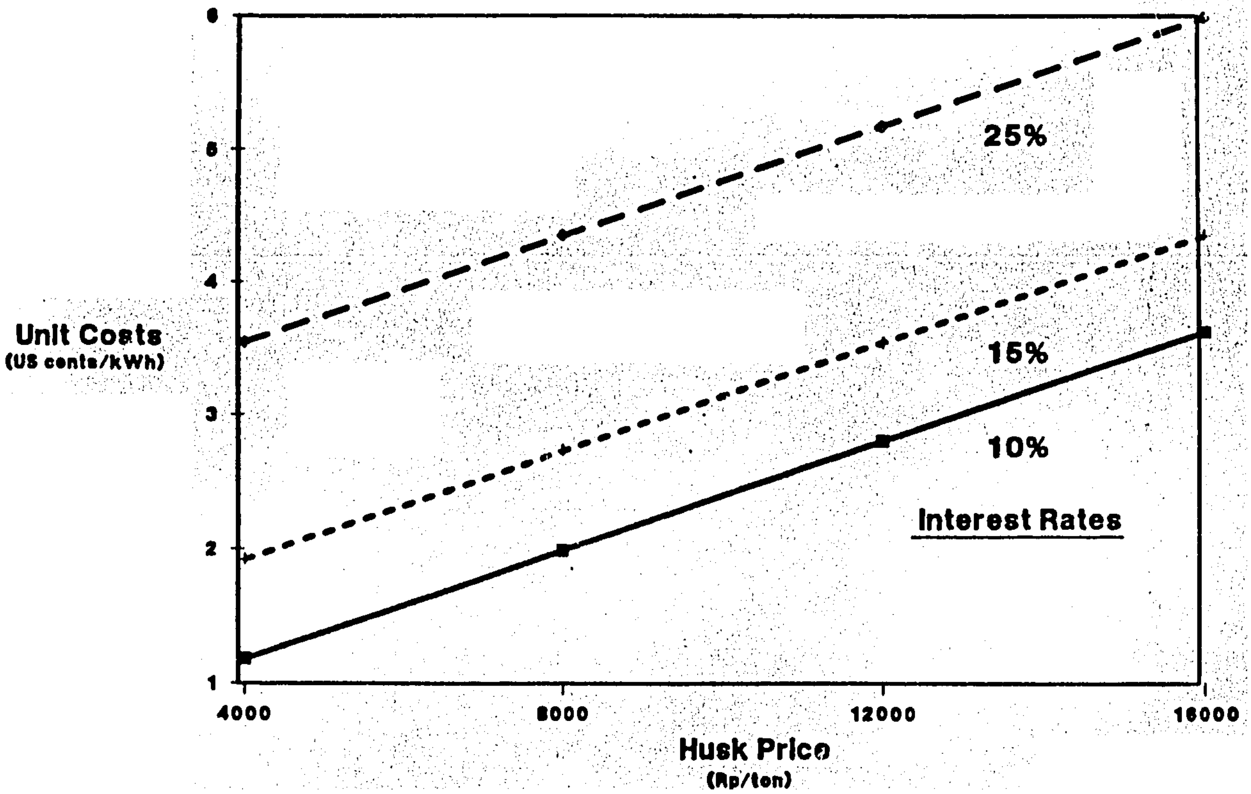


1.5 MW SYSTEM

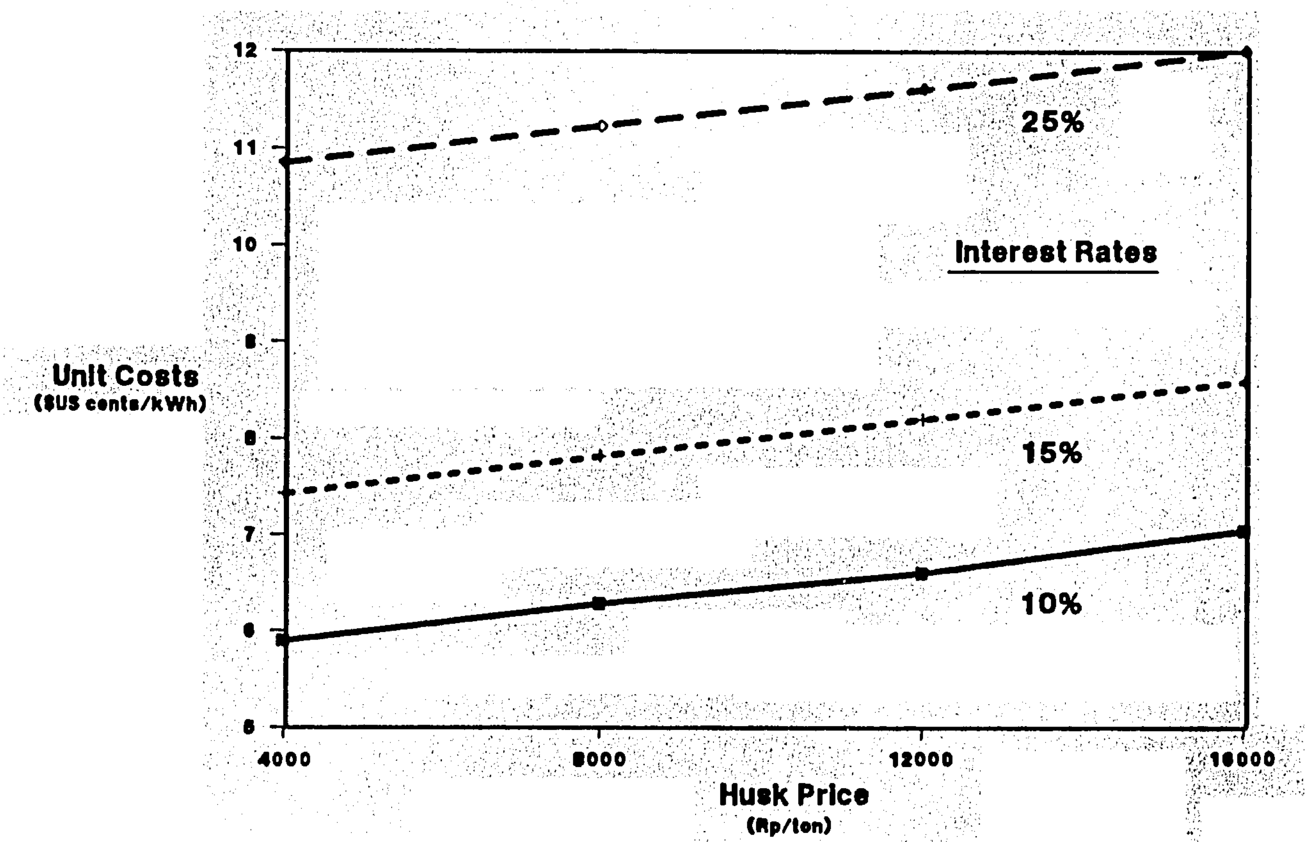


ELECTRICITY PRODUCTION COSTS BY HUSK PRICE

600 KW SYSTEM

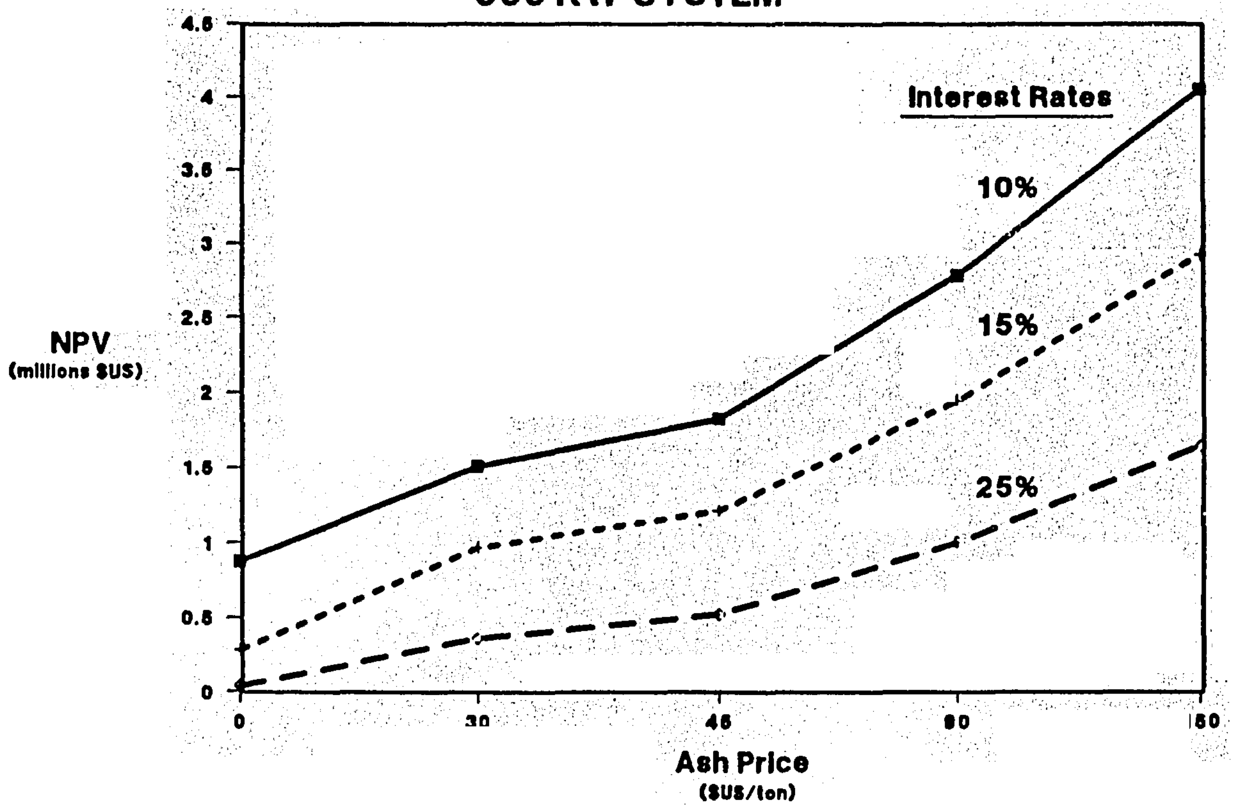


1.5 MW SYSTEM

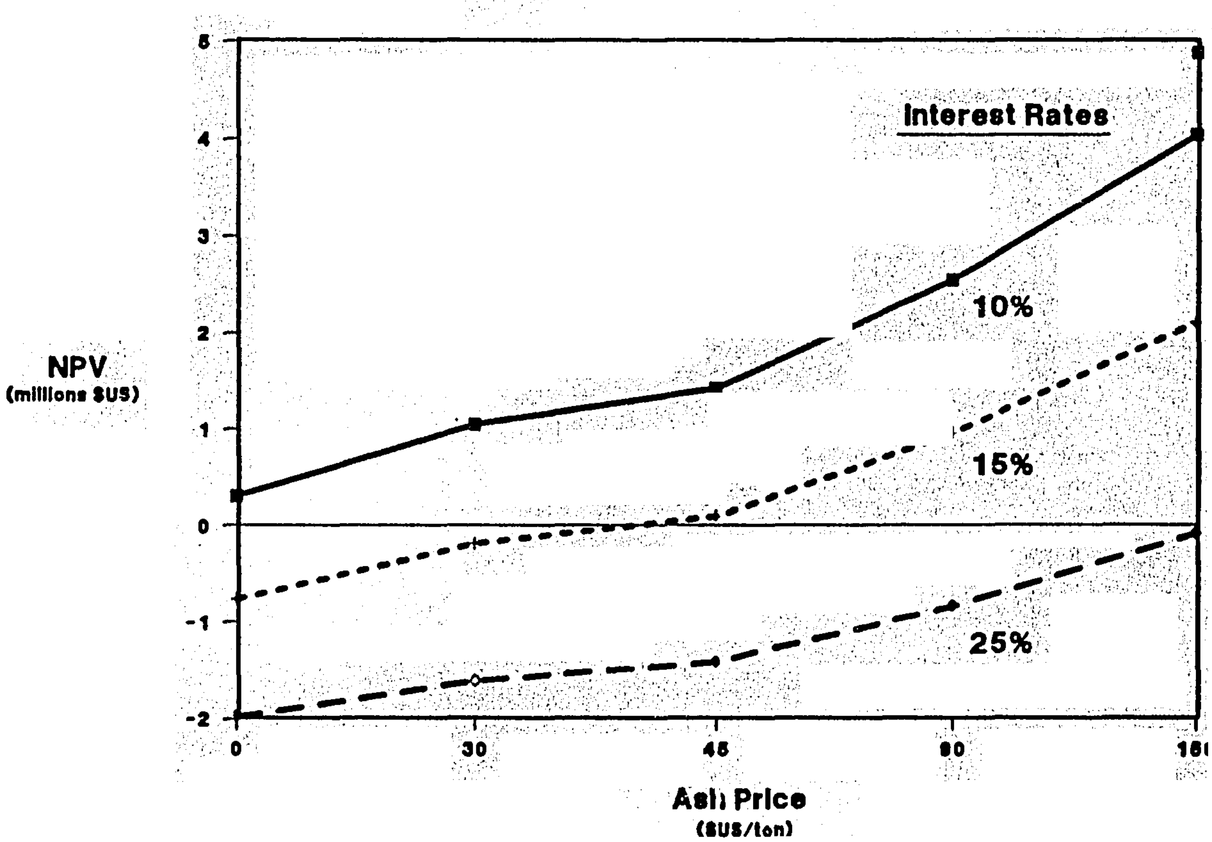


NET PRESENT VALUE BY ASH PRICE

600 KW SYSTEM

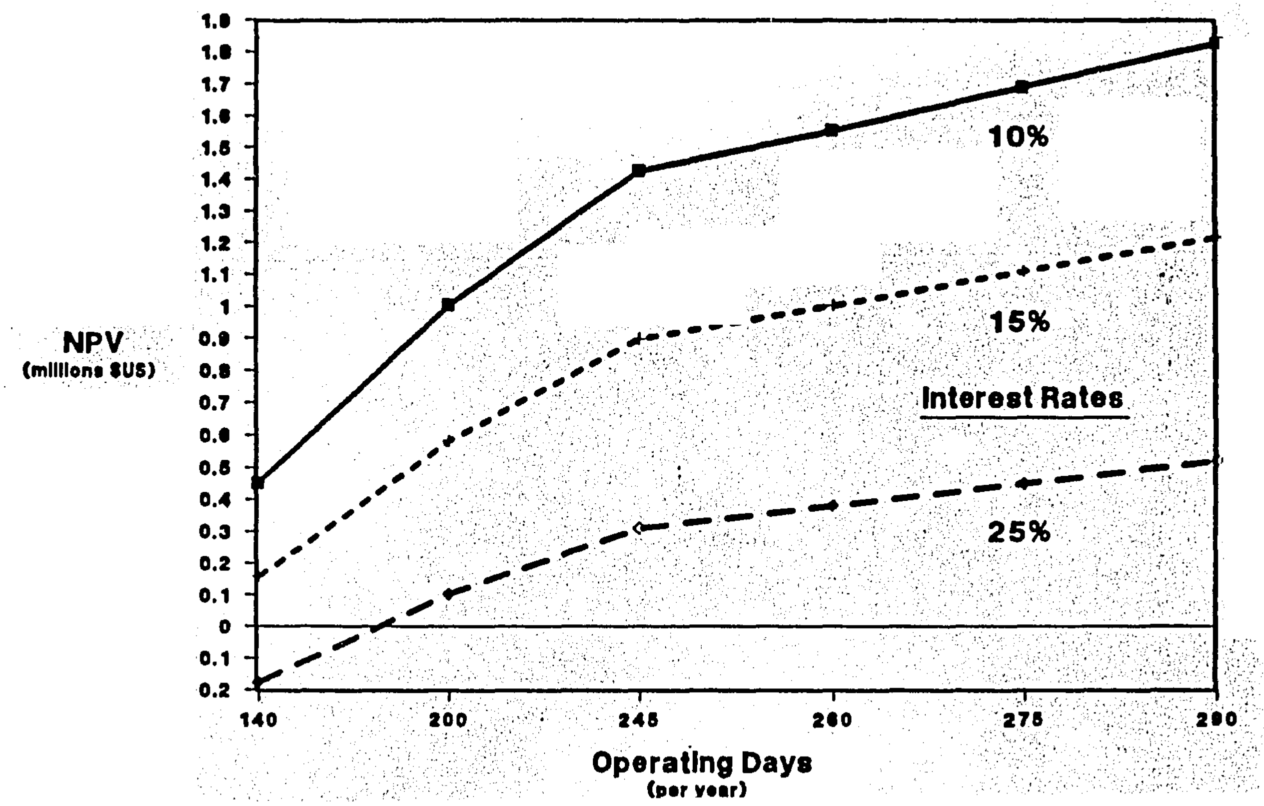


1.5 MW SYSTEM

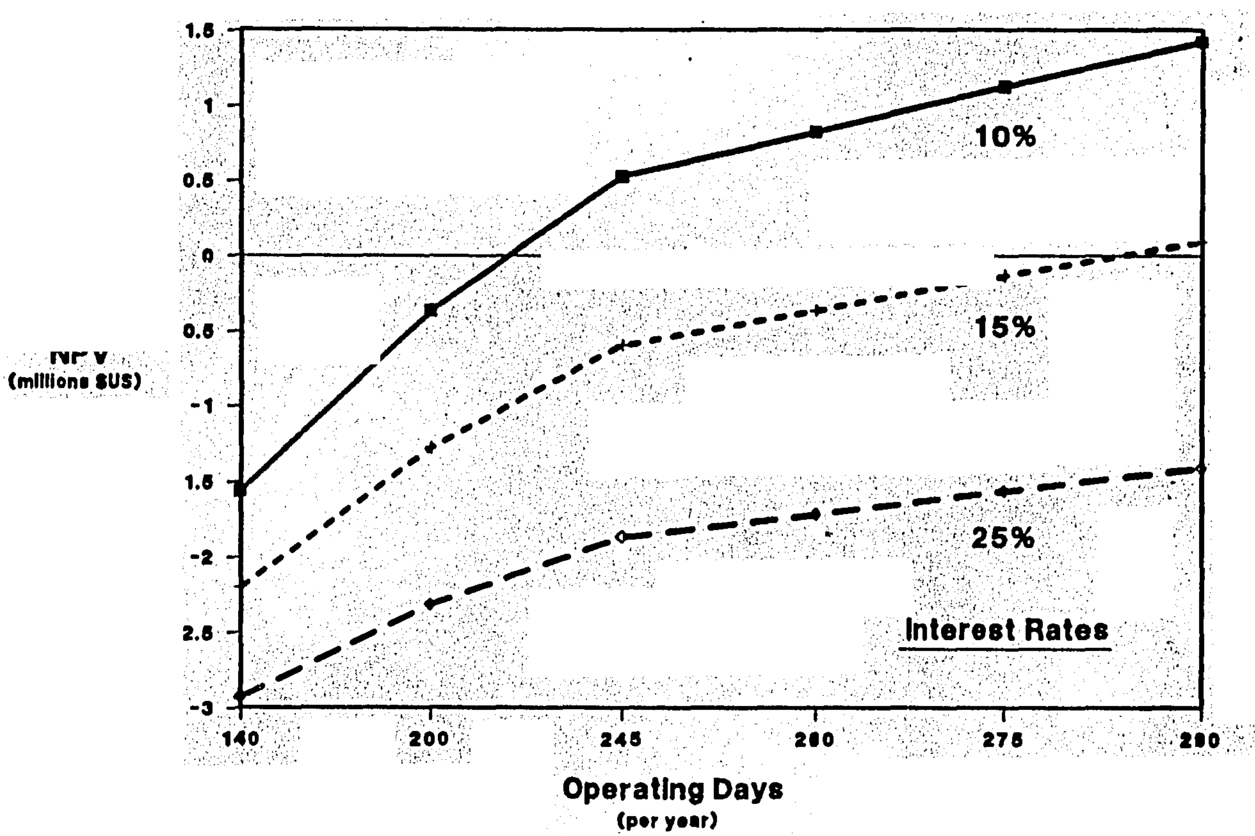


NET PRESENT VALUE BY ANNUAL OPERATING DAYS

600 KW SYSTEM

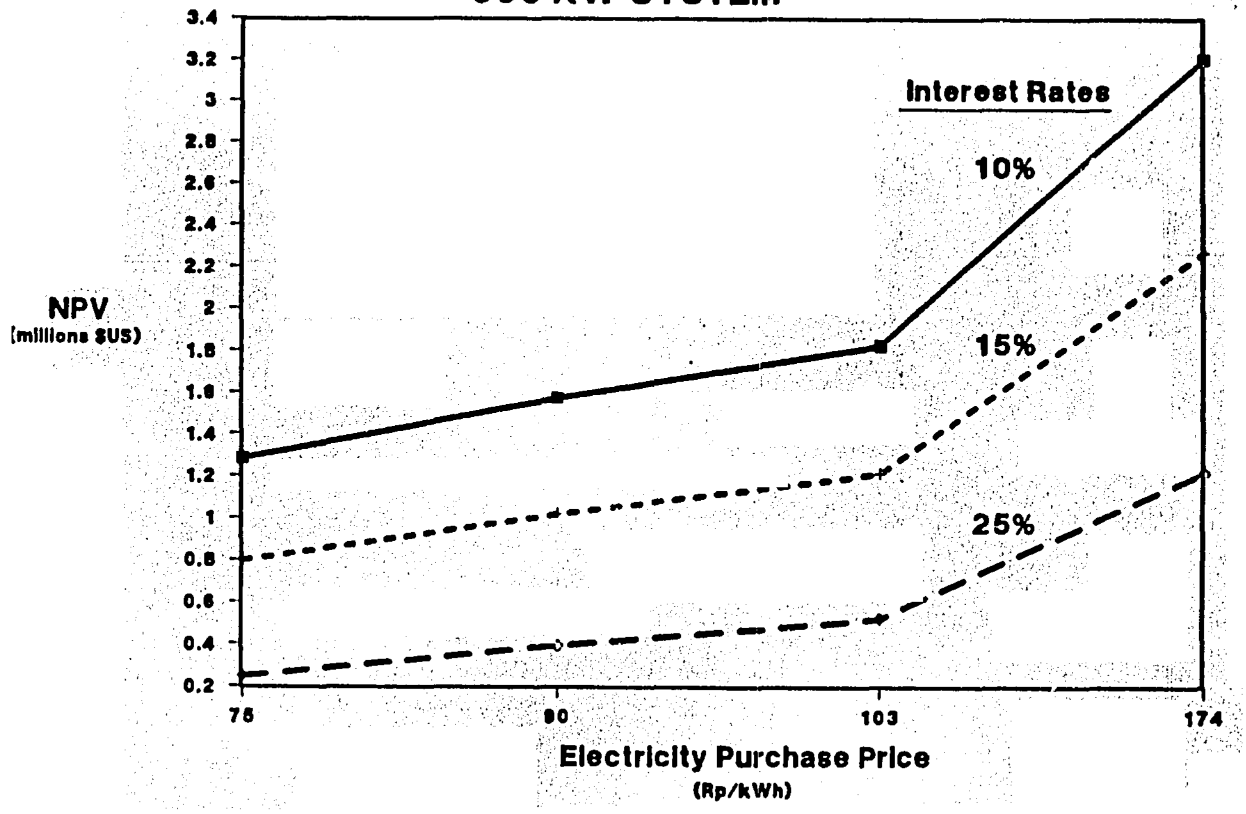


1.5 MW SYSTEM

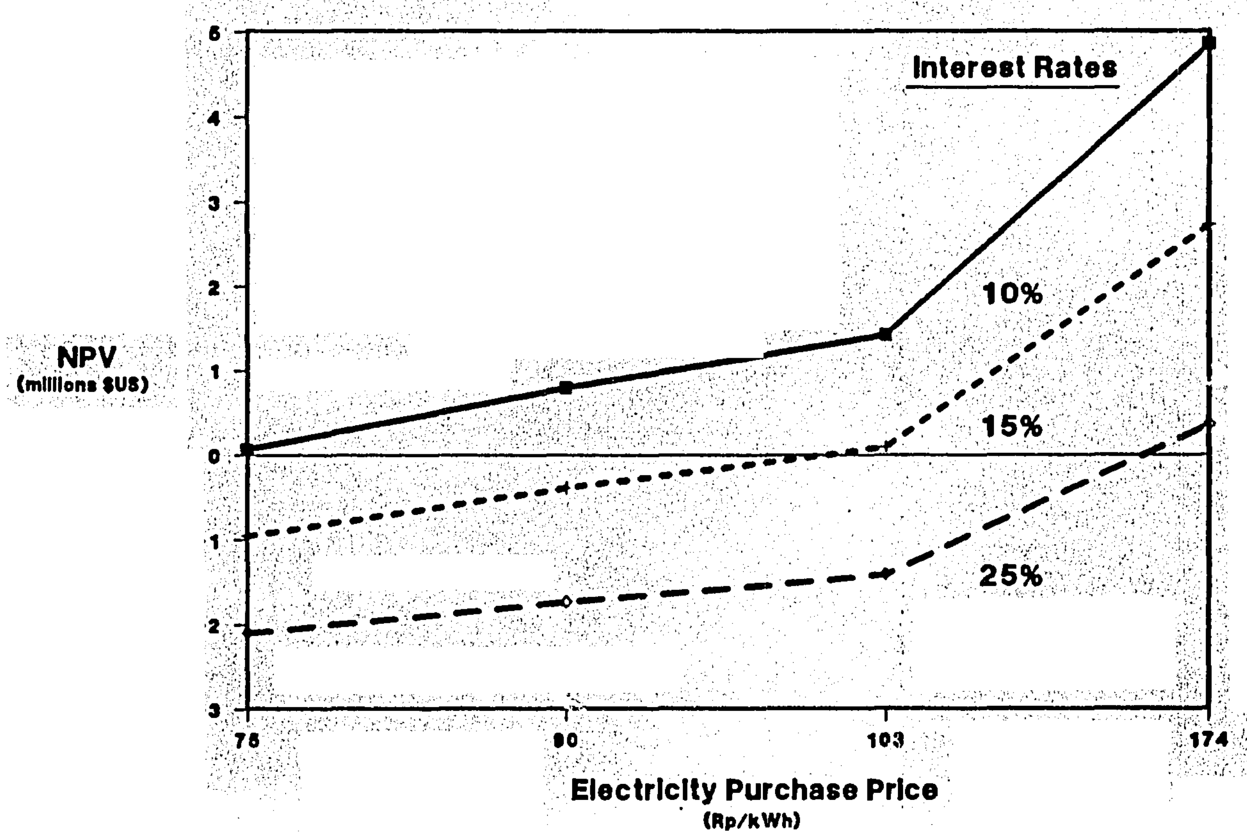


NET PRESENT VALUE BY ELECTRICITY PURCHASE PRICE

600 KW SYSTEM

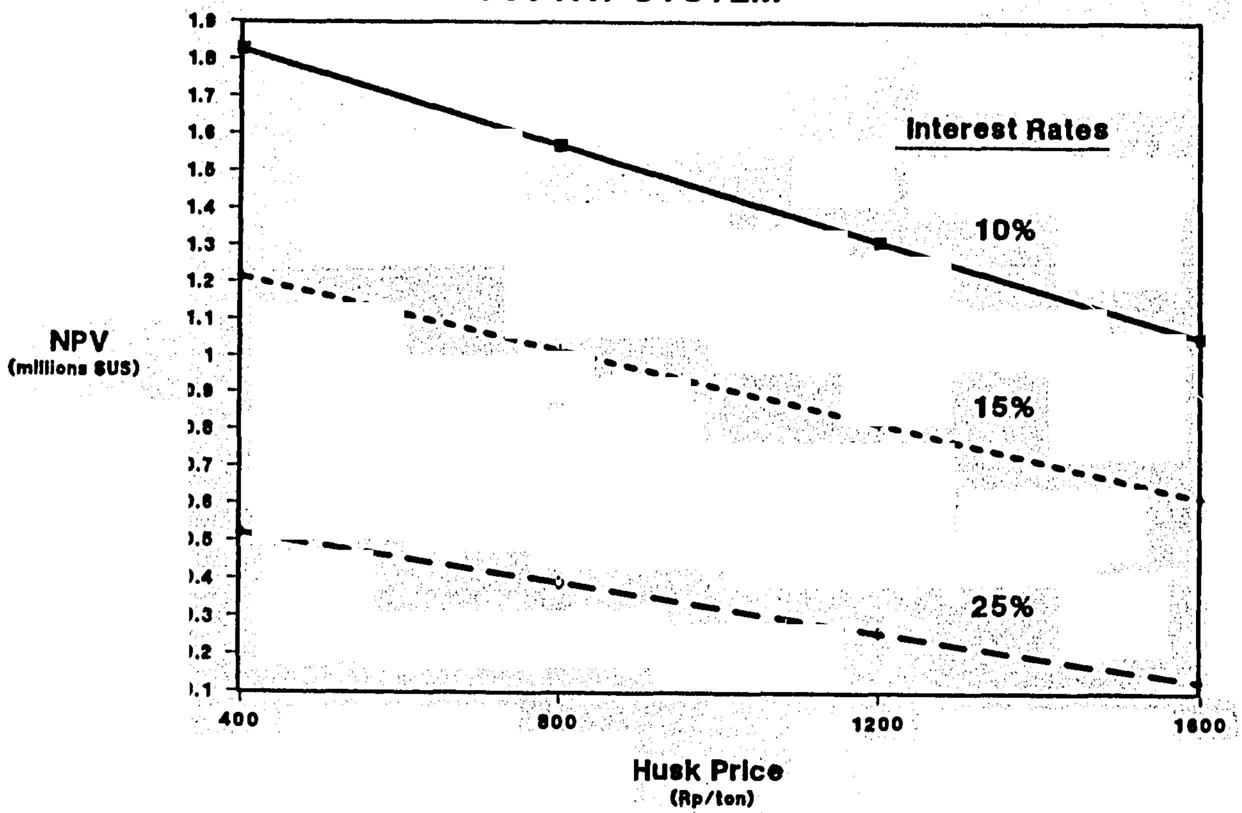


1.5 MW SYSTEM

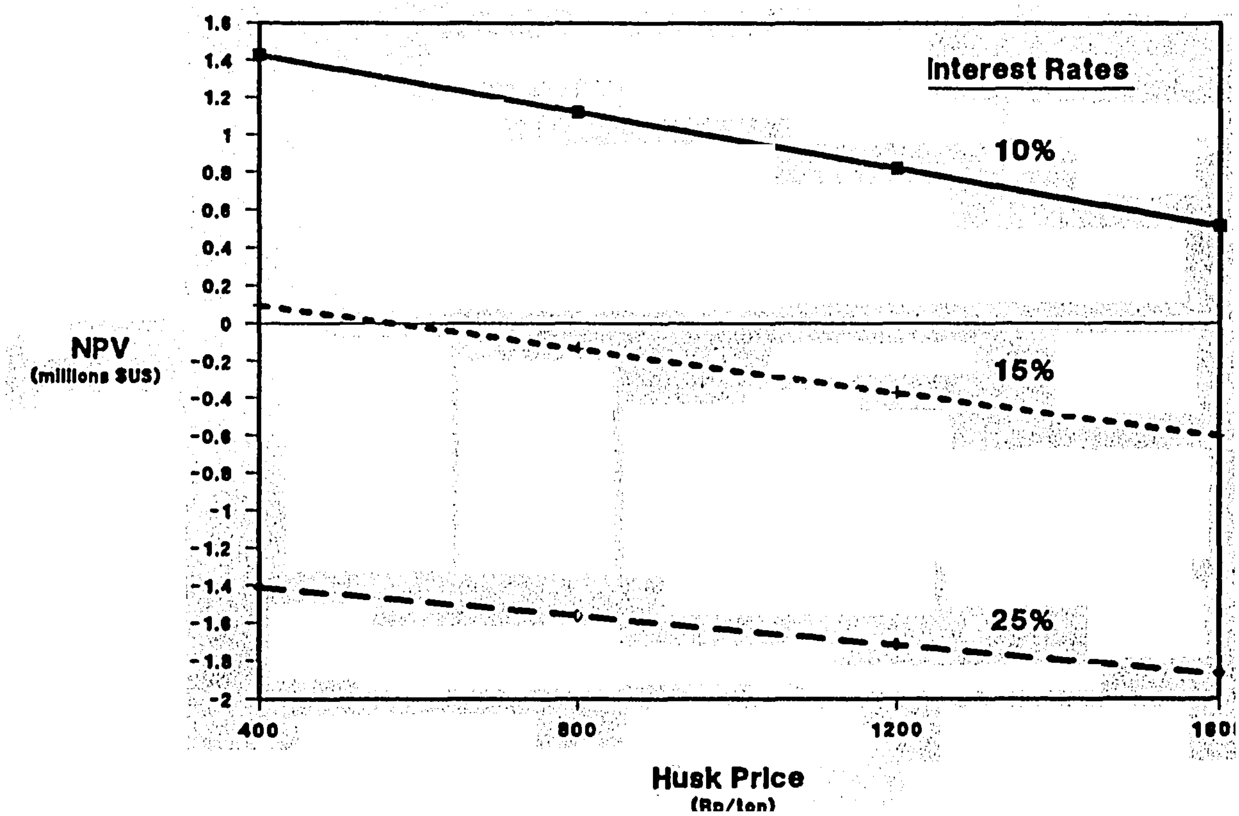


