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Foreword

A planned and orderly transition to new sources of energy is a goal common to many developing countries today. Even nations with substantial oil resources can see the longer term benefits of drawing from diverse energy sources. With a goal of drawing on new energy resources, many nations find the planning of technology development and deployment difficult at best. Aside from the obvious problems of the heavy demands placed on energy planners and managers in developing countries, the additional loads of new information on energy technologies and resources may often fail to cross national boundaries. The experiences, plans, and insights of other workers in some areas of new energy technology are valuable to others and deserve to be shared.

Within ASEAN, for example, there are a major oil refining center, two major crude producers, three nations predominantly dependent on biomass energy, and substantial reserves of lignite and low joule coals. In addition, research and limited commercialization of solar energy collectors is common to the five ASEAN nations.

Looking at the potential for cooperative efforts among the ASEAN nations, the U.S. Agency for International Development initiated a program with the Asian Institute of Technology in Thailand to foster information exchange and professional development in the energy field. Both RERIC (The Renewable Resources Information Center) at AIT and the Bandung conference were parts of this program. The conference brought together professionals in the fields of coal, solar, wind, and biomass technologies and energy planning and management.

Organized by subject areas as above, each group has specialized lectures from a number of experts in the field. Then the participants presented their own papers on a wide range of topics. Finally, each group produced a report summarizing some of the relevant findings with recommendations for future efforts.

The papers in this volume of proceedings were edited for publication, retyped, and the graphics redone at AIT. Any errors in style are the responsibility of the editor, while the content remains the authors' responsibilities.

Finally, I would like to acknowledge those whose work was vital to the success of the seminar. Dr. Nick Austriaco of AIT was involved in the planning and administration of the conference from the start. Mrs. Chalaporn Yunchanondh worked long hours to assure that all of the correspondence and administration was handled appropriately. Dr. Arjono of LIPI was responsible for the arrangements at Bandung under difficult conditions of a volcanic eruption nearby. Finally, Anita Sachaphaibulkitj did yoeman's work in retyping all of the papers, overseeing the redoing of the graphics, and in the dozens of other small tasks required to get these proceedings done. To all of these people and to the others I failed to mention go my heartfelt thanks.

Donald Hertzmark
Bangkok, Thailand
November, 1982

US-ASEAN Seminar on Energy Technology

Biomass-Coal-Solar/Wind-Energy Planning

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The Energy Policy and Energy Development Plan of Thailand In The 5th National Economic and Social Development Plan (1982-1986)

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Abstract

The paper reviews the energy demand and supply situations of Thailand during the last 20 years and the domestic energy resources. The Energy Policy and Energy Development Plan in the 5th National Economic and Social Development Plan is discussed. Long term energy strategies are indicated.

Introduction

Planning and execution of Thailand development programmes, including energy development, are formulated and coordinated through the National Economic and Social Development Plans. Thailand has gone through four Plans covering a span of 20 years (1961-1981). During this period the GDP increased 14 fold from ฿ 60 billion* in 1961 to ฿ 817 billion in 1981 and per capita income increased from ฿ 2,200 to ฿ 17,200. 1982 marks the beginning of the 5th Plan.

* One U.S. dollar is approximately 23 baht.

The major targets of the 5th Plan (1982-1986) are:

GDP growth rate	6.6 percent per year
Agricultural growth rate	4.5 percent per year
Manufacturing growth rate	7.6 percent per year
Export of goods	
- average value	฿ 311.6 billion per year
- value growth rate	฿ 22.5 percent per year

Import of Goods	
- average value	฿ 384.8 billion per year
- value growth rate	฿ 18.1 percent per year
Oil import targets	
- average value	฿ 106.7 billion per year
- value growth rate	13.4 percent per year
- volume growth rate	-3.0 percent per year

According to the Plan, by 1986 the contributions from the manufacturing sector to the exports will exceed those from the agricultural sector (42% v.s. 39%).

This paper will describe the energy situations of Thailand, as well as policies and guidelines for energy development during the Fifth Plan. It is expected that such policies and guidelines will alleviate the deterioration of economic and financial situations owing to overreliance on oils and help accomplish the abovementioned targets.

The Past and Present Energy Demand and Supply Situations

The energy demand and supply situations of the country during the First (1961-1966) and Second (1977-1981) five-year plans can be summarised as follows:

	1966	1971	1976	1981
Energy demand (in x 10^9 litres of oil equivalent	4.83	9.05	12.10	17.96
Annual demand growth rate (averaged over each Plan)	13%	13%	9%	6%
Energy supply				
- imported crude oil and petroleum products	60%	71%	79%	74%
- domestic sources	40%	29%	21%	26%
Value of energy imports		14%		>40%
Export earning				

It is clearly seen that imported oils and petroleum products constituted more than 70% of the energy supply of Thailand during the past 10 years. The increase in energy demand, the dependence on imported oils and the oil price rise are reflected in the deterioration of the financial situation of Thailand. The future energy policy of Thailand must rectify this overwhelming dependence on oil.

The sectorial energy demands of Thailand in 1979 were as follows:

	Oil equivalent ($\times 10^9$ litres)	Percent
Communication & transportation	5.197	42.44
Electricity generationg & water supply	2.433	19.87
Manufacturing & mining industries	2.122	17.33
Agriculture	1.276	10.42
Services & other	1.090	8.90
Construction	0.127	1.04
	12.245	100.00

There are, at present, 3 oil refineries having a total daily refining capacity of 175,000 barrels whereas the daily demand is 215,000 barrels. The deficiency is met through importing petroleum products, especially diesel oils for which shortages are constantly experienced.

The electricity situations can be summarised as follows:

	1966	1971	1976	1981
Installed generating capacity (MW)	411.2	1167.2	2442.6	3736.1
Electricity demand ($\times 10^6$ kW-hr)	1,529	4,793	9,414	16,512
Increase in demand per year (averaged over the Plan)	27%	26%	15%	12%
Peak power demand (MW)	319	87.1	1,652	2,693
Increase in peak demand per year (averaged over the Plan)	27%	22%	14%	10%

The two outstanding problems regarding electricity generation are:

a) Imported oil has constituted approximately 80% of energy inputs to electricity generation since 1974.

b) Additional generating capacity of 250-300 MW is required annually.

Survey of Domestic Energy Resources

The principal domestic energy resources that have been investigated and planned to be incorporated in the national energy supply in the next two decades are hydro, lignite, natural gases and biomass.

Only hydro, lignite and natural gases resources have been adequately surveyed. The estimated potentials are as follows:

	Potential/Reserve	Oil Equivalent
Hydro	10,120 MW	4.5×10^6 tonnes/year
Lignite	762×10^6 tonnes	270×10^6 tonnes
Natural gas		
- proven reserve	4.1×10^{12} ft^3	174×10^6 tonnes
- possible reserve	26.9×10^{12} ft^3	----

The proven lignite reserve and the proven natural gas reserve are approximately 9.3 and 6 times the projected total annual energy demand of Thailand by the end of this decade (equivalent to 29×10^6 tonnes of oils in 1989). Exploration for natural gas and oil on land yields positive results but the extent of the reserves remains to be determined. However, no drastic change in energy reserves are expected.

It is thus evident that Thailand cannot expect to solve her energy supply in the long run by relying primarily on her indigenous energy resources of lignite, natural gas and domestic hydro. In addition, any attempt to increase utilization of natural gas for electricity generation must be thwarted. It is clear that long term energy supply of Thailand

will be determined through proper combination of imported coal, nuclear energy and, possibly, direct and indirect solar energy in the next century.

Reliable figures for biomass (e.g. charcoal, bagasse, rice husk and firewood) are not available. It is estimated that biomasses contributed 18.5% of total energy supply in 1978, its oil equivalent figure being 2.62×10^6 tonnes. The definitive future of biomass roles will be determined by other factors such as the ultimately acceptable forest acreage of the country, land utilization for food production vs. energy plantation and roles of biomass as industrial feedstock.

In the future the contribution of biomass can be substantially enhanced through energy plantations. Pyrolysis and fermentation of biomasses will further facilitate its use. However, the impact of biomass will be restricted primarily to rural areas where energy consumption is low.

Reports on uranium bearing rocks in north eastern Thailand and monazites in southern Thailand have been made. No quantitative figures are available.

Other nonconventional energy resources that could be exploited, when they are commercially feasible, are oil shale (about 6×10^9 barrels of oil equivalent), direct solar energy (average daily insolation value of 17 MJ/m^2) and geothermal energy. Increased use of direct solar energy in the near future is expected but no major impact on the national energy is foreseen in the next decade.

Energy Policy and Energy Development of the Fifth Plan (1982-1986)

1. Review of Energy Problems

Energy problems of Thailand can be summarised as follows:

a) 75% of energy demand is met by imported oil and refined petroleum products. This results in a deteriorating financial position of the country.

b) Inefficient utilization of energy in manufacturing industries, communication and transportation sectors due to outmoded manufacturing techniques and lack of energy conservation measures.

c) Distorted price structure of petroleum products.

d) Unreliability in oil procurement and inadequate national oil reserves.

e) Inadequate oil refining capacity to meet demand.

f) Oil-dependent nature of electricity generation and distorted electricity price.

g) Large difference in energy availability and consumption between urban areas and rural areas.

h) Lack of long term energy policy and coherent energy management.

2. Energy Policy Guidelines

The energy policy of Thailand is made on the following tenets:

a) Economic stability

b) National security

c) Maximization of domestic resources utilization

d) Stable supply of imported energy

e) Diversification of energy supply sources and energy resources

f) Energy conservation

g) Development of alternative energy

In view of the aforementioned, the energy policy guidelines are:

a) Accelerated development of domestic energy resources.

b) Promotion and enforcement of energy conservation and fuel conservation measures. Emphasis will be made in communication, transportation and manufacturing sectors.

c) Establishment of energy pricing mechanisms that are conducive to efficient utilization of energy.

d) Procurement of energy supply and building up of energy reserves that are adequate for economic growth and national security considerations.

e) Diversification of energy supply sources to lessen the dependence on imported petroleum products.

f) Promotion of international cooperation in building up energy reserves and in energy developments that permit trade in energy resources and technologies.

3. Specific Energy Targets

a) Reduction of the overall national energy demand. The annual demand growth rate will be kept under 4.8% throughout the Plan. Efficient utilization and energy conservation in communication, transportation and manufacturing sectors will be emphasized.

b) Reduction of oil imports by 3% per year throughout the Plan.

c) The dependence of energy supply on imported oil will be reduced from 75% in 1981 to 46% in 1986 through accelerated production and development of domestic energy sources.

The contribution of the domestic energy sources will be:

c.1) Increase in offshore gas production from 250 million cubic feet in 1982 to 525 million cubic feet in 1986. A gas seperation plant having a daily capacity of 350 million cubic feet will be completed by 1986.

c.2) Increase in hydroelectric generating capacity from 1,269 MW in 1980 to 2,013 MW in 1986.

c.3) Increase in lignite utilization in electricity generation from 210 MW in 1980 to 885 MW in 1986.

c.4) Acceleration of development and use of other nonconventional energy sources (alcohol, city refuse, wood, microhydro, oil shale, biogas, geothermal energy, solar energy and wind energy). The oil equivalent utilization figure is planned to be 220-290 million litres in 1986.

d. Expansion of oil refining capacity to 290,000 barrels per day in 1986.

e. Expansion of rural electrification from 18,511 villages (36% of total) in 1980 to 50,034 villages (92% of total) in 1986.

f. Increase in stockpiles of crude oils and refined products from 36 days to 60 days in 1986.

Accompanying these projected targets, specific area development plans have been formulated. Alternative energy research and development plans have been reported elsewhere.

4. Energy Demand Projection

The Energy Development Plan of the Fifth Plan puts emphasis on energy conservation and alternative energy development and utilization. Table 1 shows the projected energy demand throughout the Fifth Plan.

Towards the year 2000 and beyond

The National Energy Administration is now preparing a Thailand Energy Master Plan to be made public by the end of 1982. The Energy Master Plan provides alternative energy supply and demand scenarios with available options for minimising the cost of energy to the Thai economy. The scenarios will be organized through the following sets of variables:

1. Availability of primary energy resources.
2. Cost of primary and secondary energy.
3. Demand management policy.
4. Macroeconomic developments including overall growth and composition of output.

It is now well recognized that Energy Master Plan apart, Thailand must strengthen her technological development capabilities in energy technology to overcome the present energy problems and to ensure sustained long-term growth. Project areas for emphasise must be energy conservation, nuclear technology, lignite and coal technology and renewable energy technology. Industrial restructuring must be made to bring about an industrial structure that is brain-intensive and uses resources and energy efficiently as well as creating high value-added commodities.

The draft Energy Master Plan does not incorporate nuclear energy in any of the supply scenarios. However, after considering the limited indigenous energy resources and economic incentives of using nuclear energy for base-load electricity generation, it is apparent that nuclear energy must have a dominant role in the long term energy supply of Thailand. It is imperative to make the public aware of the indispensible role of nuclear energy. Mass education will be necessary to help eradicate the ignorance and misguided public opposition and to deepen the national understanding concerning the nuclear energy safety.

Conclusions

The Energy Development Plan of the Fifth National Economic and Social Development Plan of Thailand places great emphasis on energy conservation and domestic energy resources development. Overwhelming dependence of energy supply on imported oils, characteristic of the past 20 years, will be rectified. However, limited domestic energy resources indicate that long term energy supply of the country should be based on combination of imported coal, nuclear energy and, perhaps, solar energy.

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* NESDB = National Economic and Social Development Board

TABLE 1

	1982	1983	1984	1985	1986
Petroleum products	12,619.1 (15,979.9)	12,706.8 (17,176.6)	13,036.8 (17,883.0)	11,863.0 (18,670.5)	12,786.9 (20,004.1)
Natural gas	2,121.9 (0)	2,557.6 (0)	2,818.1 (0)	4,687.8 (0)	4,892.7 (0)
Hydro	961.3 (964.6)	1,084.3 (1,089.0)	1,275.8 (1,280.5)	1,484.6 (1,498.1)	1,718.1 (1,751.1)
Coal and lignite	735.2 (661.3)	1,016.8 (683.3)	1,270.2 (965.6)	1,558.5 (1,286.8)	1,532.7 (1,276.3)
Biomasses (rice husks, bagasses, woods and charcoal)	3,193 (3,194.1)	3,275.9 (3,279.3)	3,379.6 (3,385.2)	3,388.4 (3,462.5)	3,449.1 (3,525.4)
Other alternative energy	40.9 (0)	80.8 (0)	136.0 (0)	218.3 (0)	304.1 (0)
Total (million litres of oil equivalent)	19,674.7 (20,794.6)	20,762.9 (22,223.5)	21,921.2 (23,509.6)	23,214.1 (24,904.4)	24,716.6 (26,523.9)

The values in brackets are the demand in the absence of energy conservation and alternative energy development measures.

Energy Usage and Options for Singapore

Satish Kumar

Introduction

The seventies saw unprecedented increases in oil prices. In 1973/1974, oil prices increased four fold. In 1978-1980, oil prices more than doubled. These "oil-price crises" underline the fact that oil is a depleting resource and despite the current oil glut, more crises in the future appear inevitable.

The finite and limited resource base for oil has prompted many to consider alternative energy resources. Economically recoverable reserves of oil in the World are estimated to be about 648 billion barrels (as at end 1980). The 1980 consumption of oil was 22 billion barrels. This would give an estimated life for oil reserves of 29 years. By contrast, economically recoverable reserves for coal are estimated at 3,000 billion barrels of oil equivalent. At 1980's coal consumption of 15 billion barrels of oil equivalent, the coal reserves would last 200 years! What this really means, of course, is that there is considerable scope for increased use of other energy resources, notably coal.

Singapore, like many other countries, is concerned about the pattern of its energy use. This paper gives a brief description of energy consumption in Singapore.

Current Energy Production and Use

Singapore depends wholly on oil for her energy needs. The 617.8 sq. km. island often called the "city-state", has no oil or energy resources of its own. All her oil requirements are imported. However, Singapore is an important refining center, with a refining capacity of over a million barrels per day. About 85% of oil processed by the refineries

is exported. 67% of imported oil comes from the Middle East with Saudi Arabia alone accounting for 50% of the total.

About half of Singapore's total inland consumption of about 3-4 million tonnes per year is used up by the Public Utilities Board, primarily for electricity generation. 48% of the electricity is sold to the industrial sector, 16% to the domestic sector and the remainder of about 36% to the commercial sector. About a fifth of this electricity is used for air-conditioning. The Public Utilities Board is also responsible for the production of towngas, principally used for cooking and water heating.

The remaining half of Singapore's total inland consumption of oil is used in the transportation sector (mainly diesel and gasoline) and for industrial heating. Liquified Petroleum Gas (or bottled gas) is used for domestic cooking as well as for other commercial and industrial purposes.

Unconventional Energy Production and Use

There is very little usage of unconventional energy resources in Singapore. Some biogas is produced from waste of pig farms, but the quantity is very small. The Ministry of Environment makes use of biogas produced from its waste treatment plants. This quantity is so small that supplementary electrical energy from the Public Utilities Board is required for the waste treatment plants. The Ministry of Environment also has a garbage incineration plant which provides a small quantity of surplus electrical energy for the electrical distribution network in Singapore. Solar energy usage is comparatively insignificant with some hotels, clubs, etc. using solar energy for water heating.

Energy Conservation and Efficiency

a. Energy Conservation Division in the Public Utilities Board

The Public Utilities Board has set up an Energy Conservation Division. The objective of this Division is to provide free advisory services to consumers including energy surveys of manufacturing plants and buildings such as shopping complexes and offices. An Energy Conservation Center set up at the Public Utilities Board Building is equipped with displays and exhibits to educate the public on the importance of saving electricity.

b. Energy Campaigns

Nation-wide campaigns to exhort the people to save energy are held annually. In May 1982, an energy saving campaign was launched by Dr. Tony Tan, the Minister for Trade and Industry. This energy saving campaign was mainly aimed at the industrial sector and the Government came up with a 4-point strategy in conjunction with the campaign:

(1) Greater efficiency in energy production
(2) Conservation and economising on energy usage
(3) Economic pricing of oil and oil derived products such as electricity
(4) Diversification of energy supplies

c. Building Regulations

As air-conditioning takes up a large proportion of electricity consumption, the Building Control Regulations specify insulation requirements of the building envelope (expressed by the unit of measurement called "Overall Thermal Transfer Value (OTTV)"). All new buildings are required to attain on OTTV of 45 watts/m^2 or less. Old buildings which do not meet the required OTTV condition have a 20% surcharge added to their electricity bills. The expenditure for building improvements to attain the required OTTV can be written off for tax purposes in one year.

d. Efficiency of Electricity Generation

The Public Utilities Board, on its part, has attempted to increase the efficiency of electricity generation. The efficiency of the overall electricity generation system increased 6% points, from 30% to 36% from 1971 to 1981. In terms of savings in fuel cost, this is equivalent to about S$155 million.

Alternative Energy Sources

As half of Singapore's inland energy requirement is for the Public Utilities Board (mainly for electricity generation), the significant area to look at for assessing the prospects for alternative energy resources is in electricity generation. The main energy options are discussed below. It should be noted that there is no hydro-power potential or geothermal potential in Singapore. Use of other more exotic energy sources such as wind or tidal power is considered unsuitable in the Singapore context at the present time.

a. Coal

Economics favours coal as an energy option for electricity generation in Singapore. Although the capital outlay and operating/maintenance costs of a coal-fired power station are higher than an oil-fired power station, coal cost is expected to be considerably lower than oil cost.

Factors such as coal supply security and environmental impact will first need to be resolved. The disposal of ash is one major problem which needs to be solved. A UK based consultant has completed the study on the environmental impact of a coal-fired power station in Singapore.

b. Natural Gas

If natural gas can be made available to Singapore at competitive prices, Singapore may consider its use. The Senoko Power station is equipped for dual oil and gas firing and therefore can be converted for gas burning.

c. Nuclear

The Public Utilities Board is keeping abreast of developments on nuclear energy for electricity generation. However, this energy form is not likely to be used in the near future.

d. Non-Electricity Sector

The possibility and extent of energy diversification in the non-electricity sector is dependent on the choice of energy for electricity generation. At present, the Public Utilities Board uses naphtha as fuel to produce towngas. If natural gas is to be sued for electricity generation, a amall amount of it could be diverted to be piped through the gas reticulation system. Coal, on the other hand, would be limited to the cement, iron and steel industries.

There is, however, considerable scope in the industrial and commercial sectors for savings by way of energy conservation. Frugal use of all energy will result in fuel savings for Singapore, resulting in savings in valuable foreign exchange which is now used to pay for imported oil.

Philippine Country Paper On New And Renewable Sources Of Energy

Summary

The Philippine government authorities are fully aware of the extent to which the country is dependent on imported oil and that sustenance of economic growth is dependent a great deal on the successful development and utilization of alternative indigenous sources of energy.

Thus, in response to the energy crisis in 1973, the government has formulated programs and priorities on indigenous energy utilization and R and D on new and renewable sources of energy. These include (a) conventional sources of energy exploration, development and management, (b) non-conventional sources of energy development, utilization and management, encompassing low pressure natural gas, producer gas, alcohol, dendrothermal, solar energy, ocean waves, biogas, wind, minihydro, hot springs and others, and (c) energy conservation systems/devices development and utilization. These are in conformity with the broad policy of the government relating to the development of new and renewable sources of energy in the diversification of energy supply towards the alternative sources of energy, preferably the regenerative forms.

Institutional support to such programs is now considered appropriate. On the other hand, incentives in the development and utilization of indigenous sources of energy are offered by the government as part of the overall strategy to accelerate development and utilization of indigenous energy.

To carry out such energy programs, a total investment of U.S.$ 9.5 billion is required over a period of 5 years. Power development requires U.S. $6.3 billion, representing 66% of the total investment requirements, while energy resource development involves a cumulative financing of U.S. $2.3 billion or 24%, and the development of downstream facilities accounts for the 10% balance or about U.S. $1.0 billion.

As shown in the power development targets up to 1985, hydro and geothermal will play major roles in the coming years. This projection is backed up by on-going projects on hydroelectric power plants and geothermal power plants.

While dendrothermal energy utilization has just started (1981), its potential is great considering the 6 million hectares of grassland and deforested lands in the country.

Although energy obtainable from biogas is considered small as compared with hydro, geothermal and dendrothermal, it has a place in the overall plan of energy development. Likewise, the alcohol program has a complementary role to play, particularly as fuel for vehicles.

All other projects on biomass such as charcoal, pyrolysis, direct use of biomass as fuel, hydrocarbon-producing plants, etc. are going on in a small scale via a complementary and/or supplementary way to the overall goal of self-sufficiency in energy needs.

Similarly, the use of solar energy, wind power, and ocean energy serves in the same way as biomass in areas where they are best (economically) utilized.

In all the foregoing programs, some forms of cooperations are desirable, such as exchange of scientific and technological information, technical publication, exchange of experts; undertaking joint projects to solve priority and common problems; and sharing resources and facilities. Worthy of mention are the (a) ASEAN-US Agreement, (b) the ASEAN-Australia Agreement, (c) Philippine-U.S.A. Bilateral Cooperation, (d) Philippine New Zealand Bilateral Cooperation, (e) Philippine-Italy Bilateral Cooperation, and (f) Philippine-Finland Bilateral Cooperation.

The recommendations presented in this paper have evolved, based on Philippine conditions and experience, in the development and utilization of indigenous sources of energy.

Overall, it appears that the Philippines is succeeding in its sustained and extensive efforts to develop and utilize non-oil forms of energy.

Introduction

Prior to the energy crisis in 1973, oil importations of the Philippines had never reached more than 12% of the total import bill which was only slightly more than one-tenth of total export revenues. But, the situation changed from 1973 onwards. Oil prices went up by four times in 1973-74 and more than doubled in 1978-79. Consequently, the inflation rate increased to 34% in 1974, but has been reduced to single digit levels in subsequent years. Since 1974, oil alone has accounted for over 70% of the trade imbalance annually.

In 1970, Philippine energy consumption amounted to 88.2 million barrels of oil equivalent (Table 1). By 1985, projection shows (Table 2) that total energy consumption would reach 137.4 million barrels of oil equivalent (MMBOE), indicating a very significant increase in energy demand. This picture is not, however, discouraging because oil share would have gone down to 54.94% from 84.50% in 1981. In addition, prudent policies to manage energy demand have also slowed down the energy/GNP coefficient from a historical rate of 1.5 to only about 1.0 in recent years.

Nevertheless, the sustenance of economic growth and industrialization will depend a great deal on the successful development of alternative domestic and especially regenerative types of energy sources in the future. As foreseen, the prospects and potentials for utilizing these new energy sources are tremendous in food production, industry and services.

Thus, the Philippines looks forward to the success of the ASEAN-US Energy Technology Seminar. The Philippine delegation in particular is honored to be given this opportunity to share with the other ASEAN dele-

gations our strategies, programs and experiences in the development and use of energy derived from new and renewable sources in meeting the current as well as the future national energy needs.

Institutional Framework

To provide a more effective institutional framework in response to the energy crisis, the Ministry of Energy (MOE) was created by Presidential Decree issued in October 1977. It has the power and function to formulate and implement the government's policies, plans and programs on energy-resource development. Prior to the creation of the MOE, the primary government agency involved in research, development, promotion and delivery of new and regenerative sources of energy was the National Science and Technology Authority (NSTA). The relationship of the NSTA and the MOE is shown in Chart I. The NSTA and its agencies are primarily concerned with R & D up to the pilot stage. Once fully developed and found viable, such technologies are forwarded to concerned agencies, among them the MOE. In addition, the MOE also undertakes R & D to accelerate development of the different conventional sources of energy.

The growing number of non-con energy projects led to the establishment of the Energy Research and Development Center (ERDC), formerly the Center for Non-Conventional Energy Development at the MOE in July 1979.

The various NSTA agencies, namely: The National Institute of Science and Technology (NIST), Forest Projects Research and Development Institute (FPRDI), Philippine Institute of Volcanology (PIV), and the Philippine Invention Development Institute (PIDI) are the NSTA's main implementing arms for research and development projects on non-con energy sources. The NSTA's attached agencies such as the Philippine Council for Agriculture and Resources Research and Development (PCARRD) and the National Research Council of the Philippines (NRCP) also contribute in the development of non-con sources of energy.

Besides the mentioned institutions, there are other government ministries or agencies active in energy development, such as (a) the University of the Philippine System, which undertakes R & D on new and renewable sources of energy; (b) the National Electrification Administration (NEA) which implements the mini-hydro and dendrothermal power projects; (c) the Ministry of Agriculture (MA) which, through the Bureau of Animal Industry (BAI), undertakes the widespread application and utilization of biogas; (d) the Ministry of Human Settlements (MHS) which, through the Farm System Development Corporation (PSDC), is in charge of the widespread application and utilization of proven viable technologies relating to wind power for water pumping and irrigation, gasifier technology for transportation and irrigation; and (e) the National Food Authority (NFA) which conducts research on the utilization of agricultural wastes, among them rice hulls, for alternative sources of energy.

As a necessary forward thrust and linkage, the private sector has a big and vital role to play. Thus, it is involved in the institutional framework. From only one firm in 1977, there are to date ten local identified companies engaged in the design, fabrication and marketing of solar water heating systems. One firm is manufacturing solar collectors. There are today no less than 15,000 square feet of collectors installed and operational in homes, hotels and private industries.

Programs and Priorities (including, adaptation and utilization)

Chart 2 shows how each program works.

The Ministry of Energy (MOE) and the National Science and Technology Authority (NSTA) have developed an energy R & D and delivery program for the period 1981-85, covering three areas; as follows:

a) Conventional sources of energy-exploration, development and management, covering hydro and geothermal sources focusing on source exploration, utilization and upgrading including waste utilization and treatment to safeguard the environment;

b) Non-conventional sources of energy utilization, development and management (including effluent processing and treatment), encompassing low pressure natural gas (marsh gas), producer gas, alcohol, dendrothermal, ocean waves, solar energy, biogas, wind, mini-hydro, hot springs and others, emphasizing on the production and generation of alcohol, natural gas, biogas and solar energy and their environmental effects, and

c) Energy conservation system/devices development and utilization stressing the need to evaluate and develop energy conservation systems and devices with at least 10% savings on fuel including design of buildings, and to study recycling of fuel-burned wastes for re-utilization or conversion into usable products.

The current 84.5% of oil in the energy requirements will be reduced to 55% by 1985 (Table 2), which will be realized through intensified development and increasing use of hydro, geothermal, coal and other non-con sources. To carry out such dynamic plan, a total of US $9.5 billion investment is required over the 5-year period. Power development will require US $6.3 billion, representing 66% of the total investment requirements, while energy resource development will involve a cumulative financing of US $2.3 billion or 24%, and the development of downstream facilities will account for the 10% balance or about US $1.0 billion.

On the potential of energy sources, the non-con energy source is estimated at 1.43 x 10^3 MMBOE/year; the coal potential is estimated at 4,000 MMBOE; the hydro potential is estimated at 50 MMBOE/year; and the geothermal potential is 2.30 x 10^3 MMBOE/year (Table 3). The potential of energy plantations (dendrothermal) is not indicated in this table, but would be tremendous considering the 6 million hectares of denuded and deforested lands.

It is projected that hydro and geothermal energy will play major roles in the coming years. Their contributions at present constitute

7.1 and 3.9 percent of total energy supply; these will be 12.8 and 12.2 percent, respectively, by 1985.

Hydroelectric potential is estimated at over 7,000 MW of which only over 10% has been developed. Ultimate production potential for geothermal power plants would be in the range of 2,000 to 4,000 MW.

Geothermal Energy Program

The program on geothermal field exploration and development requires a minimum of 10-year target of 300 exploratory and development wells (265 production and 85 reinjection wells) with average depth of 4,000 feet. Physical requirements include the installation of some 500 kms. of steam ducts and pipings, and rigs which escalated in number from 7 in 1978 to 10 in 1979 onward.

There are 25 potential areas for geothermal development, 5 of which have been given priority, namely: Tiwi in Albay, Makiling-Banahaw in Laguna, Tongonan-Burauen in Leyte, Palimpinon in Negros Oriental and Manat in Davao del Norte. Geothermal energy from these areas is intended for power generation.

Two 55-MW geothermal power units at Tiwi, Albay, put into operation large-scale geothermal energy utilization, which started with a 1-hp electric generating unit pilot plant in 1967, roughly 15 years ago. Two other 55-MW units were added to the Luzon Grid, at the Makiling-Banahaw fields. For 1979 alone, 220 MW of generating capacity was added to the power supply coming from geothermal energy. For 1980, another four 55-MW plants were added to the Luzon Grid, increasing the total geothermal energy utilization to 446 MW with 6 MW contributed by two 3-MW pilot plants in Tungonan, Leyte and Palimpinon, Negros Oriental. Thus, from ninth place in 1978 with only the Tiwi Geothermal Power Plant in Operation, the Philippines moved up to second place by the end of 1980 among countries engaged in geothermal energy utilization, following the U.S.A. (502 MW) which ranked first. As of 1982, however, the Philippines geothermal power

generation stands at 556 MW, which places the Philippines in the number one position.

Utilization of Energy from Hot Springs is part of the geothermal energy utilization program. The DLSU has designed and developed a turbine to operate with an organic fluid at a relatively low temperature utilizing the heat energy from a hot spring. The turbine and generator systems are undergoing final stages of testing and evaluation. A 10-kw binary type power plant utilizing hot water from hot springs will be installed and tested for rural electrification. The first site chosen for this project is Los Baños, Laguna.

Biomass Energy Program

The Biomass Energy Program includes projects on energy plantations, dendrothermal power plants, hydrocarbon-producing plants, biogas, alcohol, direct use of agricultural and organic wastes as fuel, pyrolysis and charcoal.

1. Dendrothermal Energy from Energy Plantation

The establishment of energy plantation of fast-growing trees purposely for use as fuel in wood-fired power plants is one of the priority areas. Giant ipil-ipil, grown in three-to-five year cycles, has been found to be a suitable tree species for this scheme. The initial studies have been made by the FPRD-NSTA in 1974. Subsequently, the Bureau of Energy Development (BED) and the NPC have initiated the project design of two dendrothermal power plants. The installation of the 500-KW unit has been started inside a Bureau of Forest Development (BFD) reforestation area in Occidental Mindoro. The project covers 3,260 hectares of which over 1,000 hectares have already been planted with ipil-ipil trees. A second to be situated in Antique has a capacity of 2 to 5 MW.

Currently, NEA is engaged in a nationwide program on dendrothermal energy consisting of ipil-ipil plantations and wood-fired power plants.

Fifty one sites have been identified for energy plantation with an area of 1,000 hectares per site to provide fuel for a 3-MW power plant per site. This 1,000 hectare tree plantation is divided into 10 modules of 100 hectares each. Other equally important objectives of this project, in addition to power generation, are to generate employment for slashburn farmers or "Kaingeros", to aid the reforestation of denuded areas and to set the pace for the agro-industrial development of some economically-depressed areas/communities.

2. Hydrocarbon-Producing Plants

Species belonging to the families Euphorbiaceae and pittosporum resiniferum can produce hydrocarbons which can replace crude oil. Initial results on the propagation of these species reveal that the prospect of growing said plants in the Philippines is very great.

3. Biogas

In 1974, NSTA through its agency, the NIST, has constructed a family model biogas system complete with the swine pen and biogas generator. In 1977, the BED and the BAI established 12 small-scale biogas systems, one in each of the 12 regions of the country. By the end of 1978, 344 biogas plants had been constructed, the majority are privately-installed units with less than one-third being government demonstration units.

On large-scale biogas plants, the Maya Farms project can be cited as a good example. It has 5 large biogas generators to process 38 tons of manure daily from 25,000 pigs, to produce 2,150 cu.m. of gas and 3.8 tons of feed materials. Biogas is used to fire the retorts in the rendering plants, the scalding tank in the slaughterhouse and the cooking vats in the processing plants. The rest of the biogas is used as fuel for converted gasoline engines which serves as prime movers for the deepwell pumps, feedmill machinery, refrigeration systems and electric generators.

With Maya Farms consultancy services, 16 large piggery farms now have a combined biogas capacity of 327,000 cu.ft. per day or 9,260 cu.m. per day.

Other activities worth mentioning are (a) the studies of the Economic Development Foundation (EDP) on communal biogas system using human wastes, (b) the MHS project on the construction of biogas digesters to fuel generators, produce electricity, drive water pumps, and provide fuel for cooking at the municipality of San Jose, Batangas, (c) the Central Luzon State University (CLSU) project on the design, construction, and testing of a village level biogas digester composed of a floating type gas holder to generate biogas for cooking the food of a family of 5-7 members, and (d) DLSU study on the economic implication of the use of biogas as a source of energy in the Philippines.

4. Alcohol

There are a number of projects worth mentioning in the alcohol program, including (a) the production of alcohol from molasses and other indigenous sources as cellulosic and starchy waste materials for alcohol-gasoline blend for vehicles, (b) the NIST study on microorganisms that could possibly give maximum conversions of biomass to alcohol, (c) the "alco-tipid" invention which makes it possible for hydrous alcohol (95% or below) to be fed into four stroke internal vaporization engines in an air-alcohol fuel mixture through fractional vaporization process under vacuum, (d) the NFA project on the production of ethanol from grains, (e) the Philippine Atomic Energy Commission (PAEC) project on the production of alcohol from agricultural cellulosic wastes using gamma-irradiated microorganisms, (f) the University of the Philippines at Los Baños (UPLB) projects which cover the following: diversification of raw materials sources for alcohol, management and utilization of distillery slops, farming systems integrating energy crops to traditional cropping patterns, post-harvest processing of starchy crops and fermentation of starchy crops, and (g) the Maya Farms alcohol production scheme whereby the

farmers undertake the fermentation of the cassava mash in their own premises and the distillation of the fermented mash in a central factory.

5. Direct Use of Agricultural and Organic Wastes as Fuel

Projects involving the use of agricultural and organic wastes as fuel are: (a) the NSTA project concerning the use of coconut husks in the production of gas to power a 30 Kw generator serving 100 families in a remote rural area at San Antonio, Kalayaan, Laguna; (b) a joint project of NSTA, EDF and MOE on the production of producer gas from agricultural waste to run a 65-hp, 6-cylinder diesel engine used to drive an irrigation pump for 40-hectares of riceland in Siniloan, Laguna; (c) the NFA project on the utilization of rice hulls to generate power through the use of steam boiler and steam engine for driving rice mills; (d) the commercial production of gasifiers for motor vehicles by the Gasifier and Equipment Manufacturing Corporation at the rate of 100 units per month; and (e) the CLSU rice hull furnace for grain dryers.

6. Pyrolysis and Charcoal

On the pyrolysis project, BED in cooperation with UNIDO and the UP College of Engineering has completed a one-ton per day pyrolytic converter. Using rice hulls, the results showed an output of 40% char, 25% tar/oil and 35% combustible off-gas.

In charcoal production, the beehive charcoal ovens are becoming more popular. Mabuhay Agro-Forestry Corporation is using a 17-cu.m. model of a beehive oven in its charcoaling operations of giant ipil-ipil and saw-mill wastes. The National Irrigation Administration (NIA) is currently testing three models of beehive ovens.

Solar Energy Utilization Program

Notable among the projects on the utilization of solar energy are the following:

a) On solar air-conditioning, the MOE is conducting long performance

tests on a commercially available lithium bromide solar aircon system to lower costs and to determine its adaptability to local conditions.

b) On solar refrigeration, pilot studies on absorption refrigeration are being undertaken, the foremost being the ERDC assessment study on the potential of using solar assisted aqua-ammonia refrigeration, providing guidelines and recommendations for its comprehensive future use;

c) On cooking, the study on use and dissemination of parabolic mirrors to cook rice and fish has been made and is being continued by various agencies;

d) On photovoltaic systems, ERDC has tested the application of PV in low-capacity pumping situations to demonstrate technical feasibility and to investigate economic aspects under actual field conditions;

e) On solar drying studies, various agencies are involved, including NSTA on solar dryers for fish, fruits, and onions/fruits/vegetables/grains/ and other crops; and FPRDI on a solar lumber dryer with auxiliary heater using a woodwaste-fired furnace which shall be used only during rainy days;

f) On solar water heating, there are now 10 local companies engaged in the design, fabrication and marketing of solar water heating systems; and

g) On water distillation, BED in cooperation with MHS has constructed solar stills on 693 square meters of land to meet the potable water needs of a village. Salt is also produced. There are other agencies conducting similar projects, including NSTA, ERDC and the Polytechnic University of the Philippines (PUP).

Wind Energy Utilization

Notable among projects on wind energy utilization are the following:

a) ERDC project on windmills for low-lift irrigation which can operate at low wind velocities. For moderately high velocities (15 kph), a small-scale power could be developed.

b) The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) is presently conducting a research on "Wind Turbine System". Two dunlite wind-driven generators each with an output of 2 Kw are undergoing testing.

Ocean Energy Utilization

R and D on the use of wave energy for electric generation in the rural areas is being considered. For this purpose, a double acting turbine has been designed to tap ocean waves.

Hydroelectric Power Development

The MOE formulated an energy program for the accelerated development and utilization of indigenous non-oil energy sources, principally hydro and geothermal as shown in the table below:

	1980		1981		1985	
	MW	%	MW	%	MW	%
Hydro	948	20.5	959	20.4	2821	29.8
Diesel/oil	3206	69.3	3229	68.0	3391	36.8
Coal	27	0.6	90	1.9	760	8.0
Geothermal	446	9.6	446	9.4	1726	18.2
Nuclear	-	-	-	-	620	6.6
Non-conventional	-	-	12	0.3	154	1.6
TOTAL	4627	100	4736	100	9472	100

It is significant to note that by 1985, hydro plants will account for almost 30% of total installed capacity as against 20.4 in 1981, representing an increase of 1862 MW. This figure is followed by geothermal, representing an increase of 1280 MW from 1981 figure. Coal comes in third with an increase of 670 MW, followed by nuclear at 620 MW, then diesel and fuel oil at 162 MW with 142 MW for non-conventional (dendrothermal) energy.

Among the projects under construction are:

Project	Capacity (MW)
Masiway Hydro	12
Kalayaan Pumped Hydro	300
Magat Hydro (1-4)	360
Agus I Hydro	80
Agus III Hydro	225
Agus IV Hydro	150
Agus V Hydro	55
Agus VII Hydro	54
Pulangi IV Hydro	255
TOTAL	1,491

Large hydroelectric resources are located in the two biggest islands - Luzon and Mindoro. The economically harnessable hydroelectricity potential remaining is estimated at over 7,000 MW, of which only over 10% has been developed. NPC has also started development of small hydro projects all over the country, including

Project	Capacity (MW)
Talamo Hydro Plant in Davao	3.35
Amlan Hydro, Negros Oriental	0.90
Loboc Hydro, Bohol	1.20
Balongbong Hydro, Catanduanes	0.45
Agusan Hydro, Agusan	1.60
Cawayan Hydro, Sorsogon	0.40
Buhi-Barit Hydro, Camarines Sur	1.80

Forms of Cooperation

In addition to purely national efforts aimed at fostering the development and utilization of new and renewable sources of energy, it has been considered desirable to seek the assistance and cooperation of other countries. This was obtained through bilateral, regional and multilateral arrangements, which may involve exchange of scientific and technological information, technical publications, exchange of experts; undertaking joint projects in order to solve priority and common problems; and sharing resources and facilities. Such arrangements can be regional or bilateral.

1. ASEAN and the U.S. (Regional)

In pursuance to the US commitment in the third ASEAN - U.S. Dialogue held in Manila 10-12 September 1980, the U.S. extended assistance to ASEAN energy activities in the following areas: solar, wind, biomass, mini-hydro, geothermal, coal, energy conservation and energy planning methodologies. Such cooperative activities include information exchange, professional development and technical assistance.

2. ASEAN and Australia (Regional)

It should be noted that bilateral cooperation in the development of energy resources exist between Australia and the Asean countries, information as Australian expertise and capabilities relevant to ASEAN priorities particularly in the areas of coal, solar and biomass. On national energy research, development and demonstration program, the Australian government provides grants to fund energy R & D projects on a competitive basis, taking into account the merit of individual projects and the priority accorded to particular research area.

3. ASEAN and Two or More Countries

As agreed upon recently by the ASEAN member countries, there would be one integrated ASEAN Research Proposal on non-conventional energy, and

focal points were designated on the various research areas. The Philippines was designated focal point on Bio-Energy Conversion and Geothermal Energy.

Third countries which expressed interests in assisting ASEAN in the fields of non-conventional energy research and development were identified, as US, Japan and the European Community, for solar refrigeration and air-conditioning; US, European Community, Japan and Australia, for electric power systems; US, European Community and Australia, for solar drying; European Community and US for solar pumping; US, Australia, European Community and New Zealand, for bio-energy conversion; US, European Community, Australia and Japan for coal technology; US, Japan, European Community and Australia for wind energy; US, Japan, New Zealand, and European Community for geothermal energy; US, Japan and European Community, for energy inventory and assessment; European Community and US, for micro-hydro energy.

4. Bilateral Cooperation

The Philippines has availed itself of bilateral cooperations with various countries, namely: U.S.A., New Zealand, Italy, and Finland.

In May, 1978 the Philippines signed an agreement with the U.S. for a four-year $8.6 million loan and grant from the U.S.A. Agency for International Development for research and development of non-conventional energy resources and technologies in the Philippines.

With the New Zealand government, the Philippines has availed itself of technical assistance in the initial assessment survey of geothermal fields; with Italy an agreement to explore and develop geothermal sites; with Finland a technical assistance to a silvicultural project in the Philippines which would eventually set-up a dendrothermal power plant in Bataan.

Some Obstacles and Incentives

1. Obstacles

In some cases, non-con technologies have not made much impact in terms of adoption and utilization because of certain obstacles, among them are:

a. The technologies are conceived and developed and/or introduced apart from the area/people who will ultimately use them. This results in either one or all of the following:

   1. technologies incompatible with the socio-cultural values and practices of recipients;

   2. technologies being introduced in an area where use is minimal; and

   3. technologies being introduced in an area where climate conditions are favorable, particularly in solar and wind power technologies.

b. The technologies are not yet fully debugged and tested before they are introduced to the target areas;

c. The adoption of the technology is prohibitively expensive.

d. Technologies transferred to specific rural areas may not have the skilled manpower necessary to operate and maintain it because the qualified manpower are lured to the big cities;

e. For non-con technologies which are wholly or partly developed in the western world, the access or transfer of the appropriate technology to the developing country is difficult; and

f. Bilateral or multilateral agreements may not be always favorable to the recipient country due to a number of factors. Foremost is the total dependence on the donor's expertise, technology and finances by the host.

2. Incentives

To enhance the use of energy from new and renewable sources of energy, incentives are provided as part of the strategy of the government. The following are some of the incentives:

a) In the promotion of the utilization of non-con sources of energy, significant steps have been made in the issuance of P.D. No. 1068, directing the acceleration of R & D and utilization of non-con energy. Presidential directive, LOI No. 392 followed, effecting the widespread application and utilization of non-con energy in various regions of the country. Specific agencies were designated to be responsible for the dissemination of the activities, namely: MA for biogas, MOE for solar water heating and solar crop drying, FSDC on wind power relative to water pumping and irrigation and NEA on small hydro for rural power up to 5,000 MW; and

b) In 1979, LOI No. 933 was issued directing the preparation of an Energy Priorities Program (EPP). Producers and users of non-con equipment are now entitled to the incentives granted to enterprises in the pioneer areas of investment. Subsequently, LOI No. 1121 was issued directing the Central Bank to design a program of rediscount credit support to private and government banks to qualified non-con energy projects.

Recommendations

That energy plays a crucial role in the socio-economic development of the developing countries is an accepted fact. Therefore, it is imperative that cooperation among developing countries, particularly the ASEAN-member countries, in the field of energy be strengthened. Based on the Philippine experience on non-con energy utilization, the following recommendations are forwarded to optimize the utilization of indigenous energy sources:

a) Review and/or modify existing assistance programs to ASEAN for new and renewable energy sources to make them more responsive to the specific needs and goals of the recipient countries. In particular, new initiatives must be taken to maximize, in future project agreements, the use, whenever

possible, of local expertise and capabilities, including consultancy, component testing and manufacture.

b) Develop, provide resources and activate a workable financing system for promising but high-risk new and renewable energy technologies to encourage entrepreneurs and end-users in ASEAN. Innovative means must be devised to extend financing to the neediest rural communities where traditional banking methods do not operate effectively.

c) In every development program for a new technology intended to benefit ASEAN, emphasis must be put towards the eventual (and early) manufacture of systems in the user countries. Where ASEAN complementation is the only means to make such manufacture of needed equipment economically viable, ASEAN should actively assist in initiating steps in this direction as soon as possible.

d) Enlarge assistance programs for institution building and similar activities that enhance, as rapidly as possible, the capabilities of local institutions to conduct R and D on new technology in a manner and at a level relevant not only to local needs but also to international scientific norms.

e) Assistance for the further development of the energy potential of coal and biomass should be encouraged.

f) Assistance for joint ventures in the development of energy in the ASEAN region should be strengthened.

List of Acronyms

BAI	-	Bureau of Animal Industry
BED	-	Bureau of Energy Development
BFD	-	Bureau of Forest Development
CLSU	-	Central Luzon State University
CNED	-	Center for Nonconventional Energy Development
DLSU	-	De La Salle University
EDF	-	Economic Development Foundation
EPP	-	Energy Priorities Plan
FPRDI	-	Forest Products Research and Development Institute
FSDC	-	Farm Systems Development Corporation
GNP	-	Gross National Product
LOI	-	Letter of Instructions
MA	-	Ministry of Agriculture
MHS	-	Ministry of Human Settlements
MMBOE	-	Million Barrels of Oil/Equivalent
MOE	-	Ministry of Energy
MW	-	Megawatt
NEA	-	National Electrification Administration
NFA	-	National Food Authority
NIST	-	National Institute of Science and Technology
NPC	-	National Power Corporation
NRCP	-	National Research Council of the Philippines
NSTA	-	National Science and Technology Authority
PAEC	-	Philippine Atomic Energy Commission
PAGASA	-	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCARRD	-	Philippine Council for Agriculture and Resources Research and Development
PD	-	Presidential Decree
PIV	-	Philippine Institute of Volcanology
PIDI	-	Philippine Invention Development Institute
PUP	-	Polytechnic University of the Philippines
UPLB	-	University of the Philippines at Los Baños
UPS	-	University of the Philippines System
USAID	-	United States Agency for International Development

TABLE 1

ENERGY CONSUMPTION, BY SECTOR (In MMBOE)

	1975	1976	1977	1978	1979	1980
Transportation	27.8	28.6	30.2	31.3	31.9	32.1
Industry	30.6	31.9	34.6	36.5	38.2	36.0
Commercial	5.7	6.1	6.8	7.0	7.5	7.8
Residential and Others	10.2	10.7	11.6	11.2	11.7	12.3
TOTAL	74.3	77.3	83.2	87.0	89.3	88.2

TABLE 2

National Energy Source Mix

(In Million barrels-of-oil equivalent, MMBOE)

	1980		1981		1985	
	Volume	Percent	Volume	Percent	Volume	Percent
Power						
Hydro	6.27	7.11	7.26	7.42	17.08	12.78
Geothermal	3.42	3.88	5.34	5.46	16.34	12.22
Coal	0.26	0.29	1.15	1.18	8.38	6.27
Oil/diesel	21.46	24.34	19.50	19.93	7.02	5.25
Nuclear	-	-	-	-	2.81	2.10
Nonconventional	-	-	-	-	1.37	1.02
Sub-Total	31.41	35.62	33.34	34.08	53.00	39.64
Non-power						
Oil	56.03	63.55	63.16	64.55	66.44	49.70
Coal	0.71	0.81	1.17	1.20	9.55	7.14
Nonconventional	0.02	0.02	0.17	0.17	4.71	3.52
Sub-Total	56.76	64.38	64.50	65.92	80.70	60.36
Total Commercial Energy	88.17	100.00	97.84	100.00	133.70	100.00
Oil share	77.49	87.89	82.66	84.50	73.46	54.94
Total indigenous	14.45	16.39	22.48	22.97	65.37	48.89
Per capita		1.83		2.00		2.47
Nonenergy consumption*	3.10		3.40		3.70	
Memo Total**	91.27		101.24		137.40	

* Nonenergy consumption refers to petroleum only.