NET PRESENT VALUE BY HUSK PRICE

600 KW SYSTEM



1.5 MW SYSTEM



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FINANCIAL

SITUATION

- Local investors require extremely short payback periods (6 mos to 1 year)
- High returns are required, 16-24 % prime rates of return
- Tax and legal policies discourage private investment
- Limited local equity available
- Economy suffered from loss oil revenues, major 1986 devaluation

RISKS

- Investors will require short loan periods
- Low loan rates are necessary to attract local investors
- Private sector investments, joint ventures need greater support from the government

POLICY and INSTITUTIONAL

SITUATION

Rice

Current policies encourage small mills (1 T/hr) for rural job generation, income benefits and national food supply stability

Electricity

Over 50% total electricity production comes from captive power generation

New 1985 Law allows private sale of electricity

Few cases of private power sales exist

RISKS

Either large mills must be identified to produce captive power or small mills must form consortiums for power generation

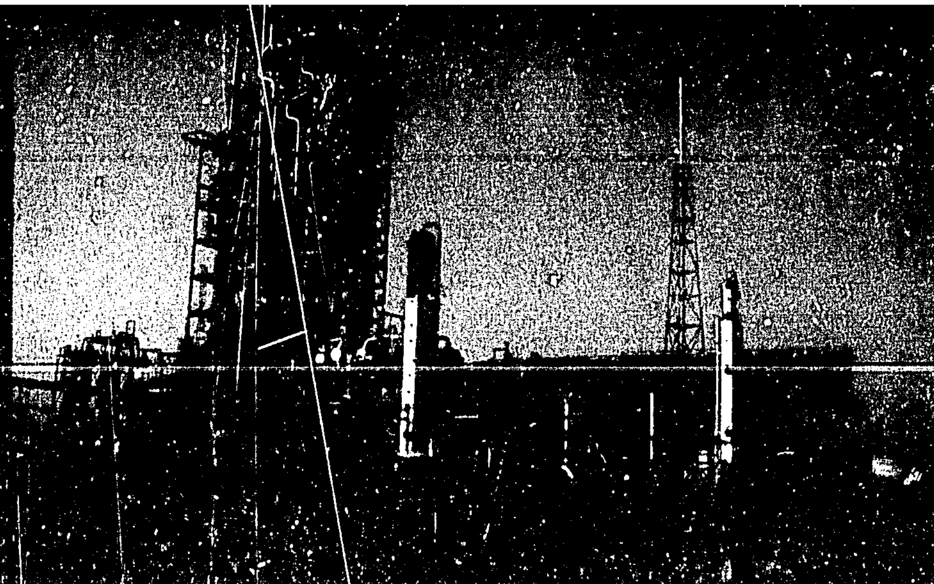
Private power sale laws and guidelines must be better established and promoted

THE
DOW SYNGAS PROJECT
DOW CHEMICAL U.S.A.

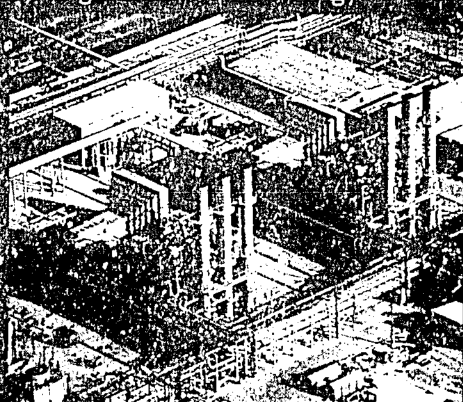
Energy may be society's most valued resource, but it is not always our most accessible one. Often the search for energy seems a futile struggle to make shrinking resources meet ever-growing demand.