** Memo total is the sum of total commercial energy and nonenergy consumption.

SOURCE: 5-Year Compressed Energy Program 1981-85.

TABLE 3

Tentative Assessment of Indigenous
Energy Resources
(in MMBOE)

Finite	Proven	Probable a/	Potential b/
Petroleum	under evaluation	under evaluation	under evaluation
Coal	175	200	4,000
Uranium		10	under evaluation
Regenerative			
Hydroelectric	18.2/yr.	12.1/yr.	50/yr.
Geothermal	12.3/yr.	23.2/yr.	2.3×10^3/yr.
Non-Con (Solar, biomass, etc.)	0.1/yr. c/	5.6/yr. d/	1.4×10^3/yr.

a/ Projects under feasibility studies

b/ Includes proven and probable

c/ Includes new facilities for 1980 only

d/ Target for 1985

SOURCE: Compressed Five-Year Energy Program, 1981-85.

NATIONAL SCIENCE AND TECHNOLOGY AUTHORITY
ORGANIZATIONAL CHART
CHART I

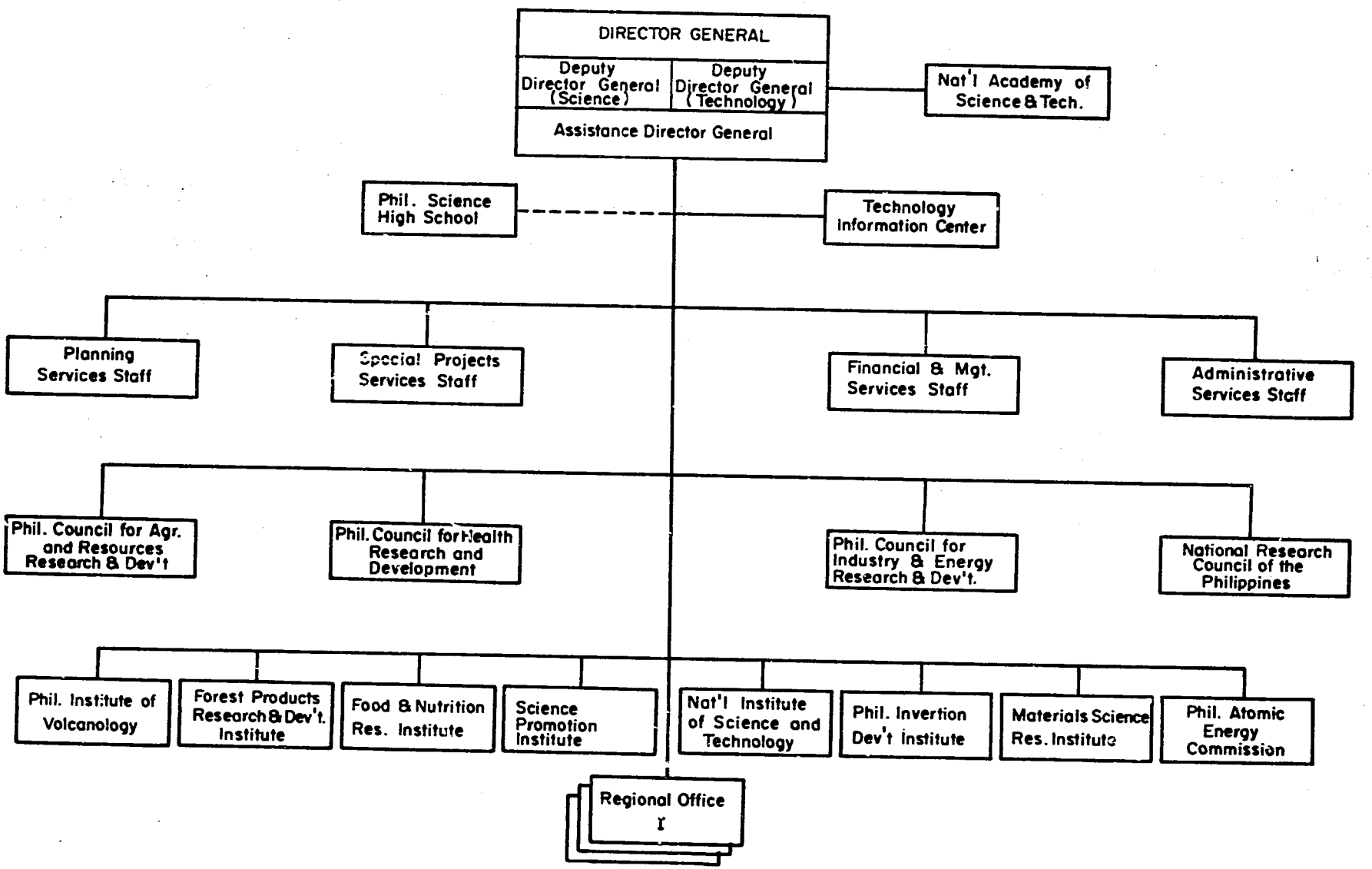
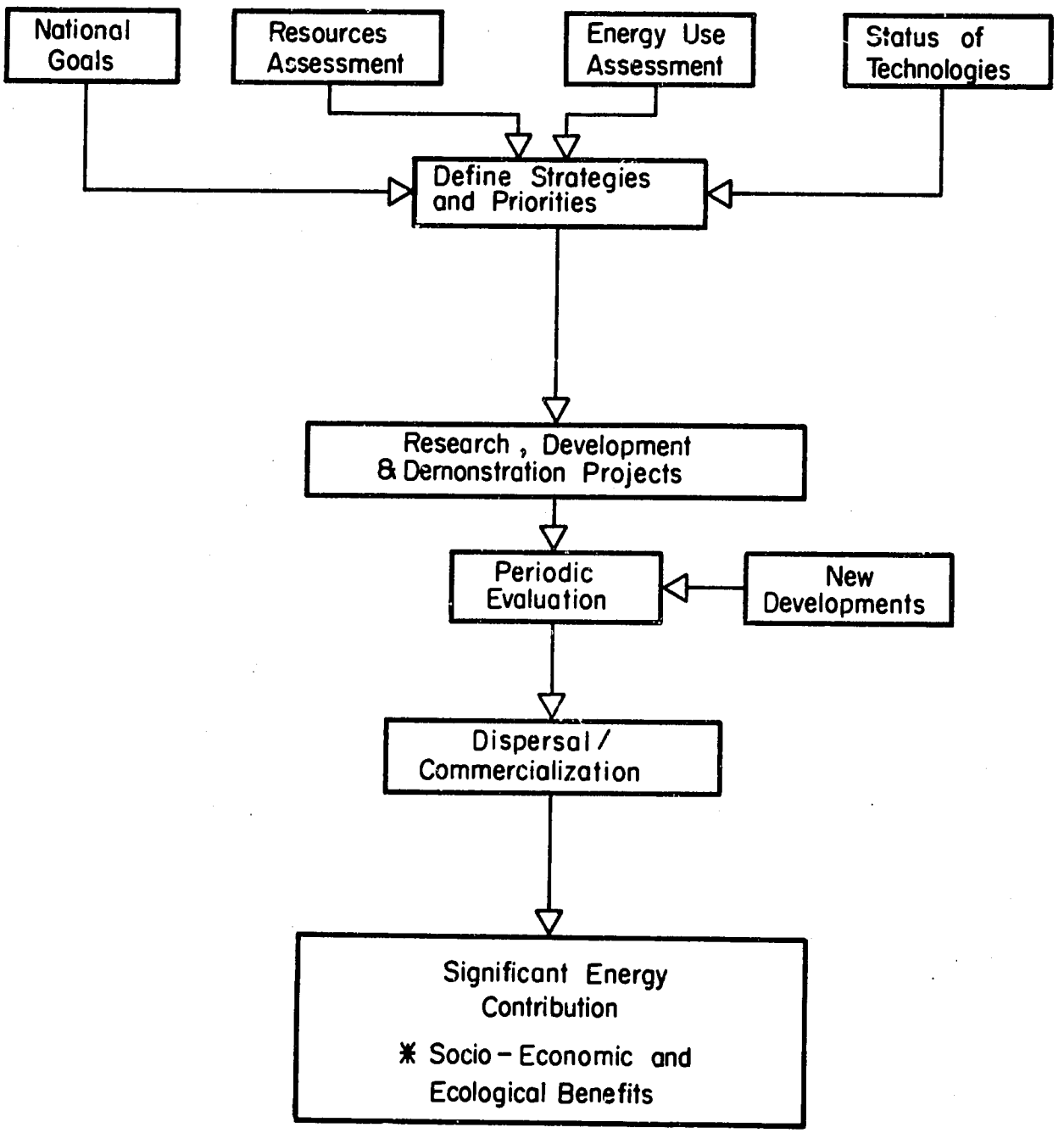


Chart 2
How the Program Works



Malaysia's Energy Program

Ministry of Energy, Telecommunications and Posts
Wisma Damasara
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Malaysia

Introduction

Malaysia is highly dependent on oil in meeting its energy requirements. The electricity generation sector is the largest energy consumer followed by transport, manufacturing, commercial, mining, household, agricultural and other sectors. At present, about 85 percent of electricity generation is based on oil. Electricity generation has shown rapid growth with an annual rate of 10.5 percent over the period 1970 - 1980.

Although Malaysia is currently a net exporter of oil, it is estimated that it will become a net importer in less than a decade. In order to decelerate the exploitation of crude oil, the National Oil Depletion policy has been adopted. As a result, oil production dropped to 260,000 barrels per day (b/d) in 1981 compared to 283,000 b/d in 1979.

Our limited oil reserves and our fast growing energy demand make it imperative that we develop alternative energy resources, both conventional and non-conventional. In Malaysia, a four fuel energy strategy based on gas, hydro, coal and oil has been adopted in order to diversify our energy resources. By giving priority to the development of our natural gas and hydro resources, our reliance on oil will be reduced.

Malaysia's Energy Resources

Malaysia is blessed with a variety of energy resources. However, many of our resources have yet to be utilised. This section describes our reserves of both renewable and non-renewable energy resources.

1. Oil

Most Malaysian oil is found off-shore. Oil exploitation in Malaysia is undertaken by private companies under a production-sharing agreement with the National Oil Company (PETRONAS). Malaysia's known oil reserves are about 2.5 billion barrels.

2. Natural Gas

Recoverable reserves of non-associated gas have been estimated at over 30 trillion standard cubic feet (scf) which is equivalent to more than 5 billion barrels of oil, that is, about double our crude oil reserves. Almost half of this is located in Sarawak with the remainder along the east coast of Peninsular Malaysia.

3. Hydro

Malaysia is relatively rich in hydro power resources. However, the hydro potential is not evenly distributed with Sarawak contributing 71%, Sabah 16% and Peninsular Malaysia 13%. Our hydro potential is estimated at 200,000 barrels per day of oil equivalent (bdoe).

4. Coal

Potential reserves of coal have been estimated at 400 - 500 million tonnes, most of which is located in Sarawak. However, our coal is mainly lignite with a low calorific value and a high moisture content.

5. Oil Shale and Peat

Oil shale and peat have never been exploited. However, 8% of the surface area of Peninsular Malaysia and 12% of Sarawak are occupied by peat deposits.

6. Nuclear Materials

Assessment of our uranium resources is being undertaken by the Geo-

logical Survey Department. Malaysia also has a considerable supply of thorium in tin tailings. However, the Government has decided that the nuclear option be deferred for the time being as priority must be given towards development of other indigenous energy sources.

7. Solar

Malaysia is blessed with abundant sunshine. Our average daily insolation level is about 4.5 kWh/m^2.

8. Biomass

Wood is used mainly by rural communities for direct conversion into heat. It constitutes less than 5% of our total energy consumption.

Amounts of agricultural wastes produced each year are substantial. The energy available from oil palm shell and fibre is estimated to be an equivalent of 11,600 barrels per day. It is also estimated that the amount of biogas that could be generated from animal and vegetable wastes may be as high as 1.6 million m^3/year.

9. Other non-conventional energy sources

These resources include geothermal, wind, tidal and wave. Apart from a preliminary survey of geothermal energy sources in Sabah, the potentials of other non-conventional energy sources have not been assessed yet.

Energy Program of Malaysia

In the past decade, our energy demand has been growing rapidly at an average rate of 9% per annum, as compared to our economic growth rate of 8% per annum. It is estimated that energy consumption in 1990 will be 374,000 bdoe compared to 170,000 bdoe in 1980. Steps are being undertaken by the Government to meet our energy demand and to reduce our over-dependence on oil.

The National Electricity Board (NEB) will be commissioning a 900 MW

combined cycle gas-fired power station in Paka, Trengganu by 1984/85. Provision has been made to increase the installed capacity of this station up to 1800 MW at a later date. If it is economical, the natural gas from Trengganu off-shore field will be reticulated across to the west coast of Peninsular Malaysia to fuel the main NEB power stations.

In 1983, an LNG (Liquefied Natural Gas) plant will start producing 6 million tonnes per year (an equivalent of 140,000 bdoe of crude oil) for export to Japan. Associated gas, on the other hand, will be utilised for the production of LPG (Liquefied petroleum gas) and will subsequently be introduced in transportation.

As to the development of hydro resources, the current development by NEB is the construction of Bersia (72 MW), Kenering (120 MW) and Kenyir (400 MW) in Peninsular Malaysia which will be completed in 1985. A master plan study on the hydro potential of Sarawak has revealed that a total of 51 projects could be developed giving a total exploitable potential of 20,000 MW and a total energy output of 87,000 GWh per annum. The possibility of transmitting the excess power via undersea HVDC (High Voltage Direct Current) cables to Peninsular Malaysia is being studied.

Mini hydro for rural electrification is also being developed. Under the Fourth Malaysian Plan, the NEB, SESCO (Sarawak Electricity Supply Corporation) and SEB (Sabah Electricity Board) will be implementing a total of 125 mini hydro schemes with capacities ranging from 50-500 KW. Mini hydro turbines are also being fabricated by the NEB using designs from foreign countries.

Under Government directive, the NEB has begun work to establish nation's first coal-fired power plant at Port Klang by 1986. The capacity of this plant will be 600 MW. Several aspects relating to infrastructure, logistics, technology and environmental considerations need to be examined before coal use can be rapidly expanded. It is forecasted that coal demand for power generation will be 1.5 million tonnes per annum in 1986.

Solar energy in Malaysia is still in the development stage although some solar-powered appliances are already in use. Various agencies have undertaken studies on the use of solar energy for electricity generation, low temperature water heating, drying and water pumping. A solar electrification program under the Fourth Malaysian Plan started with the electrification of a fishing village of 40 houses on the island of Langkawi. The system, now completely installed, is expected to be commissioned by the end of June, 1982. However, solar electrification is costly and its contribution for energy in Malaysia is likely to be negligible at least before the year 2000.

Research activities into the development and utilisation of biomass are being pursued by universities and research agencies. Research activities include the production of alcohol and biogas from animal and vegetable wastes.

Furthermore, two pilot plants utilising steam derived from the burning of rice husks are presently being implemented by NEB in Kedah. Each plant will have the capacity to generate 350 KW and will supply electricity to LPN (National Padi and Rice Board) complexes. This is the first example of a co-generation project in Malaysia, where a power plant utilising agricultural wastes is interconnected to the NEB grid.

There are now about 100 oil palm mills already utilising their wastes for production of steam and power. An incentive towards private electricity generation using wastes is now being introduced by the Government. Projects would be interconnected to the NEB grid with special tariff arrangements.

We realise the tremendous potential that exists in biomass utilisation for energy purposes in an agricultural country such as Malaysia where substantial amounts of agricultural wastes are produced every year. However, problems related to collection, resource availability and utilisation remain to be solved.

Energy conservation is another program introduced by the Government of Malaysia in 1981. This program includes education, mass media and practical measures in terms of energy management in Government offices; factories and hotels. In this respect, NEB has introduced a peak power tariff to encourage greater conservation of energy. NEB's conservation plans also include increases in efficiency of its existing power generation plants and reduction of losses in its transmission networks by proper load management. Another form of energy conservation is the current activity of power interconnection between Thailand (EGAT), Malaysia (NEB) and Singapore (PUB) which would save millions of dollars for all sides involved.

Conclusion

The search for and utilisation of alternative energy sources is vital to any nation as the supply of oil will be both costly and uncertain in the future. There must be efforts towards the development of new technologies to meet our rapidly growing energy demand. By exploiting our indigenous gas and hydro resources as well as accelerating research and development in the renewables, Malaysia will certainly go a long way towards reducing its dependence on oil.

Sectoral Energy Consumption (In %)

For Peninsular Malaysia, 1976-1980

Sector	1976	1977	1978	1979	1980*
Electricity	29.2	30.3	30.2	28.3	29
Transport	18.6	18.3	18.7	19.6	20
Manufacturing	19.8	19.4	19.0	19.2	19
Commercial	8.3	8.1	8.3	8.6	8
Mining/Quarrying	7.5	7.1	7.0	7.2	7
Household	7.1	7.4	7.3	7.3	7
Agriculture	5.9	5.6	5.6	5.8	6
Others	3.6	3.8	3.9	4.0	4

* estimate

Indonesia's Energy Programme

By The Indonesian Delegation

Indonesia's Energy Situation and Policy

It is fortunate that Indonesia is blessed by an abundance of energy sources. The potential of energy resources is shown in Table 1. As an oil exporting country Indonesia's current production is around 1.6×10^6 bbl/day. Indonesia should maintain, and if possible, increase the quantity of oil for export.

On the other hand, as a consequence of the national development and population increase, the demand for energy increases from year to year (see Figure 1).

Domestic commercial energy consumption depends on oil for more than 80% of total supply, while hydro, coal and other source of energy account for less than 20%. The overall consumption pattern for commercial energy is shown in Figure 2 and 3.

Non-commercial energy accounts for at least 50% of total domestic consumption. The rate of increase in the consumption of the non-commercial energy is very fast. Given the rates of increase of energy consumption during the past decade, it is not inconceivable that Indonesia might become an oil importing country in the future. In order to overcome the problem, Indonesia introduced a National Policy giving priority to non-oil energy sources.

Related to the policy, the government encourages the development of renewable and non-exportable energy sources; e.g. geothermal, hydro, biomass, solar, wind, OTEC, tidal, etc.

Given large domestic coal reserves, the country can use coal in the very near future to reduce the dependence on oil by domestic energy users.

The national energy policy consists of:

- intensification and extensification of energy exploration and exploitation activities
- energy conservation
- diversification and
- indexsation

As consequences of the implementation of the policy mentioned above, the energy consumption pattern in 1984 is projected as shown in Table 2.

Energy Demand and Supply Projections

Indonesia has carried out some studies on energy demand analysis by both domestic planning groups and foreign governments or firms. The result of joint studies between the Indonesian Government and US Government on energy planning for development, can be summarized as follows:

1. Future Energy Demand.

If the Indonesian economy grows at 6-7 percent per year during the 1980's, it will require the equivalent of 370-450 million barrels of oil equivalent (MBOE) by the end of the decade.

In 1978 the country used 155 million barrels of oil equivalent. This growth rate of energy use correspond to a range of 7.5 - 9 percent per year. If current consumption and government policies trends continue, then energy demand should continue to increase at 1.2 times the GDP growth rate. These figures do not include wood and other non-conventional energy. The fraction of total annual primary energy resources used to produce electricity is expected to increase during 1980's, to 20 - 30 percent by 1990 (see Figure 4, 5).

2. Future Energy Supply.

The estimates of energy resources other than oil which could contribute to meeting the demand for energy in 1990 are listed in Table 3.

The State of the Art of Alternative Energy Development

1. Coal.

The production of coal in 1980 was around 300,000 tons per year, while the projected demand in 1984 is 5,175,000 tonnes, and in 1990 should come to 15,893,000 tons.

Efforts are being made to boost production to supply such major consumers of coal as power plants and factories. Studies on various types of coal now being done in University and research institutions include fluidized bed gasification in-situ gasification. To support increases in coal production activities, we are now preparing some coal laboratories and other infrastructure. Cooperation on coal development programs has been established among Asean Countries.

2. Biomass.

Biomass is one of the major renewable energy sources which can be harnessed for future use. The study and research of utilizing biomass has been done by many institutions and universities. There are many processes that have been studied for converting biomass into more useful forms. Studies aimed at using agricultural, forestry, animal, and human wastes as a feed stock for a proper conversion technology have been done. Some pilot scale conversion units have been built. At present, production of alcohol and Single Cell Protein (SCP) is being considered seriously. A pilot alcohol plant is being built at the transmigration area, Tulang Bawang, Lampung. The plant is expected to be ready to operate at the end of 1983 with an initial capacity of 15,000 liters per day. The raw materials are starch-containing crops, such as sweet potato and cassava. The use of Euphorbia spp. to obtain oil from plant is now also being considered.

3. OTEC.

As an archipelago nation with almost 70% of her territory covered with seas, Indonesia has also studied development of energy sources from the sea. One potential source is OTEC (Ocean Thermal Energy Conversion). Depth contour and horizontal and vertical temperature distributions have been surveyed throughout the Indonesian and adjacent waters. Many potential sites for OTEC have been identified. One of them is shown in Figure 6.

A cooperative program to develop OTEC in Indonesia has been signed between Indonesia and the Netherlands. A five Megawatt experimental OTEC plant is planned to be installed in the Indian Ocean about 5 km off the south coast of West Java.

4. Solar Energy.

Solar energy is one alternative for future use in Indonesia. The potential of solar energy appears high since the average daily radiation in Indonesia is around 4 kwh/m^2.

Indonesia has begun to develop and to test solar energy systems under the frame of bilateral cooperation between the government of the Republic of Indonesia and the Government of the Federal Republic of Germany and the agency for Development and Application of Technology (BPP Technologi). In addition, several institutes and companies in Germany have established and launched a joint "Solar Village Indonesia" Project.

The project started in 1979 and comprises:

- two Pilot Villages with demonstration facilities (Picon and Citris in West Java)

- a scientific and technical programme which includes all the engineering activities required to support both villages, studies on social and economic acceptance, development of other promising technical systems and investigation of the possibility of future construction in Indonesia.

Additionally, three demonstration plants using photovoltaic cells are being set up by Directorate General for Power with one unit in Lampung (South Sumatra) and two in Central Java. Other research and development of the utilization of solar energy have also been done by several institutions and universities.

5. Wind Energy.

A survey on wind potential has been done by the Meteorology and Geophysics Center. While some other institution such as the National Aerospace Institute (LAPAN), the Directorate General for Power, and several universities (including ITB and ITS) have launched programmes on the utilization of wind energy.

Recently, LAPAN has decided to build a wind turbine with a capacity of 10 kw for rural electrification. It is located in Pamungpeuk, south coast of West Java. A second turbine is scheduled to be built elsewhere.

6. Geothermal.

The potential of geothermal energy is quite significant. It is estimated around 8000-10000 megawatts. At present, the electricity production is 60 Megawatts as a result of cooperation with the Government of New Zealand. Furthermore, the Government has signed contracts with private firms to develop a commercial size geothermal power plant near mount Salak in West Java. This installation will be followed by several other geothermal power plants.

7. Peat.

Potential reserves of peat are considered very large, since the area covered by peat is estimated around 17 - 26 x 10^6 ha. Most of the reserve is located in Sumatra and Kalimantan island.

Efforts are being made at present to utilize peat as an energy source, though it is still in a preliminary stage.

TABLE 1

Potential of Energy Resources in Indonesia (An Estimation)

Resource:	
Oil	50 Billion Barrels
Natural Gas	30.3×10^3 Billion cu. ft
Coal	13 Billion Tons
Hydro Power	31000 MW
Geothermal	8000-10000 MW
Nuclear	trace
Non Conventional (Firewood & Agricultural waste), 1978	53 Million tce

TABLE 2

Energy Consumption Pattern in 1984

Year	1978/1979 (Actual)	1983/1984 (Projected)
Oil	83.70%	77.48%
Natural Gas	11.95%	16.47%
Coal	0.68%	1.58%
Hydro Power	3.67%	4.41%
Geothermal power	0%	trace
	100.00%	100.00%

This total is the equivalent of 251 million barrels of mineral oil (BOE)

TABLE 3

Possible Future Energy Supplies At End of 1980's

Resources	Physical Units	Million MBOE
Coal	8-16 million metric tonnes	32 - 64
Natural Gas	300-330 x 10^9 cu. ft	57 - 63
Hydro	2650 - 3800 MW	20 - 30
Geothermal	350 - 600 MW	4 - 7
Biomass*		1 - 7
Wind		**
Solar		**

* Non traditional biomass

** Less than 0.5 MBOE

Members of the Indonesian Delegation

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2. Mr. Robert Manurung
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8. Mr. Mochtar Sharief

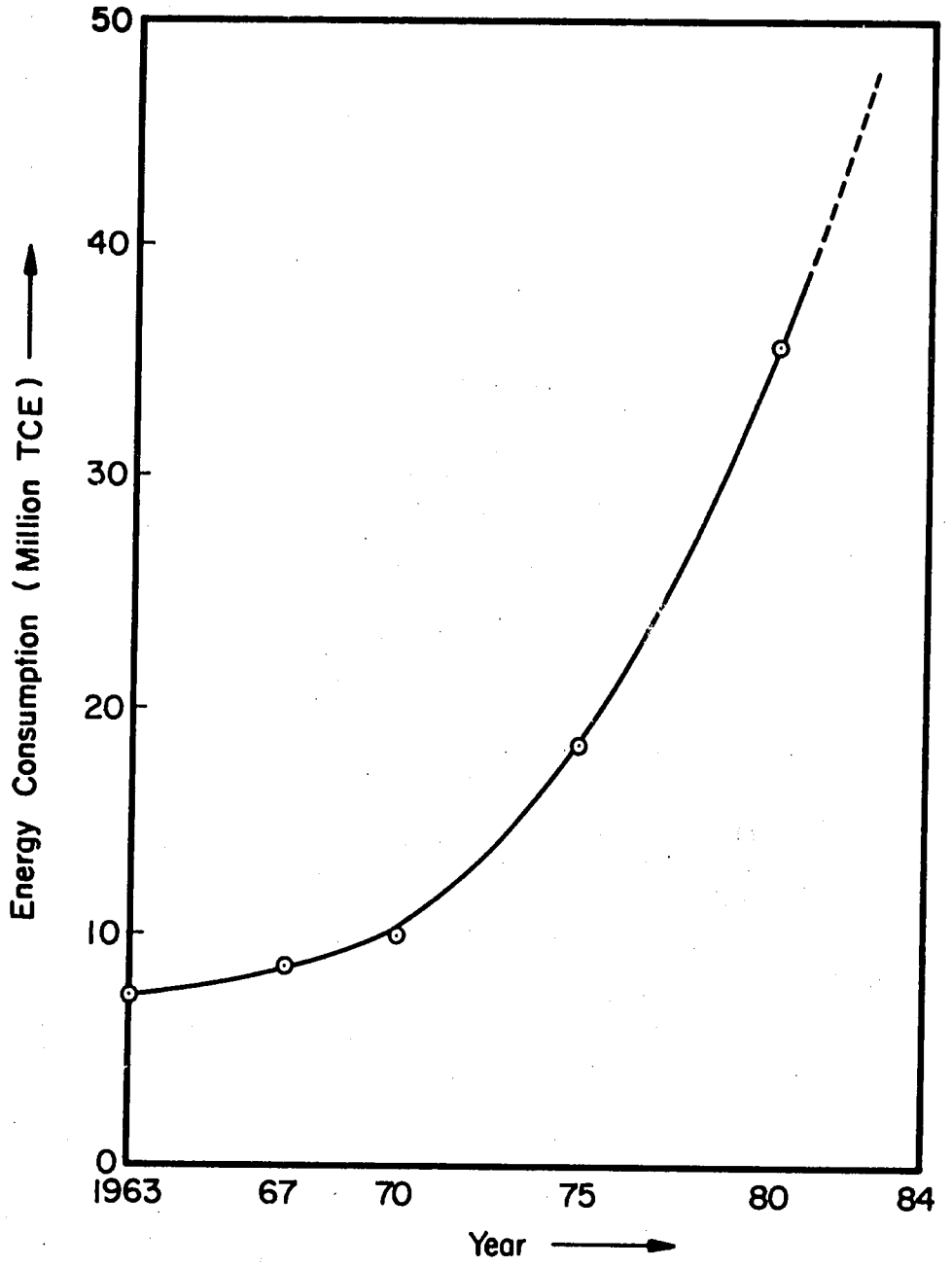


Fig. 1 – Energy Consumption , 1963-1980

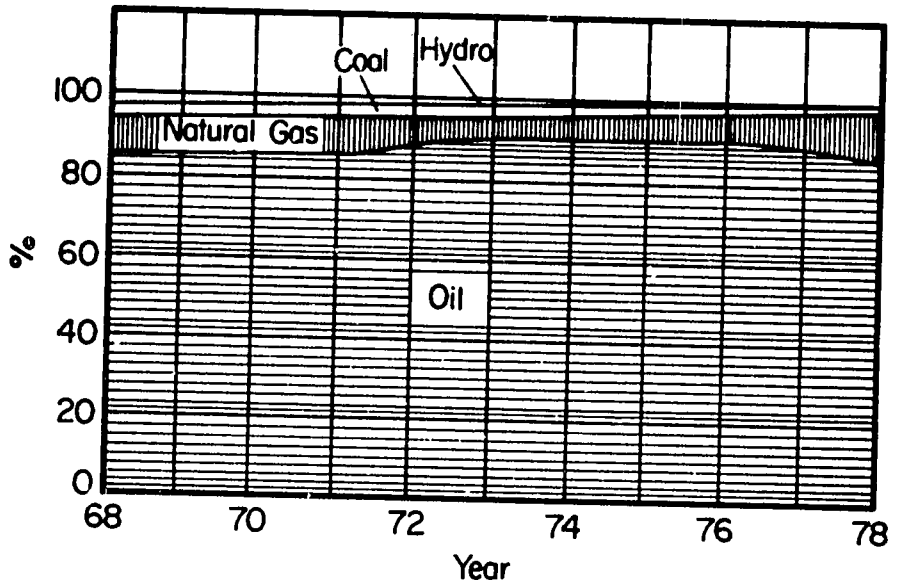


Fig.2 – Percentage of Various Energy Consumption

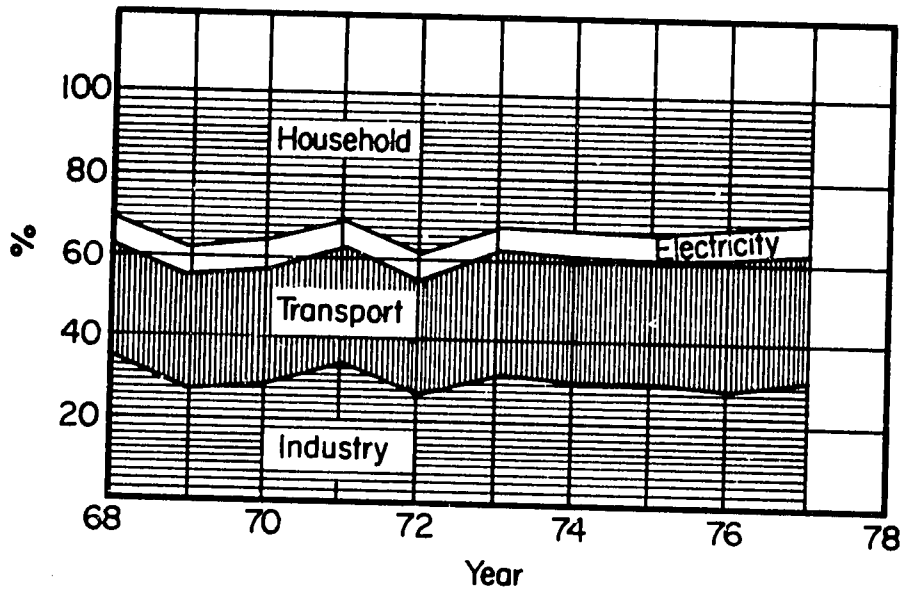
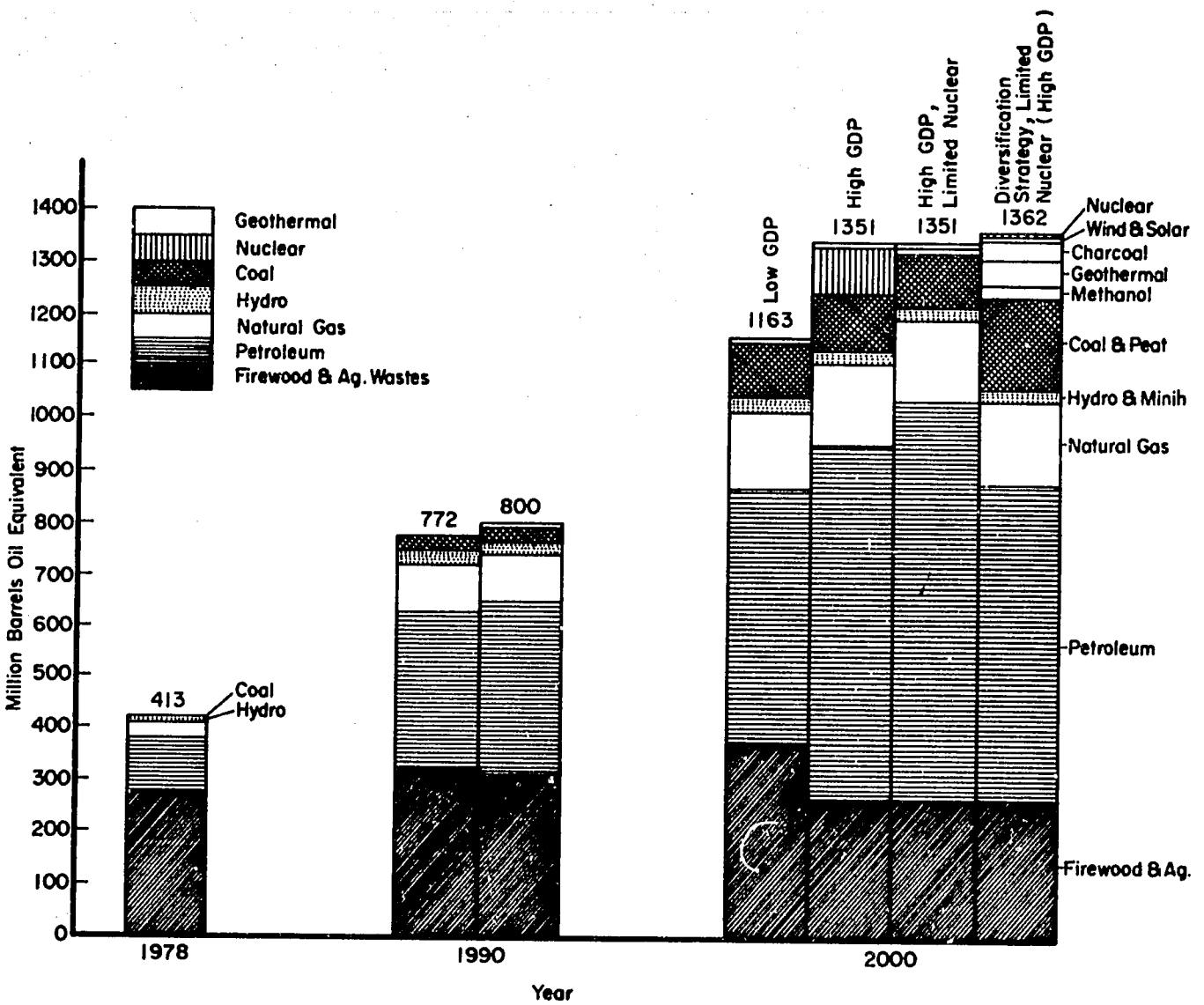
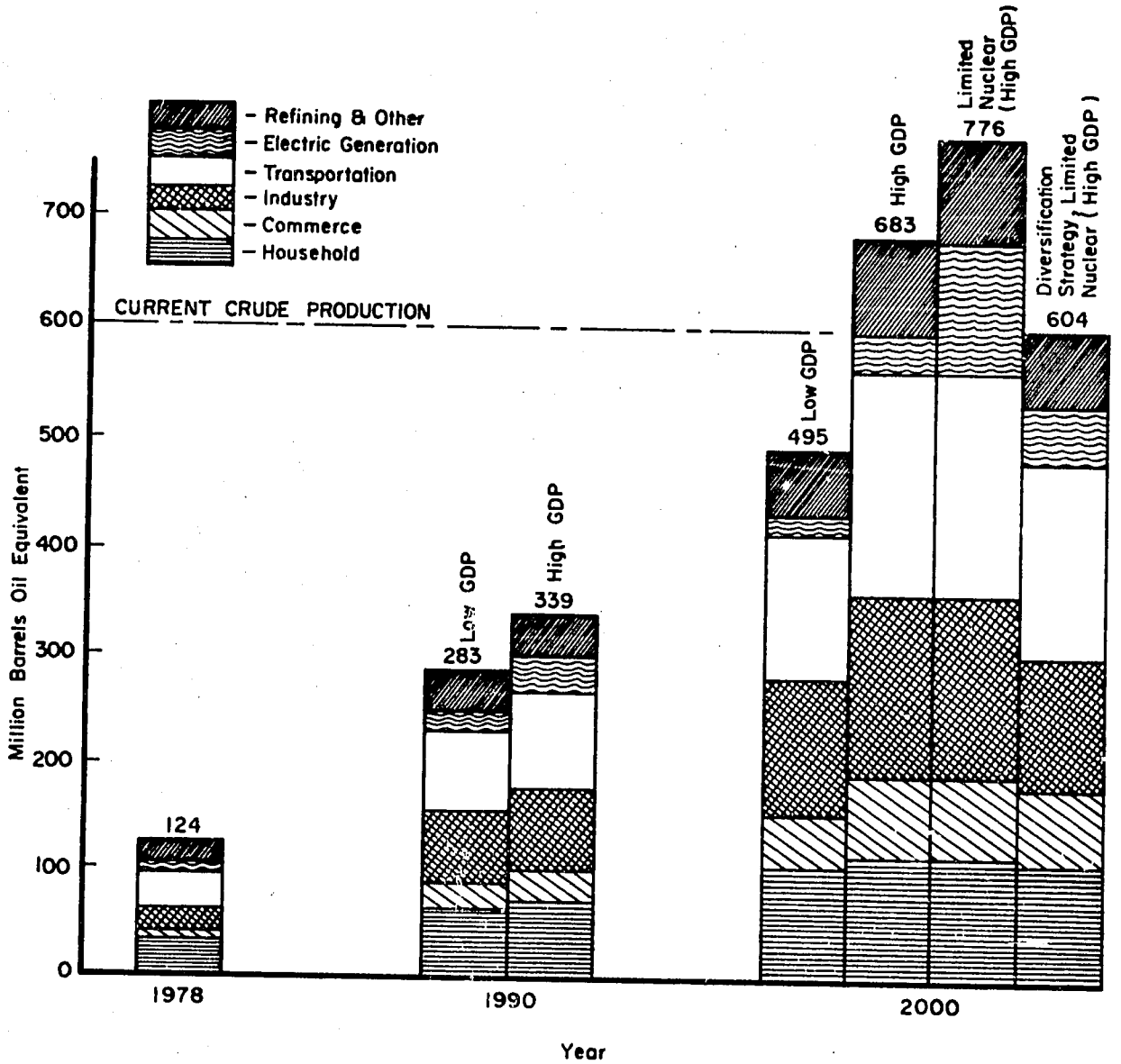


Fig. 3 – Energy Consumption of Household, Transport, Industry and Electricity



Source : Directorate General for Power "Energy Planing for Development Report"

Fig. 4 – Projected Energy Demands by Energy Source (Excludes Exports)



Source : Directorate General for Power "Energy Planing for Development" Report 1981

Fig. 5 – Petroleum Demand by Sector

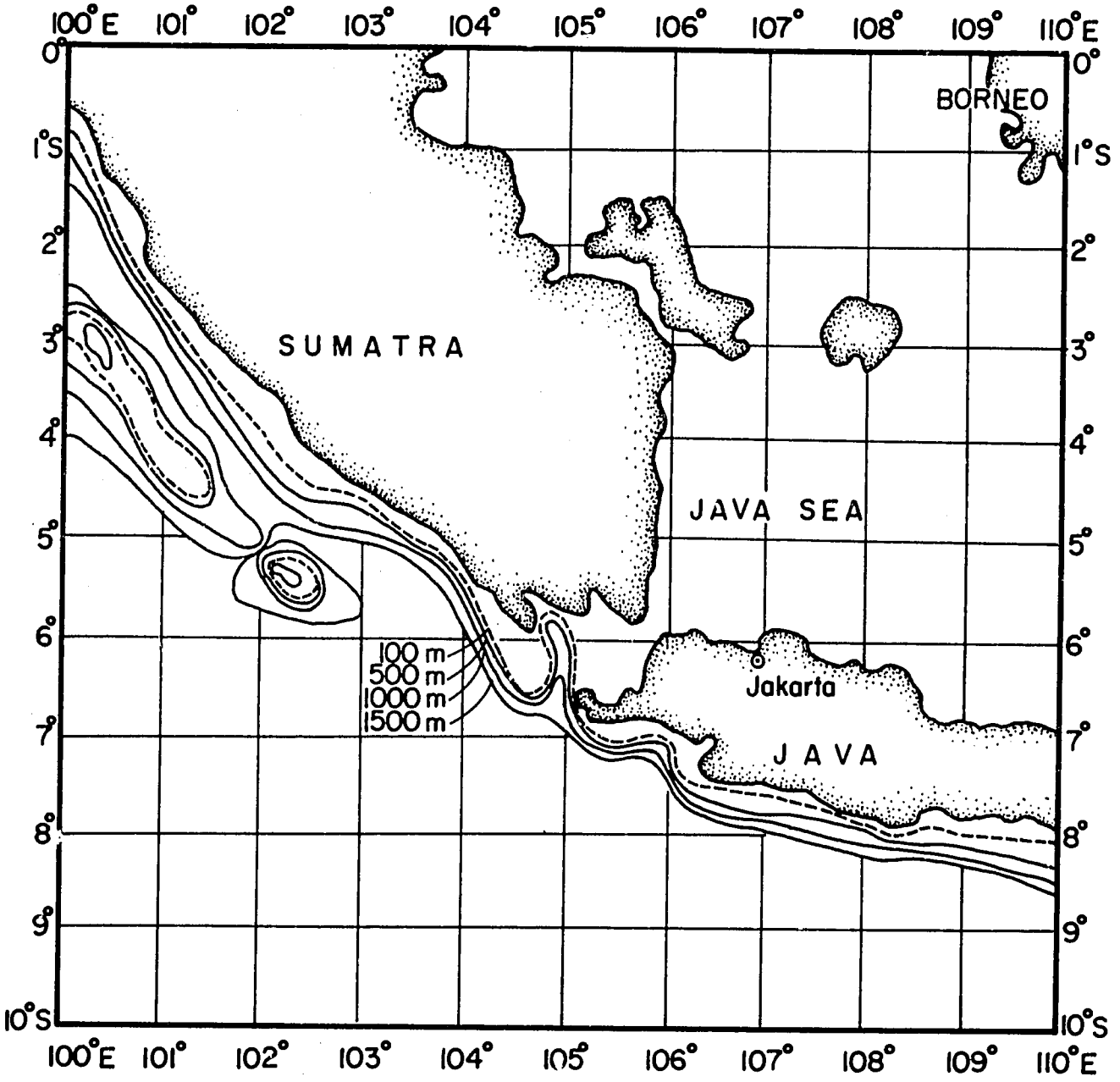


Fig. 6 – Rough Bathymatry for Jakarta

State of the Art Lecture: Biomass

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Introduction

Biomass energy currently provides a major portion of energy supplies in third World nations and is still the primary energy source in rural areas. This address is intended to highlight the dimension of bio-energy potential by highlighting the following areas:

1. The historic role of biomass energy
2. Moral dilemmas or food-fuel conflicts
3. Current ASEAN use
4. Resource assessment tecniques
5. Feedstock production
6. Conversion technologies
   a. thermochemical
   b. biological
7. Applications
   a. traditional-heat, light
   b. industrial, transport, chemical
8. Economics of bio-energy use
9. Potential contributions.

Role of Biomass in the World Energy Economy

In a single day the sun sends more energy to earth than the world consumes in an entire year. Although plants capture only 1 percent or less of that energy, this is sufficient to provide more than 1 year's energy for the world. Plants store about 20 years of world energy consumption. In theory, then, it is conceivable to meet much of the

world's energy needs from plants.

For most of human history this was indeed the case. Direct combustion of wood, crop, and animal waste, and manufacture of charcoal provided virtually all of mankind's energy needs. The real energy crisis in much of Asia, Africa and Latin America is the increasing scarcity of wood and other bioenergy resources. In Bostwana, for example, the average hauling distance for wood in villages now exceeds 40 km.

Two major culprits stand behind the falling biomass energy supplies of the Third World. On the conversion side, efficiencies are typically low: on the order of 5% or less. On the feedstock production side, poor agronomic and forestry practices coupled with rapid population growth have led to widespread loss of forest lands and increasing competition for land and water resources.

Simply improving the efficiency of direct combustion or charcoal burning to levels common in fossil fuel systems could more than treble the effective biomass supplies of many nations. Similarly, aggressive forestry and agriculture programs could increase the capture of solar energy substantially.

Finally, biotechnology offers many opportunities to increase the value of biomass resources*.

Current biomass energy use in the Third World ranges from virtually nil (Singapore and Taiwan) to 86% of all nonfood energy use (Bangladesh). Worldwide, the UN estimates biomass energy use at 6-13% of total energy

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* By biotechnology, I mean the use of biological processes to transform feedstocks from 1 form to another. More specifically, biotechnology also refers to specialized techniques for changing the genetic structures of organisms in order to more closely control their activities in transforming matter.

use. In between are ASEAN nations where nonfood energy consumption from biomass ranges from 66% (Indonesia) to less than 20% (Malaysia). Both Thailand and the Philippines derive from 40-60% of their nonfood energy consumption from biomass. Replacement of traditional energy sources in Indonesia would mean the virtual elimination of that nation's oil exports while both Thailand and the Philippines would have to double oil imports to replace the energy and chemical services of biomass.*

The Moral Dilemmas of Bio-energy Use

Many analysts and policymakers, increasingly dismayed by the rate of deforestation and concerned with the ever-precarious balance of supply and demand for food look askance at biomass energy prospects. How can we propose to increase bio-energy use under circumstances of insufficient supply? To this question come two general categories of answers: improve feedstock production; and increase end-use efficiency. In Third World countries, as elsewhere, more energy services need not entail more energy consumption.

However, the realistic prospects for enhanced bio-energy use require significant improvements in feedstock production for both social and ecological reasons. Using bio-energy as gasohol at the cost of a few pennies per-pound for beef may well be an acceptable moral trade off for well-fed Americans. Liquid fuel programs that result in rising grain and meat costs

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* I should caution you at this point to be suspicious of all statistics given (including the ones above) on biomass supply and use. Quite simply, the data are all poor and cannot be trusted as more than rough approximations - i.e. we know that the Philippines and Thailand consume roughly the same amounts of biomass fuels. To tell which nation consumes more requires statistical precision lacking in current documents. For example, a recent FAO publication shows Thailand consuming 15.1 million cubic meters of fuelwood each year. Alternative estimates range as high as 47.5 million cubic meters per year.

may be less sanctioned in nations closer to the demand-supply margin. Ecologically, feedstock programs that "mine" the soil by eliminating rotations of crops may prove to be unsustainable in the long run. Erosion, loss of minerals, and reduction in water storage may all result from improper intensive farming and forestry techniques.

In the long run, of course, we are all dead. If we are told that after the storm is past, the ocean will again be flat, we are left with nothing for the immediate and serious energy problems of ASEAN and of the Third World in general. The conflicts in land use between food, feed, fiber, and fuel will continue, regardless of prolonged debate and the anguish generated by concern over the "proper" allocation of land resources.

Such a static view obscures the differences between the short run where our technology is fixed and long run where we have the capacity to change the boundaries of the moral dilemma. In the short run, improvements in use technologies in the form of more efficient gasifiers and combustion systems can save as much as 50% of current fuelwood consumption while maintaining the level of delivered energy services. Such efficiency improvements provide breathing space for the current forest and crop land resource base. By postponing doomsday, we have time to look at ways to improve yields of traditional trees and crops or to introduce new ones that promise better results.

Without belittling the moral problems of biomass energy use, I suggest to you that the question be reposed. We need to manage farms and forests to meet the diverse and escalating demands on them in a sound and sustainable manner. Until we put off doomsday, such an approach will founder under the pressure of immediate needs. (When you're up to your waist in crocodiles, it is hard to remember that your objective was to drain the swamp.)

Resource Assessment

At its least sophisticated, assessment of biomass energy resources requires a scale, a calculator, and the cooperation of local farmers and foresters. From uniform-sized plots, it is a simple matter to figure the tons per hectare of output. Such results can be generalized over soil types or political divisions (another source of statistical inaccuracy). Though not of sufficient resolution to plan for and locate actual bio-energy projects, rough indications of the current productivity and inventories of biomass are useful for discriminating among classes of lands or regions.

Remote sensing by satellite also falls into the category of gross productivity indicators. Such techniques represent a quick and inexpensive means of determining total biomass productivity. Current work in remote sensing represents an attempt to heighten the level of detail to smaller geographic areas and to individual biomass types. Such a step is imperative to take the usefulness of remote sensing beyond gross resource assessment.

Back on the ground, more detailed traditional assessment techniques involve soil, rainfall, and slope maps as guides to the suitability and productivity of land with varying characteristics. Such studies consume large amounts of time and money but are necessary for determining biomass production capabilities and requirements over time. For example, the detailed breakdown of soil types in the US gives analysts a picture of the potential productivity of new lands to be brought into cultivation of grains should the US embark on a major gasohol program.

Combining soil, rainfall, and slope characterizations with crop experience and trials gives the most complete view of resource potentials obtainable with convertional technologies. Such trials require replication and adjustment, and, given the limitations of abnual growing cycles, may take several years to complete. Once completed, these growing trials provide a basis for writing handbooks on energy farming as with the Ipil-Ipil tree in the Philippines.

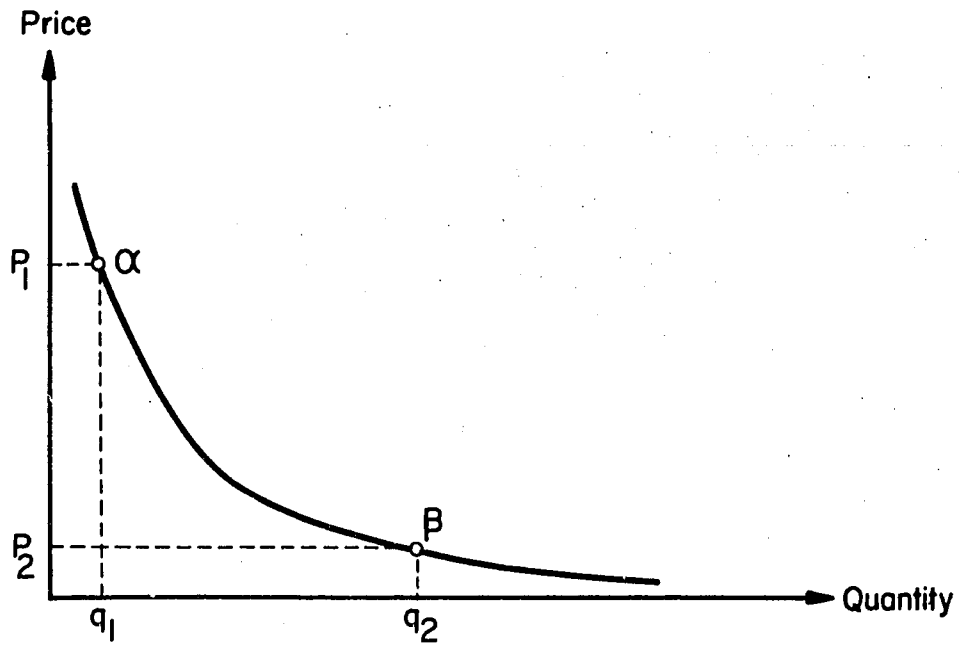
Once gross productivity and potential have been determined, the job of the resource assessor really starts. The issues of prime concern are the assessment of inventories (for forests), determination of joint production possibilities for crops and trees, survey of lands to be used for energy crops, and study of price or resource impacts of bio-energy feedstock production on food, feed and fiber prices.

Physical inventories are relatively easy to assess by both remote and ground techniques. Annual increments (or growth) can be determined by direct estimation or by using photosynthetic conversion efficiency in an algebraeic expression. The important point is to figure out how much annual growth can be taken without impairing future productivity. In a recent project for the United Nations, I made such estimates for two ASEAN nations, Thailand and Indonesia. The latter has more than 1.8×10^{18}J excess biomass growth annually while Thailand has $.35 \times 10^{18}$J/yr of excess growth. Such figures are significant to the extent that they indicate a greater biomass potential than is commonly thought.

For biomass resources with multiple uses such as maize, sugarcane, and crop and animal wastes, resource assessment requires antennae sensitive enough to see when price impacts of bioenergy might become excessive. Essentially food, feed, and fiber resources are available for energy conversion as long as their values as energy resources are exceeded by their values in other uses. In this way, only feedstock supplies beyond basic needs will be used for energy conversion. The caveat to this facile formula comes from the notorious instability of commodity markets. Only if energy foodstock demand is responsive to price changes will market stability be enhanced by additional demands.

In the following figure, food demand at α takes procedence over fuel demand at β. Only after the food supplies have been sold at $P_1 (P_1 > P_2)$ will supplies move into the lower priced fuel market. After estimating points α and β, we would consider available biomass resources to be $q_2 - q_1$. Similar analytic methods can be applied to fiber and feed resources as well. In fact, much of the economic impact literature on gasohol in the USA simply uses more elaborate versions

of the analysis of demand presented below.



At α the curve is inelastic - quantity demanded does not very greatly with price

At β the curve is elastic - quantity demanded varies greatly with price

Conversion Technologies

There are two major biomass energy pathways, biochemical and thermochemical. Both have been in use throughout the world for millenia. Included under thermochemical conversion is direct combustion of biomass, charcoaling and pyrolytic techniques and gasification for chemical feedstocks. On the biochemical side are the fermentation technologies, now widely used to produce ethanol, acetic acid, methane, and food and drink. The future promises biotechnology to improve the efficiency of biochemical energy conversion and broaden the array of usable feedstocks. In the far future, say, 40 years, photobiology may become an important energy source by mimicking photosynthesis; producing electricity rather than sugar.

A. Thermochemical Conversion Technologies

The simplest of the thermochemical technologies, direct combustion, is probably the most widely used method of converting solid fuels to energy. While the thermal efficiency (value of energy products produced/ value of energy products consumed) of a typical modern coal or wood fired boiler is 35-40% and modern wood stores have achieved efficiencies of as much as 50%, typical three rock stoves show efficiencies of 5% or less. And while the 40% figure may be unattainable for home cooking systems, 20% is certainly not out of the realm of the possible with current, low cost stoves and gasifiers.

Two major methods for improving combustion efficiency are to raise the pressure in the combustion chamber (as in an automobile engine) and to restrict the flow of oxygen through the combustion chamber. Gasification refers to restricted air flow and is now widely used in small scale and large scale units. The gasification process releases heat and also produces a low density gas suitable for crop drying or operating internal combustion engines.

Small scale gasifiers are currently produced in the Philippines as well as in the industrial countries and form a strong basis for improved efficiency in biomass energy use. When combined with efficient charcoal production, gasifiers can power stationary engines with simple and local fuel cycles.

Total reduction of air throughout in a gasifier is known as pyrolysis. Depending upon the feedstocks and on the pressure and temperature of the reactions, pyrolysis will produce a low density gas, charcoal, and a liquid product that may range from croesote to diesel in character. In fact, variants of pyrolysis have been used for thousands of years to produce charcoal. The modern twist is to control the reaction for desired product mix and to capture and use the producer gas instead of discarding it. Current experiments with pyrolysis are under way in Indonesia, Philippines, and elsewhere.

As in the feedstock production systems, the greatest overall benefits in conversion are obtained by using the joint products at their highest values. Simply capturing the producer gas from pyrolysis increases the efficiency of charcoal system by 50% or more. The synthesis gas (carbon monoxide plus hydrogen) produced by incomplete combustion of solid fuel once provided the urban energy of Britain and the US so that its usefulness is beyond question. In many ASEAN countries, gasification of biomass can provide clean fuel for demanding modern industrial needs while producing a high quality solid fuel for home use as a joint product.

Syngas is also an attractive chemical feedstock, particularly for such products as methanol and ammonia. Both products, until recently restricted to large scale coal or natural gas fired plants, can now be produced is smaller, simpler catalytic units such as the ones under development at the US Solar Energy Research Institute (SERI). By reducing both the size and pressure requirements, small scale biofueled syngas plants can produce fuels and chemicals jointly for rural needs. As with the dairy industry, the surplus methanol and amonia can then be purchased by distributors for further processing or urban use.

Whether investments in such rural energy systems are made and are attractive depend on many factors. First, methanol must replace gasoline as the primary automobile fuel or it must be blended as an octane enhancer. Second, forest product companies must integrate forward to, e.g., plywood production to use the methanol (as formaldahyde) in their own processing. Third, subsidizing natural gas prices for ammonia production must be discouraged. Fourth, local production of various gasifier systems must be encouraged.

There are numerous other potential policy recommendation to promote thermochemical technology advances. What is clear, however, is that rapid promotion of modern, highly efficient, gasifier and combustion systems can provide time to reestablish the supply-demand balance in feedstock supply.

B. Biological Conversion Technologies

1. Traditional Techniques

Fermentation of sugary materials (grains, rice, fruits) to obtain beer and wine has been available to many civilizations for at least 2,000 years. Other similar biological processes have been used to make cheeses, breads, and other foods from milk and grains. A major advance in technology was the discovery of distillation within the last 1,000 years. Using the differential boiling temperatures of water and alcohol, higher purity alcohol could be produced for use as a solvent as well as in beverages. By the 1940's several major chemical intermediates were derived primarily from fermentation including ethanol, butanol, and acetic acid. Easy and cheap catalytic cracking of petroleum ended most further development of fermentation technology. When the rise in oil prices led many nations to consider ethanol as a liquid fuel substitute, the technology they found was primitive by relation to oil refining or chemical processing. In only 6 or 7 years, the state of ethanol fermentation and distillation has seen great advances.

2. Contemporary Techniques

In addition to the advances made in the fermentation and distillation of sugars, the major activities in biological conversion have taken place in anaerobic fermentation and in biotechnology. The second of these, anaerobic fermentation, is of great interest to developing countries and will be treated first.

Anaerobic fermentation or digestion involves the decomposition of plant or animal material to small molecules, conversion of the decomposed matter to organic acids, and methanation of the acids. The entire process is incompletely understood but is known to require at least two different types of bacteria.

Important measures of digester performance include the speed of the reactions and the yield of methane from the feedstock materials. Optimum performance of a system will come from the feedstock materials. Optimum performance of a system will come from maintenance of uniform temperature and feedstock composition. Variation in temperature, starting and stopping the reactions, and changing the feedstock mix will all slow or inhibit the performance of a system.

Considerations of yields are important not only from the viewpoint of energy production but also in terms of pollution control, especially in large commercial or municipal systems. Also, unlike direct combustion of wastes, digestion has the potential to produce at least one joint product, namely soil conditioner and fertilizer. For nations currently relying on direct combustion of manure strictly for heat, biogas offers a chance to upgrade the quality of energy used by putting the output gas into internal combustion engines. Such engines can run compressors, generators, pumps, etc, and many represent one alternative to central electric generation.

At present time, tens of thousands of digester units are installed in South Asia and in China. Estimates of the number of units in China alone range as high as 750,000. India, with far fewer units, has embarked on an ambitious program to install 60,000 units per year in villages and households. Currently Indian units are estimated to produce as much as 1.10^9 l of kerosene equivalent per year ($\sim 5.8.10^6$ bbl. oil equiv.). Unfortunately, as many as 50% of the units already installed may be inoperative. Many others produce far less gas than was intended. The reasons are many but can be condensed to major ones:

a. variation of feedstock materials or feeding intervals.
b. improper maintenance and consequent corrosion of system.
c. inefficient use technologies.
d. inadequate insulation and consequent slowdown during cold weather.

For although digestion has been widely hailed as an ideal village or household technology, some of the most successful applications have

been industrial in scope and operation. For example, at Maya Farms in the Philippines, an integrated food-energy enterprise, maintenance and feeding operations are routinized as a part of normal activities. Multiple digesters are coupled with individual lots so that continuous operation of digesters is possible. In addition, the gas is cleaned in industrial applications so that corrosion is limited.

Future developments in anaerobic digestion technology may make possible more successful small applications. Particular problems to be solved include small gas cleaning or acid reduction systems, longer term storage of feedstocks, and better insulation of units in cold climates. Industrial scale units appear to have great application in confined animal lots and in selected vegetable processing plants.

In general, current microbiological research should serve to improve efficiency by more precisely identifying the reactions and organisms. In particular, the discovery of control organisms would represent a great improvement in operating efficiency. On the engineering side, adoption of systems requiring less "hit and miss" management would greatly improve the operating profile. The economics of biogas could be significantly improved if higher value uses were found for the effluent. Particular crop or field applications research would be helpful in this instance.

Alcohol fuels from sugars have undoubtedly held the limelight as the stars of biological conversion techniques. The attractiveness is clear: a clean liquid fuel from surplus agricultural commodities solved two problems at once-transport fuel and low farm prices. Consequently, interest in ethanol as a fuel has waxed and waned with the vicissitudes of both the petroleum and agricultural markets. At one time both Thailand and the Philippines had announced ambitious distillery construction programs. A strengthening of farm prices coupled with stagnant oil prices have damped the earlier enthusiasm. By comparison, the only developing nation with a successful ethanol program, Brazil, ignored fluctuations in oil and sugar markets as it built its ethanol capacity

to more than 2.8 . 10^8 l/yr (or 1.7 . 10^6 bbl. oil equivalent) in 1981 Current U.S. fermentation ethanol capacity totals at least 7.5 . 10^8 l/yr. with few signs of significant growth beyond projects now under construction (perhaps another 2-3 . 10^8 l/yr. of capacity).

For a technology that was barely beyond the 1940's just 5 years ago, ethanol production has seen several significant process improvements. In the feedstock preparation stage corn wet milling technology has permitted smaller fermentation tanks while producing higher value joint products in a separate processing step. In sugar-based plants, new technology raises the possibilities for production of paper or structural materials. During fermentation, the advent of continuous, rather than batch, technology has reduced the idle time of the expensive distillation columns. And in the final step, separation of ethanol and water, borrowing vacuum distillation technology has permitted a great improvement in the overall energy balance.

The major potential innovations in ethanol production involve the feedstocks and the micro-organisms themselves. Several groups of researchers are developing processes to hydrolyse cellulose and thereby open the cellulose to conversion to sugar and then to ethanol. Presently, at least 1 plant for converting trash and wood chips to ethnol is under construction in the U.S. Commercial versions of an older acid hydrolysis technology are still in use in the USSR for manufacturing ethanol from wood. The major barriers to successful conversion of cellulose to ethanol include the high costs of pretreatment by mechanical, chemical, and enzymatic means, low yields, and loss of process chemicals. All of these issue appear solvable and represent a great potential expansion of the ethanol feedstock base.

Another likely process improvement involves the development of organisms capable of converting sugar to ethanol under high temperatures and high concentrations of ethanol. Such a development, courtesy of the gene splicers, would greatly reduce process costs by lowering enzyme costs and by reducing the volume of a given amount of dilute ethanol for subsequent savings at the distillation step.

Other potential improvements concern the distillation step specifically. One, vacuum distillation, has already been adapted. Alternative means of separating the water from the alcohol include selective membranes, absorbtion agents, and liquid-liquid extraction. None has yet proved commercial.

Applications

A. Traditional: heat and light

Direct combustion of biomass of heat houses, water of such crafts as iron-mongering has been a staple of civilization for thousands, this means that for every 20 hectares of forest cut down and burned in fireplaces, only 1 hectare's worth of wood was usefully combusted. The remainder was pure loss. The key feature of traditional biomass combustion (including charcoal) is the uncontrolled movement of air across the combustion zone. Like a campfire, such free combustion is aesthetically rather than technologically pleasing. Another major feature of traditional biomass combustion is the disregard for the energy value of the exhaust gases.

In tropical countries where heat is used only in specific applications such as cooking or water heating, the value of material with high thermal inerties such as clays is disregarded. The result of the cycle of stating up and damping the flames is a great loss of energy potential which is expended instead on warming up water or air. In general, we cannot expect the same degree of efficiencies from sporadic use as we can from continuous use such as space heating in colder climes.

Improvements of traditional use technologies to the neighborhood of 20-30% are possible by using combustion devices to control the flow of air. For example, in cooking stoves, simply using an enclosed iron stove instead of an open flame will bring combustion efficiency to the range of 20% or more - a fourfold improvement.

Similarly, controlling the flame temperature with airflow (oxygen deficient combustion) produces combustible exhuast gases that can then be used as clean fuels for immediate applications in cooking or industry. By reducing the speed of oxidation, efficiency can be boosted to the 40-50% range - a tenfold improvement. Such efficiency improvements reduce tree removal by tenfold, as well.

With large increases in efficiencies, applications in industry requiring 1-5 tons of coal equivalent (tce) daily can be made with biomass. Previously, such uses may have required as much as 25 tons of biomass per day - clearly undesirable from the feedstock production viewpoint.

B. Industrial, Transport, and Chemical use

While the large and growing use of transport fuels captures the popular concern about energy supplies, the potential growth in industrial energy use is perhaps even more significant in developing countries. Though reliable time series data on industrial energy use in LDC's are not generally available, what data we have show industrial energy use rising fasten than overall energy use. Such results are to be expected where increasing the share of industry is one of the goals of economic growth and development.

TABLE 1

Rate of growth in industrial output and industrial Energy Demand, 1967-1976

	Industrial output (%/yr)	Industrial energy demand (%/yr)
Brazil	11	10
India	5	7
Kenya	8	16
Korea	23	20

Source: Jankowski, RFF, 1981

Even the modest 7% industrial energy growth rate of India leads to a doubling of industrial energy demand in just 10 years. For Korea, industrial energy demand may double in as little as 4 years. Most ASEAN nations fall within the domain bounded by India and Korea. And for all of them, the modest amounts of industrial energy demand at present can assume awesome proportions by 2000.

If industrial energy demand growth is to be met without increases in oil consumption and if industry is to be located beyond the reach of natural gas lines, then biomass can play a key role in energy supply. In use or under development at the present time are a variety of air gasifiers that create process heat from wood at high efficiencies (in the range of 40-60%).

While industrial energy use inexorably grows, the problems of transport fuels remain highly visible. Nations with long term supply contracts have failed to benefit from the current softness in world oil prices. For them, the Balance of Payments drain of high oil prices is as great as ever. And looking at potential future growth in transport energy demand, energy planners seek alternatives to gasoline and diesel from petroleum.

In theory, anything that can be made from long-dead biomass (petroleum) can also be made from recently alive biomass. One has simply to provide the catalysts, steam, and pressure and, yes, money. An attractive alternative is to concentrate instead on those liquids most easily produced from biomass. From both thermochemical and biochemical technologies, the most easily produced liquid fuels are methanol and ethanol, respectively. Both are currently in wide use as gasoline additives, extenders, and pure fuels.

At the present time, virtually all of the unleaded gasoline sold in the U.S. (225 billion l/yr.) contains some methanol or similar product to boost the octane rating. Ethanol blends such as gasohol (10% ethanol) also boost octane and reduce the need for butane and toluene in the fuel

blends. As an additive, the potential market for alcohols is enormous and likely to be met largely by methanol from gas, coal, and wood. Ethanol may have a smaller impact as its potential feedstock supply is less.

Wood has one significant economic advantage over other feedstocks, namely, its proximity to major potential markets. In the plywood industry, large amounts of methanol are used to make formaldahyde. Approximately 60% of U.S. methanol output goes to this use. Given likely growth by ASEAN nations in forest product industries, a major raw material source is available from biomass refuse at or around the plant.

For ethanol, the major application at the present time seems to be as a fuel extender. Only in Brazil has 100% ethanol use become widespread. However, nations with difficult distribution of conventional fuels such as Indonesia appear to be moving toward dispersed production and use of ethanol as a domestic transport fuel.

Production of ethanol has two significant attributes for developing countries. First, it can be produced using a variety of available feedstocks and technologies. Second, it provides a chemical intermediate for producing a number of petrochemical substitutes including vinyl chloride and ethylene.

Major problems involved in the use of alcohols as transport fuels center around the need to adapt automobile engines and fuel systems to take advantage of the properties of alcohols. First, compression ratios need to be increased to reflect the octane improvement from ethanol (about 2-3 points increase for each 10% in a blend). Second, "smart" carburetors or fuel injection systems permit switching among various alcohol-gasoline blends. By "smart" carburetor, I mean a micro processor system that can adjust to different fuel densities to maintain a uniform km/joule of fuel ratio. Such a system already exists for pollution control and has been tested by me and others or a variety of fuel mixtures. Results indicate that increasingly sophisticated fuel systems can reap benefits in performance with new fuels.

Brazil, successful in replacing much of its gasoline with ethanol, has found that oil refineries can only adjust the gasoline-diesel ratio within limits. As a result, that country has continued to rely on diesel imports. Experiments with diesel-alcohol mixtures have found, not surprisingly, that diesel performance is degraded by the low-cetane alcohols. Work continues on dual fuel systems injecting alcohol at 5-20%. However, a more promising line of work may well be vegetable oils.

In a number of countries such vegetable oils as castor bean, coconut, sunflower, soybean, cottonseed, and palm have been tried in diesel engines. Some oils work well, some contain too much gum, and others are suitable but too expensive. Experience has shown both coconut and sunflower oils to be excellent substitutes. And in general, oil crops yield a useful protein mash as a joint product.

The major problem with diesel substitutes is not really performance. Rather, oil crops tend to give yields that are low relative to potential demand. For this reason, they must be seen as a promising, but minor, contribution to fuel supplies.

Economics of Bio-Energy

A. Feedstocks

The costs of raw materials for energy conversion depend on a number of factors including natural productivity (rainfall, temperature, soil quality, slope, etc.), agronomic technology, wage rates, landcosts, and values of alternative crops. In general, if land is used at its highest value then the goals of feedstock production will be to achieve a maximum total value of output. If the greatest value is obtained from the land, then conversely, the cost of output will be at a minimum.

Given widely ranging conditions and goals, costs of similar energy feedstocks can vary greatly across one country. Over the ASEAN region, the differences may well be compounded by price controls or subsidies.

As a result, feedstock costs and feestock economics are not synonymous. In general, waste products carry no market prices. Instead, they are often gathered by the unpaid labor of family members. As a result, such feedstocks usually appear to be inexpensive relative to purchased energy resources, particularly for those subsisting largely beyond the market economy.

For firewood, for example, the implicit cost of obtaining 2 or 3 cubic meters of hardwood ranges from 2 hours or less in the forested parts of Southeast Asia to a day or more in treeless and crowded areas.

In regions with developed markets for wood or charcoal, the costs range from US$1.00/GJ (equivalent to petroleum at $6.00/bbl.) to $2.50 or higher (as high as $11.00/GJ in urban areas). Adjusting the raw energy price by the efficiency of the conversion devices, one finds typical costs for heat and steam to be in the same range as conventional fossil fuels. That is, cooking charcoal at $5.00/GJ used at an efficiency of 20% or so is equivalent to oil at $30.00/bbl. Charcoal costing $7.00/GJ is equivalent to kerosene in cost and at $11.00/GJ is rivaled only by electricity.

I offer such comparisons to show that traditional fuels need not be cheaper than fossil fuels. Indeed, in many developed countries, biomass fuels cost about the same as fossil fuels in many applications. The table below lists costs for common biomass energy forms. Generally, the range is sufficiently great to make biomass energy appear either favorably or unfavorably. Listed along with the costs for delivered energy are derived feedstock costs.

B. Processing

As Table 2 shows, the economics of processing become crucial as the degree of product refinement goes up. The favorable costs of ethanol from corn vis-à-vis ethanol from sugarcane are due almost entirely to the deductions from gross feedstock cost (about $12/GJ) for the valuable joint products of corn milling. Even when feedstock costs appear un-

TABLE 2

Costs of Common Gio-energy Forms

Costs of Common Bio-energy Forms

Process	Product	$/GJ of output energy	Apparent feestock cost ($/GJ)	Conventional Alternatives $/GJ
Anaerobic Fermentation -	biogas			
small scale		1.70 - 6.00	0	3.00 - 6.00[1]
large scale		2.20 - 12.00	0 - 4.00	3.00 - 6.00[1]
Aerobic Fermentation -	ethanol			
cassava		16.00	8.00	8.50 - 15.00[2]
corn		13.50 - 20.00	6.00	"
sugar cane		16.00 - 30.00	9.50	"
cellulose		12.00 - 35.00	0 - 4.00	"
Direct Combustion	steam	3.50 - 6.25	1.00 - 2.50	4.50 - 10.00[4]
of wood	electricity	16.00 - 30.00	1.00 - 2.50	15.00 - 45.00[3]
Gasification	low J gas	2.30 - 8.50	1.00 - 2.50	3.00[1] - 8.60[5]
	Med J gas	4.25 - 9.10	1.00 - 2.50	3.00[1] - 8.60[5]
	SNG - pipeline gas	10.00 - 21.00	1.00 - 2.50	3.00[1] - 8.50[3]
	Methanol	12.70 - 25.00	1.00 - 2.50	9.00[1] - 25.00[3]

Sources: "Report of the Technical Panel on Biomass Energy," UN. 1981. Petroleum Economist, various issues

Notes:
1. natural gas
2. gasoline
3. coal
4. diesel
5. LPG

favorable, the overall evaluation must rely on processing efficiencies and costs as well.

In ethanol production, process economics depend on, inter alia, yields of primary and secondary products, flexibility in output mix, capital equipment costs, and intermediate chemical costs. Generally, plants offering high yields of a variety of outputs will cost more to build than simpler ones. If the proportionate increase in plant cost per $ of output is exceeded by the proportionate increase in output value, then a more complex plant makes sense. All of this is contigent, of course, on the additional complications not causing downtime penalties. For ethanol, the stellar example of this is the corn wet milling plant which turns out variable proportions of ethanol, starch, and sweetener along with high protein animal feed and corn oil. Because of the high value of the outputs, an expensive plant producing from corn can produce ethanol for less cost than can a simpler sugar refining plant.

This discussion implies that simpler may not always be cheaper. In fact, the generally low efficiencies of small scale processing may often be feasible only if the feedstock costs are low or nonexistent. In addition, small scale processing plants can show cost advantages if they can be produced (preferbly, en masse) from locally available materials.

Experience in the Philippines with gasifiers has shown that mass production of small scale units is feasible and cost-effective. While such units are perhaps only one-third to one-half as efficient as large scale gasifiers, the improvement in efficiency gives a short payback time (2 years or less) to the units. The low J gas from these units costs less than half what LPG costs and represents a true savings to the user.

Large scale (for biomass) thermochemical products plants appear to have cost penalties. Particularly for substitute natural gas, methanol, and ammonia outputs, the pressure, steam, and temperature

requirements add a great deal to the cost per GJ without increasing the value of that output proportionately. The limitations on size for biomass units are dictated by feedstocks. As a result, these plants cannot achieve the economies of scale associated with large scale synthetic fuels ventures.

New developments that can improve the cost performance of biomass conversion include mass production of system components, retention of process chemicals and catalysts, and reduction of temperature and pressure requirements. Such innovations apply primarily to the two alcohols, ethanol and methanol, particularly, ethanol from cellulose. Pipeline gas appears infeasible at the present time (as, indeed, it does from coal as well).

Summary and Conclusions - Biomass' Role in the ASEAN Energy System

Three of the five ASEAN nation rely on biomass in various ways as the primary fuel in rural areas and for those beyond the reach of the market economy. For Indonesia, Philippines, and Thailand, complete replacement of biomass fuels is impossible. Yet, large tracts of land in each country are being denuded under the pressure of population growth and soil erosion.

Reducing the problems associated with bioenergy use and, indeed, increasing the useful energy output from biomass requires adoption of better conversion equipment in the areas of cooking, heating, and cottage industry power. With simple, mass producible gasifiers, the current conversion efficiencies can be quadrupled, reducing the pressure on forests and agricultural residue supplies.

For larger scale industrial uses, a number of companies already manufacture gasifiers that can take a variety of solid fuels. Such gasifiers, when close coupled with final users can supplant much of the heat and power requirements for rural and sub-urban industries.

In the liquid fuels and chemicals area, methanol and ethanol can

augment gasoline supplies and even replace gasoline entirely. Use of alcohol-gasoline blends is an economic rather than technical question at the moment. As long as the costs of ethanol and methanol exceed that of gasoline, then substitution can occur only for the limited amount of octane boosters put into gasoline. One way to improve the relative cost of ethanol is to produce a variety of outputs along with it, as with the corn refineries in the US. Another way is to mass produce system components for assembly on site. For methanol, the keys to improved economics are reduced pressure requirements and mass produced components as with the Reed gasifier from SERI.

Biogas can play a role in rural area if the purity and maintenance problems that bedevil these systems can be alleviated. To do so, better materials and training programs stressing routing maintenance and duties must be developed. It is clear from some of the large scale commercial plants that such activities pay off in high gas yields and little down-time.

To sum up, the current reliance on biomass energy in ASEAN is likely to be enhanced in the future as better conversion technologies permit more extensive energy use in homes and in industry. At the same time, feedstock production is becoming more sophisticated as new cropping and silvicultural systems are developed to increase yields. Fundamental advances in biotechnology may open new avenues of chemical and fuel production from wood, greatly enhancing the potential supply. And finally, it is clear that reasonable and prudent use of bioenergy need not conflict with food needs. On the contrary, enlightened programs of feedstock production and energy conversion can enhance production of some foods and feeds. The revolution in biotechnology should provide for more solutions than problems in the years ahead.

Direct Combustion of Biomass

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Introduction

Recovery of energy from biomass by thermochemical methods involves either direct combustion or conversion to gaseous, liquid or solid fuels, followed by combustion of those energy products. Direct combustion is the traditional and most widely practiced method of deriving energy from biomass. In many developing countries combustion of biomass, mostly as fuelwood, animal wastes or crop residues, provides the basic energy needs of the rural areas. Biomass combustion is also already used for steam generation in certain industries.

Wood is the most important biomass fuel. In the lumber industry, roughly 50% of wood biomass is removed from a log to produce a board. Mills often use sawdust and shavings as fuel burned in boilers. This type of fuel has the advantage of not requiring further physical preparation before being fired. The majority of wood wastes require further size reduction and is normally hogged (hammer-milled) to chips. Wood/bark fueled boilers are widely used in the paper and pulp industries.

Other important biomass fuels already used for combustion in significant quantities are bagasse and rice husk. Combustion of agricultural wastes such as cotton sticks, corn cobs, groundnut shells, etc., can also provide significant quantities of energy.

Although combustion of biomass started in prehistory and the technology is now well established, realization of the importance of energy plantations in meeting future energy requirements of the world has resulted in a renewed interest in biomass combustion.

Heating value and composition

In general, dry biomass consists of cellulose, hemicellulose and lignin. The composition is different for different types of biomass. Hardwoods generally contain about 43% cellulose, 35% hemicellulose and 22% lignin, while softwoods contain about 43% cellulose, 28% hemicellulose and 29% lignin. The heating value of holocellulose (cellulose and hemicellulose) is about 4177 K Cal/Kg while that of lignin is about 6371 K Cal/Kg. The higher heating value of wood on a dry weight ash free basis is approximately given by

$$HHv = C \times 4177 - (1-C) \times 6371$$

when C is the fraction of wood consisting holocellulose.

The ultimate analysis of a number of biomass fuels is given in Table 1. It may be noted that biomass fuels are in general characterized by low sulfur and ash contents. Also, biomass fuels have quite high oxygen contents.

Water is present in significant quantities in biomass fuels. Fresh wood may contain 22 to 67% water by weight on total material basis. The moisture content significantly lowers the heating value of the fuel. The influence of moisture on the net heating value is given by

$$NHv/Kg = HHv/(Kg\ dry\ matter) - L_w - l_{ev}$$

when L_w is the loss in weight of combustible products as water replaces wood and l_{ev} is the loss due to energy required for evaporation. As moisture content increases the net heating value decreases, and a practical limit of combustibility or black-out zone is reached at about 67% water, 33% wood.

Combustion systems

A Combustion System contains certain basic elements including a feed

system, a combustion chamber, an exhaust gas system and a residue disposal system. Ancillary equipment may include size reduction devices and air pollution control devices. The spreader-stoker system is now the most common burning system employed. Wood can also be burned in a fluidized bed combustor.

a) Spreader-Stoker System:

In spreader-stoker systems the fuel is introduced into the firebox above the grate. Smaller particles will tend to burn in suspension and larger pieces will fall onto the grate. Figure 1 shows a pneumatic-spreader-stoker. Most units, if properly designed, can handle biomass with moisture content as high as 50-55%. Moisture contained in the fuel is driven off partially when the fuel is in suspension and partially on the grate. The feed system should provide an even thin layer of fuel on the grate.

One important component of the combustor is the grate. The grate serves to transport the fuel through the furnace and promote combustion by providing slight agitation of the fuel and by allowing combustion air to flow through the fuel bed. The common types of grates are the stationary grate, the traveling grate, the reciprocating grate and the rocking grate. Traveling grates, as shown in Figure 2, are the most widely used of these. The grates convey the fuel through the furnace. Commonly two or more grates are provided at different levels because as the material drops from one grate to another the agitation enhances combustion.

Air necessary for combustion of fuel is generally partly admitted as underfire air and partly as overfire air. Underfire air is admitted through the grates from underneath the combustion chamber. Its primary purpose is to control the combustion process and to keep the grates cool. Overfire air is generally introduced to the furnace above the burning fuel bed. Its primary purpose is to create turbulence and to complete the combustion of volatile gases driven off the solids. A range of 25

to 100% of the total air requirement is generally provided as underfire air through the grates. If small quantities of combustion air are provided as underfire air, the entrainment of particulate matter in the gases is small.

b) Fluidized bed combustion:

Fluidization is a mode of contacting granular solids with gases or liquids. If a gas flows with increasing velocity upwards through a pipe containing a bed of particles, supported on a suitable grid, then a point will be reached at which pressure drop of the gas in passing through the bed is equal to the weight of the bed. The bed is then said to be at minimum fluidization. At velocities greater than that required for minimum fluidization a portion of the gas passes through the bed in the form of bubbles. Such a bed is called a bubbling fluidized bed and can be regarded a consisting of two phases: 1) the discontinuous phase or the bubbles and 2) the continuous phase or the emulsion of particles and interstitial gas through which the bubbles rise.

In FBC a fuel particle burns in a fluidized bed of inert particles utilizing oxygen of the air used for fluidization. The resultant heat produced is generally transferred to tubes immersed inside the bed. Advantages of fluidized bed combustion include a high heat transfer rate to the immersed tubes so that the length of the tubing required is reduced, increased combustion intensity compared to conventional combustors and absence of fouling and deposits on heat transfer surfaces. Figure 4 shows a schematic diagram of a fluidized bed combustor.

So far FBC has been used mostly for coals. A number of wastes, e.g. wastes from coal mining and municipal wastes, are also sometimes incinerated in fluidized beds. It has been suggested that certain quick-maturing varities of wood could be combusted in fluidized beds for generation of steam. There is indeed a global search for suitable varieties of wood for this purpose and FBC is likely to play an important role in supplying energy requirements in certain countries in the future.

Granular biomass fuels, e.g. paddy husk and chips of wood up to 2cm x 2cm x 2cm in size have been successfully combusted in fluidized beds of sand particles. Conventional combustion of paddy husk is slow and inefficient. Nearly complete combustion and high combustion intensities of paddy husk can be achieved in a fluidized bed combustor. The same combustor can also be used for burning wood chips. Thus multifuel operation of a fluidized bed combustor is possible. High combustion intensities up to about 500 Kg/hr m^2 have been achieved in fluidized bed combustors using biomass fuels.

Fouling, Firing and Pollution Considerations:

The biomass generally employed in pulp and paper industry is hogged fuel with moisture contents typically under 40%. Harvested wood biomass generally contains roughly 50% moisture and the heat necessary to dry the wood may be 15 to 20% of the heating value of the dry wood alone.

Wood has quite high oxygen content. This means lower atmospheric air requirements for combustion. The size of the forced draft fan is thus smaller compared to fossil fuel burning furnaces.

Sulfur content of biomass is almost negligible. Biomass burning furnaces are characterized by freedom from emission of sulphur oxides. Also, ash content of biomass is also generally less than 2%. Wood ash typically consists of about 50-60% CaO along with Na_2O and K_2O, both in the range of 4-7%. The alkalies may tend to accumulate in the superheater or other regions, where temperatures are lower. If wood is substituted for fuel oil in furnaces, increased fouling of the heat transfer surfaces can be expected. Using wood in furnaces designed for coal is not likely to present any more difficult fouling problems than already experienced with coal alone.

Co-combustion of biomass

The normal transportation radius for wood is 30-50 miles. Within 30 or 50 miles radius the forests and forest industries produce significant but limited quantities of fuel. Normally, wood fuels within a 50 mile radius could support, at the maximum, a 150 megawatt power plant. The optimal size of conventional power plants now, however, exceeds 1,000 MW in capacity. Thus for wood fuels to be competitive some blending of wood and coal may be desirable.

Mixing of wood and coal can also provide a solution to the problem of pollution caused when coal alone is burned. Mixed in proper proportions coal and wood can be burned to produce sulphur oxide emissions within acceptable limits. It has been reported that another important benefit occurs in case of particulate emissions when coal is fired in combination with bark. A mixture of bark and coal fly-ash are removed more effectively than either alone and very high efficiencies are achieved on mixtures up to 50% bark.

TABLE 1

Ultimate Analysis Of Selected Fuels

Fuel Material	C	H	O	N	S	Ash	Kcal/ kg
Bagasse	47.3	6.1	35.3	0.0	0.0	11.3	5,073
Douglas fir	52.3	6.3	40.5	0.1	0.0	0.8	5,023
Douglas fir bark	56.2	5.9	36.7	0.0	Trace	1.2	5,273
Maple	50.64	6.02	41.74	0.25	0.0	1.35	4,762
Poplar	51.64	6.26	41.45	0.0	0.0	0.65	4,951
Rice hulls	38.5	5.7	39.8	0.5	0.0	15.5	3,669
Rice straw	39.2	5.1	35.8	0.6	0.1	19.2	3,630

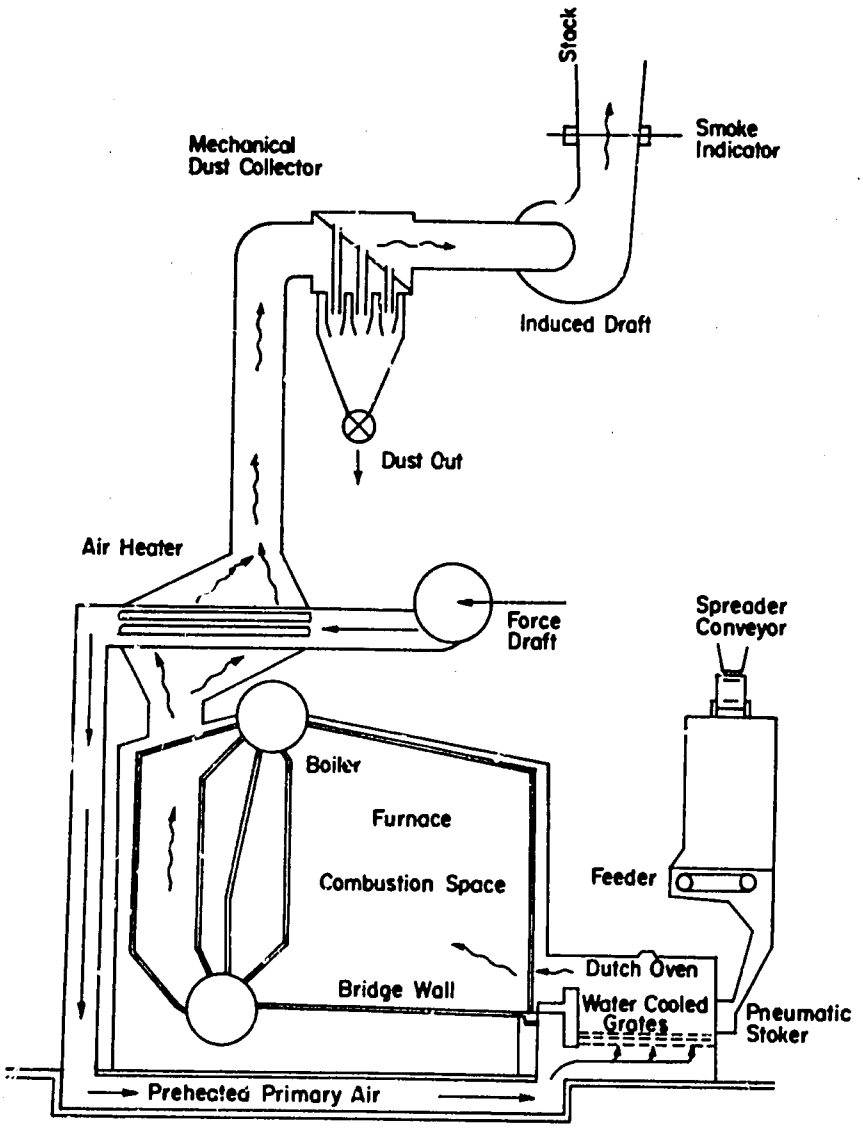

Fig. 1 - Pneumatic - Spreader - Stoker

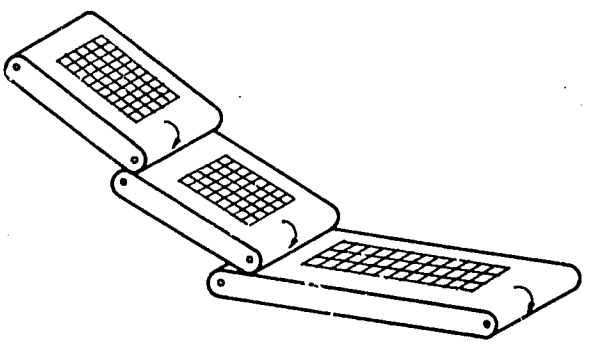

Fig. 2 - Traveling Grate

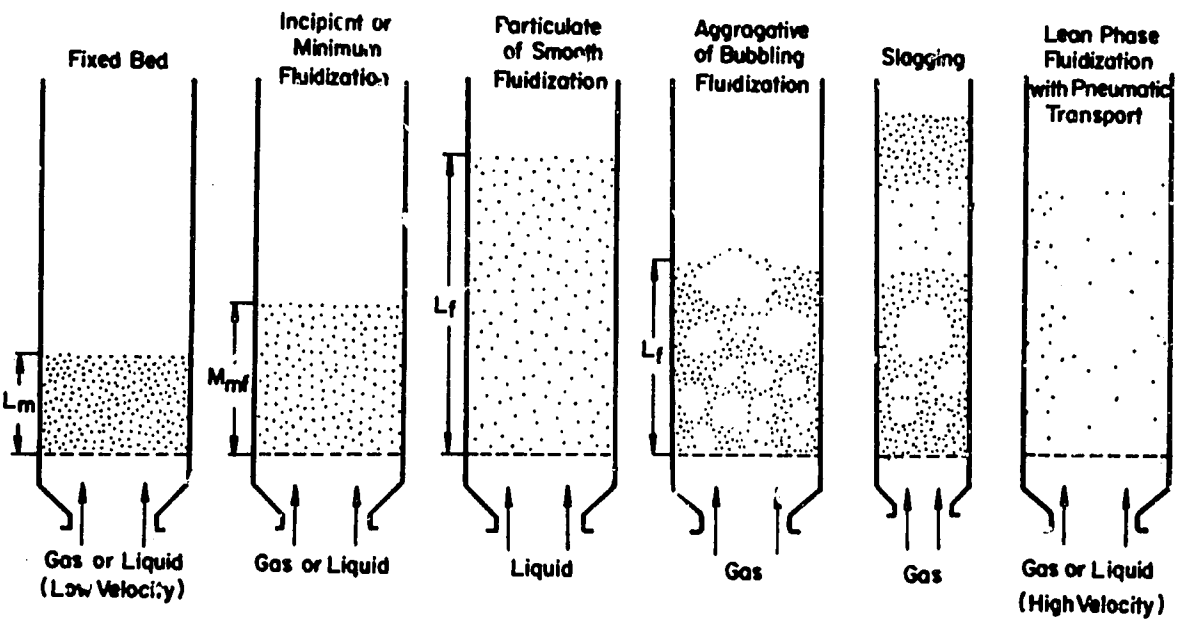

Fig.3 – Various Kinds of Contacting of a Batch of Solids by Fluid

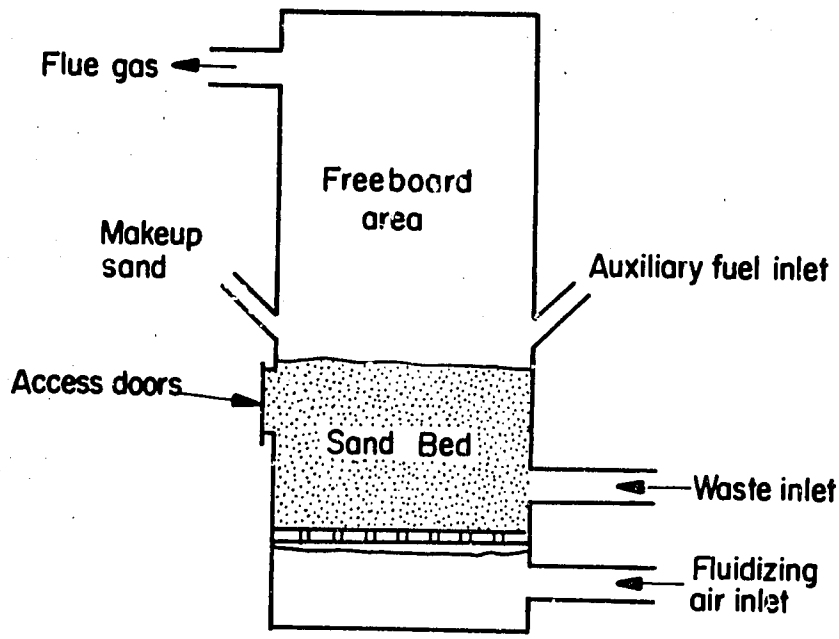

Fig. 4 - Fluidized Bed Incinerator

Pyrolysis and Gasification of Biomass

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Pyrolysis

Pyrolysis or destructive distillation is an irreversible chemical change caused by the action of heat in the absence of oxygen. Pyrolysis of biomass leads to gases, liquids and solid residues. The important components of pyrogas in most cases are hydrogen, carbon monoxide, carbon dioxide, methane and lesser quantities of other hydrocarbons (C_2H_6 etc.). The liquid consists of oils and tars and water. The solid residue consists of carbon and ash. Pyrolysis can be used to convert biomass into valuable chemicals and industrial feedstock.

Figure 1 shows a block diagram of a pyrolysis process. In a typical pyrolysis process the feed material goes through the following operations: (a) primary shredding (b) drying the shredded material (c) removal of organics (d) further shredding to fine size (e) pyrolysis (f) cooling of the products to condense the liquids and (g) storage of the products.

Upon heating, solid biomass materials begin to undergo pyrolysis at temperatures above 300°C. Certain catalysts, such as zinc chloride, lower the temperature required for initiation of pyrolysis. The reactions during the pyrolytic processes are complex and the products obtained vary greatly with the nature of the substrate and the conditions employed. There are many pyrolysis schemes available, each designed to give maximum yield of one or another product. Generally, low temperatures and slow heating give high yields of gaseous products. The operating temperature also effects the quality of the gas. If air is used to support combustion that provides heat for pyrolysis, then nitrogen will be a major gaseous component. This nitrogen takes space, forms certain oxides and lowers the

calorific value of the gas produced. Different types of pyrolytic reactors include vertical shaft reators and horizontal beds. Among these, the simplest and generally cheapest is the vertical shaft type. Fluidized bed reactors are a relatively recent development. Figure 2 shows a rotary Kiln reactor. The unit is cylindrical, slightly inclined and rotates slowly which causes the biomass to move through the Kiln to the discharge end.