The Dow Chemical Company knows the struggle. As a global manufacturer of energy-intensive products such as chlorine, magnesium and a host of petrochemicals, Dow has searched for economical energy sources and efficient conversion processes since the days of the first wood-fired plant built by Herbert Dow himself in the early 1900s.

Today, with an uncertain energy future and unstable costs for foreign oil resources, Dow has turned to a new energy source based on domestic solid fuel reserves and efficient combined cycle gas turbine technology.



The Dow Syngas Project in Plaquemine, Louisiana, began commercial operations in May, 1987.



Dow's Louisiana Division power houses burn syngas in gas turbines.

Developed in the largest research and development project ever undertaken by the company, Dow's efficient coal gasification process produces synthetic gas as a new energy option available to Dow and others in the electrical energy generation industry.

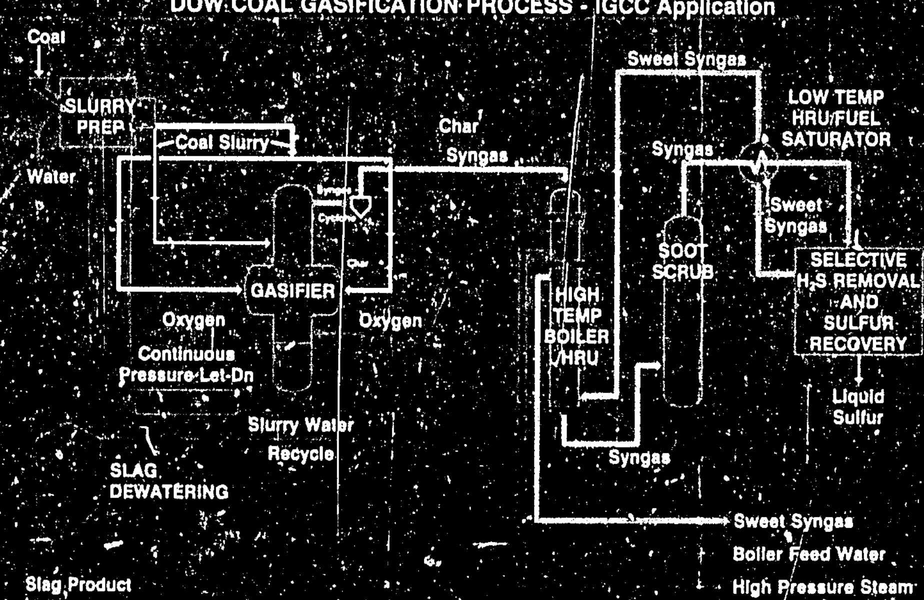
Research on the Dow coal gasification process began more than 10 years ago with the goal of developing a coal-based technology that was environmentally clean, reliable, energy efficient, capable of using a range of coals, competitive in power costs and capable of being introduced with short lead times to meet market needs.

No existing technology met Dow's criteria, so the company began work on its own process. An air-blown pilot plant using 12 tons per day of coal started up in 1978 incorporating Dow's unique two-stage process. It was later converted to a 36-ton-per-day coal oxygen-blown plant.

In 1982 Dow began construction of a 1,600-ton-per-day oxygen-blown proto plant. This plant operated from 1983 to 1985 when data had been collected to establish the design bases for a commercial scale plant.

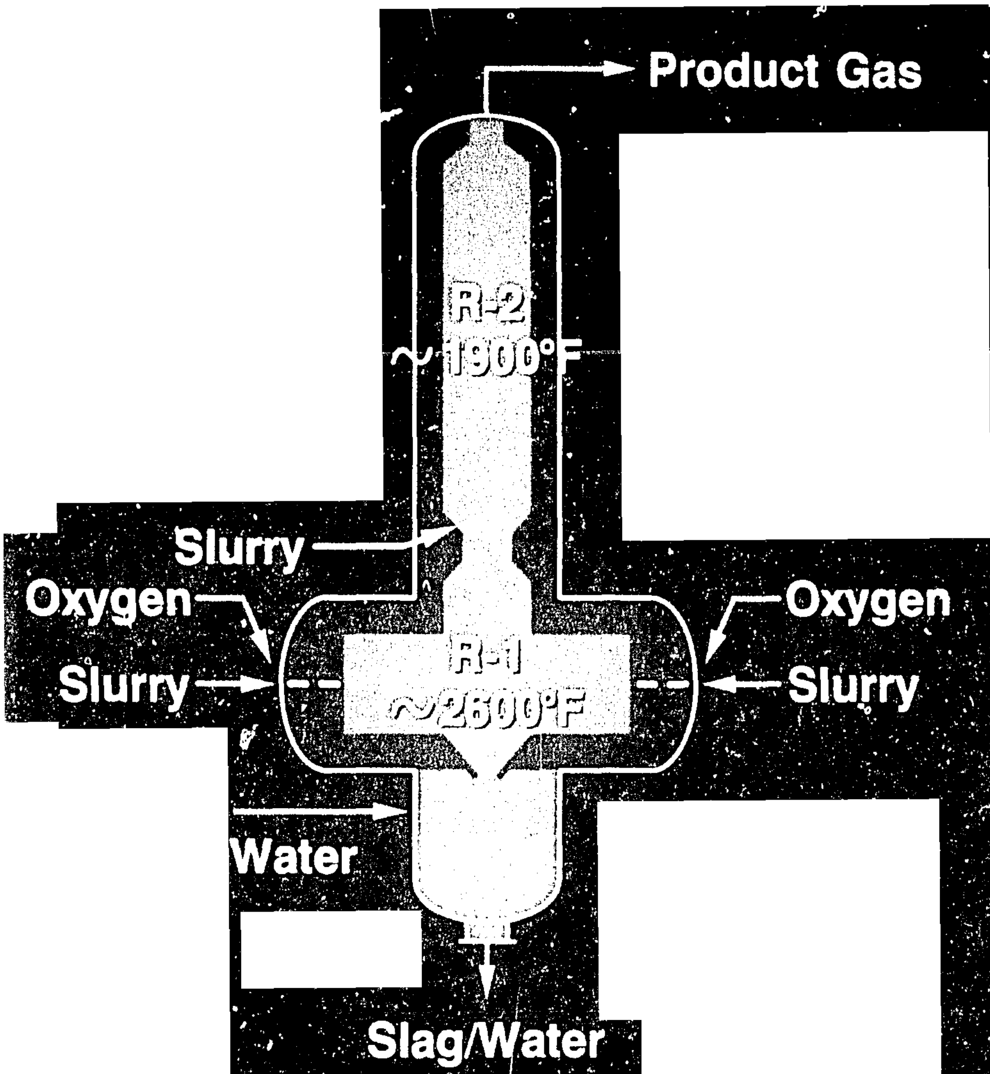
The 2,400-ton-per-day integrated gasification combined cycle plant operating in Plaquemine, Louisiana, is the first commercial-scale demonstration of Dow's technology.

DOW COAL GASIFICATION PROCESS - IGCC Application



The Dow coal gasification process uses a pressurized, entrained flow, slagging, slurry-fed gasifier with a continuous slag removal system. The process includes a unique heat recovery system which provides high efficiency on low rank coals.

The novel slurry feed technology and continuous slag removal technique eliminates high maintenance and problem-prone lockhoppers for introducing the coal to the gasifier or for removal of slag. The design prevents the combustion and raw product gases from escaping into the atmosphere during slurry feeding or slag removal.



Dow Coal Gasification Process

Coal slurry is fed to the reactor and mixed with oxygen in burner nozzles. The feed rate of oxygen is carefully controlled to maintain reactor temperature above the ash fusion point to ensure slag removal. Under these conditions, high carbon conversion is achieved by partial combustion to produce synthetic gas consisting principally of hydrogen, carbon monoxide, carbon dioxide and water. Sulfur is converted almost totally to hydrogen sulfide with small amounts of carbonyl sulfide.

The gasifier system produces essentially no tars, oils or phenols. It includes a unique heat recovery system that provides high efficiency especially on lower rank coals. Ash is fused in the flame, direct quenched in a water bath and removed from the bottom of the reactor as a slurry through a special pressure-reducing system. Slag is dewatered and stored.

Syngas exiting the gasifier system is further cooled by a conventional heat recovery boiler to near its saturation. High-pressure superheated steam produced can be used for power generation via steam turbines or to drive the oxygen plant air compressor.

Particulates are removed by water scrubbing the partially cooled gas. All particulates removed are recycled to the gasifier.

The scrubbed syngas is then cooled through a series of heat exchanges before entering the acid gas removal process. The amount of low level heat recovery is economically balanced with the heat requirements of both the gasifier and the acid gas removal process.

The acid gas removal process from the syngas stream is based on an economic evaluation of the application of several known technologies with the environmental and process constraints of the location. The particulate-free syngas from the Dow gasifier is suitable feed for any of the known commercial desulfurization processes.

The Dow Syngas Project complies with site environmental requirements via a Dow's GAS/SPEC ST-1 Technology acid gas removal system and a commercially licensed sulfur conversion unit.

The Dow Syngas Project began operating during the spring of 1987. After two short preliminary runs on coal slurry feed during April, all parts of the plant, including the use of syngas for power generation were commissioned. Commercial operations began in May.

The plant has performed well at rates up to approximately 90 percent of capacity. Syngas from the process has been used in Dow's Westinghouse gas turbines to make power for use in Dow's Louisiana Division plants.

At full capacity, the plant will provide 30 billion Btu per day of medium Btu gas. The gas and co-produced steam are sufficient to generate approximately 160 megawatts of power.