The Downdraft Gasifier

Because the tar vapours leaving an updraft gas producer seriously interfere with the operation of internal combustion engines, the downdraft gasifiers are more extensively used. In these the air is introduced into a downward flowing bed of solid fuel and the gas outlet is at the bottom as shown in the Figure.

The tarry oils and vapours given off in the distillation zone are cracked and reduced to noncondensible gaseous products while passing through the oxidation (hearth) zone. Downdraft gas producers have a reduced cross-sectional area above which the air is introduced. The throat ensures a homogeneous layer of hot carbon through which the distillation gases must pass.

Additional steam or water injection is not common in downdraft gasifiers. The combined moisture in the fuel and the humidity of the air are sufficient for the generation of hydrogen.

Chemistry Of Biomass Gasification

In both updraft and downdraft gasifiers the solid fuel reaches the combusition zone in a carbonized form with all volatile matter already driven off. In this zone air first comes in contact with the fuel and the most important reaction taking place here is the combustion reaction:

$$C + O_2 = CO_2 + \text{Thermal Energy} \qquad \ldots(1)$$

Important reactions taking place in the reduction zone are:

$$CO_2 + C = 2CO \quad \ldots(2)$$

$$H_2O + C = CO + H_2 \quad \ldots(3)$$

Reaction (3) is an important and desirable reaction. The reaction, which uses carbon to produce combustible gases H_2 and CO, ultimately reduces the amount of char formed in the gasifier. In downdraft gasifiers the reactant water vapour is generated during drying of the biomass. In updraft gasifiers the vapour produced in the drying zone does not pass through the combustion zone. To encourage the water gas reaction (3), generally, water is added to the incoming air in updraft gasifiers.

In the pyrolysis zone a wide variety of chemicals, tars and oils are produced.

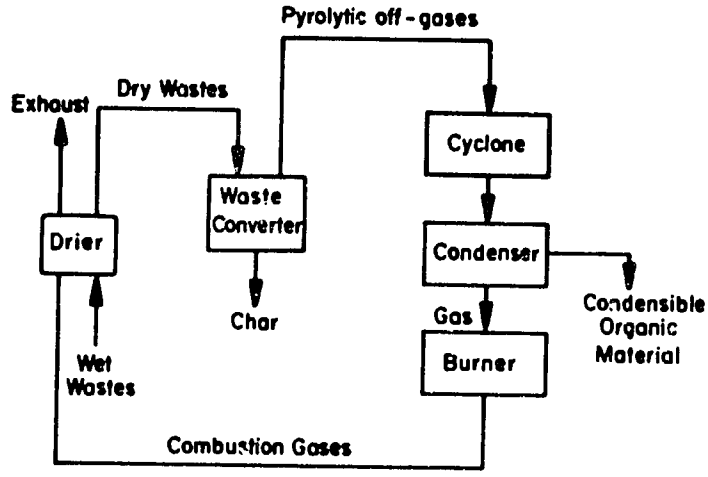


Fig. 1 - Block Diagram of Pyrolysis Process

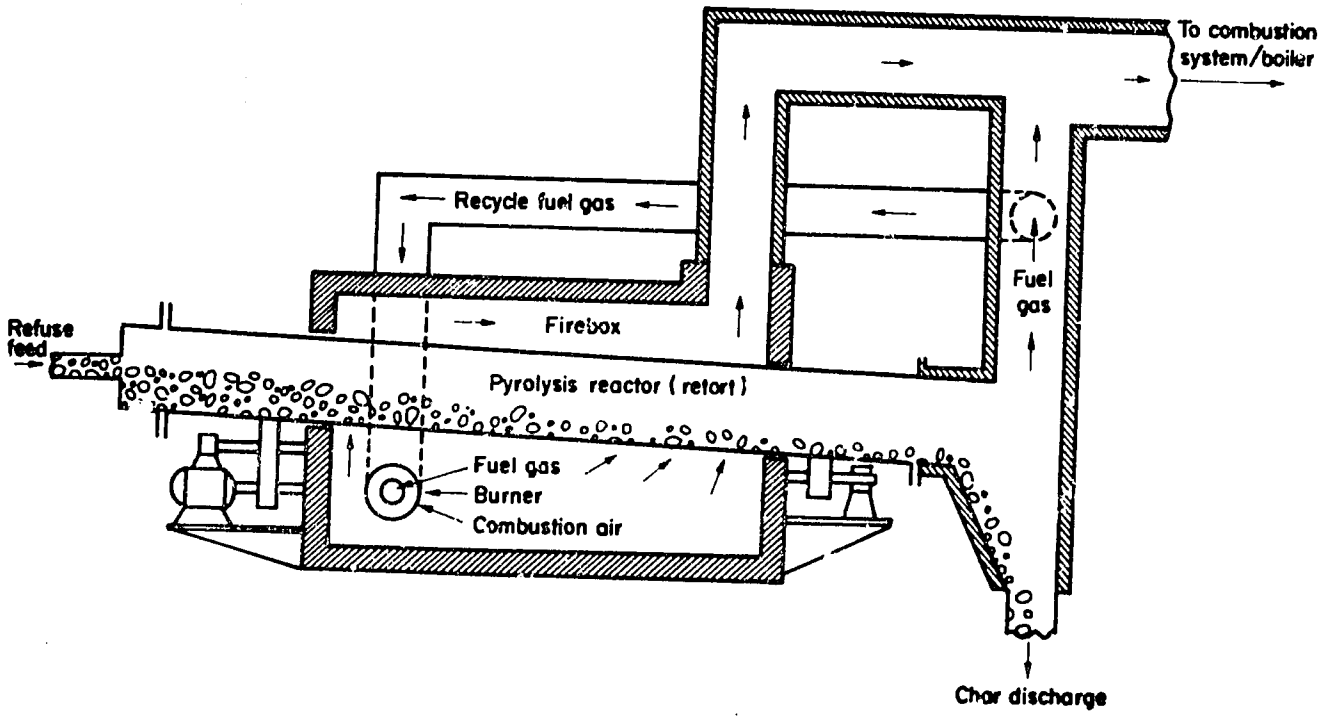
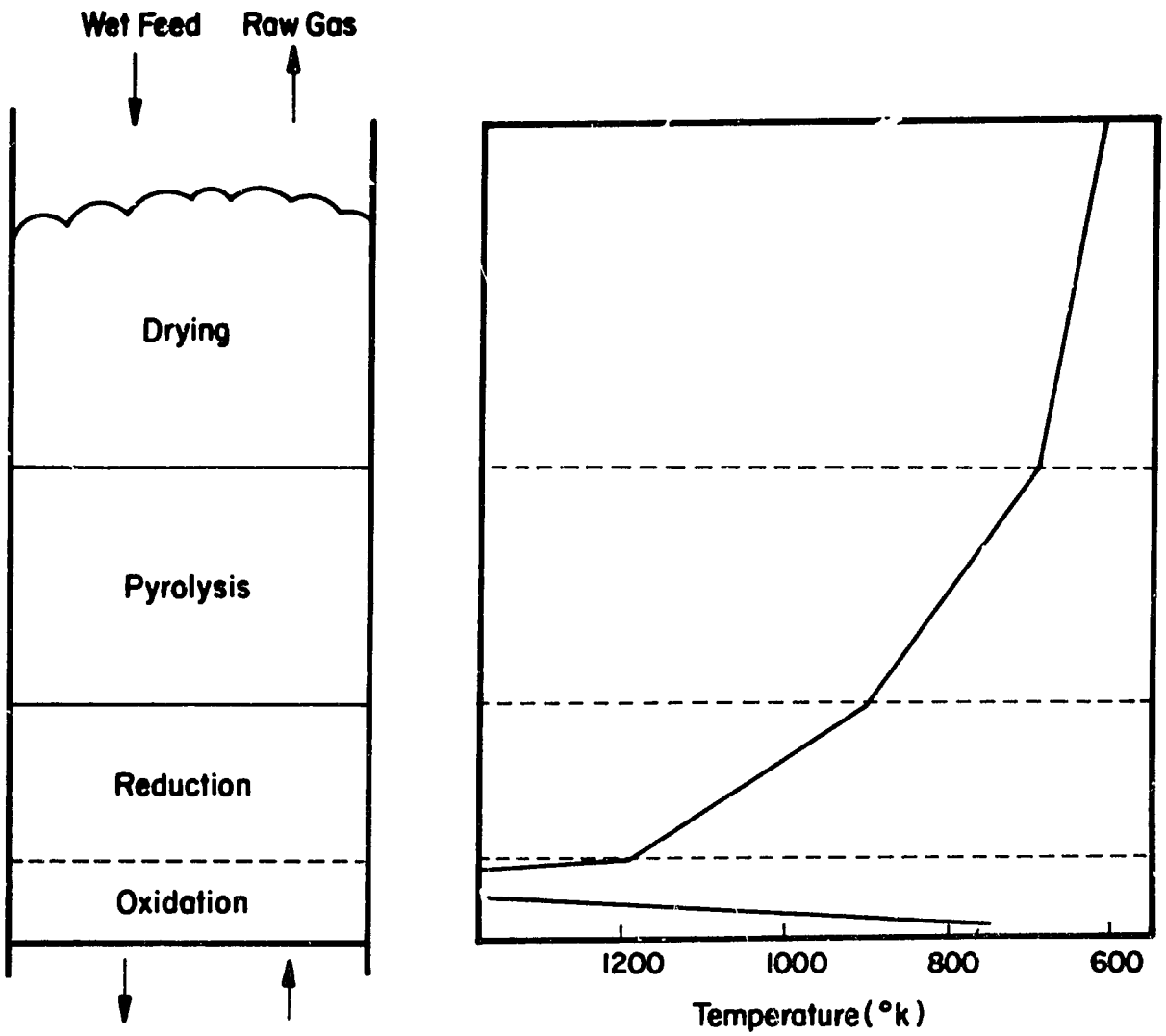


Fig. 2 - Rotary Kiln Reactor



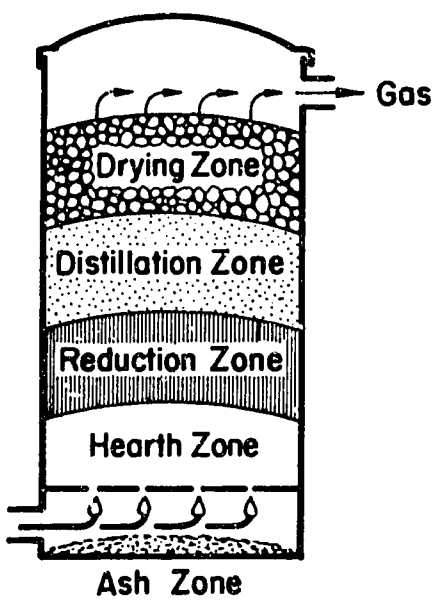


Fig.3- Updraft Gasification

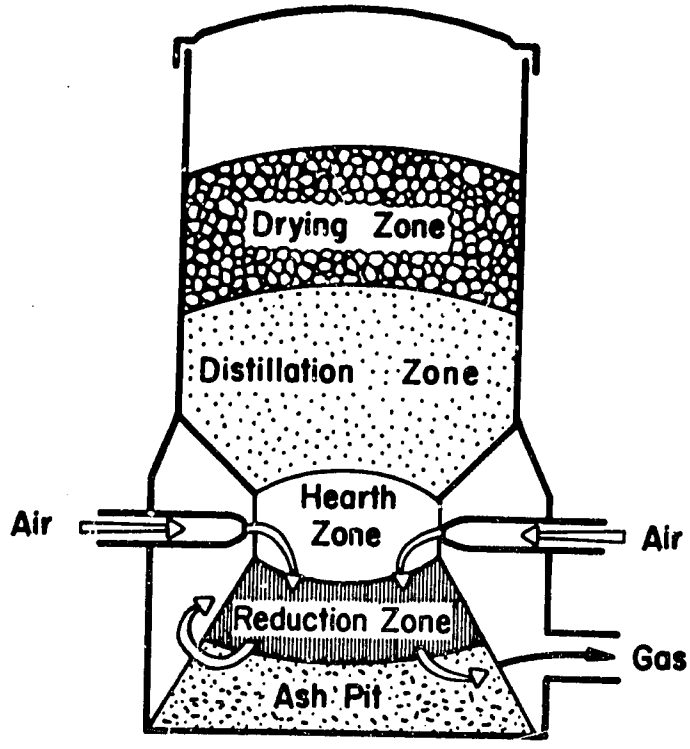


Fig. 4 – Downdraft Gasification

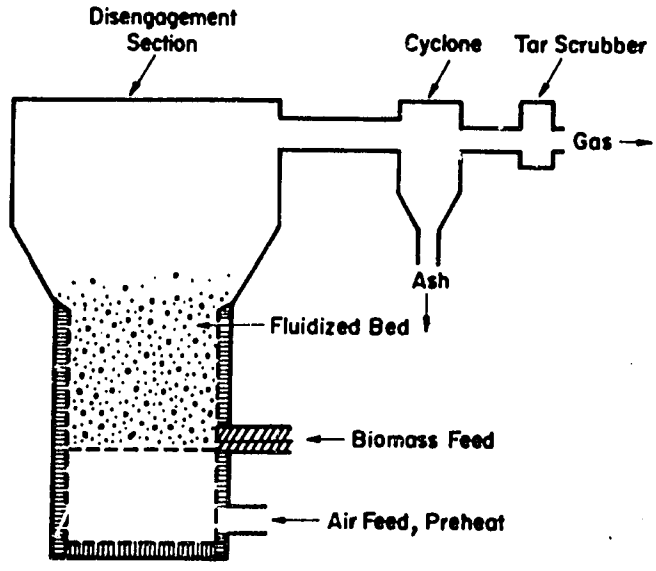


Fig. 5 – Schematic Diagram of Fluidized Bed Gasifier

Biomass Energy Through Microbial Processes

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Abstract

The paper summarizes microbial processes which are involved in the conversion of biomass to energy. These processes have already been extensively studied in Thailand and some are industrially applied. Research and development programmes are centered on biogas and alcohol technology. Biomass from food processing plants and from industrial wastes are being utilized for methane production. The possibilities of two-stage and/or thermophilic fermentation are to be further investigated to improve system efficiency of high loading. Though family biogas plants from animal wastes have been promoted in rural areas, large scale for farms should be encouraged due to the great mass of material produced. Design parameters and intensification of such processes are still to be developed.

Several factors account for technological interest in the production of ethanol from microbial biomass fermentation: starch hydrolysis, thermophilic fermentation, reactor-type and facilitated end product recovery. However, the availability of raw materials gets less attention. Apart from biomass studies, the case of bacterial leaching of oil-shale has been investigated as one alternative energy source for Thailand.

Introduction

In recent years there have been many studies of extracting energy from biomass using microorganisms. However, there is evidence to show that man has used these processes for quite a long time though they are not well understood and lack reliability. The additions of mud and lime

to biogas plants were found to stimulate and advance pH of the reactions, respectively. Since the oil crisis, Thailand has had an obvicus interest in promoting biomass energy sources for the immediate and long term futures. In an attempt to make biomass use more efficient, many aspects of anaerobic digestion and ethanol fermentation have been investigated. The paper below describes the current situation and research work done by various institutes. It is proposed that an R & D plan on alcohol and biogas technology for the fifth five year development (1982-1986) will help the country to substitute for approximately 150 million litres of crude oil by 1986.

R & D activities on anaerobic digestion in Thailand

One advantage of using energy from biomass is local availability. In Thailand most biogas plants have been fed with manure of domestic animals. In many cases, insufficient manure to the digester limits the use of biogas as an alternative source of energy. Vegetable material can be used as a substitute for manure. Theoretically, a digester should operate regardless of which organic materials are used as feed. However, the nature and compositions of organic feedstocks vary from one to another affecting the digester's performance. Aquatic weeds like water hyacinth (1) and Hydrilla (2) have been studied for biogas production in both laboratory and pilot scale. When Hydrilla was used as substrate, the produced gas was approximately 10 litre/day/kg dry feed with 10 days retention time. Though the 2.5 m^3 digester has been operated for more than 82 days, the filamentous nature of hydrilla created a problem in the loading and unloading mechanism. The light vegetable matter formed a thick surface crust. Foaming also limited the level of feed addition to avoid blocking the outlet. In the laboratory, Hydrilla chopped to a shorter length yielded the same amount of gas with lower feed volume. The best result for the rate of gas production and ease of stirring was observed with blended Hydrilla. For the field pilot plant, the technology for feeding and removing the undigested parts is being developed.

The digestion can be carried out at mesophilic (20-40°C) and at thermophilic temperatures (45-65°C). Two factors which have limited the greater application of anaerobic digestion are relatively long digester residence time (greater than 15 days) and system instability to shock loading. One approach is to employ thermophilic culture conditions as a mean of improving the process. To study the temperature effect on anaerobic acclimated to 30°C. The production of flammable gas was delayed until day 10 (Fig. 1). The serial passage at 55°C for 2 passages (approximately 6 weeks) resulted in the adaptation and selection of thermophilic microorganisms. Methane was rapidly produced and the methanogenic rate declined after 5 days of incubation (Fig. 2). When the incubated temperature was changed abruptly from 55 to 30°C, the initial rate of methanogenesis did not occur until the third week. The longer the presence at 55°C, the slower methanogenic activity was detected when incubated at 30°C (Fig. 3).

It is apparent from the results that the selection and adaptation of thermophilic cultures lead to higher gas yield and shorter retention time. Therefore, attention should be provided to control the operating temperature within an acceptable range.

Recent Developments of large scale biogas plants

At present, the application of biogas in Thailand is limited to family scale. There are 600 plants installed throughout the country. A growing concern for industrial and agro-industrial sectors has led to the examination of sources of potential supplements to the country's energy supply. Among these, the use of wastes for commercial scale biogas production represents the best opportunity for the development of indigenous energy supply. Based on the number of animals, many farms have the potential to provide most of their energy needs from methane fermentation of animal manure (Table 2). The problems with large scale efforts include lacks of both confidence and promotional efforts from the government.

Apart from commercial scale biogas from animal waste, methane fermentation from food processing plants is very attractive. The availability of wastes produced from different food handling and food-producing operations appears to be suitable for large scale anaerabic treatment. The ASEAN project on Management and Utilization of Food Waste Material was initiated in 1980. The conversion of solid waste to methane was one of 2 main parts of the project. Thailand has chosen to utilize pineapple waste because the daily amount of solid pineapple waste is approximately 1 million tons. Unlike animal manures or vegetable fiber, waste of pineapple shell and core has pH of 3.5 which is not suitable for methanogenesis. Little reported information is available on gas production from acid waste. The preliminary study from our pilot plant digester previously fed with aquatic weeds at KMIT showed that methane could be generated from anaerobic digestion of pineapple (5). A laboratory-scale research program was undertaken to investigate the operating parameters for optimum performance, especially loading concentration of highly acid waste. The purpose was to develop data for the design and operation of full scale units at the cannery site. The maximum loading was only 12.5 g wet*/l of reactor volume/day (*moisture content was 81%). This figure was very low compared to most of organic waste reported to range from 5 to 10% (2,6). However, the amount of gas was satisfactory.

Moreover, when the semicontinuous operation continued to the third week, the rate of methanogenesis was slow down then stopped. We felt that the initial pH of pineapple was too low thus the rate of organic acid production preceeded methanogenesis. As the operation went on, more organic acid accumulated with less consumed by methane bacteria. Greater attempts were made to improve the effectiveness of the process in semicontinuous application. Mixing of fresh pineapple with biogas effluent in 1:1 ratio was one way to ensure the reliability of the process (Fig 4). This application may be suitable for pilot plant digester operated on long term basis. The pH 7.8 of effluent will raise the initial pH of pineapple to approximately 4.5. The starting pH should be better for methanogenesis. Another advantage was similar to the sludge return process which increased

the microbial population in the digester. But it is not yet known whether accumulation of toxic substance will affect the reaction or not.

The studies have been extended to the pilot-plant digester. The 2 reactor types selected based upon the principles of effectiveness and practical purposes, were stirred tank and plug-flow reactors. The experiment is under investigation. We also tried to increase the amount to be loaded by setting up two stages, fermentation and the acid and methane reactions. Though we have no successful results yet, the experience on the behaviour of pineapple anaerobic digestion was essential to improve the biological efficiency of the process from long to very short retention and from low to high feed concentration.

The situation of gasohol projects in Thailand

Another microbial process energy production was alcohol fermentation. Up to now, the government showed no definite plan on using alcohol as a blend with petroleum though they had stated in the fifth five year development programme to substitute at least 100-400 million litre of crude oil. Many private groups have sent the applications for the generation of power alcohol plants but no final decision have come from the government yet. However, the sub-committee of Alcohol Industry Development has been set up to consider the gasohol project: the feasibility study, the potential and the technical problems.

The availability of raw material constitutes a large and important part of alcohol from agricultural crops. But less attention was put on the subject. Thailand's agricultural crops such as sugar cane, cassav and maize basically provide for food and feed which were consumed within the country or exported. The raw materials to supply alcohol plants could not rely on the surplus of total production of raw materials. Fluctuation of this figure is possible between one year's crop and the next given the world supply position. It is necessary that crops for ethanol fermentation

would be specifically grown for this purpose. Actions should be taken to encourage cultivation of the raw material.

R & D activities on alcohol technology

1. The raw material:

To supply cheaper raw materials and avoid conflict between food and energy, sweet sorghum was introduced to substitute sugar cane and cassava for alcohol production. The strains of Rio, Wray and Keller were gifts from the Department of Agriculture, U.S.A. An attempt to grow sweet sorghum in Thailand was successful (7). The first batch was harvested in July 1980. Though the local temperature was higher than in the United States, the percent of sugar was almost the same (Table 4).

According to the figures on production of cassava, Thailand is one of the major exporters to EEC countries. However, the quota was below the production level. Nevertheless, the energy balance of alcohol from starchy materials is still controversial. Though the process of saccharification (starch hydrolysis) is well developed, the costs of commercial enzymes remain high. Production of microbial enzymes was widely studied in various institutes. So far, no results have been reported.

2. Fermentation Technology

In view of the current search for efficient fermentation of biomass into ethanol, rapid ethanol fermentation and yeast recycling are of particular interest to many investigators. Vicha (8) has reported on alcohol fermentation of pineapple juice supplemented with ammonium sulfate and di-ammonium hydrogen phosphate. The fermentation time was reduced to 13 hours with 8% alcohol (by volume) in an air lift column reactor. His experimental conditions are shown in Table 5.

The aeration time of 4 hours at the beginning may contribute to rapid ethanol fermentation by stimulating the multiplication of yeast cells. If this is the case, aeration will be less specific when cell

density in innoculum is high. The author did not investigate this effect. However, he claimed that air bubbles with recycle tubes in the column caused the distribution and circulation of media well.

Recycle systems increase reactor cell concentration. Membrane filtration and centrifugation are both energy intensive. Recently, a fixed-film or immobilized-cell reactor has been used to increase the reaction rate. The organisms attached to a solid support mitigate the need to prepare the starter each time.

Alcohol fermentation in a column reactor packed with sand has been examined (9,10). The substrate was passed over a film of yeast attached to sand allowing reaction to occur. The fermented media was recycled back until the brix was constant. To test the activity of cell remaining in the column, new substrate was passed through the column. When the experiments had been run continuously for 3 weeks, no change in the activity of yeast cell was observed. However, CO_2 evolved during fermentation was held up in the column resulting in a slower rate of fluid through the packing material.

In the next step, a fluidized bed will be tried to improve the system performance. Different support materials will be tested in comparison with sand. The information gathered will help to determine to what extent the method will be applicable.

Other non-conventional energy related to biomass or microbial processes

1. Vegetable oil seed

The study of *Jatropha curcas* oil has been undertaken by the Industrial Finance Corporation of Thailand (IFCT) and Department of Agricultural Engineering, Ministry of Agriculture since 1979. The purpose of the study is to investigate the properties and utilization of *Jatropha curcas* oil for a substitute for diesel oil for agricultural farm machinery. The *Jatropha curcas* or Purging nut belongs to Family Euphorbiaceal orginating in Central

America. The seed and kernel have oil contents* of 38 and 62%, respectively (*Yield depends upon the method of extraction). The physical and chemical properties of oil are shown in Table 7.

The test on diesel engine run on Jatropha curcas oil indicated that the engine performance and fuel consumption were nearly equal to 100% diesel oil (Table 8,9).

Though the results were satisfactory, the development of small scale mechanisms to utilize the vegetable oil seeds needs to be continued. Improvements of strains and methods of cultivation are being studied. The Department of Agricultural Engineering, Ministry of Agriculture, had developed a machine to extract oil from the seed (hydraulic press). More designs are underway to suit local use. The refining process of Jatropha curcas oil is necessary for future engine tests.

2. Bioleaching of oil shale

Estimation of oil shale reserves at Amphoe Mae Sot, Tak Province, Thailand was approximately 18,668 million metric tons. Deposits of oil shale in other parts of the country were found to be very promising in view of their energy potentials. The major structural inorganic components that occur in Thai oil-shale are carbonates. Successful removal of carbonate will be a definite asset to the extraction and concentration technology. Bunyakiat (13) found that oil shale retorted under atmospheric carbon dioxide at 400°C and 0.010 Cu.ft./min. gave higher oil yield than Fischer assay of similar oil shale. This difference can be explained as resulting from carbon dioxide suppression of the decomposition of inorganic carbonates in oil shale leading to higher heat available for kerogen decomposition at lower temperature. Removal of carbonate by acid or bioleaching from Thiobacillus thiooxidan increased the oil yield from Mae Sot oil shale (14). The retorting temperature of leached oil shale can be reduced to 450°C compared to 500°C in a standard Fishcher assay. The construction of pilot scale leaching and retorting facilities is in progress. Results will indicate whether the method can be commercialized.

In conclusion, Thailand has good possibilities to utilize biomass as one alternative energy source. Both the conversion process and the productivity and availability of raw materials to be converted are essential. To make the biomass energy more competitive, promotion of industrial conversion of biomass should be started. The cooperation among institutions should lead to the examination of possible R & D in this field, as well as the formulation of new co-operative projects, where possible.

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TABLE 1

Biogas production from various type of crop residues (litre per kg dry matter).

Type	Fermentation period (days)	Dry matter (%)	Total Dry matter (kg)	Gas Production (l/kg dry matter)
Rice straw	33	46	4.6	5.67
Ipil - ipil	46	28	2.8	7.51
Paragrass	36	30	3.0	5.05
Sugarcane top	43	20	2.0	7.31
Cucumber leave	40	24	2.4	5.18
Duck weed	41	22	2.2	5.46
Corn top	32	19	1.9	5.43
Water hyacinth	46	12	1.2	20.3

TABLE 1b

Composition of biogas produced from 8 different types of crop residue.

Crop residues	Gas composition (% v/v)					
	CH_4	CO_2	O_2	H_2	N_2	H_2S
Ipil - ipil	24.9	19.4	6.4	0.7	48.6	-
Duck weed	11.3	32.2	1.6	0.2	54.7	-
Rice straw	22.8	24.8	1.2	0.4	50.8	-
Water hyacinth	8.2	16.6	2.1	0.5	72.6	-
Corn top	7.6	28.0	0.8	0.2	63.4	-
Paragrass	4.3	23.2	2.6	0.6	69.3	-
Sugarcane top	9.6	22.4	2.0	0.4	65.6	-
Cucumber leaves	-	14.8	1,7	1,3	82.2	-

*Source : Tumwasorn, S. 1981. (3)

TABLE 2

The number of animal per family in some area

Area and Name of Owner	Number of animals		
	chiken	duck	pig
Cholburi Province			
1. Mr. Manoon Kitticharewong		50,000	
2. Mr. Vichai Sukamongkol	35,000		
3. Mr. Saravuth Sojastakul		100,000	
4. Mr. Udom Naivongham		100,000	
5. Mr. Sompong Promsiri			5,000
6. Mr. Ah Sea			1,000
Angtong Province			
1. Chumlongmitr Farm	50,000		
2. Mr. Nirum Tunyaposaksuk	26,000		
Supanburi Province			
1. Mr. Sunan Satapanich			4,560
2. Mr. Sumitr Taweekasem			800

Data from Department of Livestock Developed 1982. (4)

TABLE 4

Properties of Sweet Sorghum Grown in Thailand

Strain	% Fiber	°Brix[1]	% Polarity	Purity
Wray	10.57	20.41	15.79	77.36 (10 ccs)
Keller	12.61	22.51	15.09	67.04 (9 ccs)
Rio	13.57	18.21	10.33	56.73

[1]°The brix average of Wray and Keller grown in the States was 20.2

Source : Kantikhun, N. 1980 (7)

TABLE 5

Selected Conditions for Alcohol Fermentation in Air Lift Reactor

Culture	Saccharomyces ellipsoideus
Raw material	Pineapple juice 14° Brix supplemented with 0.05% ammonium sulfate, 0.05% di-ammonium hydrogen phosphate
Aeration rate	0.5 VVM
Aeration time	4 hours
Inoculum size	5%
pH of wort	4.5
Temperature	30 °C

Source : Vanadurongwan, Vicha 1981 (8)

TABLE 6A

Ethnol fermentation from cane juice in column reactor packed with sand

Incubation time (hr)	Batch 1		Batch 2*		Batch 3*		Batch 4*	
	%Ethanol	%sugar	%Ethanol	%sugar	%Ethanol	%sugar	%Ethanol	%sugar
0	0.00	15.4	0.00	16.3	0.00	15.5	0.0	15.7
3	0.2	11.2	-	-	0.9	12.9	3.4	7.4
6	1.8	9.5	2.2	10.0	4.6	5.6	-	
9	2.2	9.0	5.5	4.6	6.9	2.8	6.6	2.3
12	3.1	8.0	5.9	3.2	7.4		8.1	0.3
15	3.1	4.5	5.9		8.4	0.5	8.1	
18	-		7.3	0.7		0.3		
21	6.0	4.2	7.3	0.3				
24	7.4	0.4	7.3	0.3				
48								

*reaction from yeast cell remained in the packed column after previous batch was finished

TABLE 6B

Ethanol Fermentation from Synthetic Media with 1.25% Peptone, 0.7% Dextrose and 15% Sucrose in Packed Bed Reactor

Incubation time(hr)	Batch 1	Batch 2	Batch 3
	% alcohol	% alcohol	% alcohol
3.0			3.0
5.0	1.5		
6.0		5.5	6.0
9.0	5.5		8.0
11.0		9.5	
13.0			10
15.0	6.0		
17.5	7.5		10

TABLE 7

The Chemical Analysis of Jatropha Curcas Oil

Item	Value[1]	Value[2]
Acid value	38.2	9
Saponification value	195.0	197.13
Iodine value	101.7	97.08
Viscosity (cp)	(31°C) 40.4	(25°C) 45.68 cp
(Fatty acid)		
Palmitic acid	14.2	16.17
Stearic acid	6.9	5.11
Total Sat. fatty acid	21.1	21.28
Oleic acid	43.1	44.88
Linoleic acid	34.3	33.83
Other acid	1.4	-
Total Unsat fatty acid	78.8	78.71

Source.

1. Interim Report on the Study of Jatrohpa curcas oil as a substitute for a diesel engine oil - October 1981 (11)

2. Report from Department of agricultural chemistry (12)

TABLE 8

Oil Test Comparison between Jatropha Curcas and Diesel Oil

Item		(1) Jatropha	(2) Diesel	Analysis
Specific gravity	d 15/4	0.9186	d 15/4 0.82-0.84	JIS-K-2249
Flash point	°C	240	50°C up	JIS-K-2265
Carbon residue	%	0.64	0.15 less	JIS-K-2270
Cetane value		-	50 up	JIS-K-2271
Distillation	°C	295	350 less	JIS-K-2254
Kinematic viscosity	CS	50.73	2.7 up	JIS-K-2283
Sulphur	%	0.13	1.2 less	JIS-K-2273

1. Tested by Fuji Koosan Oil Refinary Co., Ltd. Tokyo, Japan

2. Regulated by Japan Industrial Standard.

TABLE 9

Engine Performance Comparison

		Diesel oil	*Jatropha curcas* oil
(Continuous rating out-put)			
Out-put/speed	PS/rpm	6.5/2,200	6.5/2,200
Fuel consumption	Kg.h	1.294	1.508
Fuel specific	g/PSh	199	232
Exhaust gas temperature	°C	473	508
Exhaust color	Sd	2.4	2.8
(Maximum rating out-put)			
Out-put/speed	PS/rpm	7.5/2,400	7.5/2,400
Fuel consumption	Kg/h	1.513	2.052
Fuel specific	g/PSH	201	274
Exhaust gas temperature	°C	513	599
Exhaust color	Sd	3.0	5.6

Source : Takeda Yoshifumi 1981 (11)

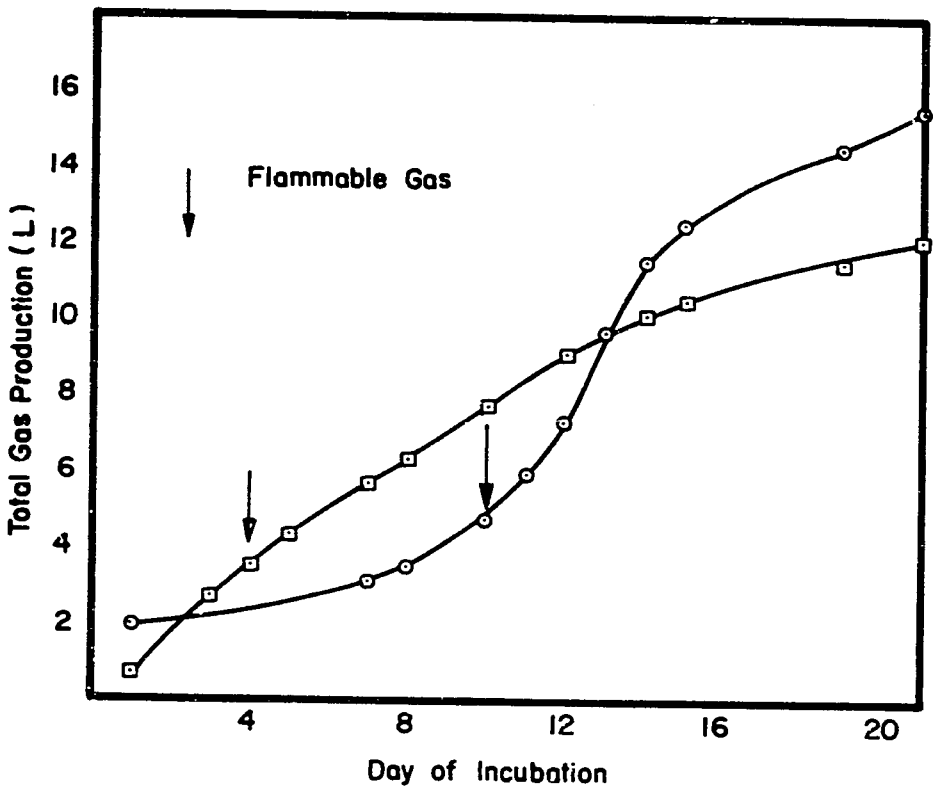

Fig. 1 – Biogas Production from Aquatic Weed Incubated at ⊙—⊙ 55°C ⊡—⊡ 30°C with Seed Culture Acclimated to 30°C

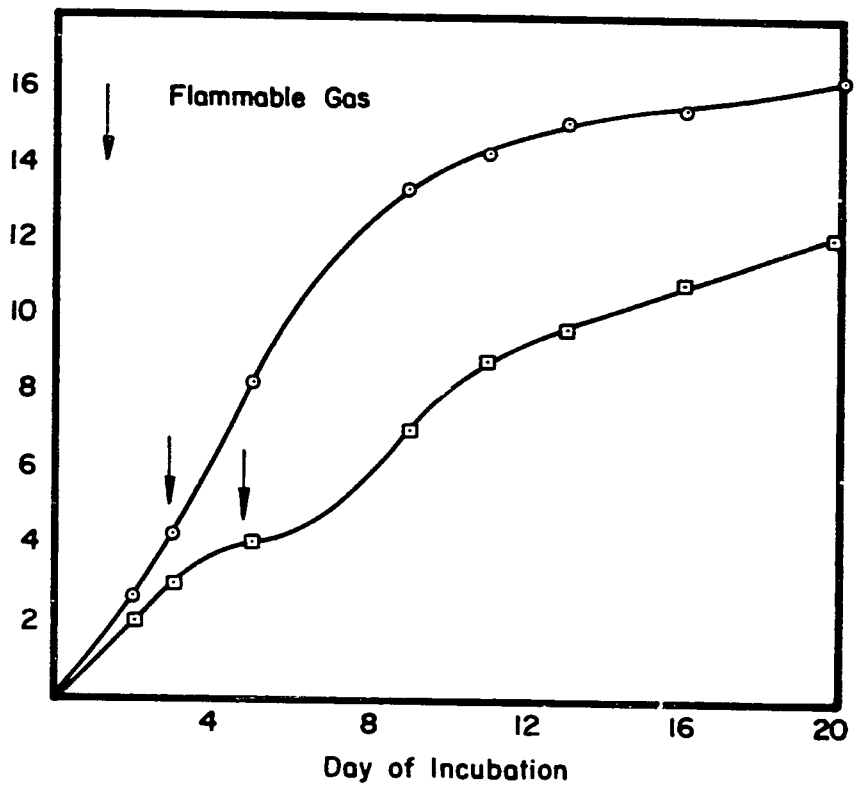

Fig. 2 – Biogas Production from Aquatic Weed ⊙—⊙ Incubated at 55°C with Seed Acclimated to 55°C, ⊡—⊡ Incubated at 30°C with Seed Acclimated to 30°C

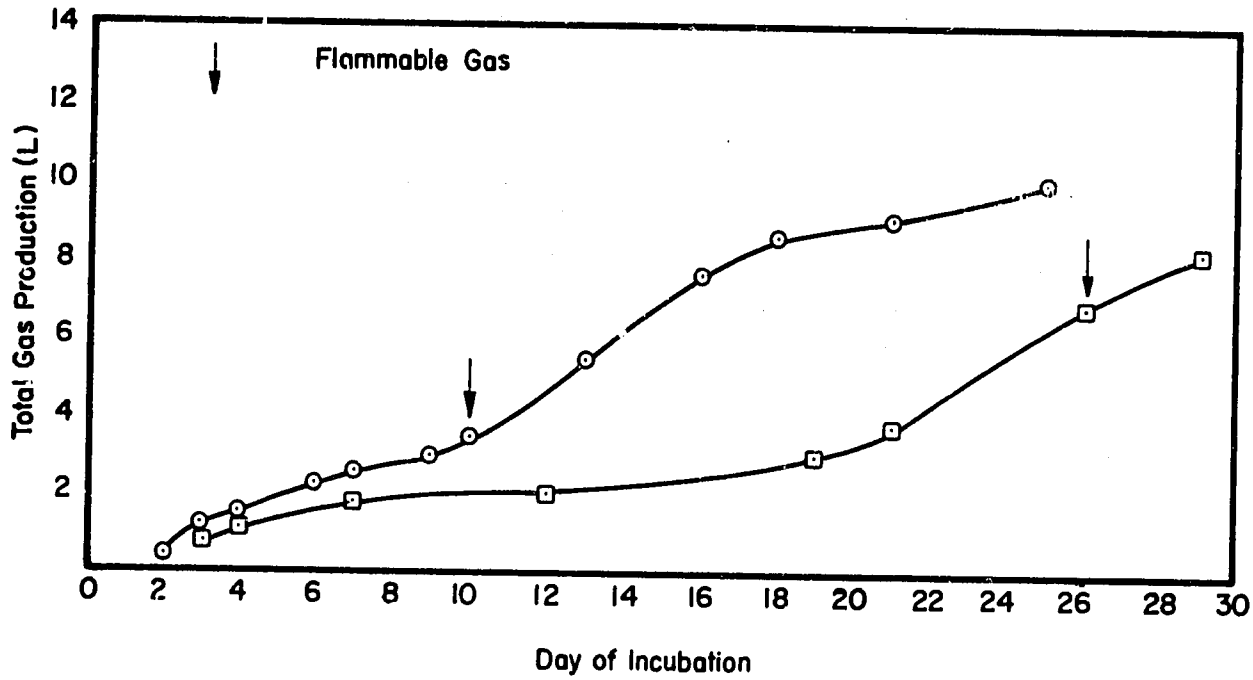

Fig. 3 – Biogas Production from Aquatic Weed Incubated at 30°C with Seed Culture Tranfered from 55°C, ⊙—⊙ Seed was at 55°C for 7 Weeks. ⊡—⊡ 15 Weeks

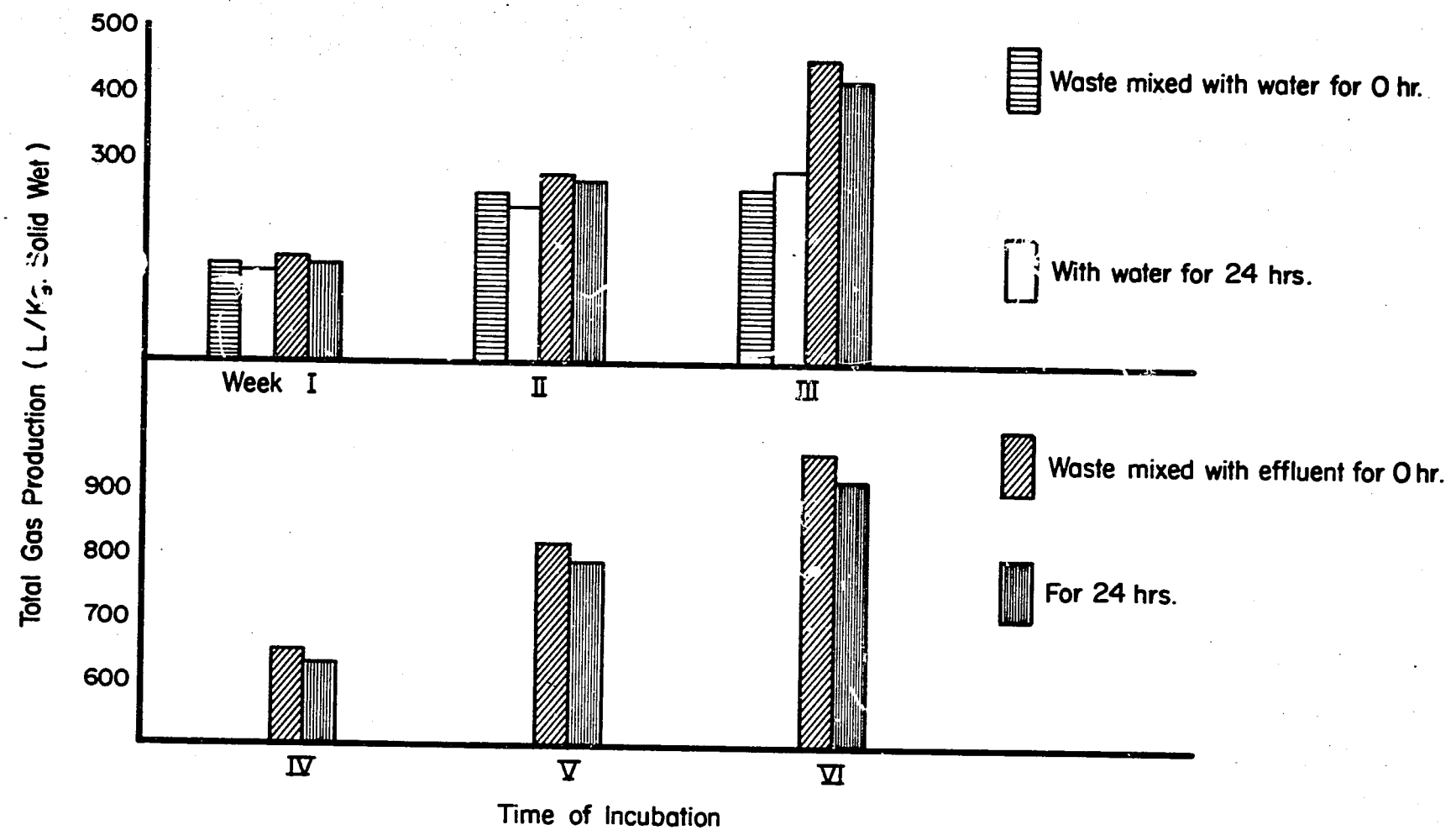

Fig. 4 – Pretreatment of Solid Pineappie Waste with Biogas Effluent Prior Loading to the Digester. (Semicontinuous with Loading of 50 grams Solid Waste / Litre of Reactor Volume in every Days) Reactors Recieved Waste Mixed with Water were Terminated after Third Week due to Acid Accumulation.

Integrated food and Energy Systems: The Maya Farms Experience

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Introduction

Maya Farms is an integrated livestock farm, meat processing and canning enterprise in the outskirts of Metro Manila, Philippines. Raised within its 36-hectare compound are 30,000 pigs, 10,000 ducks and small herds of cattle and goats. The slaughter animals are processed into ham, bacon, sausages, meat loaves and canned meat products.

The operation produces a lot of wastes and consumes a considerable amount of energy. Over 45 tons of animal manure and pen washings come out daily from the livestock farm. Bones, blood, meat scraps and industrial wastewater issue from the processing plants. Energy is used for lighting, pumping water, keeping the piglets warm, grinding and mixing the animal feed, industrial cooking, heating and refrigeration.

To control pollution, to recover some value from the waste materials, and to save on energy, Maya Farms has adopted a program of recycling, integrating indigenous sources of energy. The solid industrial wastes are cooked, dried and grounded into meat meal, bone meal and blood meal, for recycling as feed ingredients in the feed mixing plant. The animal wastes, pen washings and wastewater are processed through the biogas works, producing a fuel gas, feed materials, and fertilizer-irrigation water. The wastelands are planted with coconut and ipil-ipil trees to supplement the energy supply.

The current biogas production of 2,500 cu. m. per day is partly used as fuel for cooking and other industrial heating purposes. The rest of the gas serves as fuel for converted gas engines which drive deepwell

pumps, slurry pumps, feedmill machinery, refrigeration systems and electric generators. Aside from biogas, the other energy sources are the waste heat from the biogas-fueled engines, charcoal-fed gas producers, coconut oil and alcohol.

What possibly makes the Maya Farms experience doubly significant is the extent of its operation and the fact that it is a private, commercial enterprise. The farm has not received any aid from the government nor from any outside agency. It continues to do what it does simply because it has found that the system works - and it pays.

The Biogas Works

The first biogas plant at Maya Farms was established in 1972. That was before the petroleum embargo. It was set up primarily for pollution control. By processing the daily manure from the piggery, it effectively controlled air pollution. The digested sludge was readily disposed as fertilizer in the crop fields. As the piggery expanded, air pollution was kept under control by putting up larger biogas plants. However, the increasing volume of sludge could no longer be absorbed by the crop fields. Signs of over-fertilization started to show.

Discharging the sludge into a nearby creek was out of the question. Although the pollution properties of manure are greatly reduced by the biogas process, the sludge is still a strong water pollutant. To solve this problem, the research team at Maya Farms gradually developed the sludge conditioning system. The sludge solids are recovered and processed into feed materials. The remaining liquid is exposed to sunlight and aeration in a series of lagoons to improve its value as fertilizer-irrigation water and at the same time reduce its water pollution characteristics.

Biogas works refers to the operating combination of a biogas plant and a sludge conditioning plant. It is the center of the waste recycling activities at the farm. It now supplies all the power needs of the live-

stock farm and 70% of the energy requirement of the industrial plants. It provides 10% of the feed consumed by the pigs and 50% of the feed for the ducks. It produces more fertilizer-irrigation water than is needed for the crop field and the fishponds.

The Biogas Plant

Biogas arises from the bacterial decomposition of organic matter. The process involves several microorganisms. Non-methane forming bacteria act on the complex compounds in organic materials such as cellulose, starch, proteins, fats, etc. These products converted to more soluble compounds - the carbohydrates to simple sugars, the fats to fatty acids and glycerol, the proteins to proteosis, peptones, etc. These compounds are further converted to simpler acids, alcohols and other simpler compounds. The methanogenic bacteria then act on these acids and alcohols to produce methane and carbon dioxide. These bacteria require strict anaerobic conditions.

The biogas plant provides the proper conditions for the biogas process. It consists mainly of a digester and a gas-holder. The digester has one or more chambers where the slurry of organic materials is retained while biogas is being produced. It may be either batch-fed or continuous-fed. A batch-fed digester is fully charged and sealed to allow digestion. At the end of the desired retention time, the sludge is discharged and fresh feed slurry is again loaded into the chamber. A continuous-fed digester is charged daily with small amounts of fresh feed slurry. Each charge automatically displaces an equal volume of spent sludge from the digester.