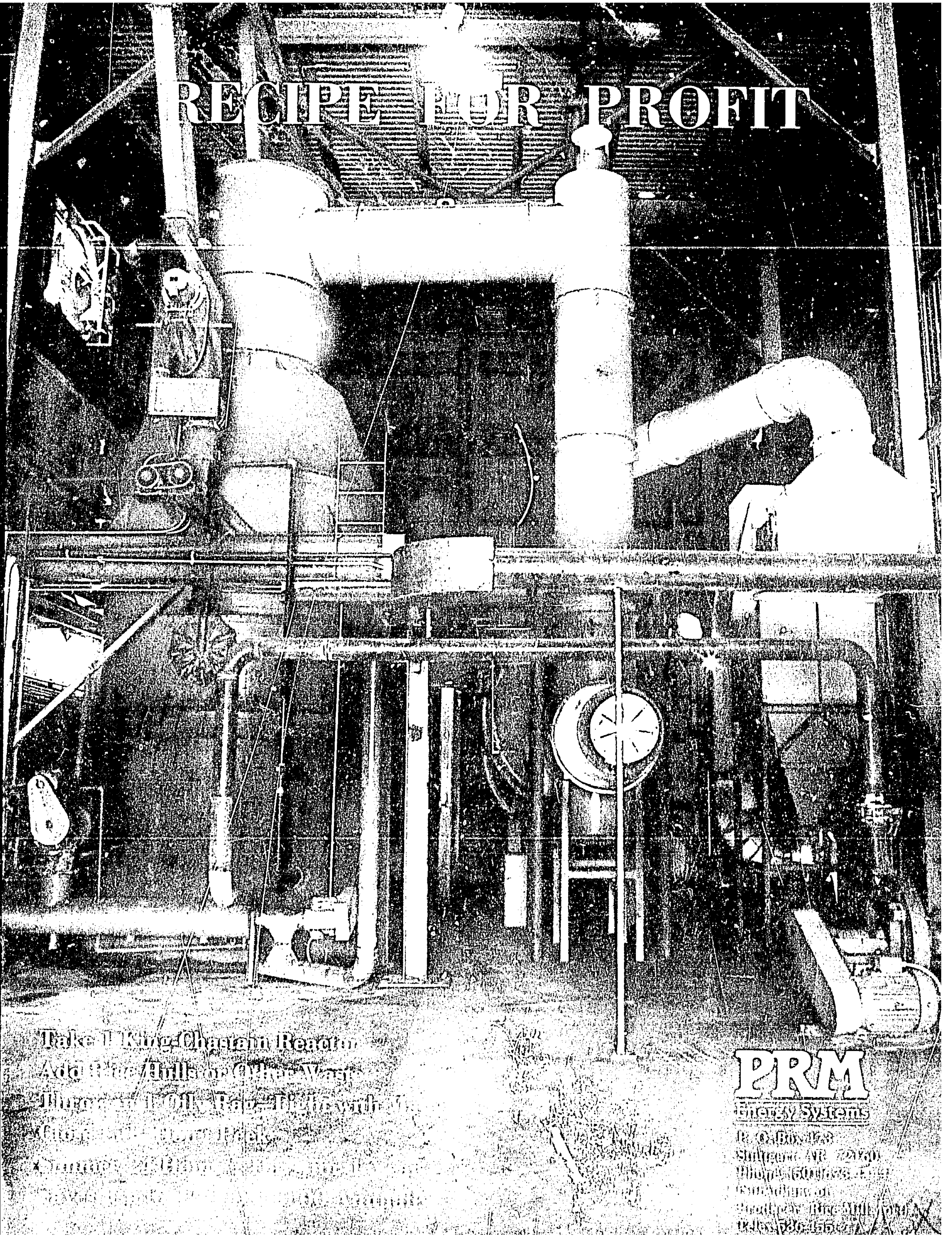
Initial plant operations surpassed original projections. Gas quality and carbon conversion have also been better than expected.

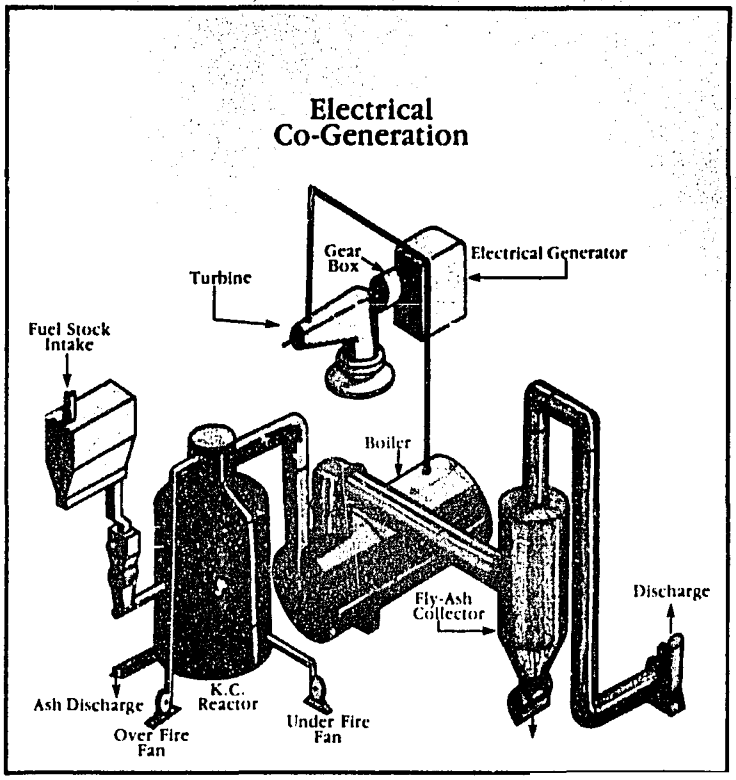
As the world's largest integrated coal gasification combined cycle power plant, the plant's successful start-up demonstrates the technology is reliable and safe on a commercial scale.

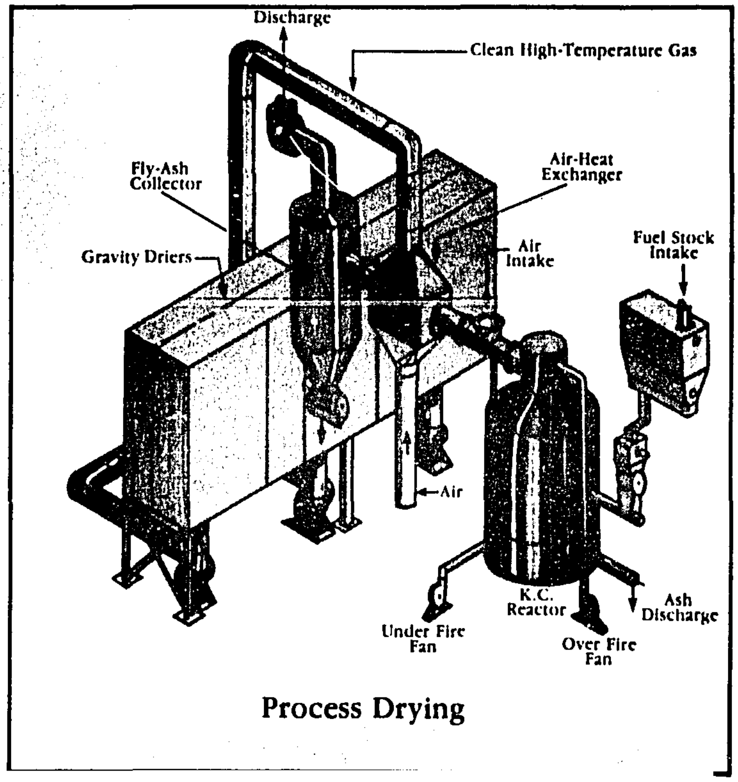
The Dow Coal Gasification Process is being commercially demonstrated in the world's largest integrated coal gasification combined cycle power plant in Plaquemine, Louisiana. The plant is owned and operated by Louisiana Gasification Technology, Inc., a wholly-owned subsidiary of The Dow Chemical Company.