Biogas evolved in the digester is stored in the gasholder. In the case of small biogas plants, the gasholder is usually integrated with the digester. It may be an inverted tank floating over an open-topped digester. The tank rises as it fills with gas and sinks in the slurry as the gas is used. In some designs the gasholder forms the dome over the digester. With a fixed dome gasholder, the gas accumulating under the dome

pushes the digester slurry into an auxiliary chamber. The slurry flows back when thegas leaves the dome. With a collapsible dome, as in the case of the bag type biogas plant, weights on top of the bag are used to drive the gas out.

Maya Farms designed its large commercial scale biogas plant with the gasholder separate from the digester. The gasholder is an inverted cylindrical steel tank floating over water in an open concrete tank. Since the manure slurry is retained in a totally sealed digester, the operation is hygienic, sanitary and controls air pollution more effectively.

The farm presently has a total digester volume of 5,120 cu. m. and total gasholder capacity of 1,620 cu. m. Under construction are additional digesters, and gasholders to take care of the piggery expansion from 30,000 to 50,000 pigs by 1983. The estimated biogas production by then should exceed 4,250 cu. m. per day, more than enough to supply all the energy requirement of Maya Farms.

The Sludge Conditioning Plant

The sludge is a good fertilizer and soil conditioner. Aside from nitrogen, phosphorus and potassium, it contains small amounts of calcium, magnesium, sulfur, iron, copper, manganese and other elements which are essential for plant growth. These elements are normally available in the soil, but unless they are replaced, the supply in the soil may be depleted through leaching and repeated croppings using only chemical fertilizers.

In a small biogas operation, there is usually enough land around to absorb all the sludge as fertilizer. Where there is a high concentration of animals and limited crop land, the sludge solids may be separated from the liquid. The liquid still contains sufficient nutrients to serve as fertilizer-irrigation water.

It may not pay to sell the solids as organic fertilizer because of the high cost of drying and handling. Maya Farms research disclosed that

the sludge solids can be recycled as feed materials. The solids have a relatively high Vitamin B_{12} activity, which is a valuable growth promoting factor for animal feeds.

The sludge conditioning plant developed at Maya Farms consists of settling basins, precipitation canals and sludge conditioning lagoons. The sludge from the digestor goes to the settling basins. Grass cuttings at the end of the basins retain the solids while the liquid filters out. Fine entrained solids precipitate as the liquid flows through the canals to the conditioning lagoons. Excess washings from the livestock farm and the wastewater from the processing plants join the sludge liquid flowing through a series of shallow lagoons. Exposure to sunlight and aeration eliminates such toxic substances as hydrogen sulfide and brings the water pollution levels within acceptable limits. The conditioned liquid serves as fertilizer-irrigation water for the crop field and fishponds.

Biogas as Fuel

Biogas consists of around two-thirds methane and one-third carbon dioxide with some hydrogen and traces of carbon monoxide, hydrogen, hydrogen sulfide and other gases. Methane is combustible, making biogas a good source of energy. In heating value, biogas is comparable with coal gas, much better than water gas or producer gas. It can be used as fuel for direct heating purposes or as fuel for internal combustion engines.

The 2,500 cu. m. of biogas produced daily at Maya Farms is used as fuel for the following:

1. Cooking and running gas refrigerators in the canteen and workers' dormitory.

2. Cooking and heating in the meat processing and canning plants.

3. Heating the retorts and drying rooms in the rendering plant.

4. Running gas engines which drive:

   a. 3 deepwell pumps, 580 gpm total capacity

   b. 3 slurry pumps used for the handling of manure slurries and sludge

   c. 3 feed mixers and 2 corn grinders in the feedmill which currently produces 45 MT mixed feed per day

   d. 16 refrigeration systems with a total capacity of 80 tons of refrigeration in the meat processing plant

   e. 4 electric generators rated at 12.5 KVA, 37.5 KVA, 60 KVA, and 188 KVA

Other Energy Sources

Engines produce a lot of waste heat. The farm has started harnessing such heat from the biogas fueled engines. Heat exchangers utilize the hot water from the engine cooling systems and the hot exhaust gas to preheat the feed water to the steam boiler and to supply the hot water needs of the processing plants. A pilot plant producing alcohol from cassava uses energy from the cooling system in preparing the cassava ferment and the exhaust gas in distilling the alcohol.

The ipil-ipil trees planted on the wastelands will be ready for harvest by next year. The leaves will be dried and ground into ipil-ipil leaf meal, a high protein feed material. The trunk will be made into charcoal. Charcoal-fed gas producers will supplement biogas as fuel to run the deepwell pumps.

The coconuts may still take some years before bearing fruit. The coconut shell will also be made into charcoal for the gas producers. The husks and fronds will serve as fuel for direct burning. Crude coconut oil makes a good substitute for diesel fuel. Maya Farms has a jeep with a diesel engine running on straight crude coconut oil. Another jeep and a car with gasoline engines run on straight hydrous alcohol.

The cattle, goats and ducks also participate in the energy saving system. As part of the waste recycling, such crop residues as rice straws and corn stalks were charged together with the manure slurry into the biogas digesters. They increased gas production considerably, but the hauling, chopping, crushing, drying, charging and discharging required a lot of energy. Then somebody had a bright idea. Why not raise cattle and use the crop residues as cattle feed? Aside from saving energy, the farm got beef and milk; and the cattle dung produced more biogas than the crop residues.

The goats took over the work of the grounds maintenance crew trimming the weeds around the farm. The ducks keep the sludge conditioning lagoons clean by feeding on the scum, and they help aeration by flapping and swimming on the water. Before the ducks came, laborers had to skim off the scum from time to time to expose the lagoon surface to sunlight and aeration.

Integrated Agriculture

Seeing the benefits of waste recycling and integrated farming, Maya Farms set up a 1.2 hectare demonstration farm to see how integrated agriculture would work out on a small farm operation. It had a farmhouse, a piggery for 4-sow units, that is, 4 sows and their off-springs up to 8 months old, a work carabao, a milking cow with a calf, biogas works, a 200 sq. m. fishpond and one hectare of cropland. A farmer and his family were brought in from the province to run the farm.

The animal manure produced enough biogas to supply all the fuel needs of the farm family for lighting, ironing clothes and running a gas refrigerator. The sludge solids were fed back to the pigs. The sludge liquid was sufficient to fertilize the growth of algae in the fishpond and provide fertilizer-irrigation water for the crop field raising one crop rice and 2 crops of corn per year. The large animals fed on the crop residues, grasses and leaves of ipil-ipil trees planted along the perimeter of the farm. The

piggery produced 4 to 5 porkers per month. With integrated agriculture, the farm family was able to maintain a decent, comfortable standard of living on the 1.2 hectare farm.

The Maya Farms experience shows that a farm operation, large or small, can be self-reliant and self-sufficient in energy in an ecologically balanced environment through integration and waste recycling.

The Ethanol from Biomass (Cassava and Sweet Potato) Project in Lampung

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Project Background

The idea for developing the production of ethanol from biomass was first put forward by the Minister of State for Research and Technology/ Head of BPP Teknologi, Prof. Dr.-Ing. B. J. Habibie, at the beginning of 1980, with the following aims:

(a) raising the standard of living of transmigrant farmers;
(b) supporting the diversification of energy;
(c) increasing the capacity of domestic industry; and
(d) creating job opportunities.

a. Raising the Standard of Living of Transmigrant Farmers

At the present time, most areas available as transmigration sites are far from towns. They often have inadequate transportation facilities, so that there is a lack of transportation between production and marketing areas. Transmigrant farmers, therefore, have difficulties in marketing their produce and sell it on local markets at very low prices. They are reluctant to plant market crops or more than is sufficient for their own needs. Consequently, the income of transmigrant farmers remains low.

If ethanol were produced in the transmigration areas, expensive long-distance transportation of crops would not be necessary for their sale. The ethanol plants envisaged would use cassava and other root crops containing carbohydrates as raw material. The use of such root crops is considered best for the first stages of development of ethanol

production, since nearly all farmers are already well acquainted with the cultivation of these crops. Since the land used for root crops would amount to only one-eight of the land allocated to the transmigrant farmer (1/4 ha out of 2 ha), and since the ethanol plant would provide a stable market and pay a proper price for the crops, the project will help raise the farmers' incomes.

b. Diversification of Energy

Indonesia is presently commencing the third stage of the development plant. With a rate of economic growth of 6% to 7% a year and an annual population growth rate of 2.3%, Indonesia needs large amounts of financing for development. In the past, most of these funds came from foreign exchange earnings obtained through oil exports. However, oil is also used domestically, and this domestic use of oil is increasing rapidly, while production hardly increases at all. If this situation continues, oil exports cannot be maintained. Therefore, immediate steps have to be taken in order to maintain crude oil export as an important foreign exchange earner to support development, while at the same time satisfying domestic energy demands.

For this reason, the Government initiated a program for the diversification of energy, which will increase the utilization and development of other non-exportable energy resources such as coal, geothermal, hydropower, biomass, solar energy, etc. The program for the production of alcohol is one of the energy diversification programs.

c. Increasing the Capacity of Domestic Industry

After an investigation was made, it was shown that an ethanol plant could be designed by Indonesians and that 60% of its components could be made in Indonesia. Therefore, the building of alcohol industries will also stimulate the capacity of Indonesian engineers and increase the capacities of Indonesian workshops to make factory equipment.

This construction will also have a multiplier effect on other economic activities.

d. Creating Job Opportunities

Job opportunities in the country are a high Government priority, since it is estimated that the labour force will grow from about 54.8 million in 1978 to 61.3 million in 1983. Considering this situation, a policy promoting job opportunities in the country was formulated by the Government. Alcohol program is also aimed to support this policy.

It is obvious that with the opening of energy farms, the operation of alcohol plants and the distribution of their products, more job opportunities will become available in the agricultural sector and processing industries, in the manufacturing of factory equipment, and in the distribution systems. New job opportunities will also arise as a consequence of the impact on the transmigration areas concerned with the opening of industries.

Having discussed the project background, the following discussion will be divided into four phases, i.e.

Phase 1: Planning, Appraisal, and Design.
Phase 2: Selection, Approval, and Activation.
Phase 3: Operation, Control, and Handover.
Phase 4: Evaluation and Refinement.

Division into these four phases was taken from L. J. Goodman and R. N. Love, "Biomass Energy Projects", Pergamon Press, 1981 (p. 18-29).

Emphasis of the explanation in this paper is given to the Ethanol Pilot Plant in Tulang Bawang, Lampung Province.

Phase 1: Planning, Appraisal, and Design

Aims of the Ethanol Pilot Plant

The aims of ethanol pilot plant are as follows:

1. The ethanol pilot plant in Lampung will be a model project for the next factories to be built in other parts of the country.

2. The ethanol pilot plant in Lampung is an educational place for prospective managers and workers, and

3. The pilot plant should be considered a place to conduct research.

Supporting Facilities

The pilot plant will also be equipped with a supporting research facility in the form of a laboratory and an experimental farm. Research in the field of agriculture and processing will be concentrated here; for instance, in the experimental farm, sweet potatoes will be planted and the suitable varieties for the area with high production levels will be studied. The farm will also function as a place to train farmers and to spread the best methods of cultivating sweet potatoes among them.

Design of the Ethanol Pilot Plant

The data and other material for the basic design of the ethanol pilot plant were collected in the months of August, September and October 1980. These activities were undertaken by a Design Team consisting of research personnel from BPP Teknologi. The basic design was finished in January 1981 and the Design Team then began to make detailed design. Simultaneously with the drafting of the detailed design, various domestic industries were also sounded out as to their possible contribution. Preparations were finished in May 1981 and were followed by tendering. It was

estimated to take 12 months to make the equipment and a further 2 months to install it. It is thus expected that the pilot plant will be able to begin work and commence production in the middle of 1983.

In designing the Ethanol Pilot Plant, the following item had to be considered by the designers in BPP Teknologi:

1. The factory would be in an isolated area, therefore, the process must be as simple as possible so that it can be managed by intermediate level trained personnel from the surrounding areas.

2. The chosen equipment must be easy to handle. For instance, the amount of sophisticated equipment used should be reduced as much as possible and sensitive equipment should be avoided.

3. Overall efficiency must be kept at a high level. By reducing the use of raw material and fuel, it will be possible to keep the price of alcohol low.

4. The factory is a pilot plant, and so it must be possible to make experiments of making alcohol by using different processes already known.

Location of the Ethanol Pilot Plant

This first Ethanol Pilot Plant was located in Tulang Bawang Transmigration Area, Lampung Utara, after a thorough study.

The Capacity of the Ethanol Pilot Plant

The capacity of the Tulang Bawang Ethanol Pilot Plant has been signed at 5,000 kilolitres a year (15,000 l a day). This size was chosen by considering the aim of the pilot plant and the following factors:

1. The Pilot Plant must be easy to manage both from the number of employee point of view and also from the technical point of view.

2. Raw material can be supplied sufficiently from surrounding areas. A very large pilot plant would require a large supply of raw material.

3. Make it easy to distribute its products. With a small output, it will be easy for the pilot plant to market.

With a production of 15,000 litres a day, it is estimated that the pilot plant can be managed and operated economically. Further, at this production capacity the raw materials for the pilot plant can be supplied from the Tulang Bawang transmigration area, which will be able to provide the average of 100 tons of cassava needed by the Pilot Plant each day.

Issues and Problems

The problems that are to be faced in the alcohol program can be divided into four groups as follows:

1. agronomy and agriculture.
2. production techniques.
3. marketing and economics of ethanol.
4. social affairs and transmigration.

Problems related to Agriculture

This group of problems is mainly related to the biomass raw materials. Three types of plant will yield ethanol; they are:

1. the sugar-containing plants like sugar-cane.
2. the starch-containing plants like cassava and sweet potatoes.
3. woody plants that contain cellulose.

The characteristics of these raw materials need to be studied in more detail. For this first Ethanol Pilot Plant, we decided to use cassava and sweet potatoes. Of these two crops, sweet potatoes can produce three harvestings a year, while cassava takes about 10 months to reach maturity.

However, cassava is more resistant to plant pests and produces more stem which, after drying, can be used as firewood and can contribute towards the fuel which the plant must consume.

Problems Related to Production

Since starchy raw materials are to be used from which the ethanol is to be produced, the production process uses fermentation, long known and applied in Indonesia. Studies are expected to show how the process can be made more efficient and cheaper.

Another problem in this field that needs close attention is the energy balance. Care must be taken to ensure that the fuel consumed in the process of manufacturing is less, and less valuable than the energy (as ethanol) produced. Since there may be problems of fuel for consumption in Tulang Bawang, consideration is being given to the planting of a special area with quick-growing trees, the timber of which can serve as fuel.

Economic Problems

One of the problems in this group refers to the comparative prices of fossil oil fuels and ethanol at the present time. It is estimated that, when produced from sweet potatoes, it will be possible to sell ethanol at between Rp. 260 and Rp. 300 a litre, whereas the price of gasoline is only Rp. 240 a litre. More efficient production from planting to factory output may ameliorate this problem.

A more difficult question may be the Food versus Energy issue, which could become acute since both cassava and sweet potatoes are customary foodstuffs in Indonesia. Even if ethanol plants do not use cellulose, nipah, palm and other raw materials that are not competitive with food, it may still be possible to minimize the problem through using marginal lands not used for growing food supplies and through increasing the yields per hectare of the crop.

Social Impacts

Careful attention also needs to be given to the social impacts of the ethanol pilot plant; in particular, in relation to the transmigrant settlement in which it is to be located. Transmigrants usually come from rural surroundings devoid of factories requiring a discipline of working hours not common in farming communities.

Phase 2: Selection, Approval, and Activation

The following factors were taken into consideration in determining the location of the factory:

1. the facilities available, notably the transportation network,
2. the availability of sufficient arable land to ensure a supply of raw materials from the area around the pilot plant.
3. the availability of water for processing.
4. the possibility of bringing fuel from a Pertamina depot or the availability of land for a wood fuel estate, and
5. the possibility of carrying the output to a port for easy distribution of the ethanol produced.

Using these criteria, four alternative transmigration locations were chosen, namely: a) Tulang Bawang in North Lampung; b) Sekayu, at Palembang, South Sumatera; c) Tajau Pecah in South Kalimantan, and d) Moramo II in Southeast Sulawesi. After a number of surveys had been conducted and consideration had been given to the different locations, the Tulang Bawang transmigration area was chosen as the area for building an ethanol pilot plant.

In fact, the technology of ethanol has long been mastered in Indonesia. After a number of studies had been made, we found that the equipment for the pilot plant could be made in Indonesia. The advantage of designing and making the plant ourselves is that it adds to experience, increases skills, and hastens the process of transfer of technology. The manufacture of ethanol is carried out by a simple process, out of consideration for adaptation to local conditions and the level of education. A simple process was chosen so that the local population could operate the plant and assimilate technological process involved. This is parallel to the drive to utilise local manpower.

As far as possible, the equipment used in the plant is made in Indonesia, while the greatest possible opportunity is being given to Indonesia contractors and experts to increase their capacities and their skills.

The National Alcohol Committee

The long-term plans for the program call for building future plants (5,000 kiloliters/year) in other transmigration areas that support at least 40,000 farm families. This calculation is based on estimates of fuel oil substitute requirements. Research and studies in various fields will need to be conducted beforehand.

Considering the cross-sectoral field involved, the Minister of State for Research and Technology formed an Interdepartmental Committee, consisting of members from several Departments (Finance, Agriculture, Industry, Mining and Energy, Public Works, Manpower and Transmigration), Universities, Industry, Research Institutes, State Oil Company (Pertamina).

According to the required fields of research and studies, the Committee is divided into four divisions, as follows:

1. Agronomy Sector. Problems connected with developing and managing energy farming and efforts to raise crop yields, including soil fertility, cultivation techniques, plant breeding, plant diseases, starch content, and other agricultural development efforts.

2. Production Sector. Improving the energy balance, increasing efficiency by improving the production process, waste processing, and solving technology transfer problems.

3. Economic Sector. The marketing system, including pricing and distribution, evaluation of energy farming, monopoly of selling alcohol, incentives for alcohol plants, potential of alcohol as a substitute fuel for diesel oil and kerosene.

4. Transmigration/Social Sector. The social impact of the ethanol program on farmers/transmigrants and on other Indonesians, the most suitable types of energy farming and development of energy farming or farm management in transmigration or surrounding areas.

Activation

Work for the Ethanol Pilot Plant and Energy Farm was begun in April 1981. The design was made by young employees of BPP Teknologi working together with experienced persons from the ethanol industry. The manufacture of equipment was undertaken in Surabaya, where there are businesses with prior experience in making spare parts for alcohol factories. For the work of construction on the site at Tulang Bawang, a special effort was made to conform with the regulations in force, particularly Presidential Ordinance 14A, which concerns the involvement of local enterprises in the work, particularly for infrastructure. The equipment requiring intensive supervision was the direct care of BPP Teknologi.

Work has proceeded to the point where the equipment is ready for installation. It is expected that the ethanol pilot plant in Tulang Bawang will be able to commence its test run in the middle of 1983.

It should be mentioned here that the Japanese Government has shown much interest in this alcohol program. In the context of the Scientific

and Technology Agreement with the Government of the Republic of Indonesia, the Government of Japan is providing aid for setting up an Energy and Biomass Research and Development Center with the following sections:

1. a laboratory to study alcohol processes.

2. an experimental alcohol factory with a production capacity of 8,000 liters a day, and

3. an experimental farm to study and develop sweet potatoes.

After a survey and thorough study had been made, it was decided that the Biomass Energy Research and Development Center would be located at Sulusuban, Terbanggi Besar, Central Lampung. The construction commenced in 1981 and is expected to be finished in 1983.

The Biomass Energy Research Center will specialise in the study of biomass materials from which alcohol can be made. Sweet potatoes will obtain first priority for study with a special sweet potato research farm. This research farm will develop high yielding varieties that will keep well and can be planted in a variety of soils.

Testing of Vehicles

Studies in the field of the use of alcohol as a substitute fuel for oil are made by testing vehicles and equipment with ethanol and methanol. The tests are made by BPP Teknologi in:

a. testing cars and motor-cycles that use straight ethanol as a fuel (95% v/v).

b. testing 50 cars and motor-cycles that use mixed "gasohol" fuel of 80/20, and

c. testing 2 cars using methanol fuel.

The chief purpose of the tests is to find out the performance of cars

in Indonesia that use alcohol as fuel. For the gasohol tests (point 2), the main purpose is:

a. To find out the performance of motor vehicles using hydrous alcohol as fuel under Indonesian conditions, particularly those in Jakarta.

b. To learn the result of tests using gasohol mixtures of 80/20, without any changes to the engine.

c. To find out the influence of these mixtures upon the different parts of the engine, the fuel system and the other parts of the car.

d. To introduce the use of gasohol to the public as fuel for motor vehicles. In this case, to do so by stimulating an extensive program for expanding experience in mixing, distributing and use.

e. To study the possibilities of gradually replacing gasoline by ethanol as a fuel.

Phase 3: Operation, Control, and Handover

The Tulang Bawang Ethanol Pilot Plant and Energy Farm are planned to commence operation in the middle of 1983, and therefore activities in this phase are still only plans.

Operation of the project in this phase will be supported by a well-defined structure of organisation, financing, personnel and scheduling. The project manager, as the official responsible for implementation, has a complex task at this stage, working with policy makers and outside bodies as well as the internal organisation.

Supervision and control procedures are to be effected through accountancy, manpower reports, scheduling, statistical reports, special reports on research progress, scientific discussions and analysis of feed-back. It is important that control procedures identify and isolate problem areas, whilst various forms of network analysis will be useful as tools of manage-

ment. It should also be remembered that there may be control requirements to meet that originate from outside the project in some other government institution or funding agency.

Completion of the project at some time in the future prepares it for handing over the further operation of the plant to the research organisation that will continue to run it after the pioneering stage is over. Some of the project personnel will remain but some will surely be transferred to other undertakings. Possibly the plant will be expanded and otherwise modified at this stage depending on the research program.

Phase 4: Evaluation and Refinement

Evaluation and refinement of the ethanol project will be made with an eye to efficiency and effectiveness in reaching goals quickly.

It is planned that after the ethanol pilot plant is finished it will run for a minimum of 3 years for purposes of evaluation and refinement. Special attention will be paid to the question of whether such plants can be effectively and beneficially located in transmigration areas, while problems that arise and the solutions found for them will be carefully recorded. Attention should also be given to related follow-up of smaller projects.

Conclusion

The ethanol program in Indonesia is an integrated program involving many subjects, disciples and several sectors.

The main field of activity is the building of a pilot project with a capacity of 15,000 liters a day in the Tulang Bawang transmigration area in the Province of Lampung. Further, a Biomass Energy Research Center is being built at Sulusuban, Lampung, in which priority will be given to the study of sweet potato as feed stock for alcohol factories with research in other biomass materials as well, including sago, wood, etc.

In the consumption sector, studies will be made of the feasibility in using alcohol as fuel in Indonesia.

Finally, for the long-term implications of introducing alcohol as fuel, an Interdepartmental Team was appointed by the Minister of State for Research and Technology which will discuss the problems arising out of the execution of this program. The Team is divided into four sub-teams, i.e. Agronomy, Production, Economic, and Transmigration/Social. This team is expected to make recommendations so that the program can be effective, both at present and in the future.

At present the planning and selection of the pilot plant is finished, and the building and equipment are still under construction.

The next phases, operation and evaluation, are being prepared.

Gasohol: Does it or doesn't it? (produce net energy)

Energy Balance Worksheet

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There are four major categories of controversy in the great gasohol (10% etoh, 90% gasoline) debate:

1. agricultural energy inputs
2. conversion energy inputs
3. efficiency of use -i.e. how much gasoline does etoh replace?
4. Refinery energy use changes (for etoh-gasoline blends only)

Within each category, the earth is rent asunder with the anquish of clashing opinions and dashed reputations. In fact, the basic question of what type of net energy output has never been properly settled. But more on this later.

1. Agricultural Energy Inputs

a. Process analysis approach (e.g. corn-to-etoh plant in U.S.)

1. determine direct and indirect energy costs of corn used to feed wet or dry mill

   a) use agronomic process analysis

   b) use input-output tables

   Points of controversy: agronomic process analysis gives actual energy costs for corn used in plant vs. U.S. average figures for input-output (I-O) approach. Also, I-O approach cannot capture 2^d and 3^d round energy costs. But, I-O does not require knowledge of <u>where</u> each plant will be located. In general agronomic process analysis energy costs will be <u>lower</u> than I-O costs for high productivity regions (e.g. Illinois, Iowa) and <u>higher</u> than I-O in high

cost regions (e.g. High Plains of Kansas, Colorado).

2. determine substitution coefficients of etoh joint products for other crops.
   e.g. 1 bu. corn produces 2.5 gal. etoh plus 16-18 lb. distillers' dried grains (ddg) by dry milling.
   1 bu. corn produces 2.5 gal. etoh. or equivalent corn sweetener/starch plus 3.1 lb. corn oil, 3.4 lb. corn gluten meal, 11 lb. corn gluten feed
   By feeding trials or other methods, determine coefficient:
   dry milling: ddg from 1 bu. corn replaces 0.17 bu. soybeans
   wet milling: joint products from 1 bu. corn replace $\geq$ 0.21 bu. soybeans

3. determine additional feed energy to be grown to make up for starch converted to etoh and CO_2
   - about 28 lb. forage crop for each bushel to etoh.

b. Econometric approach: some economists remark that real economies allocate at the margin, not at the average. That is, given price changes induced by ethanol demand, the actual changes and corn, soybean and forage crop outputs may differ from values predicted in a process model. In particular, the elasticities of demand and supply are likely to attenuate the ultimate changes. And then, it's only the energy cost of the increment that is of value. So it is important to determine where the additional or lost output is -e.g. is the additional corn grown in Kansas or Iowa? were the lost soybeans from Alabama (high energy cost) or Missouri (low cost), etc. Results of agricultural sector econometric modeling indicate that up to levels of 3.10^9 gal. etoh. annually, the following production changes occur per 100 gal. etoh.

	econometric	process
corn	+ 12.5 bu.	+ 40 bu.
soybeans	- 0.17 bu.	- 6.8 - 8.4 bu.

c. Savings in soybean processing - each bu. of soybeans not milled saves ≈ 80,000 BTU

2. Conversion Energy inputs

a. Process analysis

1. 1 round (direct energy changes)
   each gal. etoh requires 30-60,000 BTU to grind, separate, ferment, and distill
2. 3 round (accounts for energy costs of capital and other inputs)
   each gal. etoh requires 40-80,000 BTU
   Points of controversy: should we assume state of art conversion efficiency -e.g. vacuum distillation, etc. or traditional beverage technology? If demand for octane is held constant, then energy for capital equipment is needed to construct octane boosting facilities be they etoh plants, MTBE plants, or cracking towers - if one accepts this premise, then counting 2^d and 3^d round effects will lead to double counting.
3. Use efficiency
   a. fuel substitute: BTU value of etoh ± net change in refinery energy inputs from gasoline savings + savings in process energy by leaving 10% H_2O.
      Point: whether to include refinery savings
   b. octane booster:
      energy value of etoh + refinery savings (toluene, butane, additional cracking) ± fuel economy change
      Point: should one assume an engine or fuel system optimized for oxygenated fuels or not?
   c. econometric approach: determine least cost mix of gasoline additives for market-determined blends with and without etoh => determine energy costs of octane boosters replaced by etoh in optimum mix
      e.g. 1 lb. etoh replaces 0.4 lb. MTBE (arguendo) => 1 lb. etoh is worth natural gas cost (content + process) of 0.4 lb. MTBE

0.4 lb. mtbe represents about 0.73 lb. natural gas (converted at $\eta = 0.55$). 1 lb. etoh contains 11,600 BTU, 0.73 lb. nat. gas contains 16,220 BTU

each gal. etoh (85,000 BTU) displaces 118,850 BTU natural gas equivalent.

Worksheet - for 1 gal. etoh ('000 BTU)

Agricultural Energy	Process	OR	Analytic Technique Econometric (where different)
+ corn grown	32 - 56		10 - 17.5
- soybeans grown	6.8 - 8.4		0.17
- soybeans processed	2.2 - 2.7		3.3*
+ extra feed	5.0		2.5
Total	26.9 - 52.0		8.0 - 16.5
Processing Energy			
ferm, dist. etc.	30 - 60	⇐>	30 - 60
Use Energy			
a. ETOH	85		
Δ ref. energy	10		
process energy savings	5		
	100		
OR			
b. blend		OR	118.8
etoh	85		
refinery savings	12.5		
Δ fuel economy			
regular engine	- 2.5		
optimized engine	0		
Total	97.5 - 100		118.8
Grand Total	-14.5 to +44.1		+42.3 to +79.8

* - results show fall in soybean processing >> fall in soybean output.

Results: process analysis shows marginal overall energy balance (positive for liquid fuels only) with potential for ultimately ending up negative. No comparison with alternative uses of resources (e.g. natural gas, coal) to produce liquid fuels. Econometric approach shows variable but unambiguously positive balance when alternative uses for resources are accounted for i.e. each gal. of fermentation etoh. augments net national energy supply by $\geq$ 42,300 BTU. The econometric test automatically determines that this is desirable relative to export of that corn for purchase of oil.

Similar exercises can be performed for other feedstocks.

Tree Plantations And The Concern For Sustainability and Stability

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Tree plantations for such biomass products as wood, pulp and paper materials, energy are generally characterized as monocropping attempts by man in favor of selected tree species. This type of man-made landscape/ land use is gaining popularity especially in the face of dwindling materials and energy resources. However, this goes against the natural tendency of tropical ecosystems to maintain diverse structure. To prevent this highly man-influenced ecosystem from reverting to its natural state, various inputs are necessary to maintain a dominantly monocropping pattern or simpler ecosystem structure (Nor 1982).

Concern for Sustainability and Stability

The tropical rainforest as a climax ecosystem is known for its high productivity, sustainability and protective characteristics which are believed to be associated with its complex and diverse structure (Richard, 1972: Rehm, 1981). Reduced diversity of tree plantations is a significant alteration in structure of the natural forest, a fact which has alarmed some silviculturists and ecologists. Nor, for example, has asked whether this transformation is leading to forest "sterilization" (1982). This sterilization process may be reflected in the ecosystem properties of stability and sustainability which eventually affect long term productivity. Stability as an ecosystem property is the ability to withstand minor perturbations measured by the fluctuations about the mean or trend-line while sustainability is the ability to persist in time (also termed

resilience) (Conway, 1982). Conceptually, these ecosystem properties are illustrated in Figure 1. Sustainability and stability of tree plantations are ecological concerns that will be discussed in this paper with emphasis on such specific processes as:

1. Nutrient budget.
2. Runoff of chemicals or pollution.
3. Biotic stability and pest problems, and
4. Disturbance of habitat and genetic loss.

Nutrient Budget

The closed nutrient cycling pattern of a tropical rainforest is known to be mainly responsible for its high degree of stability and sustainability (Rehm, 1981). In this natural ecosystem, nutrient loss is minimum and the elements are efficiently conserved and cycled from within for high biomass productivity. The nutrient budget of a tree crop is important because it will determine the amount of fertilizer inputs necessary to maintain productivity on a sustainable basis. As shown in Figure 2, nutrient losses occurs in 3 major pathways:

1. Surface runoff and sediment loss.
2. Leaching, and
3. Biomass harvest.

The first pathway also implies some externality effects such as pollution of adjacent aquatic and terrestrial areas. Road construction in tree plantation areas for greater accessability can also cause considerable deposition of sediment into aquatic and low lying areas. The ecological ideal is to have no net loss of nutrient, making fertilizer applications unnecessary to sustain the plantation (Marten et al., 1981).

A rough nutrient budget of a Leucaena - Gliricidia plantation was monitored in Mt. Makiling, Philippines for a one-year period in an upland area covering 3 slopes (36%, 50% and 70%) using runoff plots of 8 m^2.

Nutrient losses (N and P) from runoff and sediment load and nutrient input from litterfall and soil elements except rate of mineralization were determined (Upland Hydroecology Program Policy Report, 1978). As shown in Table 1, build up of soil N especially at the top soil was observed but considerable removal of P from sediment load was observed in a Leucaena - Gliricidia tree plantation. These preliminary findings need to be examined more closely especially concerning the effect of this tree plantation type on soil P on sloping lands. This type of vegetative cover has a relatively simple undergrowth as shown in Table 2. Leucaena leucocephala and Gliricidia sepium are both popular tree legume plantation species which are possibly acting as active nutrient pumps especially with regard to soil P which is readily released due to rapid decomposition of litter and is carried away as sediment load due to high rainfall in hilly areas.

Christanty (1981) cited the work of Ghosh et al. to show that for 3 species of Eucalyptus (E. globulus, E. camaldulensis, E. gomphocephala), the elements P, K and Ca are higher in the residue component (consisting of branches, bark and leaves) than in the timber component. The values are 6.4 - 16.6 kg/ha of residue versus 8.0 - 10.0 kg/ha for trunks; 60.3 - 296.1 kg/ha for residue versus 34.5 - 289.3 kg/ha for timber; 277.7 - 478.1 kg/ha for residue versus 30.8 - 136.5 kg/ha for timber for the elements P_2O_5 K_2O and CaO respectively.

From the few studies to shed light on the nutrient cycling pattern in tree plantations, the following considerations for sustainability and stability characteristics emerge as important:

1. Incorporation of soil conservation practices for tree plantations especially in hilly lands.

2. Strip planting, especially of diverse tree crops, instead of intensive monoculture.

3. Promoting decomposition in situ of leaves, branches, and barks whenever possible.

Runoff of Chemicals and Pollution

Marten et al. (1981) stated that pesticide loads on the environment are proportional to the intensity of pesticide applications and the magnitude of runoff and erosion. This is a general guide that one can consider relating runoff from tree plantations to its externality effects. Since insecticides, herbicides and fungicide are needed for maintenance of tree plantations, the chemicals applied could affect not only endogenous plant and soil microflora and microfauna at the site but also those of neighboring ecosystems.

Biotic Stability

Natural forests generally seem to have natural checks and balances against the outbreak of pests and diseases (Bond, 1953 as cited by Nor, 1982). A popular ecological principle that supports this contention is the relationship between diversity and stability. The functional interrelationships among various organisms at several trophic levels confers one possible mechanism for stability (Fig. 3).

Man-induced simplification of ecosystem structure of tree plantations leads to the disruption of these functional interrelationships.

For example Nor (1982) mentioned that in a 6-year old pine plantation at the Forest Research Institute, Kepong, only six species of plants were found under the pine trees with the fern *Dicranopteria linearis* being the dominant species.

The Upland Hydroecology Program (1976) reported only 5 unique mite species in a *Leucaena* - *Gliricidia* plantation compared to 18 species in a secondary forest (Table 3).

The disruptions of these natural homeostatic mechanisms in monospecific tree plantations have been obvious in several reports.

Albizia falcataria tree plantations in Bislig, Surigao Del Sur, Philippines have reportedly been attacked by fungus - causing canker (Corticium salmonicolor) (Eusebio et al., 1979). In the same area, a Eucalyptus deglupta plantation was attacked by gall midge with infestation rates as high as 30% (Viado, 1979).

Pure plantations in the Cordillera, Northern Luzon are presently suffering from infestation of ips (Ips calligraphus German).

Pest infestations of several pine species and Agathis in temperate countries are also well documented (Warren, 1968, Syme, 1975).

In Mount Makiling, Laguna, Philippines, Hengsawad (1980) conducted a study on degree of infestation of bean lycaenid (Catochrysops cnejus F.) on pigeon pea (Cajanus cajan) in pure culture as well as intercropped with Gliricidia sepium. He found that in terms of mean population densities of adults and mean number of eggs, the intercropped pigeon pea has significantly less infestation than the pure plantation (Table 4 and 5). He attributed this to the visual and olfactory confusion received from host and non-host plant species leading to disruption in normal host-finding behaviour of the insect pest.

Rodents prefer Leucaena leucocephala seedlings over those of Albizie procera so that intense damage occurs on grasslands where Leucaena are planted alone (Upland Hydroecology Program Report, 1979).

The non-sustainability and instability of tree plantations due to disruptions in biotic relationships is a cause for concern. The following are suggested strategies:

1. Basic studies on biotic interactions among components of tree-plantation ecosystems

2. Species diversification in tree plantations

3. Studies on biological control and population dynamics of host-predator components of the simplified ecosystem.

Habitat Disturbance and Genetic Loss

At present, large tracts of national forest, secondary forest and even marginal grassland are being converted into tree-plantation monocultures. Disturbances of natural habitats and landscape is inevitable. The FELDA scheme in Malaysia reported that rampaging elephants whose habitats were disturbed were responsible for overnight losses of millions of dollars of investments in oil-palm and rubber plantations.

Nor (1982) also echoed the concern that the preferential growing of some tree species is narrowing the genetic base. It is reported, for example, that the whole stock of *Acacia mangium* in Sabah originated from a single parent in Australia. This narrow genetic base makes the tree-plantation system very vulnerable to catastrophic pests and diseases occurance.

What should be done

In the face of increasing energy demands and the frantic search for alternative energy sources, environmental considerations may assume a secondary role to production. However, the sustainability or such biomass production system is in fact highly dependent on environmental integrity. The following courses of action are suggested:

1. Large scale transformation of natural areas into tree-plantations must pass through a very tough environmental assessment which will identify environmental concerns, affected groups, socio-economic concerns and social and political issues (Matthews and Siddiqi, 1980; Marten et al., 1981; Pimentel et al., 1981).

2. Conscious diversification efforts must be part of the planning for tree plantations. Utilization of endogenous plant species such as *Trema*

orientalis, Mallotus sp., Grewia sp. and other secondary forest species should be encouraged.

3. Intensifications of basic research on biotic relationships, nutrient cycling, population dynamics, hydrology and other functional attributes of tree plantations.

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TABLE 1

Net loss/gain total N and P in a Leucaena leucocephala - Gliricidia sepium tree plantation at Mt. Makiling, Laguna, Philippines (Upland Hydroecology Program Policy Report, 1978).

Nutrient Element Budget	Total Nutrient/Slope (%)		
	36	50	70
A. NITROGEN			
Input: (kg/ha/yr.)			
Litterfall	318.72	320.04	236.04
Top Soil (0-10 cm)	5800.00	5800.00	4200.00
Total	6118.72	6120.04	4436.04
Output: (kg/ha/yr.)			
Runoff	-	3.55	-
Sediment	-	0.67	-
Total		4.22	
Net Gain	6144.50	6115.82	4431.82
B. PHOSPHORUS			
Input: (kg/ha/yr.)			
Litterfall	23.28	20.04	16.32
Top Soil (0-10 cm)	3.56	3.70	2.72
Total	26.94	23.74	19.04
Output: (kg/ha/yr.)			
Runoff	-	1.42	-
Sediment	-	78.58	-
Total		80.00	
Net Loss	53.06	56.26	60.96

TABLE 2

Plant species composition of a *Leucaena leucocephala* (native variety) *Gliricidia sepium* mixed plantation at Mt. Makiling, Puting Lupa, Calamba, Laguna, Philippines (Upland Hydroecology Program Report, 1976).

Family	Species
Apocynaceae	1. *Ervatamia pandacaqui* (Pori) Pitchon
	2. *Ichnocarpus volubilis* (lour.) Morr.
	3. *Stropanthus cumungii* A.D.C.
Araceae	4. *Amorphophallus campanulatus* (Roxb.) Blm.
Gramineae	5. Cyrtococcum patens (L.) A. Camus
Lomoariopsidaceae	6. *Bolbitis apendiculata* Willd. J. Sn.
Malvaceae	7. *Lorena lobata* Linn.
Papilionaceae	8. *Abrus precatorius* Linn.
	9. *Desmodium laxiflorum* D.C.
	10. *Pueraria phaseoloides* (Roxb.) Benth.

TABLE 3

List of species of mites found unique to various ecosystems in the Hydroecology Program Main Basin at Mt. Makiling (UHP, 1978).

Scientific Name	Superfamily	Comments
Kaingin		
1. Undet. Suctobelbidae	Oppioidea	Appeared only IX in 9 months
Grassland		
1. *Cosmochthonius nagsangaeus Corpus-Raros	Cosmochthonoidea	IX
2. Eremobelba capitata Berlese	Eremuloidea	2X
3. *Oppia buhokmagae C-R	Oppioidea	2X
4. Suctobelba medialis Balogh and Mahunka	Oppioidea	1X
5. *Xylobates cogonales C-R	Oribatuloidea	4X
Plantation Forest		
1. *Annectacarus mahabaeus C-R	Lohmannoidea	1X
2. Berobates tagosansillae	Oribatuloidea	1X

* Manuscript names to be published in paper, Corpuz-Raros, L.A. 1978. Philippine Oribatei. I. Preliminary list of Philippine species and description of some new species from Mt. Makiling.

TABLE 4

Mean relative population densities of *Catochrysops cnejus* adults visiting flowers of pigeon peas grown under varying degrees of shading by *Gliricidia* (number/4 m^2/5 min: average of 3 replications) (Hengsawad, 1980)[1/]

Treatment	Weeks After Flowering							
	2	3	4	5	6	7	8	Mean
PP	6.33a	13.0a	21.67a	10.33a	15.67a	17.0a	4.67a	12.67a
PPK_1	3.33ab	9.67ab	19.67a	9.0ab	10.67a	14.0a	3.67ab	10.0b
PPK_2	2.33.b	6.67bc	16.67ab	5.33bc	10.33ab	11.67ab	2.0ab	7.86c
PPK_3	2.67b	4.67c	11.67bc	4.0c	6.67bc	7.67bc	1.33b	5.52d
PPK_4	1.33b	3.0c	9.33c	3.33c	3.0c	4.0c	1.33b	3.62e

1/ In a column, means followed by a common letter are not significantly different at 5% level of DMRT.

TABLE 5

Mean number of eggs of Catochrysops cnejus deposited on flowers of pigeon peas grown under varying degrees of shading by Gliricidia (number per 300 flowers, average of 3 replications) (Hengsawad, 1980)[1/]

Treatment	Weeks After Flowering								
	1	2	3	4	5	6	7	8	Mean
PP	13.67a	51.33a	29.67a	39.0a	41.67a	24.67a	24.67a	9.33a	30.50a
PPK_1	9.0ab	39.0a	23.67ab	35.33a	40.67ab	21.67a	27.67a	6.0a	25.38b
PPK_2	10.0ab	21.0b	24.0ab	32.67a	28.0bc	16.33a	27.33a	6.67a	20.75c
PPK_3	5.67b	15.33b	15.67b	27.33ab	19.0c	14.33a	26.33a	5.33a	16.13d
PPK_4	6.33ab	14.67b	15.67b	18.33b	20.0c	15.0a	15.67b	4.0a	13.71d

1/ In a column, means followed by a common letter are not significantly different at 5% level by DMRT.

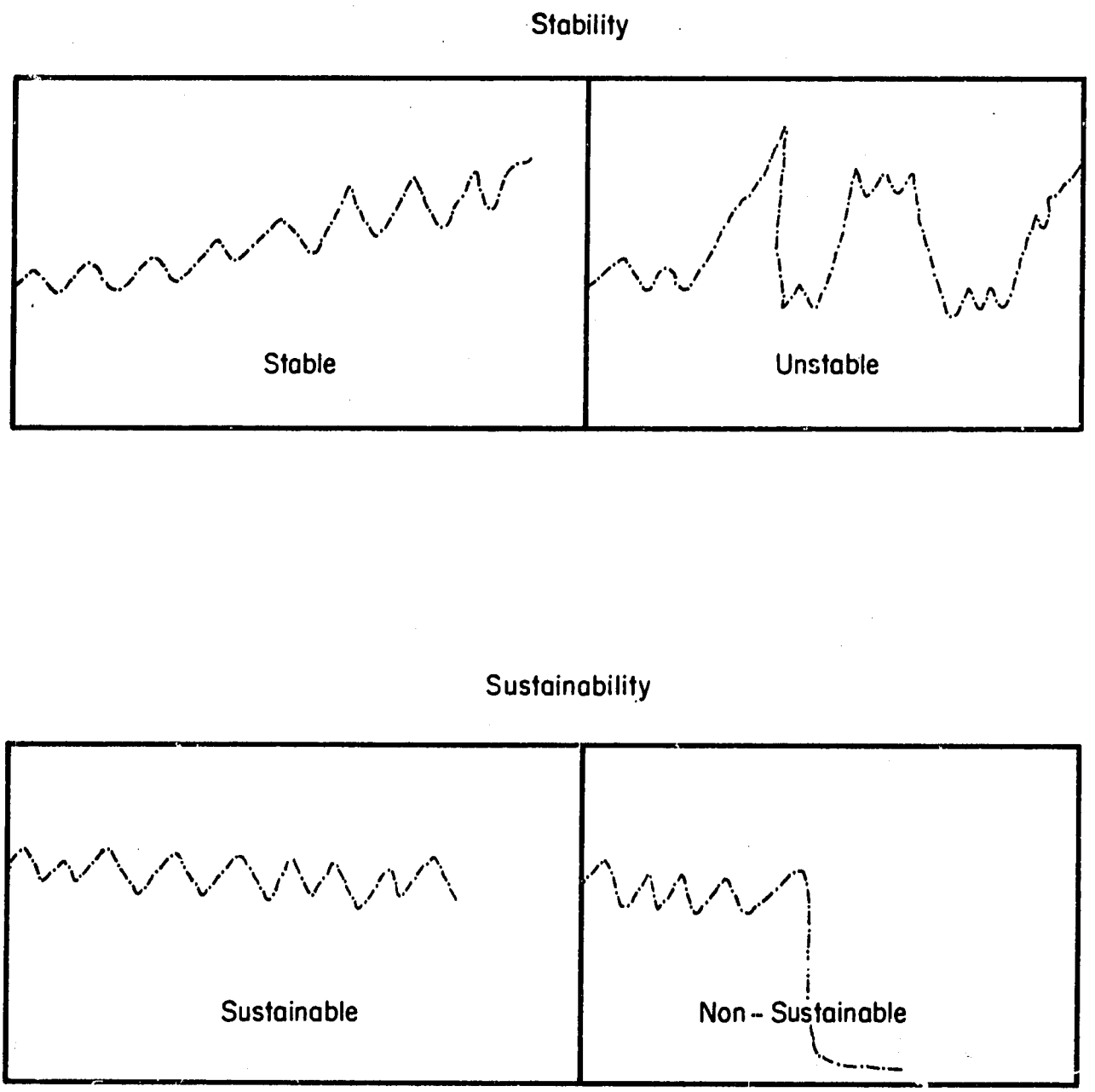

Fig. I – Conceptual Representations of Stability and Sustainability of Ecosystem

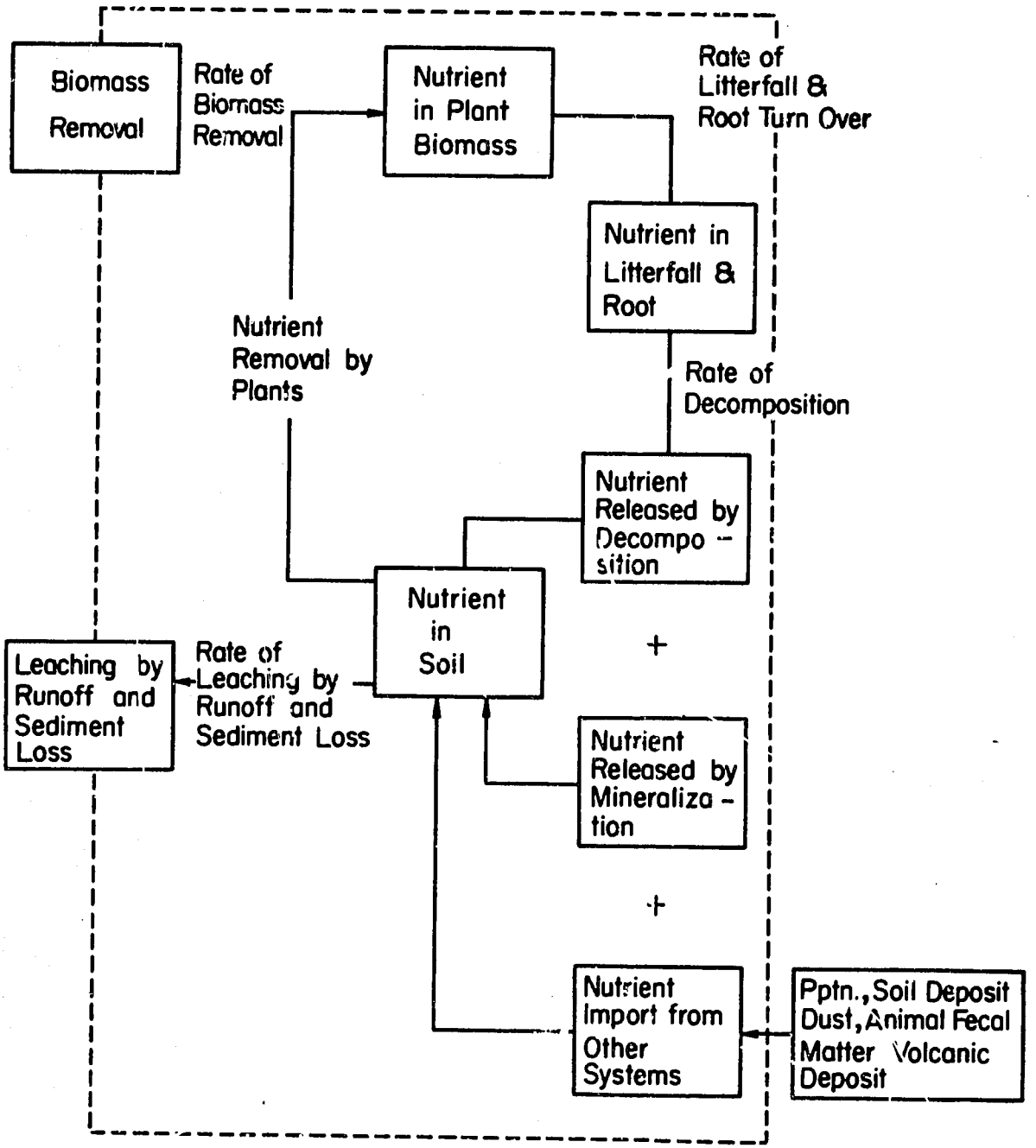

Fig. 2 – Conceptual Model of Nutrient Flow in Ecosystem

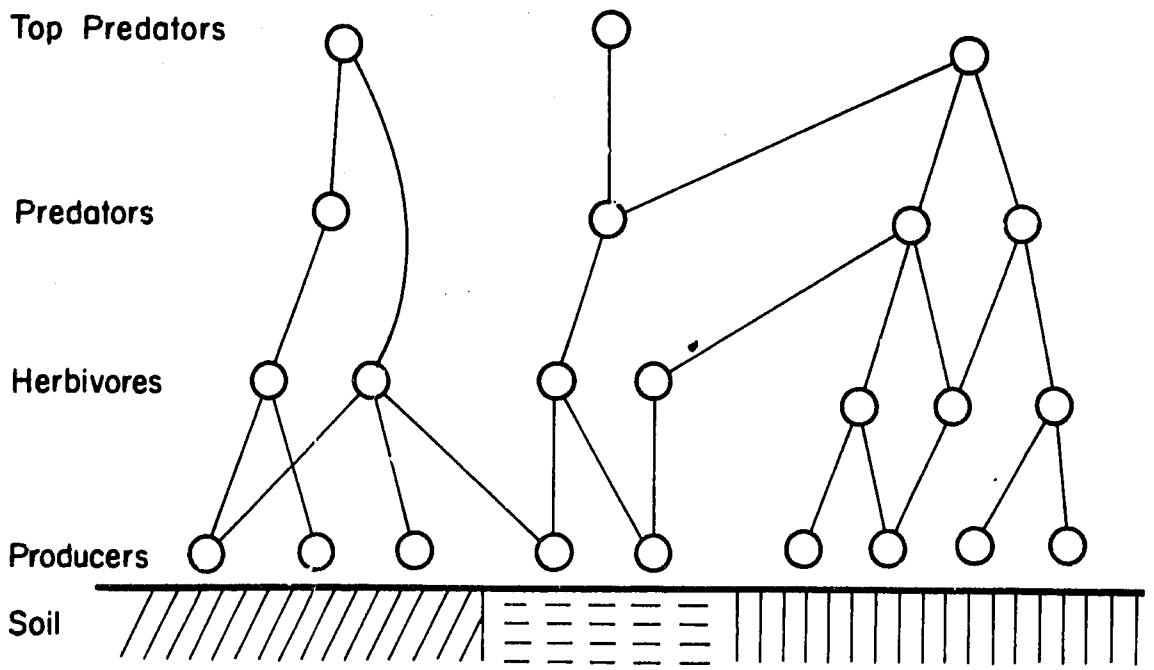

Fig. 3 – A Loosely Coupled Ecosystem Illustrating Diverse Functional Interactions at Various Trophic Levels

Hydrocarbon Producing Plants As Alternative Energy Source

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Abstract

This paper will briefly touch the status of research and development on hydrocarbon producing plants and the plans for these plants in the Philippines. It will also cite some of the hydrocarbon producing plants that have potentials as alternative energy sources.

Preliminary studies have identified a number of hydrocarbon producing plants that have potentials as energy sources. Some of these plants are Euphorbia lathyris, Euphorbia tirucalli, Cocus nucifera, Pittosporum resiniferum and others. Although little research has been done on hydrocarbon producing plants in the Philippines, scientists are now starting studies on Euphorbias and Aleurites.

There are research agencies undertaking or planning to undertake research and development studies on hydrocarbon bearing plants. In view of this the National Science and Technology Authority (NSTA) initiated the creation of a Technical Advisory Committee to integrate and coordinate R & D activities on hydrocarbon producing plants. An initial task of the Committee is the preparation of a report on the joint NSTA-RCTT project on Hydrocarbon Producing Plants.

A regional workshop on hydrocarbon producing plants is planned to be held in the Philippines towards the end of the year as part of the Regional Research and Development Program on Hydrocarbon Producing Plants.

Introduction

This paper will attempt to briefly touch the status of research and development on hydrocarbon producing plants and the plans for these plants in the Philippines. It will also cite a few of the hydrocarbon producing plants that have potentials as alternative energy sources.

Like any developing country, the Philippines was adversely affected by the energy crisis of 1973. At that time, the country was 95% dependent on imported oil. This prompted the government through its research agencies, to embark on research and development on alternative sources of energy. The National Science Development Board (NSDB), now the National Science and Technology Authority (NSTA), started the research studies by granting financial assistance to an initial twenty-one research projects. The research projects included studies on solar, wind, biogas, dendrothermal, producer gas, and others.

The five-year (1981-1985) Energy Program of the Ministry of Energy (MOE) which incorporates the nonconventional energy plan is aimed at reducing the Philippines' dependence on oil, managing demand to appropriate levels and diversifying the country's sources of energy toward renewable, preferably indigenous sources.

Prior to the promulgation of Presidential Decree (PD) 1068 on 12 January 1977, the NSTA had undertaken R & D on alternative energy sources. This decree directed the acceleration of research, development and use of nonconventional energy resources, the overall integration of which was entrusted to the Ministry of Energy. However, the NSTA and the MOE maintained a close working relationship and linkage as the Minister of the latter sat as member of the Board of Governors of the former.

With the recent creation of the Philippine Council for Industry and Energy Research and Development (PCIERD) under the administrative supervision of the NSTA, the Deputy Minister of the MOE becomes a member of the

Governing Council. This will still provide linkage and coordination with the MOE for energy research and development.

Some of the notable developments in the nonconventional energy technologies are: solar water heating, biogas, alcogas program, mini-hydro electric and small impounding projects, dendro-thermal, agricultural wastes utilization, and natural marsh gas.

Hydrocarbon producing plants as energy source

The potentials of hydrocarbon producing plants as energy sources had been and are being considered in many countries.

Melvin Calvin, a well-known Nobel laureate, believes that energy and chemicals in the future could come from factories based on the farming of semi-arid, hydrocarbon producing green plants.

The "green factories" (that is, the green plants) are, in absolute terms, one of the most effective means we have available to us to restore a positive balance in our energy bank account. The way in which plants can convert the energy of sunshine into food, fuel and fiber of useful type provides an example of how basic science can be used in the service of mankind. Calvin added that hydrocarbon producing plants can be grown on land that is today unproductive.

Green plants offer a never ending supply of oil, much of which, gallon for gallon, is worth more than petroleum. In the Philippines, attention has veered to Euphorbias, Aleurites and the like - plants that yield oil and hydrocarbons - to produce a wide range of products that are competitive with synthetic petrochemicals.

Australian scientists are seriously looking into a noxious weed, Cryptostegia grandiflora, that produces a prolific amount of latex as a source of hydrocarbon. Max Strong and his colleagues at Bio-Energy Australia, who are working with this plant obtained crude oil that is identical to petroleum fuel with the added advantage of its having no

sulfur. Strong claims that approximately 10% of the dry weight of the plant is hydrocarbon and that it can produce about 40 barrels of sulfur free oil per hectare at a cost of A$20 (US$23.52) per barrel.

T. R. Peoples, et al of the University of Arizona concluded that E. lathyris is a prime candidate as a renewable source of high-quality, hydrocarbon-like materials (biocrude) based on their research and published findings.

Eucalyptus essential oil from Eucalyptus globulus has been regarded as an alternative source of hydrocarbon fuel as an additive to gasoline for automobiles.

The gopher plant, Euphorbia lathyris, a member of the Euphorbiaceae or Poinsettia family, is a biennial herb that grows wild along the California coast and can attain a height of six feet. Gopher plant seeds have also been used as a substitute for coffee and capers, as a treatment for dropsy, and as an emetic. It is currently being evaluated by the University of Arizona as a potential source of liquid fuel. One year's data indicates that a yield of three tons per acre dry weight is attainable, which translates to approximately four barrels of crude oil per acre, without the benefit of optimum irrigation or fertilizer and with unimproved seed.

The stickplant, Euphorbia tirucalli, a member of the Euphorbiaceae is an erect, glabrous, unarmed shrub or small tree 2 to 5 m high with somewhat fleshy green branches and few and scattered leaves that fall off easily. The hydrocarbon material which can be extracted from the plant resembles crude oil.

Calvin's work which began in 1977 with experimental plantings of Euphorbia lathyris and Euphorbia tirucalli proved that plantings produced oil at a rate of 8-12 percent of total dry weight. He extrapolates it to 8-10 barrels per acre for lathyris and 15 barrels per acre for tirucalli.

According to Calvin, hydrocarbon yields from plants can be improved by selection and genetic manipulation just as the Malaysians improved rubber tree yields.

The Japanese have successfully developed an E. tirucalli plantation in Okinawa which they have calculated to produce between 10 and 20 barrels of oil per acre per year. As reported, the oil yield from E. tirucalli in Okinawa which resembles that of E. lathyris seems to be higher than the E. lathyris of California.

Another plant belonging to the Euphorbiaceae is the Jatropha curcas or Physic nut. The seeds yield an oil which has been used for illumination in some parts of the Philippines. It is commercially known as curcas oil and is employed in the manufacture of soaps and candles and as an illuminant and lubricant. The Physic nut kernels yield by extraction with chloroform 63.05 percent oil corresponding to 34.65 percent, calculated on the basis of the whole nut.

The Pittosporum resiniferum, locally called "hanga" is an epiphyte, commonly and usually found in mountain ranges attached to a bigger or independent tree with circumference of about one meter. It reaches a height of 25 meters. Based on laboratory analysis, the fruit juice contains dihydroterpene ($C_{10}H_{18}$) and considerable amounts of heptane which are also found in petroleum. The juice burns brilliantly when lit and as such it has been used as fuel for lamps. Firewood from this plant ignites easily. Earlier studies showed that a kilo of fresh nuts yielded as much as 68 grams of juice. One fruit yields about 2-3 ml of liquid extract. This extract also has medicinal value.

The economics of producing oil from P. resinferum have not been thoroughly studied. However, initial observation and test results made in the Philippines show that a full-bearing tree could yield as much as 100 kilograms of fruits per year.

Other related species of Pittosporum resinferum are found in Japan, New Zealand, Himalayas, Malaysia, Thailand and Nepal.

"Coco-diesel", a diesel fuel substitute developed by the National Institute of Science and Technology (NIST), an agency of the NSTA, from Cocus nucifera (coconut tree) has been analyzed and tested. It was successfully road tested on a diesel car and jeep. The C. nucifera is also called the "tree of life". It is used as a source of food, low cost building material, chemicals, fuel etc. It grows abundantly in Asian countries.

These are just some of the hydrocarbon producing plants with potentials as energy sources not discounting, of course, their other uses as food, medicine, lubricants, etc.

Status of R & D on hydrocarbon producing plants

There are about nineteen species of Euphorbias known to exist in the Philippines (Table 1) which could be potential sources of hydrocarbon for energy. Research conducted at the College of Forestry of the University of the Philippines at Los Baños regarding hydrocarbon yields of some of these species as reported as shown in Tables 2 and 3.

In addition to the 19 Euphorbia species, there are a number of wild and semi-cultivated plants found in the Philippines that could also be potential sources of fuel, hydrocarbon materials and such other useful compounds as rubber, essential oils and resin (Table 4).

Except for early studies on some locally available oil producing plants, there is not much research that has been done.

Recently, scientists launched studies on plants that yield oils and hydrocarbons. They are considering Euphorbias, Aleurites and the like to produce a wide range of products that are competitive with synthetic petrochemicals.

Recognizing the potentials of some of these hydrocarbon producing plants as energy source, the NSTA organized an inter-agency Advisory and Technical Committee in July 1981 that would formulate, implement and monitor a national R & D integrated program on hydrocarbon bearing plants.

An initial undertaking of the Committee is a joint project of the NSTA and the Regional Center for Technology Transfer (RCTT) with the cooperation of some government agencies like: the National Institute of Science and Technology, a research agency of NSTA; the Bureau of Plant Industry of the Ministry of Agriculture; the University of the Philippines at Los Baños; and the Forest Research Institute of the Ministry of Natural Resources. The project entitled, "Study on the Prospects for Cultivation of Hydrocarbon Producing Plants in Asia and the Pacific", is aimed at conducting a study and preparing a report on hydrocarbon bearing plants with special reference to the potentials for their cultivation and development in Asia and the Pacific region.

A team of scientists conducted a study tour in some Asean and ESCAP countries including Japan, Australia and the United States of America.

The report that is being prepared will indicate the botanical name, common name and family of each plant. Each plant will be described and its promising attributes, including distribution, yield, processing technology, environmental requirement, cultural management and uses will be identified.

A list of species studied in various countries and extent of R & D is shown in Table 5.

Plan for an integrated R & D program on hydrocarbon producing plants

There are some research agencies and educational institutions in the Philippines that are involved in R & D activities on hydrocarbon producing plants. These are the Bureau of Plant Industry, the Forest Research Institute, the College of Forestry of the University of the Philippines at Los Baños, the Philippine Women's University, the National Institute of Science and Technology and the Energy Research and Development Center.

The NSTA has initiated the creation of an inter-agency Technical and Advisory Committee on Hydrocarbon Producing Plants to formulate, implement and monitor a national R & D program on hydrocarbon producing plants. The committee shall identify the agencies/institutions involved in research studies on hydrocarbon producing plants.

Part of the plan for an integrated research and development program is to conduct a regional workshop on hydrocarbon producing plants towards the end of the year in the Philippines. Representatives from Asia/Pacific countries shall be invited to present papers relative to R & D activities on hydrocarbon producing plants in their countries.

The regional workshop as envisioned shall assess the status of R & D, discuss and formulate strategies of implementation for the Regional R & D Program on Hydrocarbon Producing Plants. It shall also define member-countries' responsibilities and participation in the regional program and shall identify various activities that will propel technical complementarity and collaboration.

The regional program is aimed at: (a) promoting R & D on hydrocarbon producing plants; (b) promoting collaboration among countries within the region; and (c) establishing a regional coordinating center to carry out the set objectives.

However, the need for the establishment of the coordinating center shall also be discussed in the regional workshop.

Recommendations

On a regional level, there should be an exchange of technical information and expertise among ASEAN countries; and on the national level, government support should be extended to develop or expand, as the case may be, R & D activities relative to hydrocarbon producing plants as alternative sources of energy.

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TABLE 1

Some species belonging to family Euphorbiaceae which are potential sources of crude oil.

Scientific Names	Common Names	Distribution
1. Euphorbia antiquorum	Malayan Spurg	Southeast Asia
2. Euphorbia atoto	Tairas (iv.)	Along sandy seashores throughout the Phil.
3. Euphorbia capillaris	--	Luzon (Manila and vicinity); locally abundant
4. Euphorbia cotinifolia	Malapascuas	Luzon (Manila and vicinity)
5. Euphorbia fulgens	Scarlet plume	Cultivated mostly in Baguio
6. Euphorbia heterophylla	Painted leaf (Engl.)	Manila and other towns; in waste places
7. Euphorbia hirta	Golondrina	Throughout the Phil. in waste places, open grasslands
8. Euphorbia lactea	Mottled candle stick	Southeast Asia
9. Euphorbia luzoniensis		Luzon (Ilocos Norte); in open dry places at low altitudes
10. Euphorbia makinoi		Luzon (Ilocos Norte); in open dry places at low altitudes
11. Euphorbia splendens	Corona de espina	Cultivated in Manila and other large towns for ornamental purposes but nowhere spontaneous
12. Euphorbia nerifolia	Common milk hedge (Engl.) Soro-soro (Tag.)	Widely distributed in the Philippines. Also found in India to Malaya
13. Euphorbia trigona	Tuba	Widely distributed in the Philippines
14. Euphorbia plumeroides		Luzon (Batangas), on ridges and slopes in thin soil among boulders, sea level to 500 meter altitude
15. Euphorbia prostata		Occasional in waste places, along streets in and about towns
16. Euphorbia pulcherrima	Poinsettia, Pascuas	Widely distributed in the Philippines; on most tropical and sub-tropical countries

TABLE 1 .... (continuation)

Scientific Names	Common Names	Distribution
17. *Euphorbia serrulata*		Throughout the Phil. in open grass-lands at low and medium altitudes
18. *Euphorbia tirucalli*	Stickplant (Engl.) Consuelda (Sp.) Suerda (Tag.) Pobreng-kahoy (Tag.)	Northern Luzon to Mindanao; occasionally planted in gardens, hedges, bur apparently nowhere spontaneous
19. *Euphorbia thymifolia*		Throughout the Phil. in waste places, along the roads and trails
20. *Pedilanthus tithymaloides*	Picara Solsoldong	Throughout the Phil.; in dry locations
21. *Excoecaria bicolor*	Picara	Throughout the Phil.

TABLE 2

Acetone and benzene extractables from various plants. Data are given in percent of plant dry weight. The plants (obtained from the vicinities of Los Baños and Bay, Laguna) were air-dried, finely ground in a mortar and extracted in a Soxhlet apparatus for 8 hours with acetone and then for 8 hours in benzene.

Plant	Acetone Extract	Benzene Extract (with initial acetone extraction)	Benzene Extract (without initial acetone extraction)
Euphorbia tirucalli	24.50	1.23	22.50
E. neriifolia			
leaves	18.28	0.60	35.52
stem	18.49	1.32	23.70
whole plant	22.33	1.48	16.16
E. lactea	18.57	1.07	20.76
E. pulcherrima			
leaves	10.07	2.58	5.47
stem	3.67	1.24	18.60
whole plant	6.81	0.99	3.91
E. hirta	9.36	0.32	1.98
E. cotinifolia			
leaves	13.85	0.84	7.60
stem	6.23	0.24	2.50
whole plant	9.26	0.58	8.38
E. splendens	12.26	0.87	3.72
Pedilanthus tithymaloides (variegated)			
leaves	17.48	1.56	28.76
stem	13.78	0.54	15.78
whole plant	18.37	1.28	20.48
Pedilanthus tithymaloides (non-variegated)			
leaves	13.37	0.52	25.26
stem	20.36	0.86	24.66
whole plant	16.08	0.94	23.63
Excoecaria bicolor			
leaves	8.68	0.68	1.24
stem	2.73	0.38	1.40
whole plant	5.52	2.39	1.66
Vacanga globuza			
leaves	5.04	1.10	4.79
Erythroxylan coca			
leaves	9.44	0.96	19.32
stem	19.60	0.56	5.90
whole plant	9.44	1.33	3.65

TABLE 3

Hexans and methanol extractables from various plants. Data are given in percent of plant dry weight. The plants (obtained from the vicinities of Los Baños and Bay, Laguna) were air-dried, finely ground in a mortar and extracted in a Soxhlet apparatus for 8 hours with hexane and then for 8 hours in methanol.

Plant	Hexan Extract	Mathanol Extract
Euphorvia tirucalli	6.12	16.50
E. neriifolia		
leaves	9.32	9.09
stem	4.50	24.04
whole plant	4.10	15.58
E. lactea	8.10	16.91
E. pulcherrima		
leaves	9.73	9.24
stem	1.45	5.32
whole plant	2.36	15.88
E. hirta	2.12	4.50
E. cotinifolia		
leaves	8.22	7.35
stem	2.93	10.92
whole plant	4.38	9.92
E. splendens	2.64	10.65
Pedilanthus tithymaloides (non-variegated)		
leaves	2.98	22.46
stem	1.64	22.75
whole plant	2.63	22.44
Pedilanthus tithymaloides (variegated)		
leaves	3.36	5.54
stem	6.16	21.32
whole plant	2.11	14.52
Excoecaria bicolor		
leaves	3.18	17.16
stem	1.70	3.40
whole plant	2.45	14.94
Vacanga globuza		
leaves	2.24	8.32
Erythroxylan coca		
leaves	8.66	10.25
stem	4.30	13.06
whole plant	2.18	7.82

TABLE 4

Plant Sources of oils used as illuminants of for candle-making

Scientific Name and Family	Common Name	Part Used	Distribution
1. Aleuritis moluccana Euphorbiaceae	Lumbang	seed (tree)	Throughout the Philippines at low and medium altitudes; in second-growth forests, thickets
2. Anisoptera thurifera Dipterocarpaceae	Palosapis	trunk (tree)	Widely distributed throughout the Philippines in primary forests at low altitudes
3. Barringtonia asiatica Lecythidaceae	Botong	seed (tree)	Along the seashores throughout the Philippines, ornamental
4. Calophyllum inophyllum Guttiferae	Palomaria	seed (tree)	Throughout the Philippines along the seashore
5. Barringtonia racemosa Lecythidaceae	Putat	seed (tree)	Along seashores, streams at low altitudes throughout the Philippines
6. Calophyllum blancio Guttiferae	Bitangol	seed (tree)	In primary forests at low and medium altitudes. Often abundant from Cagayan to Sorsogon, Ambil, Palawan, Masbate, Leyte, Panay, Mindanao
7. Canarium spersum Burseraceae	Pagsahingin	resin (tree)	Widely distributed in the Philippines
8. Canarium ovatum Burseraceae	Piluai	fruit pulp	Abundant in southern Luzon, in primary forests at low and medium altitudes, also in Polillo, Samar, Leyte, Surigao
9. Cerbera manghas Apocynaceae	Baraibai	seed (shrub)	Along the seashore throughout the Philippines
10. Chisocneton cumingianus Meliaceae	Balukang	seed (tree)	In primary forests at low and medium altitudes in Cagayan to Albay, Catanduanes, Samar, Leyte, Camiguin de Misamis Mindanao
11. Dipterocarpus gracilis Dipterocarpaceae	Panau	trunk (tree)	In primary forests at low and medium altitudes from northern Luzon to Palawan and Mindanao

TABLE 4 .... (continuation)

Scientific Name and Family	Common Name	Part Used	Distribution
12. Dipterocarpus grandiflorus	Apitong	trunk	In primary forests at low and medium altitudes
13. Elaeis guinensis Palmae	Oil palm	Fruit (tree)	Cultivated as an ornamental
14. Ganophyllum falcatum Sapindaceae	Arangen	seed (tree)	In dry forests at low and medium altitudes from northern Luzon to Mindanao
15. Hernandia ovigera Hernandiaceae	Koron-koron	seed (tree)	Along the seashore, from central Luzon to Palawan, Mindanao and Sulu
16. Jatropha curcas Euphorbiaceae	Tubang-bakod	seed (tree)	Throughout the Philippines
17. Jatropha multifida Euphorbiaceae	Mana	seed (tree)	Cultivated as an ornamental
18. Madhuca betis Sapotaceae	Betis	seed	In primary forests at low altitudes in Cagayan, Cavite, Rizal, Quezon and Camarines
19. Momordica cochinchinensis Cucurbitaceae	Patolang-uwak	seed (vine)	In thickets, secondary
20. Moringa oleifera Sapindaceae	Malunggay	seed	Very common in Luzon in primary forests at low and medium altitudes
21. Nephelium mutabile Sapindaceae	Bulala	seed (tree)	Very common in Luzon in primary forests at low and medium altitudes
22. Palawuim philippense Sapotaceae	Malakmalak	seed (tree)	Very common and widely distributed at low and medium altitudes from northern Luzon to southern Mindanao
23. Pangium edule Flacourtiaceae	pangi	seed (tree)	In primary forests at low and medium altitudes in Camarines, Sorsogon, Palawan, Samar, Leyte, Panay, Negros and Mindanao
24. Pittosporum resiniferum	Petroleum - nut	seed	On high mountain ridges from Bontoc to Sorsogon, Mindoro and Catanduanes
25. Pongamia pinnata Leguminosae	Bani	seed (tree)	Along seashores throughout the Philippines
26. Seasamum orientale Pedaliaceae	Linga	seed (tree)	Cultivated

TABLE 5

Research and development of hydrocarbon-producing plants in various countries

Country	Species	Type of Studies					
		Species screening evaluation	Propagation/ plantation/ establishment/ management	Extraction/Processing			
				Laboratory scale	Semi-pilot	Pilot	Commercial
Australia	*Asclepias* spp.	x	x	x			
	Calotropis procera	x	x	x			
	Calotropis gigantea	x	x	x			
	Cryptostegia grandiflora	x	x	x			
	Helianthya spp.	x	x	x	x		
Indonesia	*Euphorbia* spp.	x	x				
	Pedilanthus spp.		x				
Japan	*Eucalyptus* spp.	x	x	x	x		
	Euphorbia spp.	x	x	x	x		
Malaysia	*Elaeis guineensis*	x	x	x			
	Hymeneae courbaril		x				

TABLE 5 con't

Philippines	*Agathis* spp.	x	x				
	Canarium spp.	x					
	Cocos nucifera	x	x	x		x	x
	Dipterocarps	x	x	x			
	Euphorbia spp.	x	x	x			
	Jatropha curcas	x	x	x			
	Pedilanthus spp.	x	x	x			
	Pinus spp.	x	x	x			
	Pittosporum spp.	x	x	x			
Sri Lanka	*Hevea brasiliensis* seed oil			x			
	Thevetia peruviana seed oil	x		x			
Thailand	*Euphorbia tirucalli*	x	x	x			
	Sterculia foetida	x		x			
	Thevetia peruviana	x		x			
	Simmondsia chinensis	x	x	x			
	Jatropha curcas	x	x	x			
	Calotropis gigantea			x			
	Euphorbia species	x					
	Arachis hypozea	x	x	x			

TABLE 5 con't

USA	*Amsonia* spp.	x	x	x			
	Asclepias spp.	x	x	x	x		
	Chrysothamus spp.	x	x	x			
	Euphorbia spp.	x	x	x			
	Grindella camporum	x	x	x			
	Pedilanthus macrocarpus	x	x	x			
	Xanthocephalum gymnospersnoides	x	x	x			
	Helianthus spp.	x	x	x	x		

The Scope for Bio-energy Technology Programme in Malaysia

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Introduction

Malaysia covers a land mass of 330,434 km^2 which comprises Peninsular Malaysia (131,587 km^2) and the East Malaysian States of Sarawak (124,449 km^2) and Sabah (74,398 km^2). About four-fifths of Malaysia is covered by forests and swamps.

The agricultural zone lies between the coasts and the mountains interiors.

Malaysia's economy is agriculturally based, which supports a much larger population than any other form of economic activity. It is the world's premier exporter of rubber, palm oil and tropical hardwoods and, as in most developing countries, its industrialisation is underlaid by the production of agricultural raw materials. The acreage of the major crops grown in Malaysia in 1980 is indicated in Table 1.

The rural population is engaged mainly in agriculture, fishing, animal rearing and small-scale industries. Energy consumption in these rural industries and homes amounts to less than 15% of the total energy consumption presently running at 60 million barrels of oil equivalent annually (Table 2).

Basic energy needs in the rural areas are currently met by firewood, kerosene, diesel, liquefied petroleum gas (LPG) and electricity from the rural electrification programme. Rural electricity, kerosene and diesel oil are heavily subsidised by the Government.

Heat for cooking is generated mainly from firewood, with kerosene and to a small extent LPG and electricity supplementing the rest. Present

energy consumption of firewood in homes and small-scale industries is approximately 1.7 million barrels of oil equivalent with rubber wood accounting for the greatest share. With a programmed rubber replanting scheme, the supply of rubber wood is almost constant.

Lighting of dwellings and essential buildings is provided mainly by kerosene and electricity. 1976 figures indicate that only 215,000 households in 2,400 villages were provided with electricity under the rural electrification programme. For the year 1977/78 the Federal Government further allocated $41.33 million ringgit (US$20 million) for implementation of 506 projects covering approximately 760 villages benefiting about 34,500 households. Implementation of the programme has been constrained somewhat by capital costs and shortages of transmission line poles.

Mechanical power for rural transportation, fishing boats, agricultural tractors, etc. is provided almost entirely by diesel oil.

Malaysia has only 1.8 billion barrels of remaining recoverable reserves of oil. At the present production rate of 280,000 barrels a day, these reserves will last only another 18 years. In 1979 some 10 million barrels of oil were used as the main electricity generation source with projections of 15, 30 and 90 million barrels for 1985, 1990 and 2000 respectively. Electrical energy consumption indicates the following percentage usage pattern: domestic (15%) commercial (30%) industrial (52%) and others (3%). This consumption pattern is important in the selection and implementation of any programme in energy substitution.

The natural gas reserve has been estimated at 30 trillion (10^{12}) standard cubic feet, equivalent to about 5 billion barrels of oil. Gas, considered an immediate alternative to oil, will only be made available in 1985.

Hydro-electric power has been used in Malaysia for quite some time now and is regarded as a conventional source of energy which is non-polluting and renewable. Indeed, there are plans to expand further the exploi-

tation of this form of energy. Hydroelectricity presently contributes approximately 15% of total electricity generated.

While Malaysia's energy policy is in the process of being formulated, broad guidelines of energy strategies have been identified. The country will attempt to reduce her reliance on oil by promoting the development of indigenous alternative energy sources. In this context, the development and utilisation of our gas and hydro resources will receive considerable emphasis as part of the national energy diversification programme.

While non-conventional renewable energy alternatives (solar, biomass, synthetic fuel etc.), admittedly cannot make a significant impact on total energy consumption before the turn of this century, whether in Malaysia or elsewhere, there is, nevertheless, a definite place for the development of such energy forms. Mass utilisation of these resources on a cost effective basis would be in accordance with the government policy of diversifying the utilisation of natural energy resources.

This paper will explore the potential and impact in the utilisation of some of the indigenous biomass resources for energy generation in fulfilling the national aspiration of self-sufficiency in energy.

Biomass Energy Potential

The warm and moist tropical climate of Malaysia exerts a major controlling influence on the possibility of utilising biomass as a source of energy. The potential exists for a constant rate of production the year round; therefore, energy-recovery schemes could operate continuously, utilising biomass in an identical form at all times.

The energy from the sun which results in the photosynthetic production of organic material (biomass) can be utilised in two ways. Organic material can be grown specifically as a source of heat energy or the waste organic material derived from harvesting or processing can be collected and either burned directly or converted to various fuels (see Summary of

Organic Material Conversion Processes). Malaysia is predominantly an agricultural country and during the primary and secondary processing of the agricultural commodities, a substantial amount of agricultural wastes is generated which could be considered as potential bioenergy resources. The developing livestock and forestry industries also contribute substantial amounts of related wastes which together generate a pool of biowastes (Table 3) with scope for consideration for energy generation.

1. Biogas from Livestock Wastes. Table 4 shows the livestock census (1967 - 1977) for five categories of livestock. It is estimated that the total biogas available per year in West Malaysia from this sector is about 7×10^9 cu. ft. or 570,000 barrels of oil equivalent.

Most of Malaysia's rural population is involved in some form of traditional livestock farming activities carried out on a small family scale in backyards and villages. There are more than half a million buffaloes and other cattle in Malaysia of which about half are found in the rice growing regions of north-eastern and north-western States of Kelantan and Kedah. Most of them are draught animals owned by Malay padi farmers. Each farmer owns only a few heads.

It is unusual to confine these animals at night and they are driven to areas of 'pastures' during the day. They depend to a large extent on such pasturage as is available on grazing reserves, forest clearings, vacant and waste land and on padi land during the fallow period. Cattle dungs are thus scattered which makes collection difficult. It is only during the period of confinement to milking shades that an appreciable amount of dungs are produced.

The potentials of livestock rearing are limited by the lack of natural pastures in Malaysia. There is, therefore, no tradition of cattle rearing. Only recently have various State Development Agencies initiated programmes to commercialise the livestock industry through development of pastures from primary and secondary jungle. The Department of Veterinary Service of the Ministry of Agriculture has developed a total area of 500 acres with high quality grass in Trengganu, Kedah, Pahang and Negeri Sem-

bilan. The National Livestock Development Authority (Majuternak) has to date established eight dairy and meat production projects covering a total area of about 27,000 acres carrying about 13,000 heads of cattle. Smallholder operations of a few acres would be encouraged through a programme of assistance for livestock and also poultry development.

Pig rearing is exclusively confined to the Malaysian Chinese community. A medium sized farm may have as many as 500 - 1000 pigs while smaller pig ownership may average about 30 per farmer. Pig rearing in association with fish pond culture is also common. Wastes from piggeries are fed into fish ponds as a source of fish food. As these animals are confined in pig sheds a substantial quantity of pig wastes is generated, particularly in the larger pig farms. The farmer is thus concerned with the complete disposal of a concentrated manure within the confines of his property.

From an environmental and social view point piggery wastes stand out prominently as the most problematic of all livestock wastes where urgent attention has to be directed to seek immediate solution of treatment. It is in this sector that biogas technology can be introduced to fulfill the dual role of treatment and utilization.

2. Biogas from Agro-Wastes. An agro-waste of significance which can be singled out as having tremendous potential for biogas generation is the palm oil mill effluent (POME) generated by the Malaysian palm oil industry. Malaysia leads in the world's production of palm oil, accounting for some 40% of the world's total. In 1977, West Malaysia alone produced 1.47 million tonnes of crude palm oil. This amount is expected to increase at an annual rate of 10%. This is reflected correspondingly in the increased number of mills. About 50 more mills are now at various stages of development adding to the present figure of 122 already in operation.

In the year under discussion some 4.4 million tonnes of POME were discharged into water courses, estuaries or the sea. POME is characterized by its high BOD and high total solids (Table 5) which pose serious environmental problems to the country. Regulations for the control of its discharge are provided for under the Environmental Quality Act of 1974.

The Act has given the much needed impetus to the oil palm industry to come up with appropriate technology for the treatment or utilisation of the mill effluent. Studies have indicated that biogas of about 1.6 x 10^9 cu. ft. (or 130,000 barrels of oil equivalent) can be obtained through anaerobic digestion of the palm oil mill effluent.

Several plantation groups are currently working on anaerobic digestion of the POME with the primary objective of treating the effluent to meet national environmental discharge standards. Some have extended the idea by incorporating a closed-tank system for methane gas generation. Fig. 1 refers to a system for the treatment of POME in one mill which operates as follows:

a. The centrifuge and the steriliser wastes which constitute the POME are pumped to a cooling pond for air-cooling.

b. The cooled effluent is fed to Acid Pond 1 with equal volume of supernatant liquor from digestors to facilitate acid formation prior to entry into digestors. Retention time in the pond is about 1 day. Feeding into Acid Pond 1 and 2 on alternate days to allow the 1 day retention time.

c. Wastewaters from acid pond are fed in parallel to the 3 mild steel digestors. Hydraulic retention time: 20 days.

Digested effluent is fed to an aerobic pond having 2 mechanical aerators (15 hp each) for a further 20-day retention time.

The overflow from aerobic pond runs into settling tank from which supernatant flows by gravity to discharge pond while the underflow returns to aerobic pond to replenish loss of aerobic microbes and to reduce suspended solids in final discharge.

Design Features

a. The system is designed for a 20 ton mill (20 t ffb/hr) for 20h/day. Based on 0.6 t effluent/t ffb processed.

b. The acid and cooling ponds are lined with bakau piles, stones, mining ballast and cement to avoid choking of pumps by bottom soil.

c. All ponds have average depth of 8 ft.

d. The digester height is 25 ft. (working depth about 24 ft.), with an open top. Temperature is regulated at 35°C with stirring effected as the sludge is pumped into the tank. The gas produced is flared directly into the atmosphere. The biogas composition is indicated in Table 6.

e. The total cost of the system excluding land cost is about M$600,000 (US$260,000) inclusive of 3 digestors, 2 acid ponds, 1 cooling pond, 1 aerobic pond, 2 aerators, pumps, pipelines fencing etc. The cost of the 3 digestors is approximately M$250,000 (US$105,000).

The amount of digestor gas produced and its energy value at various mill capacities, operating on a 20-hour day basis are given in Table 7.

With increasing emphasis and attention being given to the energy available in the gas produced by the anaerobic digestion of the mills' liquid waste it is possible that palm oil mills may be a source of energy for other consumers in the not too distant future. It has been estimated that a 60 FFB tonnes/hr mill will generate about 12,000 m^3 of gas per day, which when used as a fuel for a reciprocating gas engine coupled to an alternator, would generate about 770 kWhr of electricity.

Except for a few small-scale biogas plants in the States of Kelah, Kelantan, Selangor and Penang, utilization of biogas derived from animal wastes in Malaysia can be considered minimal. This is mainly attributed to the availability of inexpensive and highly subsidised alternative fuels.

Unconventional energy sources like biogas may suffer from a lack of momentum in that they are 'new' and run against the familiar patterns of energy production traditionally associated with economic growth. The Malaysian Government has recently increased the subsidies on petroleum-related fuels from M$331 million (US$165 million) in 1979 to M$638 million

(US$319 million) this year. While there are other, perhaps more important, considerations behind such a policy measure, it is likely to encourage the over-use of oil and render the task of promotion of biogas technology even more difficult. Social attitudes will also determine the success of such a programme. It may even be necessary for the Government to take on a more active role by providing economic and fiscal incentives to encourage biogas programme in the country. Various government agencies, such as the Standards and Industrial Research Institute of Malaysia, the Penang Development Corporation, the Agricultural Bank of Malaysia, have tried to promote biogas technology through provision of technical and financial assistance to farmers interested in the construction of biogas digestors for treatment of animal wastes.

The traditional livestock rearing practice in rural Malaysia where ownership numbers a few head per farmer for the majority poses a constraint to the widespread adoption of biogas technology. However, with a more organized and coordinated programme in livestock farming, farms are becoming larger in size and complete disposal of a concentrated manure within the confines of the farms has become increasingly problematical. There exist in the country a fair number of medium and large-sized livestock farms where biogas technology can be introduced.

The Environmental Quality Act of 1974 has indirectly provided the much needed impetus for the development of biogas technology in Malaysia. Enforcement of the Act through the Division of Environment of the Ministry of Science, Technology and Environment has impressed upon pig farmers, particularly, on the need to treat piggery wastes prior to discharge into public water-ways. The urgency of treatment of the palm oil mill effluent, which is regarded as the most problematical agro-waste in Malaysia, has led to the development of huge closed tanks systems for methane gas generation. Unfortunately, the gas is not used in the mills since such mills are self-sufficient in energy through burning of palm fibres for steam generation. However, the use of the biogas generated has not been discounted for rubber drying in nearby factories in the future. While biogas generation is not the primary concern of a palm oil mill, the volume of

gas generated warrants further application studies to consider, e.g., piping the gas for the use of families of estate workers or nearby rural communities, or compressing the gas for use in estate vehicles.

The annual energy equivalent of biogas derived from animal wastes and palm oil mill effluent is approximately 700,000 barrels of oil equivalent, which is comparable to about three days oil production. Viewed in that perspective biogas does seem insignificant in our overall national energy scenario and we must immediately accept the premise that biogas programme in Malaysia cannot serve as a panacea to our national energy ills. But at the micro-level of the rural farm and palm oil mill scenario, the M$48 million/annum (US$20 million) worth of renewable energy source cannot be viewed lightly.

3. Primary Bioenergy. Wood has long been known as a good fossil fuel. However, sources of wood have become so depleted that they no longer form a feasible option for fueling public utility power or other industrial plants in many parts of the world. In Malaysia it is estimated that at the present rate of annual forest harvesting of 500,000 hectares, forest resources will be depleted within a period of about 12 years. In anticipation of this, the government is in the process of formulating forestry policies directed towards planned forest management and more effective utilisation of forest resources in line with requirements so as to maintain Malaysia's position as a major supplier of tropical hardwood. In this respect, the country has planned a reforestation programme involving a reduction in the forest harvesting rate and the planting of such quality and fast growing species as the Eucalyptus, Alrizzia and Gmelyna which can be harvested within a period of 15 years.

The amount of timber waste in Malaysia is tremendous. In any logging operation about 35% of the wood is utilized and processed into timber at a sawmill. The remaining 65% of the wood, such forest residue wood as short legs, butt logs, branches and top logs is not utilized to any significant extent. Over and above the availability of forest residual wood, the amount of mill wastes generated during the processing of timber is

also significant. Sawlog and sawn timber production in 1980 is estimated at 25.1 x 10^6 m^3 and 5.8 x 10^6 m^3, respectively.

Malaysia has approximately 2 x 10^6 hectares of land planted with rubber trees and it is estimated that the total availability of rubber wood is about 6.55 - 9.08 million tonnes per annum through the annual programmed rubber replanting scheme throughout the country.

Rubberwood is usually scarce in industrial areas where it is used as a primary fuel in brick kilns and for carbon production for steel plants. On the other hand there are inaccessible areas where the rubber wood is usually left to rot or is burnt wastefully. It is difficult and costly to transport rubber wood from the plantations with abundance of rubber-wood to areas which require them. However, if the abundant rubber wood were to be converted to charcoal then transportation would be made much more easier due to its lower bulk density. The advantage of charcoal over wood fuel is that charcoal is a smokeless fuel having twice the calorific value of wood and hence it would be more attractive for use both in the home and in the industry. Presently, there is a shortage and an increase in price of charcoal derived from mangrove timber wood especially bakau (Rhizophora sp.). Rubber wood would be a suitable substitute for charcoal production. The Standards and Industrial Research Institute of Malaysia (SIRIM) has experimented with the production of rubber wood charcoal using transportable charcoal kilns suitable for rural areas. Developing a de-centralised rubberwood charcoal industry will certainly make an important contribution toward developing the rural economy and directly towards the development of an important primary fuel source. Other forms of timber wastes can likewise be considered for charcoal production.

Rubberwood and other wood wastes, or the charcoal derived therefrom, can be pyrolysed to produce oil, char and gas which can be used in existing oil and gas fired engines with slight modifications.

The potential energy that can be derived from the forest (including mangrove forest) and rubberwood resources is conservatively estimated at

174.5×10^{12} BTU (or 30 million barrels of oil equivalent per year).

All palm oil mills in the country have a renewable energy source in the palm fibre and shells obtained from the processing of oil palm fresh fruit branches (FFB). This renewable energy source, when converted into thermal and electric energy, is sufficient to meet all the the energy demands of the mills. Fibre and shells are fed as fuel to the boilers where 1 kg of fibre/shell mixture when burnt in the boiler will produce 3.3 kg of steam at $235^{o}C$ amd 22.5 kg/cm^2 pressure.

In Malaysia only a few rice mills utilise rice husk as a fuel to operate the mills and their dryers. All National Padi and Rice Authority and new rice mills are powered by electricity and augmented by diesel oil engines. Rice husk constitutes the largest by-product of the rice milling industry and offers tremendous potential as a source of heat energy for the drying operations, including possibly the in-situ generation of electricity for other operation, within the mill or nearby industrial operations. There are plans to look into the feasibility of producing electricity from rice husk. While reducing the operation cost of rice mills through utilisation of the husk for energy generation, it has the added advantage of reducing pollution problems posed by the accumulation of husks within the vicinity of the mills.

Biowastes from the forestry, agricultural and livestock sectors are potential sources of energy and based on the extent of the availability of such wastes, the potential energy is estimated at 235×10^{12} BTU or 40 million barrels of oil equivalent per year (Table 8). While constraints in the utilization of these biowastes such as seasonal availability, geographic distribution, economics, the availability of appropriate energy technology, cultural and social acceptance, can be readily recognised, the country can ill-afford to ignore the pressing need for more effective utilization of all energy sources for her energy economic well-being.

4. Energy Farming. Malaysia has extensive plantation management experience as can be seen in the development of her rubber and oil palm plan-

tation industry. The concept of energy farming, which consists of the cultivation of selected trees or crops solely for their fuel value, could be easily extended, if the need arises. A main point to be considered for energy farming, however, is the requirement of vast areas of land which will compete with existing and future agricultural, reforestation and housing programmes. Nevertheless, the vast forest land of Malaysia has tremendous potential for the development of energy plantations even allowing for competing land uses.

Stored plant energy may be released by drying the material and burning it directly, or various processes may be utilised to obtain potential fuels such as ethanol, methane, or other gaseous or liquid fuels (Table 9).

The vast rubber, oil palm and coconut plantations in Malaysia are indirectly energy plantations themselves in the sense that through the annual replanting and harvesting of such crops, a vast amount of biomass in the form of wood and other biowastes can be converted to energy equivalent to about 23 million barrels of oil.

The sago palm has been known to grow well in swampy lands. It requires no fertilizer and is resistant to diseases and other pests. The palm can be harvested all year round and the trunks can be stored for a period of about 3 months with little loss in starch. With about 2 million hectares of swampland available which are not suitable for other agricultural activities, the concept of sago plantation for energy merits further investigation. One disadvantage lies in the long maturity period but plant breeding could shorten this considerably. Other starch root crops like tapioca, sweet potatoes, yam etc., have tremendous adaptability and can thrive on marginal land. These are potential carbohydrate resources suitable for fermentation to liquid fuels such as ethanol.

In view of the importance of sugar, the government encourages sugarcane planting with the objective of reducing our dependence on imported raw sugar. To date many of the integrated sugar projects have shown poor results. Research is being undertaken by the Malaysian Agricultural Re-

search and Development Institute (MARDI) and the integrated sugar companies to develop new cane varieties with higher yields, higher sugar content and greater resistance to pest and disease attack. This has a direct relation to the concept of the use of sugarcane as an energy crop. Plant species, like sugarcane, have the so-called C_4 biochemical system which is capable of high rates of CO_2 fixation and high temperature tolerance.

Quick growing trees that can thrive on marginal land with possibility of soil enrichment by nitrogen fixation, such as Leucaena Leucocephla, kenaf etc. are good candidates for energy plantation. It has been estimated that an energy plantation of 12,000 hectares of Leucaena would produce energy equivalent to a million barrels of oil annually.

5. Research and Development Strategy. The rapid rate of social and economic development in the Asean countries is linked directly to high energy consumption. High costs of conventional fuels have now necessitated the need to look for alternative energy resources. Renewable biomass energy offers a possible solution to this challenge. Development of this form of energy will require innovative, adaptive and collective research and developmental efforts by Asean scientists since Asean countries share many similarities in geography and resources, both human and material. The following strategy may be worthy of consideration in harnessing biomass energy for economic development.

a. Establishing an Agronomic Strategy. An agronomic strategy in the establishment of energy-crop schemes would have to be initiated. Information available in current literature covering principles of maintaining highly productive systems, methodology in field experimentations, sampling population and evaluation of results can be compiled into a detailed training manual. Preparation of inventories of local resources including crop residues and potential harvests from untilled land should also be initiated. The task can be commissioned to expedite the collection of this information resource.

Local or regional research on cropping schemes such as the identification of optimum species, selection of combinations for multiple-cropping schemes, evolution of management schemes for maximum productivity and efficient use of fertilizers should be conducted. Proven high productivity non-native species can be considered for such schemes.

b. Research and Development in Energy Conversion Processes. In support of the above agronomic research an engineering plan for recovering energy from biomass has to be formulated. The choice of the energy conversion processes will have to be carefully evaluated to ensure their suitability and harmony with the local environment. Where the conversion processes are microbiological in nature, there is merit in exploring the potential of microorganisms known to perform the desired conversions on substrates already proven to be useful. Further research needs include isolation and screening programmes for new microorganisms capable of performing the desired conversion of indigenous carbohydrate and cellulosic wastes. The development of fermentation systems and product recovery schemes would have to be initiated.

Attachment training programmes or workshops for agronomists and technologists at relevant R & D energy organisations within the Asean countries or outside will facilitate the technology transfer process to enhance local experience in implementing this form of energy scheme.

Research organisations in developing countries have achieved significant success in the generation of process know-how but the majority of them are unable to transfer these findings to the users/user industries. There is a need for effective understanding of the different stages and their optimum interactions in the energy technology transfer process for development.