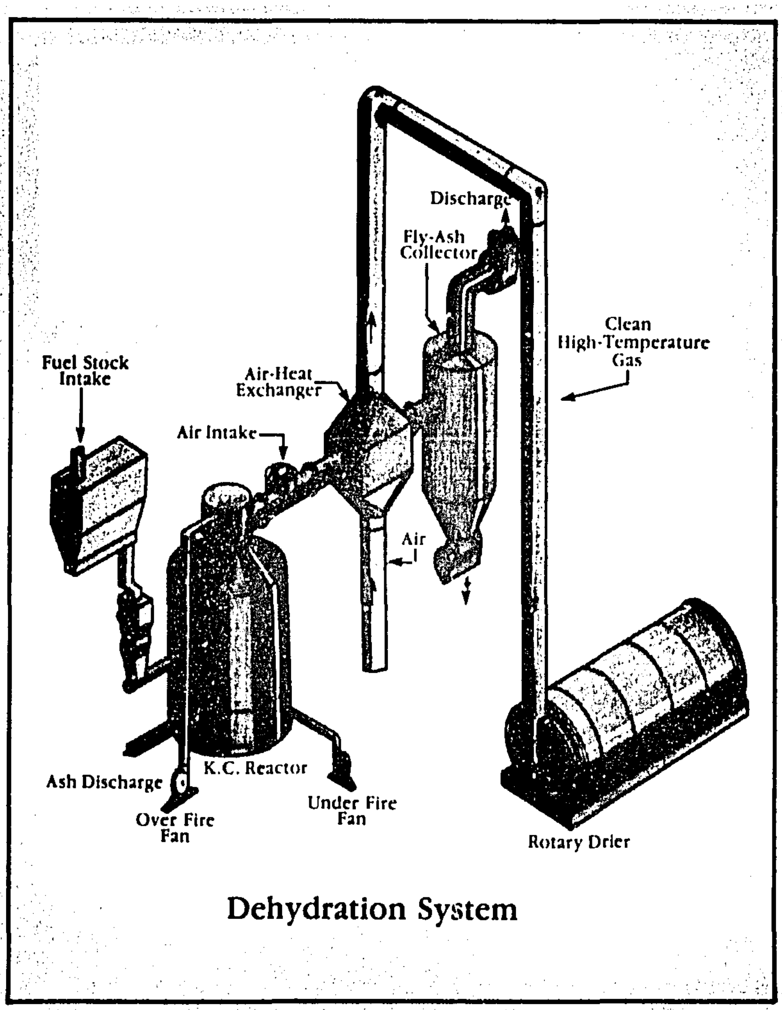
Dow

Energy Resources
The Dow Chemical Company
P.O. Box 3387
Houston, Texas 77253-3387
September, 1987


RECIPE FOR PROFIT
PRM
Energy Systems







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Discussion Draft

OPTIONS TO INCREASE PRIVATE PARTICIPATION IN ELECTRIC POWER DEVELOPMENT IN A.I.D.-ASSISTED COUNTRIES

prepared by:

)ffice of Energy
Bureau for Science and Technology
U.S. Agency for International Development
Washington, D.C.

December 23, 1987

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Interest in private power is proceeding rapidly. Pakistan, the Philippines, Indonesia, Jamaica, the Dominican Republic, Costa Rica, Brazil, Turkey, and other countries are formulating, and in some cases, implementing private-power policies. This introduction of private-market forces into what has traditionally been an exclusive government domain offers two much needed benefits:

- competition and its resultant more efficient management, both within power facilities and more generally within the power sector, and
- the mobilization of private capital to augment scarce public resources for needed power development. (page 1)

Despite the clear advantages of private participation in electrical power development and the expressed interest of private firms and developing countries, to date no private-power generation projects are yet firmly committed. Numerous barriers have discouraged or prohibited private investment in the power sectors of developing countries. These include the following:

- institutional and policy barriers,
- weak domestic economies,
- political risk,
- technical risk,
- financial risk. (page 2)

To overcome these barriers a range of U.S. and host-country government policy initiatives are needed. Currently, neither A.I.D., nor any other U.S. agency, has specific programs devoted solely to private power projects. A.I.D. has, however, devoted considerable resources to the subject through its development assistance and economic support programs to provide technical assistance, policy studies and conferences, as well as prefeasibility and feasibility studies. Some of these have been carried out in

collaboration with other agencies, especially with the Trade and Development Program and with the Department of Energy. Other U.S. programs are provided by the Overseas Private Investment Corporation, the International Trade Administration, the Department of State, and the Export-Import Bank of the United States. (page 5)

Multilateral development institutions, such as the World Bank, the International Finance Corporation, the Asian Development Bank, the Inter American Development Bank also provide limited amount of technical and feasibility study assistance. These multilateral development institutions are currently exploring innovative ways to facilitate private investment in the power sectors of developing countries. (page 6)

Existing U.S. programs share a number of limitations: amidst competing priorities there is a lack of clear policy direction as to the priority of encouraging private investment in developing country power projects, limited staff and financial resources are available for the task, and except in the renewable energy area, limited coordination exists among federal programs and with multilateral programs.

OPTIONS TO INCREASE PRIVATE PARTICIPATION

Since mobilizing market forces to foster economic growth is a major objective of A.I.D. and since U.S. industry is a world leader in electric power, the Agency has a clear opportunity to accelerate this private-sector movement. Based on the status of private participation in the power sectors of developing countries, the Agency challenge is to improve the policy climate for private investment, facilitate actual project development, provide necessary training, and coordinate a well targeted U.S. government effort to accelerate private-power development. The goal of this effort should be to establish a limited number of successful pilot investment projects in A.I.D.-assisted countries that can serve as models for future investments on a broader scale.

Options available to A.I.D to accomplish this goal are the following:

Improve the Policy and Institutional Climate for Private Investment

Option 1: Country-Specific Private-Power Strategies

To help create more favorable investment environments for private power in developing countries, A.I.D. could develop a detailed "private-sector power development strategy" on a county-by-country basis to identify needed policy changes, to examine private-power opportunities and to identify potential private-sector parties interested in power projects. (page 11)

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Facilitate Project Development

Option 2: Private-Power Data Base

The Agency could develop a Private-Power Data Base to track specific project opportunities and to provide information to developers, other private parties and to other U.S. agencies involved in private-power development. (page 16)

Option 3: Definitional Missions and Trade Conferences

In collaboration with TDP and Commerce, A.I.D. could increase the number of definitional missions to countries that have favorable policies for private participation. (page 17)

Option 4: Private-Power Investment Promotion Program

Modeled in part on the Investment Promotion Office in Egypt, A.I.D. could establish this program to assist companies on targeted projects to obtain information and technical assistance on potential market opportunities, government policies, and regulations, business assistance programs and contacts in developing countries. (page 19)

Option 5: Private-Power Feasibility Study Program

In collaboration with TDP and other U.S. agencies, the Agency could establish an expanded Private-Power Feasibility Study Program using formal and informal solicitation mechanisms and targeted toward technologies where the U.S. private sector has a competitive edge. (page 23)

Option 6: Innovative Technology and Environmental Assessment Program

This option would provide resources for assessments of innovative energy technologies that are applicable to private-power projects and for assessments of the environmental effects of projects to minimize adverse impacts. (page 24)

Option 7: Energy Loan Guarantee Program

Under this option the Agency would provide a full guarantee against default on loans made by private U.S. financial institutions to finance private-power projects either through the host country government or utility (Housing

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Option 8: Direct Energy Loan Program

Under this option the Agency would provide direct loans to private sector firms for private-power projects in developing countries, either directly or through financial intermediaries. (page 36)

Option 9: Energy Grant and Export Credit Program

This option would build upon existing legislative and regulatory authority to combine A.I.D. grant and export credit funds with Eximbank "war chest" funds for more affirmative government action for international procurements where U.S. companies are competing with firms from other countries. (page 37)

Option 10: Energy Equity Program

This option would use U.S. funds as equity or to guarantee equity funds for private-power projects in developing countries through any of four mechanisms: venture capital loans, direct equity purchase programs, equity guarantee programs or direct equity grants. (page 39)

Option 11: Negotiation Advisory Team

The Agency, under this option, would create a pool of technical consultants that could provide assistance to the parties in private-power contract negotiations. (page 42)

Provide Training on Private-Power Development

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A.I.D. would create a Private-Power Training Program targeted toward government officials, state utility officials and businessmen from developing countries and toward businessmen in the U.S. power industry. (page 45)

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Option 14: Integration of U.S. Trade and Aid Policy

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