TABLE 1

The Acreage (In Hectares) Of Major Crops Grown In Malaysia In 1980

Rubber	2,019,000
Oil Palm	992,000
Paddy	735,215
Coconut	349,370
Cocoa	65,100
Sugar Cane	25,300
Pineapple	10,935

SOURCES: Economic Report, 1980/81, Ministry of Finance, Malaysia

TABLE 2

Malaysia Energy Consumption (1979)

Source	Million Barrels of Oil Equivalent Per Year
1. Oil (for electricity generation)	10.5
2. Oil (for petrol, diesel, kerosene etc.)	45.0
3. Hydroelectricity	1.9
4. Firewood/charcoal	1.7
5. Gas	(Onstream in 1985)
TOTAL	59.1

Oil Production in Malaysia (1979): 103 million barrels of oil

TABLE 3

Estimated Annual Production Of Biowastes In Malaysia

BIOSYSTEM	BIOWASTES	TONNES
1. Oil Palm	Shell	490,000
	Fibre	660,000
	Bunches	1.64×10^6
	Sludge	4.92×10^6
2. Padi	Straw	1.6×10^6
	Husk	412,000
	Bran	58,000
3. Coconut Palm	Husk	207,300
	Shell	103,700
	Copra Cake	37,000
4. Cocoa	Pod Husk (dry)	28,800
5. Tapioca	Pulp (dry)	44,800
6. Sugar Cane	Bagasse	341,000
	Leaves/Tops	310,000
7. Pineapple	Bran	32,000
8. Sago	Waste	32,700
9. Maize	Stalk	12,800
	Cob	2,130
10. Groundnut	Shell	3,500
11. Forest	Sawn Timber Wastes	3.8×10^6
12. Rubber Tree	Wood	7×10^6
	(charcoal equivalent)	1×10^6
13. Animals (mainly buffalo, cattle, pigs)	Dung	5×10^6

TABLE 4

Livestock Census (1967 - 1977)

Period	Buffaloes	Oxen	Sheep	Goats	Pigs
1967	238,000	286,000	37,000	308,000	601,001
1968	227,000	286,000	36,000	321,000	692,000
1969	225,000	300,000	39,000	320,000	678,000
1970	233,000	301,000	38,000	333,000	725,000
1971	215,000	317,000	37,000	322,000	742,000
1972	205,000	330,000	40,000	310,000	733,000
1973	201,000	334,000	41,000	304,000	745,000
1974	204,000	363,000	43,000	310,000	790,000
1975	213,000	380,000	45,000	329,000	1157,000
1976	212,000	412,000	47,000	332,000	1308,000
1977	211,000	428,000	52,000	332,000	1186,000
AVERAGE:	217,000	340,000	41,000	320,000	851,000

SOURCE: Department of Statistics, 1979

TABLE 5

Constituents Of Oil Palm Effluent

PARAMETER	mg/l	
	mean	range
BOD	20,800	17,000 - 26,700
COD	57,900	42,900 - 88,250
Oil (vegetable)	6,300	4,400 - 8,000
Nitrogen	643	500 - 800
Phosphorus	110	94 - 131
Potassium	1,620	1,281 - 1,928
Magnesium	295	254 - 344
Calcium	315	276 - 405
Sodium	43	29 - 71
Manganese	3.3	2.1 - 4.4
Iron	117	75 - 164
Zinc	1.5	1.2 - 1.8
Copper	1.2	0.8 - 1.6
Chromium	0.17	0.05 - 0.43
Cobalt	0.05	0.04 - 0.06
Cadmium	0.01	0.01 - 0.02
Total solid	38,500	29,600 - 55,400
Suspended solids	18,500	14,100 - 26,400
Dissolved solids	20,400	15,500 - 29,000

TABLE 6

Biogas Composition

CH_4	- 64.5 %
CO_2	- 35.4 %
N_2	- 0.06%
C_2H_6	- 0.02%
H_2S	- 500 ppm
S.G.	- 0.896
Gross calorific value	- 646 BTU/cu. ft. at STP

TABLE 7

Biogas Production From Palm Oil Mill Effluent At Various Operating Mill Capacity

Mill Capacity (FFB Tonne/hr)	Quantity of Raw Effluent (Tonnes/day)	Digester Gas (M^3/day)	Energy Value (kcal/day)
10	100	2,000	10.6×10^6
20	200	4,000	21.2×10^6
30	300	6,000	31.8×10^6
40	400	8,000	42.4×10^6
50	500	10,000	53.0×10^6
60	600	12,000	63.0×10^6

TABLE 8

Potential Biomass Energy Sources

Biosystem	Sources	BTU (in 10^{12})	Million Barrels Of Oil Equivalent Per Year
1. Oil Palm	Shell	8.02	
	Fibre	6.34	
	Bunches	10.1	
	Sludge	0.6	4.25
2. Padi	Straw	20.3	
	Husk	5.41	4.37
3. Coconut Palm	Husk	3.0	
	Shell	1.5	0.76
4. Sugar Cane	Bagasse	0.576	
	Leaves/Tops	0.495	0.18
5. Forest	Sawn Timber Wastes	57.0	9.68
6. Rubber Tree	Wood	105	17.83
7. Mangrove Forest	Charcoal	12.5	2.12
8. Animals (Buffalo, cattle, pigs)	Dung	4.7	0.80

Malaysia energy consumption (1979): 59 million barrels of oil equivalent.

TABLE 9

Types of Raw Materials Potentially Useful For Microbial Conversion To Fuels

Ethanol	Acetone-Butanol	Butanol-Isopropanol	Acetone-Ethanol
Molasses	Molasses	Molasses	Molasses
Cellulose Pulp	Corn Cobs	Sugarcane	Potatoes
Pineapple Juice	Wood Sugars	Raw Sugar	Corn
Tapioca	Starchy Products	Wood Sugars	Peanut Hulls
Sago		Starchy Products	Corn Cobs
Sweet Potato			Wood Sugars
Yam			
Potatoes			

Summary of Organic Material Conversion Processes

Summary A

Process	Feedstock	Conversion Temperature	Conversion Pressure	Characteristics Of Process	Product Form	Process Yield (% of original mass)	Product Heating Value	Percent of Feedstock Heating Value Recovered (Assuming 8000 BTU/LB)
Fermentation	Aqueous slurry (3-20% solids)	20° to $50^{\circ}C$	Atmospheric	Fermentation of wastes or algae grown on wastes of energy crops	50 to 70% Methane Remainder CO_2	20 to 26%	Unpurified 600BTU/SCF Purified 1000BTU/SCF 330 BTU/SCF	60 to 80% 10% (Maximum) of total insolation
Biophotolysis	Aqueous slurry for algae, bacteria and/or protein/ enzyme complexes	20° to $50^{\circ}C$	Atmospheric	Sunlight produces intracellular enzymatic reduction of H_2O (2H + to H_2)	Hydrogen			
Acid Hydrolysis	5% acidified slurry (H_2SO_4 with cellulose)	20° to $50^{\circ}C$	Atmospheric	Glucose fermented to ethyl alcohol Cellulose hydrolized to glucose	Ethyl alcohol			
Enzyme hydrolysis	Aqueous slurry (cellulose rich)	20° to $50^{\circ}C$	Atmospheric	Extracellular enzymatic conversion of cellulose to sugar to alcohol	Ethyl alcohol	90%		

Summary B

Process	Feedstock	Conversion Temperature	Conversion Pressure	Characteristics Of Process	Product Form	Process Yield (% Of Original Mass)	Product Heating Value	Percent of Feedstock Heating Value Recovered (Assuming 8000 BTU/LB)
Combustion	Dried feedstock (10% to 25% H_2O)	1200° to 1300° C	Atmospheric	Augments (i.e. 5 to 20%) boiler fuel (i.e. coal oil or gas)	Heat steam can be converted to electricity		3150BTU/LB	Heat, 90% Steam, 90% Electricity, 40%
Pyrolysis	Dried feedstock	500° to 1200° C	Atmospheric	All of the gas and 1/3 of the char produced is used to supply heat in typical process. Oxygen-free environment used	Oil char gas	40% 20%	12000BTU/LB 9000BTU/LB 770BTU/ SCF	82% (60% for oil only)
Chemical Reduction	Aqueous slurry (15% solids)	250° to 400° C	1500 - 5000 psi	Uses CO & H_2 3/8 of product oil used by process	Oil	23% (2 barrels/ ton)	15000BTU/LB	37% (corrected for CO use) 65% (anticiapted, not counting oil used by process)

Summary C

Process	Feedstock	Conversion Temperature	Conversion Pressure	Chracteristics Of Process	Product Form	Process Yield (% of Original Mass)	Product Heating Value	Percent of Feedstock Heating Value Recovered (Assuming 8000 BTU/LB)
Hydro-Gasification	Animal manure (other wastes can also be used)	550°C	1500 psi	Hydrogen atmosphere produced from manure. Purification and methanation of product gas required	C_2H_6 (12%) CH_4 (42%) CO_2 (37%) or CH_4/C_2H_6	40%	1000 BTU/SCF	60%
Catalytic Gasification	Dried feedstock mixed with alkali carbonate catalyst (12-25% by wgt.)	650° - 750°C	30 to 260 psi	Nickel catalysts used for second conversion step. Inert atmosphere required	CO_2 CH_4 or CH_4 only	90%	500 BTU/SCF 1000 BTU/SCF	50% (dried feedstock) 78% (charred animal waste)

SOURCE: Solar Energy Task Force Report, Project Independence Blueprint, Federal Energy Administration, November, 1974.

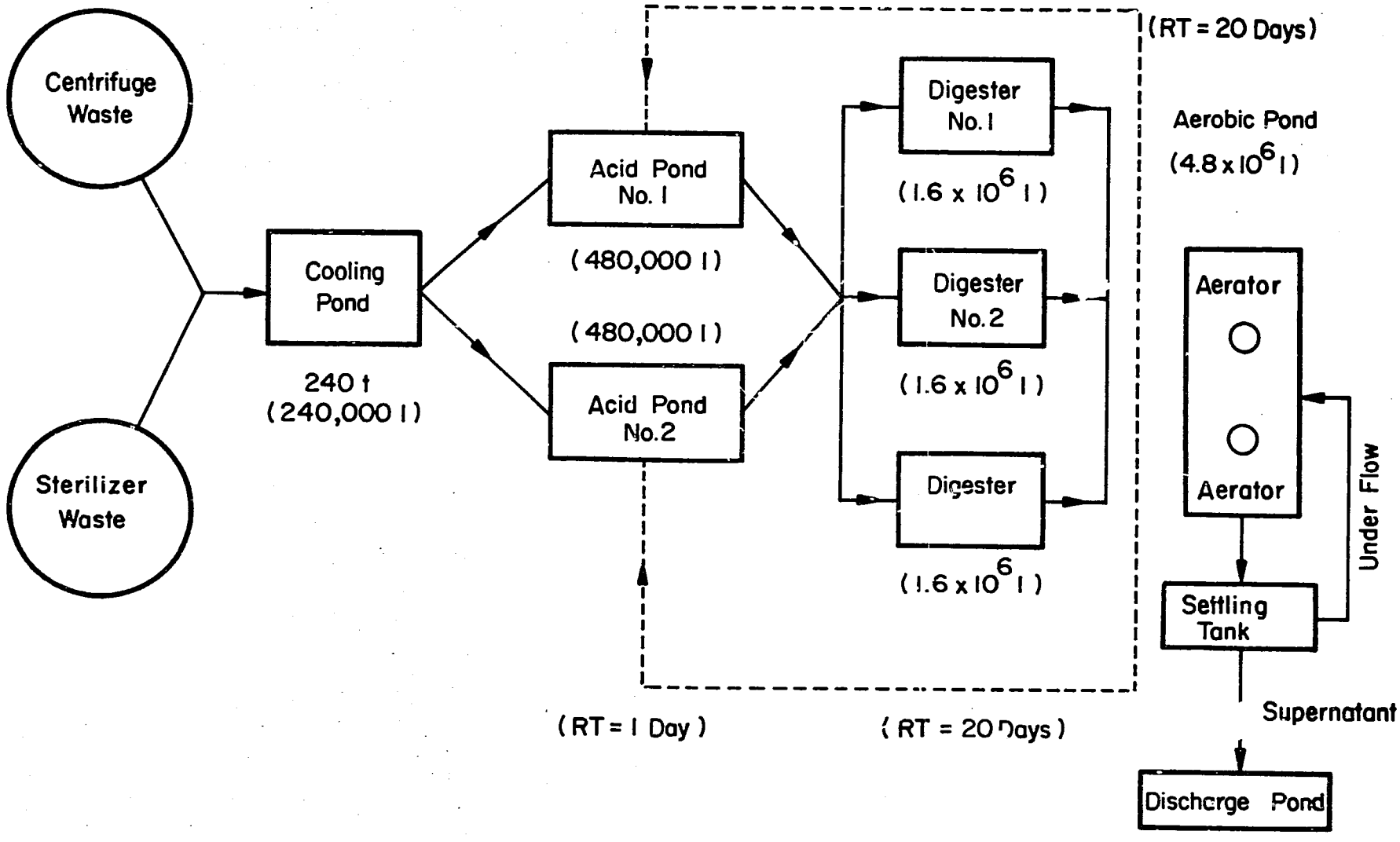

Fig. 1 — Palm Oil Mill Effluent Treatment System

Biomass Uses, Conversions, and Productions In Thailand

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Introduction

While the energy from biomass is often considered as a nonconventional type form of energy, its consumption in Thailand for various needs both in household and industrial sectors is significant and can be compared equally with the use of conventional energy from petroleum products. Statistics have shown that, as late as 1977 (1), energy uses from wood, bagasse, and rice husks accounted for 130 x 10^{12} kilocalories, equivalent to 54 percent of the country's total energy consumption. The situation today has not changed much.

In spite of this, research and development programs dealing with bioenergy to improve its use or to substitute for oil have been quite limited. It is the purpose of this paper, therefore, to elaborate on the potential role of bioenergy R & D toward formulating a dependable national energy program.

Biomass conversion technology

Thermochemical conversion of biomass into any usable form of energy, generally can be classified into three types according to technology, namely:

1. Combustion
2. Pyrolysis
3. Gasification

Each type of technology can be further discussed with special reference to Thailand as follows:

1. Combustion technology

Combustion technology is the oldest form of biomass energy conversion known to mankind. The level of technology employed today, however, varies widely depending on final applications. It is considered as the most important process in energy generation for both small and large scales. In Thailand, applications of combustion may be divided into 3 groups:

1.1 Combustion for household cooking. Surveys of rural and suburban populations show that using biomass fuels is very popular in Thailand. Results of a 1981 survey (2) on biomass consumption and distribution in rural households are shown in Table 1.

From Table 1, it is clear that the most popular fuels among rural households are firewood and charcoal while other types of fuels are used as secondary or supplemental sources.

A cooking stove is the sole hardware used for rural household combustion. Three generic types of stoves are commonly found in Thailand, charcoal, wood, and agriresidue (some prefer to call the last an economic stove). From the survey in 1981 (3), it was found that the distribution of household stoves in 50 villages of 10 provinces surveyed were as shown in Table 2.

While recognizing that portable bucket stoves are the most popular in rural households and should receive attention in performance improvements, the emphasis must also be placed on three rock stoves so that suitable models be found to replace this poor performance model. It is also interesting to note that while the country's production of paddy is well over 15 million tons annually, thus producing rice husks of approximately 4.5 million tons, the number of households using rice husk stoves has been negligible. Therefore, the promotion of rice husk stoves should be accelerated wherever applicable.

1.2 Combustion for local industries. Small scale local industries in Thailand are quite numerous and are evenly spread throughout the country. Common industries are brick making, lime making, earthen ware/fired clay/ ceramic products, tobacco curing, rubber drying/preserving, coconut palm sugar products and hand/agricultural tool forging. Process heat required for these industries always comes from traditional biomass sources. However, in general, the energy requirement per unit of production is quite high since designing of kiln or drying systems are customarily oriented toward low initial investment rather than energy conservation or long run product quality control. For example, the practice of open firing of bricks and earthen ware products still exists in many places. Improvements and/or redesigning of kilns and drying systems for these local industries would not only help reduce the demand for biomass per unit of production but also contribute to better products quality. Furthermore, there exists room for development in the field of miniboilers using biomass for local drying and curing processes.

1.3 Combustion for medium-large scale industries. Important industries using principally biomass for heat process in Thailand are shown in Table 3.

Problems relating to industrial combustion in Thailand include low efficiencies of boilers and heat exchangers. For example, in most sugar refinery plants, it was found that bagasse consumption of the boiler was as high as 95% and, therefore, left only 5% for other uses (such as for Kraft pulping and insulation board making). Practices elsewhere have shown that with good combustion and heat exchanging systems the bagasse consumption can be reduced to the level of 75 - 80% of the quantity produced.

Research and development aimed at reduction of present biomass consumption of these industries through the improvement or introduction of efficient boiler and heat exchanging system would directly contribute to: 1) the redistribution of biomass then usable elsewhere 2) the reduction of air pollution, and 3) increase the substitution for fuel oil by biomass in economic terms.

The other aspect of industrial combustion in Thailand involves the employment of steam engines. This technology has been widely used for almost a century, particularly in saw and rice mill operations. Even though the conversion efficiency of the engine is considered low, it still offers a good economic choice when compared with internal combustion engines or commercial electricity. The scope for improvements in this engine system is questionable at present.

2. Pyrolysis technology

In biomass combustion, there are certain drawbacks with biomass raw materials that may preclude its proper use. For example its bulkiness and nonuniformity in size, shape, moisture condition, and wood quality have limited economic transportation distances. The applications in metal reduction processes, meat grillings and clean flame indoor cooking require biomass energy as charcoal.

Wood pyrolysis in Thailand is widely practiced throughout the country in the form of charcoal production. Scales of production can be classified into two groups, as follows:

2.1 Small scale charcoal production for self use and for sale. This type of production is customarily practiced in the nonmarket sector in rural areas. The number of people involved cannot easily be estimated, but this is where the major portion of charcoal for cooking comes from. As an example from a 1981 survey (4), 48 out of 50 villages sampled were in the possesion of charcoal kilns and 22 villages had at least 2 types of kilns. The amount of production throughout the country for this group may be estimated to be at least 30 - 50% higher than the rural charcoal consumption shown in Table 1 since a part of the production is also sold to suburban and urban centers. Using this estimation, one can estimate that small scale rural charcoal production may reach 14 - 16 million cubic meters annually.

When considering present practices in rural charcoal production, however, it is unfortunate that the open pit or earth mould method is still predominant. Charcoal yield from this method as compared with other types

of permanent kilns is usually low and variable. Further, heat content of charcoal produced is also low (5). In this regard, the alternative or improved technology must be found and effectively promoted in order to conserve valuable wood raw material and to upgrade charcoal quality.

2.2 Large scale commercial charcoal production. The large scale production of charcoal is produced in a formal sector. Each owner has a battery of kilns ranging from 4 - 24 in continuous operation year round. All kilns employed are brick beehive type which requires operating cycle of approximately 20 - 60 days depending on type and size of wood and size of kiln. Up to the present, large scale industrial charcoal comes from two main sources, namely mangrove forest and rubber wood plantation. Level of activities and magnitudes are summarized in Table 4.

Mangrove charcoal is sold primarily for cooking purposes in both domestic and neighboring country markets. Rubber wood charcoal, on the other hand, is used exclusively as a steel reductant. To meet use specifications, therefore, the firing technique of rubber wood charcoal is quite different from mangrove charcoal. However, in both operations, the recovery of by-products is lacking.

In wood pyrolysis, besides the charcoal solid, products in the form of condensable liquid such as acetic acid, methyl alcohol and wood tar can be as high as 5 - 25% of dry wood raw material depending on the operating temperature (and pressure). These by-products, when seperated, have higher value per unit weight than that of the charcoal itself.

Research and development to find an effective and practical method for collection and separation of charcoal by-products can significantly contribute to the versatility of wood raw materials and to the conservation of energy. The other important aspect for improvement of industrial charcoal production is the possibility of employing briquetting techniques with mangrove charcoal fines and other inferior species charcoals; particularly from rubber wood since the raw material is abundant though the demand from steel industry is still limited.

3. Gasification technology

Wood, charcoal, and rice husk gasifiers in Thailand were said to be used during and after World War II in connection with fueling engines for buses, passenger boats, and small rice mills. In the past few years, attempts have been made once again to promote the gasification technology, particularly for small scale rural electrical generation (6,7). Small downdraft gasifier units, developed locally to drive the 1500 cc gasoline engine coupled with electrical generator load of 5 - 10 kilowatts, have shown very promising results for short term tests using either charcoal or firewood. However, starting the gasifier and the engine requires experienced operator. Potential applications waiting for this technology include stationary farm machines, water lifting, cargo hauling boats, and village electrification. R & D on this technology to accomodate various needs and long term dependability must be intensified since its application not only help the substitution of petroleum fuels but also contribute to the establishment of biomass plantations.

Biomass Production

Thailand, like other countries in this region, suffers rapid depletion of forest resources, largely due to the uncontrolled conversion of forest land to agricultural use. It has now reached the point that gathering firewood for household consumption has become a problem for many rural villages. The rate of forest depletion in the past 20 years in shown in Table 5. In spite of the claim that energy from biomass is renewable, so far, it is still doubtful whether a nation can make it truly renewable since production has fallen far behind the consumption. Moreover, the establishment of a biomass plantation is often faced with complex social and economic problems.

At present, research and development programs, particularly from the public sector, have not fully geared toward the promotion of biomass for energy.

Biomass energy production potential

While the establishment of industrial plantation for construction timber would take at least 20 - 30 years, the establishment of biomass plantations for energy and fiber products will take a much shorter rotation; 5 - 10 years. Growth conditions of any tree, however, depend on species and variety, soil condition, climate, silvicultural practice, and level of management. With those constraints, growth conditions of natural forest and tree plantation in Thailand can be as shown in Table 6.

From Table 6, it is encouraging to note that the growth rate of tree plantations is many times higher than the natural forest. When considering land scarcity and the public pressure on forest land for other uses, the promotion of forest biomass plantation is probably the only way to solve the problems of environmental degradation, wood product and biomass energy shortages simultaneously.

However, to promote biomass production in larger scale, there remain a series of problems to be solved through integrated R & D programs, these include tree species selection and improvement, nursery techniques, plantation design and management, marketing of biomass produce, financial investment and return, as well as method and strategy to induce more private participation and etc.

Biomass energy research and development

Programs for biomass energy R & D which are being carried out by various Thai government agencies and by the private sector in the attempt to alleviate some of those problems previously mentioned can be summarized as follows:

1. Village wood lot. The purpose of this project is to evaluate the reaction of village people in the promotion of wood lots near their village for community uses. It is anticipated that if this demonstration project is successful, extensive operations in the future can solve firewood and

charcoal shortages for all villages. At present 10 - 50 hectare wood lots are being established at various villages in North-eastern Thailand. This R & D project is targeted to cover the establishment of approximately 1000 ha. within 3 years.

2. Private mangrove wood lot. Small scale forest biomass plantations have been in existence for years in provinces along the tidal coast of the Gulf of Thailand particularly in Petchaburi, Samutsakorn, Samut Songkram, and Nakorn Sri Thamaraj. In those provinces a number of private owners raise Kongkang plantations (Rhizophora spp.) with the plot sizes ranging from 2 - 100 ha. However, cutting rotation is in the order of 8 - 12 years for the tree to reach the average diameter of 10 centimeters since planting space is close and thinning is seldom practiced. Wood harvested is either ssold as firewood and props for orchard and temporary construction or converted into cooking charcoal for nearby urban and suburban markets.

3. Private fast growing tree plantation. In recent years, the establishment of Casuarina plantations has become popular among private land owners particularly in central provinces of Patumtani, Ayudhaya, Chonburi, Chacherngsao, Rayong, Samut Songkram, Samut Sakorn, Nakorn Pathom, and Rajburi. A rough estimate of Casuarina plantations in these areas, at present, may exceed 10,000 ha. Since the species is well adapted to the acidic heavy clay soil of the central plain, the tree can easily reach a diameter of 15 centimeters within 5 years with the average yield of approximately 200 m^3/ha. The primary purpose of this tree plantation is for foundation pilings and struts in scaffolding works for which the demand is quite high in the Bangkok area. A good portion of the timber left after the harvest, especially crooked stems, top trimmings, and branches, has been widely used for firewood and charcoal making.

4. Cooking stove improvement. The purpose of this project is, a) to evaluate performance of stoves presently used in Thailand. b) to develop or improve the design to enhance fuel saving in normal Thai household cooking, particularly on charcoal and wood stoves which are most popular. c) to encourage the substitution of charcoal and wood stoves with

the economic type that use lower valued biomass such as rice husk, other agri-residues, leaves, and household ligneous scraps and d) to make a public campaign for the use of better performance stoves.

5. Small scale charcoal production improvement. As previously mentioned, the production of cooking charcoal in rural areas is normally made by an open pit method. With respect to energy conservation and technology, this method is inferior to others. The purpose of this R & D project, therefore, is aimed at solving the problem through, a) investigation of various small scale charcoal production technologies presently employed in Thailand and in other countries. b) establishment of a research center to evaluate and improve charcoal production technology appropriate to Thailand rural conditions, and c) promotion and training of rural people with better charcoal production technology found. At a later stage, the project will investigate methods for recovery of charcoal byproducts at large scale commercial charcoal production centers and also for the briquetting of charcoal fines.

6. Agglomeration of saw dust and rice husk. Research and development on making pressed log from sawdust and rice husks for firewood was initiated by Forest Industry Organization, Royal Forest Department, and Thailand Institute for Science and Technology Research with the collaboration of private groups. At present, progress has been made in developing an inexpensive screw press locally for industrial uses. The machine developed so far can be designed to suit production capacities ranging from 100 - 400 kg/hr/machine. There are at least 6 entrepreneurs producing sawdust and rice husk press to logs for sale in Thailand at present. Further R & D is required regarding the minimization of electrical energy input per unit output, increasing the durability of pressing screw and die, as well as obtaining ideal pressing conditions for various and/or nonuniform raw materials.

7. Pyrolysis of rice husk. The concept of this project is to increase the use of rice husks for energy in the form of storable liquid and compressed char. R & D activities involve the design and construction of a

pyrolytic converter and a system that can be operated on a self sustaining basis from the balance of gas phase products.

8. Development of biomass gasifier. Among various biomass gasifier designs being proposed and developed in recent years in Thailand, none has a full technical report on its performance. It is the purpose of this R & D project to bring together those relevant designs and informations under one intensive long range development and testing programs. At this initial stage, research activities are concentrated on small size (5 - 10 kwe) gasifier for rural applications.

9. Production of physic nut seeds for engine oil. The physic nut is a fast natural growing tree of Thailand belonging to the species Jatropha curcus Linn. It is normally found to grow healthily even in the poor soils of the North-eastern region and can be propagated easily either from seeds or by cuttings. According to preliminary tests conducted recently, the oil from its seed (as high as 25 - 30% by weight) can be effectively used as a substitute for diesel fuel without any engine adjustment or modification. With this substitution potential, the R & D project is set forth to evaluate the socio-economic possibility in establishing physic nut tree plantations particularly among farmers so that they will be less dependent of commercial fuel for their farm machines. In addition, the study of properties and characteristics of physic nut seed oil and the method for oil extraction and improvement are also in progress.

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TABLE 1

Noncommercial Energy Consumption
In
Rural Households in Thailand (2)

Fuel Type	Annual Consumption	
	Per Capita	Total x 10^6
Firewood, m^3	0.41	13.40
Charcoal, m^3	0.31	10.79
(Charcoal in roundwood equivalent), m^3	0.54	17.66
Rice husk, kg	24.56	803.0
Rice straw, kg	5.37	171.0
Coconut branch, kg	1.69	62

TABLE 2

Stove Census by Number
Of
Households in Thailand (3)

No.	Stove type/kind	Type of Fuel	Number of Household	% of Total
1	Portable bucket	Charcoal/firewood	1521	71.0
2	Three rock	firewood/agr.res.	394	18.4
3	One port cement/clay/ earth	firewood/agr.res.	31	1.5
4	Multiport cement/clay/ earth	firewood/agr. res.	18	0.8
5	Electric and rice cooker	commercial	108	5.0
6	LPG gas	commercial	17	0.8
7	Biogas	animal waste	15	0.7
8	Economic cement/ fireclay	mostly rice husk	5	0.2
9	Other	-----	34	1.6
	TOTAL		2141	100.0

TABLE 3

Type of Industry, Number of Mills, and Technology/Hardware

For

Medium-large Scale Biomass Combustion in Thailand

Type of Industry	Annual Raw Material Uptake 10^6	Number of Mills	Type of biomass used	Technology/ Hardware
1. Sugar refinery	25-35 ton	198	bagasse	boiler, extractor, dryer
2. Rice mill	15-18 ton	41,714	rice husk	boiler, steam-engine
3. Wood Processing				
- Sawmill	2.5-5 m^3	464	mill slabs, sawdust	boiler, steam-engine
- Veneer & plywood mill	0.2-0.4 m^3	23	bark, offcut, trimming	boiler, dryer, hotpress, steam cooking vat
- Fiberboard & particle board mill	0.1-0.12ton	6	bark, trimming, degraded wood	boiler, defibrator, dryer, hot press
- Match factory	na	11	bark, offcut, trimming	boiler, dryer
- Lumber drying & planing mill	.15-.2 m^3	100*	planer shaving	boiler, dryer
- Furniture & joinery plant (large size)	.12-.17	337	shaving, sawdust, sander dust	boiler, dryer, hot press
- Other woodwork factories	na	2405	shaving, sawdust, sander dust	----
4. Fishmeal plant (large size)	0.10 ton	12*	rubberwood	boiler, dryer
5. Provincial distillery plant	na	na	firewood	boiler, distiller

SOURCE: Department Of Industrial Plant and Royal Forest Department

* Author estimated number

TABLE 4

Large Scale Industrial Charcoal

Production Activities in Thailand

		Mangrove	Rubber wood
Forest or plantation area	km^2	2,198	17,600
Annual timber harvested	m^3	700,000	6,800,000
Annual timber used for charcoal production	m^3	700,000	300,000
Number of charcoal kilns		1,280	258
Size of kilns; range & (ave.)	m^3	70-360(150)	60-80(70)
Total capacity kiln	m^3	195,000	21,000
Total charcoal produced	m^3	350,000	120,000
	ton	231,000	25,000

SOURCE: Royal Forest Department 1981.

TABLE 5

The Comparison of Forest

And

Non-forest Areas of Thailand

	1961		1972		1980	
	km^2	%	km^2	%	km^2	%
Country area	514,800	100	514,880	100	514,880	100
Forest area	273,600	53.1	199,360	38.7	128,720	25.0*
Agricultural area	78,880	15.3	175,040	34.0	270,400	52.5
Others	162,320	31.6	140,480	27.3	115,760	22.5
Forest/agri. area ratio	3.5 : 1		1.1 : 1		0.5 : 1	

SOURCE: Royal Forest Department and Department of Land Classification.

* Unofficial statistics

TABLE 6

Annual Increment Potentials

Of

Forest Tree Grown In Thailand

Natural forest	
Southern moist evergreen	2 m^3/ha/yr
NOrthern mixed deciduous	1.25 "
N. & N.E. dry diptercarps	0.5 "
Mangrove forest	8.0 "
Tree plantation	
Eucalyptus camaldulensis (moderate management 5 yrs. old)	18 - 75* m^3/ha/yr
Casuarina junghuniana (intensive management 5 yrs. rotation)	13 - 44 "
Other fast growing species (poor management 10 yrs. old)	10 - 15 "
Teak (moderate management 15 yrs. old)	9 - 12.5 "
Mountain pine (Pinus khesiya) (moderate management 15 yrs. old)	6 "

SOURCE: Royal Forest Department

* Primary estimate based on data available

Biomass Energy Report

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Resource Status

Despite the poor quality of data, we found that non food energy consumption from biomass among ASEAN countries is quite significant both in quantity and importance especially in rural areas. Increased use of biomass energy is also a generally stated goal of the energy programs of these countries. Its distinct advantage, of course, is its renewability.

Table 1 shows the presently available biomass resources among ASEAN countries both in kind as well as quantity.

The present states of biomass conversion technologies among ASEAN countries is shown in Table 2. As can be seen from the Table, biological energy conversion has yet to achieve commercial application while combustion, pyrolysis, and gasification are all currently used with renewed emphasis on improved efficiency.

Problems/Constraints

A. Production Aspect

Constraints on biomass production for energy assumes several dimensions including socio-cultural, silvicultural, and ecological.

A1. Socio-cultural - Insecurity of land tenure status especially for long term tree crops as well as incompatibility with prevailing cultural patterns are constraints to community acceptability of energy plantations. Economic viability as well as equity issues are also important considerations for production of biomass for energy conver-

sion. Included in calculations of economic viability are the risks associated with long project lead times and wide potential variability of both costs and revenues.

A2. Silvicultural - silvicultural technology is involved in selecting the proper plant species which will be most adapted to specific agroclimatic zones. Cultural practices necessary for establishment and management of energy plantations is still inadequate.

A3. Ecological - little is known about the stability and sustainability of energy plantations as well as its externalities; soil erosion, genetic instability, pollution, pest and disease problems and habitant disturbance.

B. Technology for Conversion

It is generally recognized that there is a need to increase the energy conversion efficiency of biomass. More specifically, the following problems were identified:

B1. Bioconversion - low conversion efficiency and inefficient design and operation of biogas digesters for different types of raw materials.

B2. Combustion - poor design resulting in energy inefficient stoves, kilns and boilers.

B3. Pyrolysis - poor or improperly designed equipment as well as lack of proper knowledge of operation resulting in poor recovery of products as well as by-products. In rural areas, this is very relevant to charcoal production.

B4. Gasification - improper design especially with regards to types of raw materials used.

B5. Hydrocarbon & Oil Plants - problems on extraction and product instability.

C. Technology Transfer and Adoption

Technology transfer and adoption occur at various levels; intra - or within countries as well as inter - or among ASEAN and other countries.

Slow or low levels of biomass energy technology diffusion and adoption is a problem. It is usually associated with either low absorptive capacities of clienteles and lack of adequate supportive mechanisms to promote technology adoption. Low absorptive capacity can be attributed to lack of skills, motivation and knowledge on the part of target clienteles. Inadequate support including poor infrastructure could be due to inadequate financing, planning, poor implementation and absence of effective monitoring and evaluation systems. Problems may even start with the inability to perceive the needs of the clientele as well as the constraints posed by the environment.

Recommendations

Based on identified problems and constraints, the following are the group's recommendations:

A. Researchable Areas

Energy Plantations

1. Integrated study on different types of energy plantations to cover the silvicultural, socio-cultural and ecological aspects. Research of this nature must necessarily be interdisciplinary.

2. Comparative studies of energy plantations made up of natural species versus exotic or introduced species.

3. Studies on parameters for effective monitoring and evaluation of the impact of energy plantations.

4. Screening and selection of promising tropical species of hydrocarbon and oil plants.

5. Silvicultural and yield studies of hydrocarbon plants at plantation scales.

6. Development of process technologies for extraction and use of hydrocarbons as fuel oil substitutes.

Thermo-Chemical Combustion

1. Improvement of cooking stove efficiency should be aimed at reduction of firewood and charcoal use. Lower value biomass such as agri-residue should be evaluated as substitutes.

2. Improvement of physical properties to facilitate handling of agricultural/mill residues through agglomeration or biquetting of sawdust, rice husks and charcoal.

3. Improvement of kiln designs to enhance conversion efficiency particularly for local industries such as lime, brick, ceramics/earthenware, tobacco and rubber curing.

4. Improvement of boiler system designs to enhance conversion efficiency in medium - large scale industries such as sugar refineries, rice mills, wood products, fish meal plants and distilleries.

5. Studies and applications of selected commercial conversion technologies suitable to rural development.

Pyrolysis

1. Improvement of small scale charcoal production technique to increase yield and quality.

2. Development of continuous self-sustained charcoal production systems for use with plantation - grown firewood.

3. R & D on pyrolysis or gasification of wood and other cellulosic materials by fluidazation.

Gasification

1. Development and introduction of reliable small scale wood - fed gasifiers in the region.

2. Design/improvement of biomass gasifiers to accomodate alternative raw materials.

3. Introduction and/or development of advanced gasification technology for dendrothermal power plants and other large scale industrial uses for improved efficiency and reduced pollution.

4. Techno-economic studies of wood gasification system to replace oil (up to 80 or 90%) in oil-fired steam boilers.

Bioconversion

1. Comparative studies of different types of biogas digesters with varied raw materials inputs.

2. Temperature study for increasing rates of bio-energy conversion.

3. Utilization of liquid-cellulose materials for alcohol production.

4. Screening microbial strains which can give high yields of amylase from cellulose.

5. Comparative studies of different methods for increasing fermentation efficiency by yeast recycling and improved recovery of by-product.

6. Improved distillation or separation methods for increased alcohol concentrations.

INFORMATION DISSEMINATION

There is a need to enhance information dissemination and to promote institutional collaboration both within the various countries as well as among ASEAN countries. Recommended activities to promote these goals

are the following:

- regular publication of a newsletter devoted to energy
- professional exchange
- cooperative research
- joint seminars/training/workshops

It is probably necessary to evaluate existing ASEAN areas of cooperation to see if these activities could be incorporated into such a program or whether there is a need to form a new structure to carry on the identified activities.

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TABLE 1

Biomass resource available among ASEAN countries

Biomass Type	Quantity (x 10^6 Tonnes/yr.)					
	Indonesia	Malaysia*	Philippines[a/]	Singapore	Thailand	
					Potential	Consumption
A. Fuelwood						
Tree biomass	2.4[b/]	7.00			22-25	22
Residue		3.80			1.90	0.70
B. Agricultural Residue			0.1 proven 5.6 probable			
Rice	40.0	2.00	1.4 x 10^3 potential		4.5	0.8-1.5
Oil Palm	1.0	3.00			-	-
Coconut		0.35			-	0.06-0.12
Corn	0.80		Note: more than 5M hectares of marginal grassland area is also being looked at as a potential energy plantations		3-4	
Sugar cane	3.0	0.65			4-6	3.5-4.0
Pineapple	-	0.03				
Tapioca	1.20	0.05			10-15	-
Others	0.90	0.08				
C. Waste						
Animal	1.0	5.00			1.25	-
Industrial	-	-				

* Actual Production

a/ In Million barrels of oil equivalent (MMBOE) per year which includes solar E.

b/ Only in Java

TABLE 2

Levels of technology for Biomass energy conversion among ASEAN countries

Type of Conversion	Indonesia	Malaysia	Philippines	Singapore	Thailand
A. Biological					
Biogas	Small Scale (Implementation)	Small Scale (Implementation)	Commercial		Implementation Family level
Alcohol	R & D	Big Scale R & D (Implementation) Commercial; R & D	Commercial (molesser substrate)		Big Scale (R&D) R & D
B. Thermo-chemical					
Combustion Pyrolysis }	limited (Implementation)	Commercial R&D (Small)	Commercial (wood industry) Commercial		Commercial Commercial
Gasification	R & D	R & D	Commercial (Vehicles)		R & D
C. Others					
Hydrocarbon plants	R & D	R & D	R & D		R & D
Plant Oils }		R & D	R & D		R & D

An Overview of the Status of Coal Conversion Processes

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Introduction

A summary of the contribution of primary fuels to energy utilization in the U.S.A., illustrated in Figure 1, shows that with the turn of the century, coal replaced wood to become the primary source of energy (by direct combustion and gas manufacture).[1] However, during the last 60-70 years, the increased availability of inexpensive, energy-intensive, and clean-burning oil and gas caused a precipitous decline of coal as a major fuel source. In the same period, interest in coal conversion and utilization became sporadic and continued until the first oil embargo, nearly a decade ago. Since then, in the U.S. the interest in coal conversion has been revived, but the approach to develop the much-needed indigenous coal-based synthetic fuels industry is still less than satisfactory. The world as a whole has witnessed a similar coal utilization pattern as shown in Figure 1.

The last five decades have seen an unprecendented advancement of industrial growth and a material increase in the quality of life, which could be primarily attributed to inexpensive oil and gas. Significant developments in chemical processing industries - those based on petrochemicals - have led to efficient gas-solid contacting methods, high-pressure reactor designs, and improved reactor operation and control. During this period, efficient energy transportation, storage and utilization systems were also developed and are already in place in many parts of the world.

Coal conversion research in the last four decades has matured into processes for producing clean-burning fuels from coal.

It is interesting to note that of the total world fossil energy resources, over 75% of the energy is contained in the form of coal resources (Table 1).[2] In the U.S. coal constitutes over 80% of the proven and recoverable fossil fuel resources (Table 2) with an inherent energy content equivalent to the Middle East's remaining recoverable reserves of oil and gas.[2] However, the current energy consumption pattern of the world and the U.S. illustrated in Figures 2 and 3, respectively, show that coal contributes only about 20 to 30% of the energy derived from the primary fuels. Lee[2] considers this as "...major mismatch...between what we have most of and what we have been using the most." Reviewing the proximity of resources to the major population regions of the country (Table 3). Lee observes that..."Many densely-populated developing countries lack significant indigenous energy sources...in total contrast, nations in the Middle East, which are sparsely populated have tremendous energy resources...the developing countries which aspire to a high standard of living...must compete with the developed countries for allocation...from few energy rich global areas. This global mismatch of resources and consumption aggravates world tension and leads to the formation of power blocs." The unpleasant consequences of being overly dependent upon politically sensitive resources became evident during the 1973 oil embargo. In the years to follow, the interrelationship between standard of living, national security, and energy self sufficiency has been assigned a very high national priority by several countries. Consequently, oil importing countries should consider developing policies less sensitive to global events and extending their imports to include the abundant fossil fuel, coal. The world nations have, in general, inadequately explored and underutilized nonrenewable fuels (eg. coal, shale and nuclear fuel) and renewable fuels (eg. forest and crop residues). It is proposed to use these fuels as transition sources of energy until long-range alternatives are developed.

What is coal?

Coal is a carbonaceous rock derived by metamorphosis of plant debris. The plant material usually deposited in swamps, covered with layers of

more plant material, flooded with water contaminated with organic and inorganic compounds, and compacted by massive overburden for centuries to form coal. Since the origin of coal is susceptible to a wide range of conditions, coal is heterogeneous in its physical and chemical properties.

Coal primarily consists of C, H, O, N, S, and a mixture of mineral constituents. The coal mineral matter consists of minor elements (eg. compounds of Si, Al, Fe, Ca, Mg, Na, K, P, Ti) and trace elements (eg. compounds of Be, Cr, Cu, Mn, Ni, Pb, V, Zn, Hg). Some typical elemental and mineral compositions of coal are shown in Tables 4 and 5 along with the measured heating values. Over the last century, extensive research was conducted to understand the structure of coal. Some examples of the models developed are shown in Figures 4 and 5. Due to the wide variation in the type of plant materials and the conditions over which coal is formed, there is no single formula for coal. However, the information gathered on the extensive number of coal samples available around the world and the experience gained from coal conversion over 150 years has transformed coal utilization from an art to a science.

Coal Conversion and Utilization

In the development of alternative energy conversion and utilization methods, it is essential to understand the technoeconomics as well as the environmental impact of the energy conversion processes. Since the ultimate purpose of energy generation is to extract and transform the heating value of coal, it is asked on occasions whether coal could be burnt directly instead of going through a coal gasification or liquefaction process. As stated earlier, coal consists of complex organic compounds in combination with sulfur, nitrogen, and a mixture of inorganic compounds as mineral matter. Upon direct combustion some of the coal constituents are transformed to potentially harmful emissions.[3] A summary of the major emissions from coal combustion is given in Table 6. For comparison, emissions from combustion of coal, natural gas and fuel oil are included in the same table. There is no doubt that converting coal to a form similar to natural gas or fuel oil, and then burning these substitute fuels

would significantly lower levels of emissions. In addition, the clean fuels resulting from coal conversion are easy to store and transport and are adaptable to a wide range of coals.

Principles of Coal Conversion

The compositions of coals and some fuels, characterized by the H/C atomic ratio, are given in Table 7. This table implies that coals could be converted to substitute fuels either by adding hydrogen or rejecting carbon. In practice, coal conversion involves both addition of hydrogen and rejection of carbon as carbon dioxide. The multitude of coal conversion processes, including gasification and liquefaction processes, differ in the methods by which the H/C ratios in the feed materials are transformed to the desirable ratio in the fuel product. This is achieved not only by using different contacting mechanisms between reactants, but also by selecting appropriate operating conditions of temperature and pressure. Lee[2] observes that coal conversion should be considered as a "fuels refining" operation. Similar to an oil refinery which produces both gases and liquids. It is well known that all gasification processes produce some liquids and all liquefaction processes produce byproduct fuel gases. Also, almost all of the liquefaction process schemes consists of a gasification process step, primarily to produce hydrogen which is used to hydrogenate coals to increase their H/C atomic ratio. Hence, a study of coal utilization should consider all aspects of it, including coal gasification, liquefaction, and combustion.

Coal Gasification Processes

The primary reactants for coal gasification include coal, water, and air (or oxygen) or an external heat source (at a minimum of 1800°F). Using air as a partial oxidizing medium results in a low-Btu gas (LBG) consisting mostly of CO, H_2, CO_2 and N_2. The product gas is diluted with nitrogen derived from reactant air. The coal gasification processes using oxygen or an external heat source could produce either a synthesis gas

(SYG), a mixture of CO and H_2, or a medium-Btu gas (MBG) which is essentially a synthesis gas mixed with CH_4 derived from coal. Simplified schematic drawings of the LBG, SYG, and MBG/HBG coal gasification processes are shown in Figure 6. The most common applications for the coal derived fuel gases are summarized in Table 8.

It should be noted that MBG could be converted, using commercial technology, to SYG and like MBG, SYG can also be catalytically upgraded to HBG which is considered to be a substitute for natural gas.

A summary of commercially available first generation coal gasification processes is given in Table 9. These gasifiers are fairly large in size. For example, each Lurgi Mark IV (4 meters ID) gasifier at SASOL II in Secunda, South Africa, has a rated capacity of 1000 tons per day (TPD) and the four-headed Koppers-Totzek gasifiers in India and the Winkler gasifiers in Turkey can also handle up to 1000 TPD of coal.[4]

The basic process principles derived from the first generation coal gasification technology have been significantly improved, employing advanced solid-fluid contacting mechanisms (e.g., entrained and fluidized beds) and high pressures. In constrast to the existing first generation processes the advanced or second generation processes under development are known for their abilities to handle a wide variety of coals, high throughput rates, improved efficiency and hence, lower costs, and minimizing effluents disposal to the environment.

A summary of the second generation processes, tested at least at a pilot-plant scale, is given in Table 10.[2]

Coal Liquefaction Processes

In general, bituminous coal with 82 to 87% (d.a.f.) carbon content are well suited for liquefaction. However, coals of lower rank can be successfully liquefied. Coal liquefaction processes can be broadly classified into:

a. Pyrolysis and Hydrocarbonization
b. Donor Solvent Extraction
c. Catalytic Liquefaction
d. Indirect Liquefaction Processes

Figures 7 and 8 illustrate simplified process schemes for the four types of coal liquefaction processes. A brief description of these processes follows.[2,5,6]

a. Pyrolysis and Hydrocarbonization. In this process coal is heated in the absence of air (pyrolysis or carbonization) or in the presence of hydrogen (hydropyrolysis or hydrocarbonization) at temperatures of 800° to 1600^{0}F and pressures up to 100 psi. The products of coal decomposition are richer in hydrogen compared to coal and include light hydrocarbon fuel gases (eg. CH_4 and C_2H_6) and aromatic tars. The residual char, lower in hydrogen and often enriched in sulfur compared to coal, could be either used as a low-grade boiler fuel or gasified to produce a hydrogen rich gas. The product distribution is dependent on the rate of heating, operating temperature and pressure, gas-solid, contacting method. The total conversion to gases and tars usually ranges from 30 to 50% by weight of coal. A ton of coal yields about a barrel of tar and 1 to 2 x 10^6 Btu of fuel gas.

Donor Solvent Extraction: In this direct non-catalytic coal liquefaction process, loosely bound hydrogen atoms in a hydrogen donor solvent (eg. anthracene oil, tetralin, etc.) is transferred to coal in the presence of a hydrogen atmosphere, thus increasing the H/C atomic ratio of coal. In the liquefaction process, the three phases of coal, donor solvent, and hydrogen are usually heated at mild conditions of 750 to 850°F and at 1000 to 3000 psig. External heating weakens the bonds of the coal structure and the high pressure favors incorporation of hydrogen into the weakened coal structure. An alternative approach includes hydrogenating the donor solvent in a separate catalytic hydrotreater and recycling it to the extraction step. It has been found that recycling the coal mineral matter to the extraction step promotes catalytic hydrogenation to produce

light aromatic oils. The nature of extracted coal depends upon the method and operating conditions of the process; the extracted coal could be a solid deashed material or a substitute fuel oil at room temperature. The conversion to deashed coal or substitute liquid fuel ranges from 50 to 60% by weight of coal which corresponds to the equivalent of 2 barrels of oil/ton of coal.

Catalytic Liquefaction: In the catalytic liquefaction process, coal slurried in a process derived oil, mixed with either disposable or recoverable catalysts, is heated in presence of hydrogen at about 850°F and 2000 to 5000 psig. Conversions in excess of 60 percent are achieved producing about 3 barrels of aromatic oil/ton of coal.

Indirect Liquefaction: The three liquefaction processes described above would involve the critical process step of seperating unconverted coal and its mineral matter from coal derived substitute liquid fuel. In the indirect liquefaction process coal is completely gasified, for example with steam and oxygen, to produce essentially a synthesis gas, which is cleaned to remove particulate matter, and sulfur compounds. The mixture of CO and H_2 is subject to water-gas shift, to adjust the H_2/CO ratio, cleaned to remove CO_2, and catalytically processed to produce sulfur and nitrogen-free aliphatic and olefinic liquid hydrocarbons.

The products of coal liquefaction include fuel gases and substitutes for gasoline, diesel fuel, and fuel oils. The applications for these products are well known.

Some of the salient features of selected first generation commercial processes and the advanced second generation coal liquefaction processes are summarized in Tables 11 and 12 respectively. Compared to the first generation processes, the second generation processes use lower operating pressures, convert coal to lighter substitute liquid fuels which require less refining, superior catalysts (in catalytic processes), and liquid fuels with little or no sulfur, nitrogen, and oxygen compounds.

Fluidized Bed Combustion of Coal: In the last two decades considerable research was conducted to develop fluidized bed combustion of coal, at atmospheric pressure and at elevated pressure (150 psi) as an efficient alternative to conventional burning of coal. The advantages of fluidized bed combustion include:[7]

- Ability to handle high sulfur coals with low SO_2 emissions
- Reduced combustion temperature (1400° to $1800^{\circ}F$ versus $3000^{\circ}F$ for conventional combustion)
- Reduction of NO_x emissions
- Burn a wide range of fuels
- Simultaneously burn low grade combustibles (e.g. agricultural, forest, and industrial wastes)
- Reduction in combustor size because of high in-bed heat transfer rates and hence reduction in capital and operation costs
- Suitable for constructing small modular units of about 150,000 lbs/hr of steam
- Easy disposal of granular ash
- Reduced ash slagging or deposition in the boiler eliminating the need for soot blowing

The additional advantages of pressurized fluidized bed combustion include:

- Higher combustion efficiency
- Higher volumetric heat release
- Simpler design with fewer coal feed points
- Improved SO_2 capture and low NO_x emissions
- Suitable for combined cycle applications

A simplified schematic of an atmospheric fluidized bed combuster is shown in Figure 9. Limestone and coal are fluidized with combustion air and the heat released is absorbed by a submerged heat transfer coal to

generate steam. The SO_2 released from the oxidation of sulfur contained in the coal is absorbed by the limestone which in turn could be withdrawn either to discard or regenerated and recycled to the combustor. Dolomite is considered an alternative sulfur absorbent limestone. To burn coals free of sulfur, other inert bed materials, such as alumina, zirconia, mullite etc., could be used. The combustors are usually operated with 2 to 6 feet bed heights, at 1400° to 1800°F using superficial gas velocities of 3-12 ft/second, and Ca/S ratios of 2 to 4.

Pressurized fluidized bed combustors are operated at about 150 psi and due to the high volumetric heat rel ase they are usually much smaller in size compared to atmospheric fluidized bed combustor for similar heat loads.

With the extensive research conducted in the U.K., U.S.A., Germany, and China, the experts in the field believe that fluidized bed combustion is at the threshold of commercial readiness.[8] This implies that there are some inadequacies that need to be resolved to add credence to the technology. These include, demonstration of long-term performance in the range of 10-20,000 hours in industrial size units, simpler coal feed systems, simpler and efficient sorbents regeneration methods, improved design of water-tube banks to minimize the stresses, use of a variety of coals, improved design of water-tube banks to minimize the stresses, use of a variety of coals, improved start-up procedures, load following capabilities, design of cyclones for pressurized operation, and sound engineering designs for scale-up models.

Slurry Firing of Coal: The interest in combustion of coal-oil or coal-water slurries has been sporadic, even though the idea was conceived nearly a century ago. Usually coals are ground to permit 70% to pass through a 200 mesh, mixed with oil and/or water to produce stabilized slurries. The oil could be a crude or residual fuel oil. The resulting fluid fuel has several advantages including easy handling, utilization of all types of coals, greater ease of burning, and most importantantly extension of limited oil supplies.

In the U.S. several major public utilities have demonstrated the feasibility of commercial operations with coal-water slurries. Tests have shown that a suitably designed cyclone furnace can be fired directly with slurries of high volatile coal with solids concentration of about 60%.[9] Adiabatic reaction temperature of 3500°F is estimated and slag discharge did not encounter any special problems. However, because of the high moisture in the feed and a lower exit gas temperature, the overall thermal efficiency is reduced by 4 to 5%.

Coal-oil slurries are easier to burn than coal-water slurries. However, these slurries when used in existing oil-fired boilers would lead to derating the boiler capacity. Some examples of boiler modifications include ash handling provisions and spacing of tubes in the convective section because of the observed differences in gas temperatures and velocities.

Recently, the U.S. DOE has initiated several programs to determine the long-term operational problems with slurry firing of coal.

Coal Conversion Programs Around the World

The only nation with an active and concerted effort to commercially process coal to substitute fuels is South Africa. Since this country has no significant oil deposits, it initiated a successful program in the early 1950's to convert its large deposits of low grade coals (about 11.7 x 10^9 tons of recoverable resource) to electric power and substitute fuel oil. The well known SASOL-I plant was built using the Lurgi gasification and Fischer-Tropsch technologies, in Secunda, South Africa in 1956, and started full production in 1961. The 16 Lurgi gasifiers with a total capacity of 10,000 tons/day of coal produces about 10,000 barrels/day of substitute petroleum liquids. Under the SASOL-II project, initiated in late 1974, 36 large Lurgi gasifiers were built in 1980, to produce about 40,000 barrels/day of substitute liquid fuels. In this plant, with improvements in coal conversion and synthesis of liquid fuels about 1.6 barrels of liquid fuel could be produced from one ton of coal. In early 1979 the

SASOL-III project was launched, to duplicate SASOL-II. A 1980 process economics study showed that a SASOL type plant with a capacity of 40,000 TPD of coal conversion to 58,000 barrels/day of gasoline, diesel, and jet fuel, based on processing U.S. western subbituminous coals, would cost about $\$3.6 \times 10^9$ (1980 dollars). The estimated cost of these products would be equivalent to refinery processed products using $48/per barrel crude oil.[10]

Of the European countries, West Germany is actively pursuing the development of coal conversion to reduce its dependance on imported oil. With an estimated recoverable resource of 43×10^9 tons of bituminous coal and lignite, they could easily reduce one-third of present natural gas and oil consumption and substitute with energy derived from coal.[11] Germany has considerable experience in coal conversion and utilization, by the role played by Rheinbraun and its predecessors and other companies during World War II. Commercial plants, based on moving bed, fluidized bed, and molten-bath processes were in operation till the mid-sixties. A summary of recent coal conversion demonstration projects finished or nearing completion is given below:

- Steag A.G.
  - Lurgi, 1700 TPD coal to 170 MW electric power plant demonstrated operation at Lunen, F.R.G.

- Consortia led by Ruhr Kohle A.G.
  - Ruhr-100, 170 TPD coal to HBG plants constructed in 1979, tests in progress.
  - Pressurized Texaco, 144 TPD coal to MBG plant, constructed in 1978, tests in progress.
  - Catalytic liquefaction, 200 TPD coal to naphtha, middle distillates and fuel gases, constructed in 1981, tests in progress.

  Deutsche Shell A.G.
  - Shell Koppers, 150 TPD coal to MBG plant constructed in 1978, tests in progress.

- Saarbergwerke A.G.
  - Saarberg/Otto gasifier, 240 TPD coal to SYG/HBG constructed in 1978, tests in progress.
  - Catalytic liquefaction, 144 TPD coal to naphtha, middle distillates and fuel gases, constructed in 1980, tests in progress.

In addition, W. Germany is participating in the U.S. coal liquefaction programs under development by Gulf (SRC-II), Exxon (EDS), and Ashland Oil (H-coal).

The commercial plants planned for operation in the late 1980's include:

- Consortia led Ruhr Kohle A.G.
  - Ruhr-100, 10,000 TPD coal to MBG, SYG, HBG
  - Pressurized Texaco, 1300 TPD coal to MBG and SYG
- Deutsche Shell A.G. - Shell Koppers, 1000 TPD coal to MBG
- Deutsche Texaco A.G. - 1300 TPD coal to MBG and SYG
- PCV (Flick) - moving bed, 1660 TPD coal to MBG, HBG
- Saarbergwerke A.G. - Saarberg - Otto, 1300 TPD coal to SYG/combined-cycle power
- VEW - 6000 TPD coal to combined cycle power.

In the United Kingdom, the Coal Research Establishment, Cheltenham, Glouchester is considering plans to build a demonstration plant for super-critical extraction of coal. The extract, which is easily separated from the residual coal char, could be hydrotreated to produce distillate fuels. The British Gas Corp., Westfield, Scotland is planning to build a large scale BGC/Slagging-Lurgi process pilot plant with a capacity of 170 TPD of coal to produce gaseous fuels which could be upgraded to HBG/SNG.

In the Netherlands, Shell Nederland is currently operating the Shell-Koppers process in a 6 TPD pilot plant to produce MBG/SYG. A semicommer-

cial plant is being evaluated for construction at Moerdijk, with a capacity of 333,000 to 500,000 tons/year of SYG for use as petrochemical production feedstocks or for power generation. A similar plant is also planned for Australia, where Shell owns large coal reserves.

In other parts of the world, Brazil's Petrobras is considering building a Koppers-Totzek process pilot plant is San Jeronimu. Japan Electric Power Development Co., is planning to use the Hitachi process in a pilot plant considered for Iwaki City. Poland was planning to build a large coal gasification plant, based on W. Germany technology in Katowice.

U.S. Coal Gasification Programs

The first commercial coal gasification project, based on the Lurgi Technology, sponsored by American Natural Resources (ANR), Detroit, Michigan, known as the Great Plains Gasification Project, is under construction at Beulah, North Dakota.[12] The nominal capacity of this plant is 125 x 10^6 cubic feet/day of HBG. The estimated raw material requirements are about 22,000 tons/day of lignite (14,000 tons/day for gasification) and about 5,000 acre-feet of water. An illustration of the block flow diagram for this project is shown in Figure 10. The project will employ 14 Lurgi Mark IV gasifiers, of which two gasifiers will be set aside as spares to backup overhauling gasifiers. The energy output of this plant is equivalent to 20,000 barrels/day of oil or about 1,200 MW electricity. The ANR plant, is funded by a consortia of pipeline companies under the utility financing method. The U.S. government, through the Synthetic Fuels Corporation (SFC), has approved loan guarantees for this plant. The estimated cost to construct this plant is about \$2.02 x 10^9, which also includes the cost to develop the open-cast lignite mines. The proposed selling price for an average return on investment of about 15% of the HBG or SNG is about \$6.75/10^6 Btu. The ANR plant is expected to be operational by late 1984.

The second coal gasification plant is a demonstration scale Texaco coal gasification combined cycle plant, under construction near Barstow, CA.

This project is led by Southern California Edison Co., and is confounded by Texaco, Inc., and the Electric Power Research Institute (EPRI) at Palo Alto, CA. The plant is designed to gasify 1000 TPD of coal and to produce 100 MW combined cycle power. An illustration of the block flow diagram for this process is shown in Figure 11. The estimated capital investment cost is about $\$300 \times 10^6$. Operation and testing of this plant is scheduled for 1984. The summary of an economic evaluation by Fluor Engineers and Constructors, comparing the Texaco gasification combined cycle system with conventional direct coal firing with stack gas cleaning-up is given in Table 13.[4] This table shows that the Texaco gasifier integrated with a commercially available combustion turbine (inlet temperature of 1980°F) has a slight advantage over conventional direct coal firing. With the introduction of advanced turbines (inlet temperature of about 2600°F) and coupling the gasifier with fuel cells should offer substantial advantages, for the gasification combined cycle power systems, in terms of net heat rate or thermal efficiency, capital investment and cost of electricity.

About six months back, SFC solicited and received 65 proposals to build commercial substitute fuels plants using domestic coal, oil and shale. In the end of March 1982, SFC announced the selection of five proposal for further rigorous scrutiny.[13] These include:

1. An $880-million coal gasification plant for producing MBG for Memphis Light Gas and Water, a publicly-owned utility. The plant will gasify about 3100 TPD of coal to produce nearly 50×10^9 Btu/day of MBG for industrial users.

2. A $380-million plant for producing 1,900 bbl/day of methanol from peat at a site in Creswell, NC, sponsored by Energy Transition Corp. of Washington, DC.

3. A $2-billion, 22,000 bbl/day plant in Gillette, WY, a joint venture of Kaneb Services, Koppers, and Northwestern Mutual Life Insurance.

The unit would use indirect-liquefaction technology for converting coal to gasoline and petrochemicals.

4. A plant for producing liquid fuels and chemicals from coal in Breckinridge County, KY, a joint-venture of Ashland and Bechtel. Initially estimated to cost $5.2 billion, the Kentucky synfuels plant is almost certain to be down-sized to less than half its current 48,900 bbl/day capacity.

5. A $49-million plant for extracting heavy oils in California, sponsored by a group including Tenneco and California Synfuels Research. The plant size is 5,1000 bbl/day.

Of these the first three are coal gasification plants. The Memphis Light, Gas and Water project will employ the U-GAS process developed at IGT, Chicago, while the remaining two projects will use the KBW gasifiers. The fourth project is based on the H-coal catalytic liquefaction process which was developed at the Hydrocarbon Research Inc.

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Table 1. TOTAL WORLD FOSSIL ENERGY RESOURCES
12-31-80

	Proved & Currently Recoverable		Estim. Total Remaining Recoverable	
	10^9 tce	%	10^9 tce	%
Natural Gas	94	9	320	5
Natural Gas Liquids	10	1	34	1
Crude Oil	125	12	392	6
Syncrude (Oil Shale and Tar Sands)	77	8	592	9
Coal	717	70	5141	79
		100		100

One Metric Ton of Coal Equivalent (tce) = 22.778×10^6 Btu = 7×10^6 kcal

Table 2. U.S. FOSSIL FUEL RESOURCES
12-31-80

	Proved & Currently Recoverable 10^{18} Btu	Estim. Total Remaining Recoverable 10^{18} Btu
Dry Natural Gas	0.20	0.95-1.18
Natural Gas Liquids	0.03	0.11-0.14
Crude Oil	0.18	0.79-2.10
Coal	6.18	20.67-35.71
Shale Oil and Bitumens	0.44	6.04
Total	7.03	28.56-45.17

Table 3. REGIONAL DISTRIBUTION OF ESTIMATED WORLD FOSSIL FUEL RESOURCES, %
12-31-80

	Natural Gas	Crude Oil	Syncrude	Coal
Africa	10.0	8.5	5.8	1.8
North America	17.2	10.7	45.6	24.7
Latin America	6.5	10.5	20.1	0.2
Europe (Excl. U.S.S.R.)	5.3	4.5	6.0	6.3
Asia (Excl. U.S.S.R.)	31.6	53.7	7.3	13.3
U.S.S.R.	23.5	10.0	14.5	47.4
Oceania	5.9	2.1	0.7	6.3
Total	100.0	100.0	100.0	100.0
Middle East Only	22.3	42.5		

Table 4. ANALYTICAL DATA FOR SOME COALS OF DIFFERENT RANKS [2]

Coal	Seam	County and State	As Received Moisture (%)	As Received Ash (%)	Ultimate Composition, maf (%) C	H	N	O	S	Methoxyl	Calorific Value (cal/g[a])
Lignite	Coteau	Ward, N.Dak.	32.5	5.0	72.38	5.30	1.12	20.53	0.67	2.22	4477
Subbituminous B	Unnamed	Weld, Col.	20.7	3.9	77.69	[illegible] 24	1.60	14.98	0.49	0.25	5818
High-volatile C bituminous	5	Fulton, Ill.	13.7	10.3	81.41	5.64	1.56	7.89	3.50	Trace	7005
High-volatile B (vitrain) bituminous	6	Franklin, Ill.	5.4	2.2	81.96	4.98	1.65	10.23	1.18	Nil	7611
High-volatile A bituminous	Pittsburgh	Allegheny, Pa.	1.7	7.8	82.92	5.91	1.80	6.34	3.03	—	8352
Medium-volatile bituminous	Sewell	Fayette, W. Va.	1.4	1.8	89.47	4.93	1.66	3.49	0.45	—	8559
Low-volatile bituminous	Pocahontas 3	McDowell, W. Va.	0.6	7.4	91.36	4.60	1.24	2.07	0.73	—	8697
Anthracite	Lykens	Luzerne, Pa.	4.2	2.4	94.88	1.83	0.67	1.78	0.84	—	7878

[a] Moist, mineral matter free. Multiply by 1.8 to get Btu/lb values used in ASTM classification by rank.

Table 9. SUMMARY OF COMMERCIALLY AVAILABLE COAL GASIFICATION TECHNOLOGY

Process	Developer Location	Reactor Type†	Gasifier Capacity TPD* Coal	Operating Data Pressure (Psi)	Operating Data Particle Size	Gasifier Diameter (ft)	Product	Remarks
Lurgi	Lurgi, Frankfurt W. Germany	MB	600-1000	400	1/4 to 1 3/4 inch	11 to 15	MBG, HBG	Commercial since 1930's 18 plants built in East and West Germany, Czechoslavakia, S. Africa, Australia, India, UK, Pakistan and Korea. The first US plant under construction in Beulah, N. Dakota. Limitations: Does not handle caking coals and less than 1/4 in. coal. Produces oils tars. High steam requirements.
Wellman - Galusha	Wellman Galusha Co. UK	MB	55	Atm††	1/4 to 1 inch	11	LBG	Commercial since 1930's. Limitations: Restricted to small scale applications and to produce Low-Btu gas. Does not handle caking coals.
Winkler	Davy Int'l, Ltd., UK	FB	700	Atm	Up to 1/8 inch	-	MBG	Commercial since 1920's 16 plants built in W. Germany, Japan, Czechslovakia, Yugoslavia, Spain, Turkey, India. Limitations: Does not handle caking coals. High gas compression costs. Low throughputs. Elutriation of carbon.
Koppers Totzek	Sasol Secunda, S. Africa	EB	400 (two burners) 500 (four burners)	Atm	-200 mesh	-	SYG	17 plants built around the world. Limitations: Requires gas compression.

†MB = Moving bed
FB = Fluidized bed
EB = Entrained bed
*TPD = Tons per day
††Atm = Atmospheric pressure

Table 10. SUMMARY OF SECOND GENERATION COAL GASIFICATION PROCESSES

Process	Developer, Location	Reactor Type†	Gasifier Capacity (TPD Coal)*	Operating Data		Gasifier Diameter Size (ft)	Product	Remarks
				Pressure (Psi)	Particle Size			
Ruhr - 100	Ruhrgas, Ruhr Kohle, Steag, Lurgi Dorsten, W. Germany	MB	170	1500	1/4-2in	4.5	HBG	More than half of total CH_4 is made in the gasifier compared to 1/3 in the 450 psig Lurgi process.
Slagging - Lurgi	British Gas Corp., Westfield, Scotland, UK	MB	360	350	1/4 - 2 in with 25% below 1/4	6.0/9.0	MBG	Can handle caking coals, less steam compared to Lurgi, by discharging ash slag total carbon conversion is achieved, slag discharge zone critical to gasifier operation
Kiln Gas	Allis Chalmers Milwaukee, WI USA	Rotary Kiln	-	-	-	-	LBG	Low coal throughput and difficult to scale up
Pressurized Winkler	Rhainische Braunkohlen Werke, AG Frechen, W. Germany	FB	25	150	Up to 1/4 inch	-	MBG	In early stages of development.
U-Gas	IGT, Chicago, IL U.S.A.	FB	24	50-300	Up to 1/4 inch	3.0/4.0	MBG	By discharging agglomerated ash, over 98% carbon conversion is achieved.
Westinghouse	Westinghouse, Waltz Mill, PA USA	FB	24	200	Up to 1/4 inch	-	MBG	Similar in many respects to to U-gas
HYGAS	IGT, Chicago IL, U.S.A.	FB	75	1000	-14 mesh	2.0	HBG	Staged gasification including hydrogasification, results in the production of 2/3 CH_4 in the gasifier.
Synthane	Pittsburgh Energy Research Center, Bruceton, PA U.S.A.	FB	70	600	-14 mesh	3.0	HBG	Tested dry lockhopper for short periods at 600 psig. Process discharges char as a boiler fuel.
CO_2 - Acceptor	CONOCO Rapid City S. Dakota U.S.A.	FB	36	150	-8 mesh	-	HBG	Process employs circulating CO_2 adsorbing dolomite. Does not need oxygen. Cannot Handle caking coals.
COGAS	COGAS Corp. Princeton, N. Jersey, U.S.A.	FB	50	50	-	-	HBG	Of the two gasification process steps pyrolysis was tested at Princeton, N.J. while char gasification was tested at BCURA Leatherhead, UK.
KBW	KBW Inc., Pittsburgh, PA, U.S.A.	EB	800-1200	ATM	-170 mesh	-	SYG	Modified version of a pulverized combustor.

Table 10. SUMMARY OF SECOND GENERATION COAL GASIFICATION PROCESSES (Cont.)

Process	Developer Location	Reactor Type	Gasifier Capacity (TPD)	Operating Data Pressure Psi	Operating Data Particle Size	Gasifier Diameter (ft)	Product	Remarks
Shell - Koppers	Shell Int'l and Krupp-Koppers, Amsterdam, Netherlands and Harburg, W. Germany	EB	6 and 150	450	-200 mesh	-	HBG	Starting in 1977, a 6 TPD pilot plant at Amsterdam operated on several coals. In 1979 tests began in a 150 TPD plant in Härburg, W. Germany. Several runs without steam.
Texaco	Texaco, Inc., Montebello, CA, USA	EB	170	600	-200 mesh		SYG	A 150 TPD unit is operated by Ruhrchemie and Ruhrkohle in Oberhausen-Holten, W. Germany A 170 TPD plant to produce ammonia is under development by TVA at Muscle Shoals, AL, U.S.A.
BIGAS	BCR Inc., Homer City PA, U.S.A.	EB	120	1000	-200 mesh	2	HBG	Pilot plant tests in progress.
Saarberg - Otto	Saarberg-werke Voelklingen, W. Germany	Molten bath	240	360	Up to 1/8 inch	2	SYG/HBG	Pilot plant tests in progress.

Table 11. SUMMARY OF COMMERCIAL COAL LIQUEFACTION PROCESSES

Process	Developer, Location	Process Type	Operating Conditions: Pressure psi	Operating Conditions: Temp. °F	Operating Conditions: Capacity TPD	Products	Catalyst	Use of Hydrogen	Remarks
Bergius	Galsenberg, Germany	CL*	3000-10,000	800-900	31	Distillate Fuels	Disposable Iron	Yes	The pilot plant was built in 1931. About 12 plants were built during the II World War in Germany to convert brown coal to about 70,000 barrels/day of substitute gasoline.
Fischer-Tropsch	Ruhrchemie A.G., West Germany	IL	300	750-840		Gasoline, Diesel oil, Alcohols	Iron	Yes	During II Worl War, the German Fischer-Tropsch plants had a total capacity of 4600 TPD. The SASOL-I plant in Secunda, S. Africa converts about 11,000 TPD of coal. Three different types of synthesis reactors are available at present.
Lurgi-Ruhrgas	Lurgi-Ruhrgas AG, Dorsten, W. Germany	PY	ATM†	800-1100°F	-	Middle Distillates and Char	None	None	Commercial technology. Four plants constructed with a capacity of 4000 TPD. The process is also useful for oil shale and heavy crudes.

* Abbreviations

CL - catalytic liquefaction.
IL - indirect liquefaction.
PY - pyrolysis/carbonization
DS - donor solvent.
ATM - atmospheric pressure

Table 12. SUMMARY OF SECOND GENERATION COAL LIQUEFACTION PROCESSES

Process	Developer, Location	Process Type	Operating Conditions: Pressure psi	Operating Conditions: Temp. °F	Operating Conditions: Capacity TPD	Products	Catalyst	Use of Hydrogen	Remarks
IG Farben	I.G. Farbenindustrie, W. Germany	CL	3000-5000	800-900	220	Distillate Fuels	Sulfur Resistant Tin and Tungsten	Yes	An improved Bergius process. Pilot plant built at Bottrop.
H-Coal	HRI, Catlettsburg, KY, USA	CL	1500-3500	825-875	600	Distillate Fuels	Cobalt Molybdate	Yes	The process can be operated to produce either a low-sulfur heavy fuel oil or a substitute crude.
CSF	Conoco, Cresap, WV, USA	DS	400-3500	750	20	Distillate Fuels, Char	Zinc Chloride	None	The multi-stage process includes coal extraction (400 psi), hydrogenation of extract (3500 psi) and carbonization of residue. Pilot plant had several mechanical problems.
SRC	Pittsburgh Midway Coal Mining Co., Fort Lewis, WA, USA	DS	1000	800	45	Deashed Coal	None	Yes	Process improvements including two-stage liquefaction followed by hydrocracking led to SRC-I and by recycling mineral matter containing fractions, SRC II was developed to produce lighter products.
EDS	Exxon Baytown, TX, USA	DS	1700-2300	800-880	250	Distillate Fuels	Used for Solvent Hydrogenation	Yes	Process produces about 2.6 barrels/ton of C_4^+ The performance of the flexicoking process to convert the residual solids is an important step to be tested.
COED	FMC Corp., Princeton, NJ, USA	PY	ATM	550-1550	36	Substitute Crude, Char and Fuel Gases	None	None	Pilot plant tested several bituminous coals. Produces a barrel of crude per ton of coal. Char unsuitable for combustion because of sulfur.
MTG	Mobil R&D Corp., Princeton and Paulsboro NJ, USA	IL	300	570-750	4 barrles per day	Gasoline	Zeolite	None	The process converts synthesis gas to methanol which is converted with 95% efficiency to gasoline. Further catalysts under development to convert synthesis gas directly to gasoline.

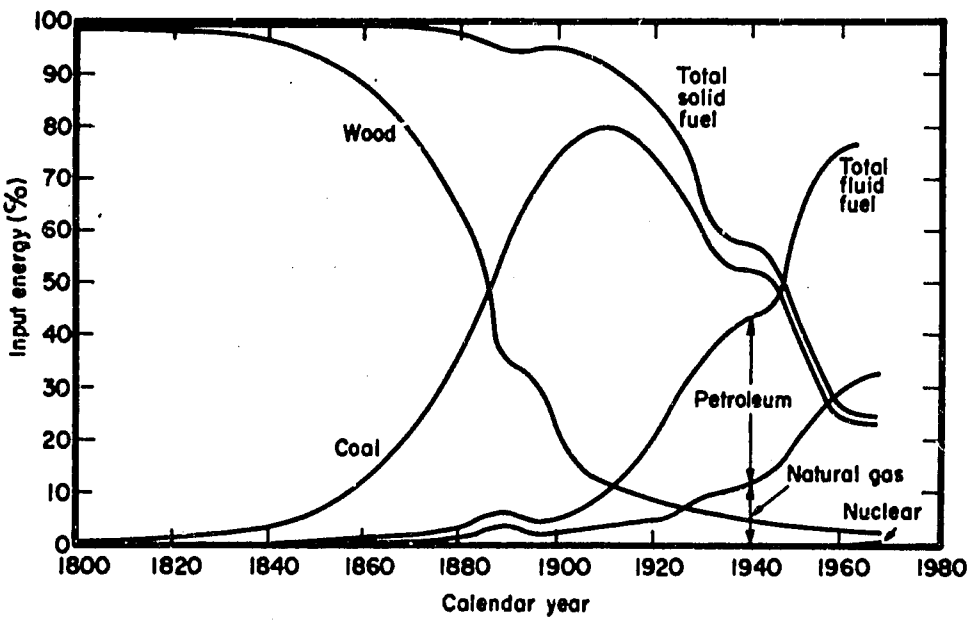


Fig. I - The Contribution of Primary Fuels to U.S. Energy System for the Period of 1800 to 1975 (Reference I)

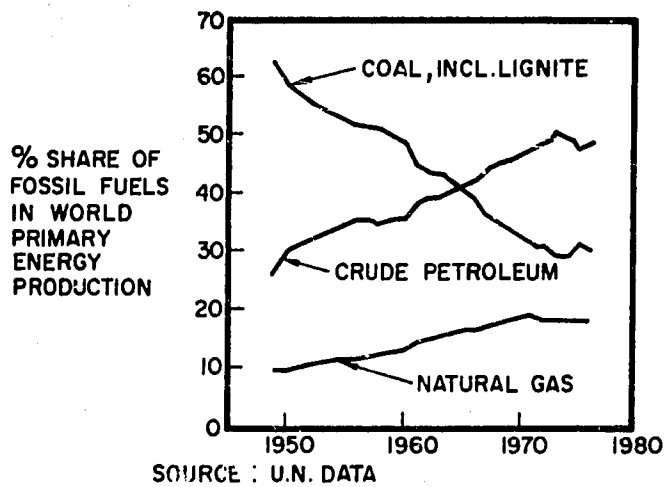


Fig. 2 – Fossil Fuels Use for World Energy

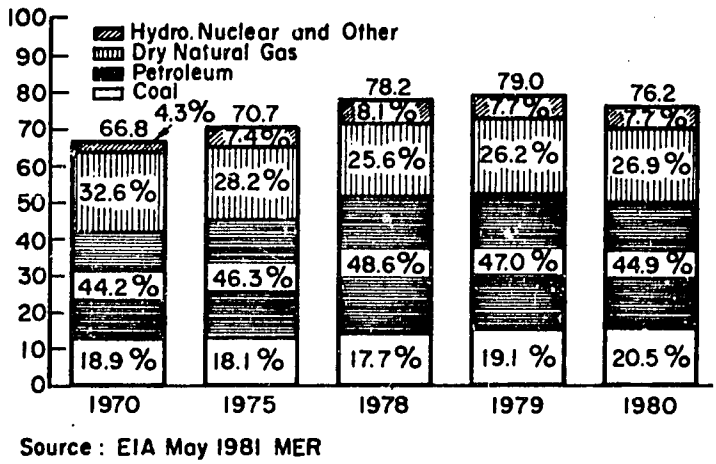


Fig. 3 – U.S. Energy Consumption, 10^{15} Btu

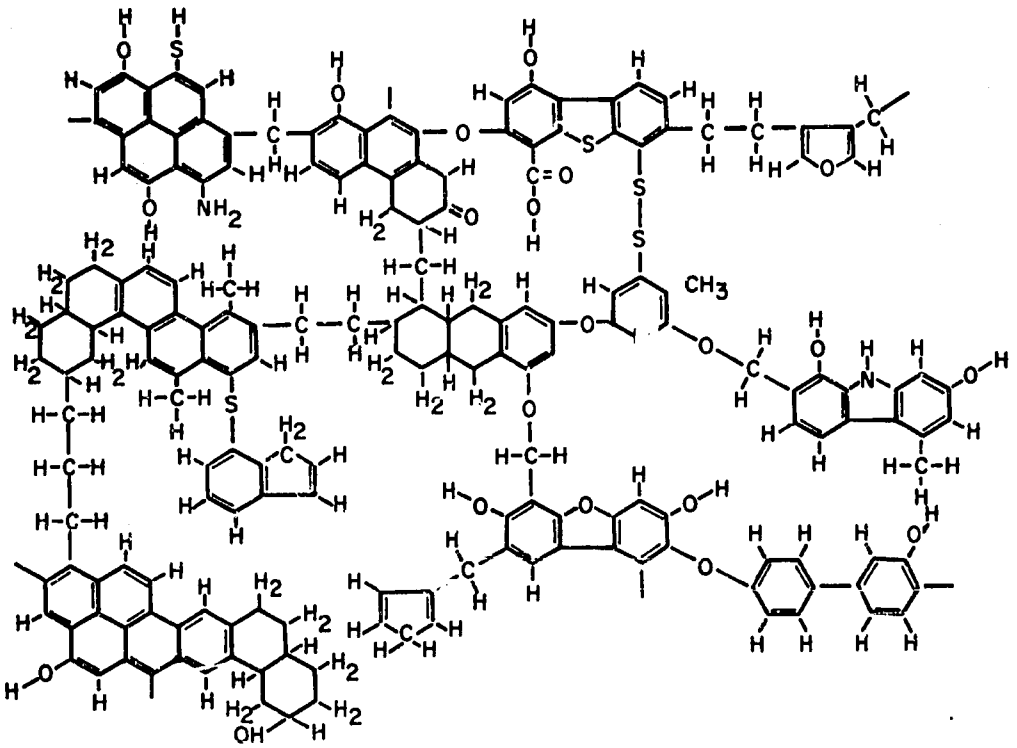


Fig. 4 - Coal Model Proposed by W. H. Wiser[2]

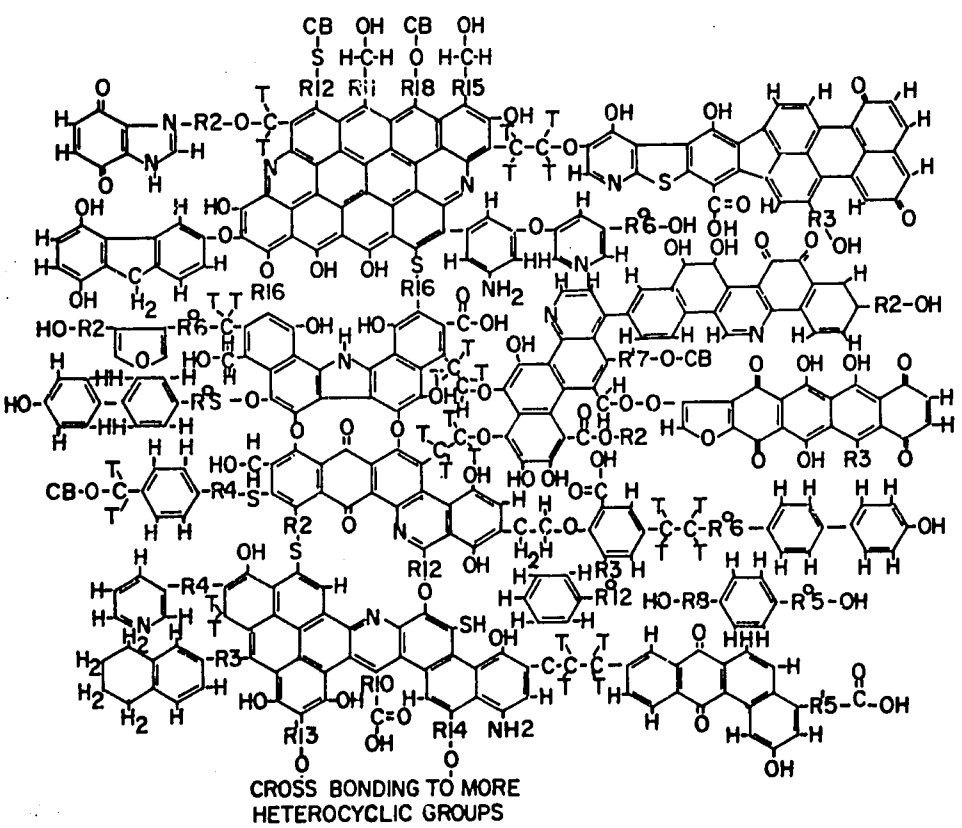


Fig. 5 - Coal Model Proposed by G.R. Hill and L.B. Lyon[2]

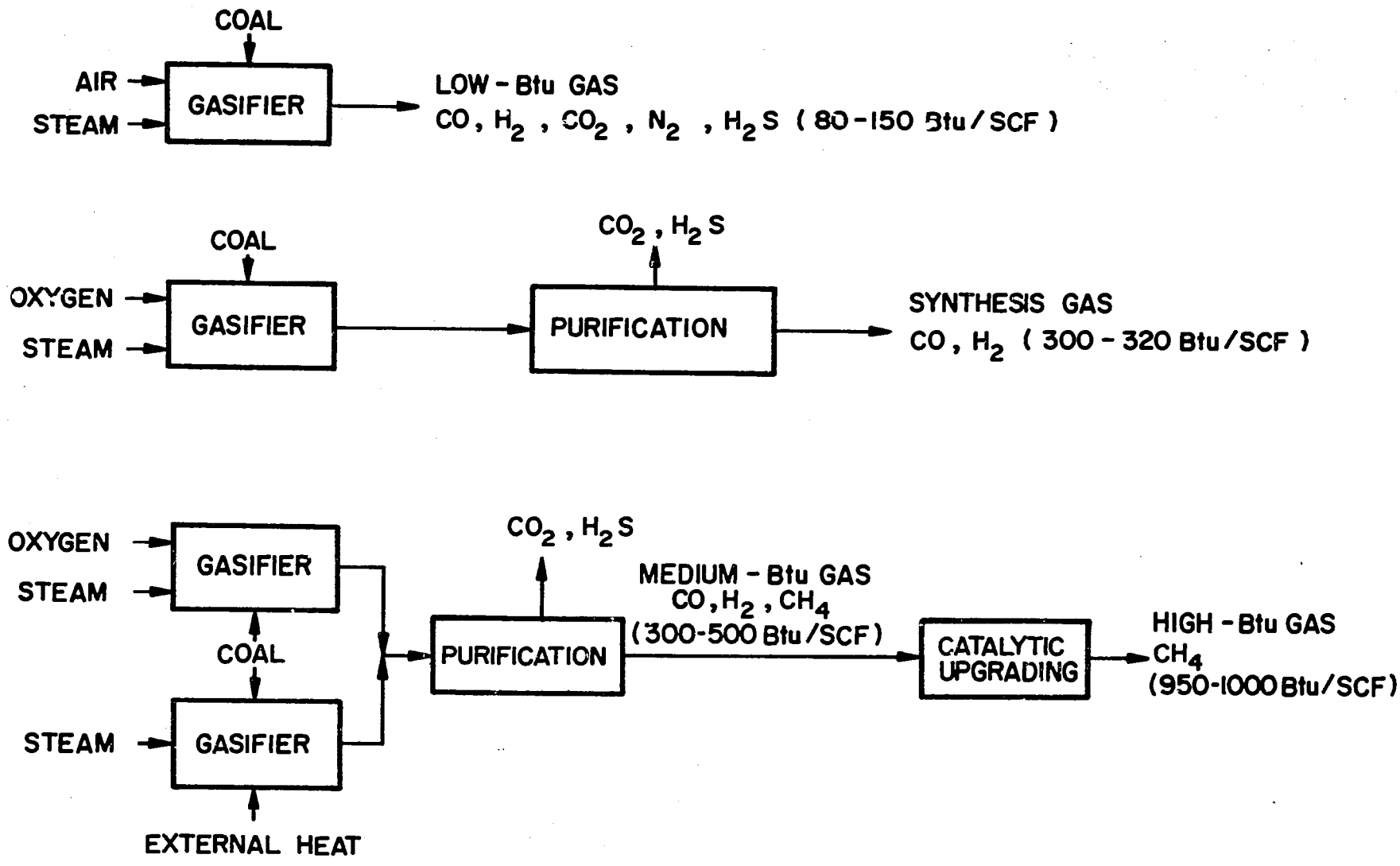


Fig. 6 – Simplified Process Schemes for Coal Gasification

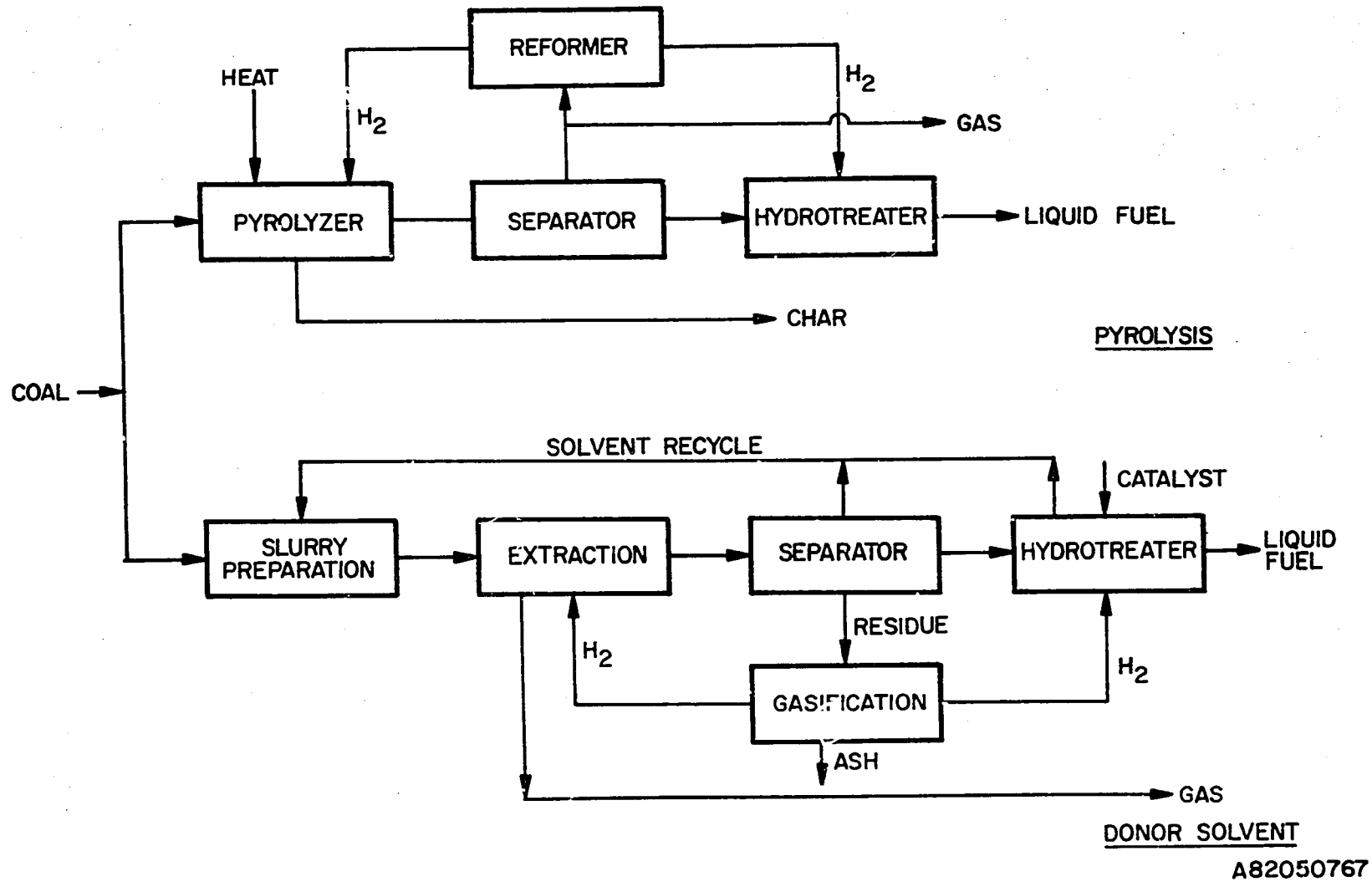


Fig. 7 – Simplified Process Schemes for Pyrolysis and Donor Solvent Coal Liquefaction Processes

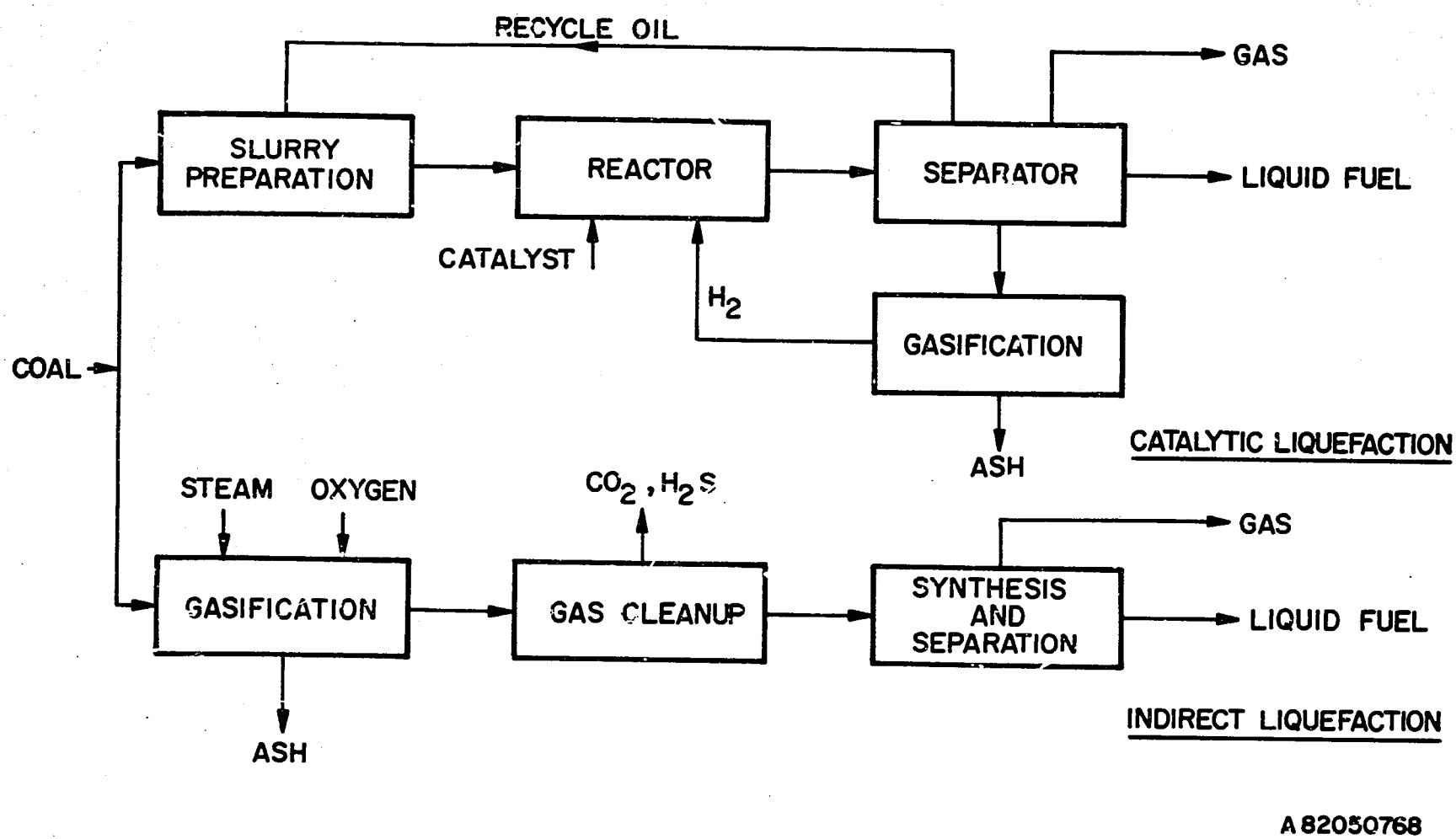
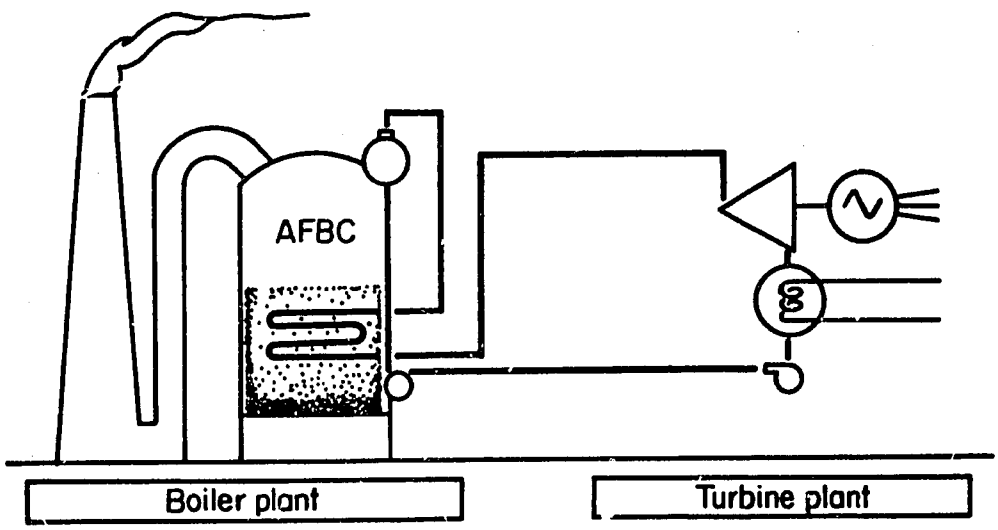


Fig. 8 – Simplified Process Schemes for Catalytic and Indirect Coal Liquefaction Processes



(Reference 8)

Fig. 9 – The AFBC - Boiler Power Plant

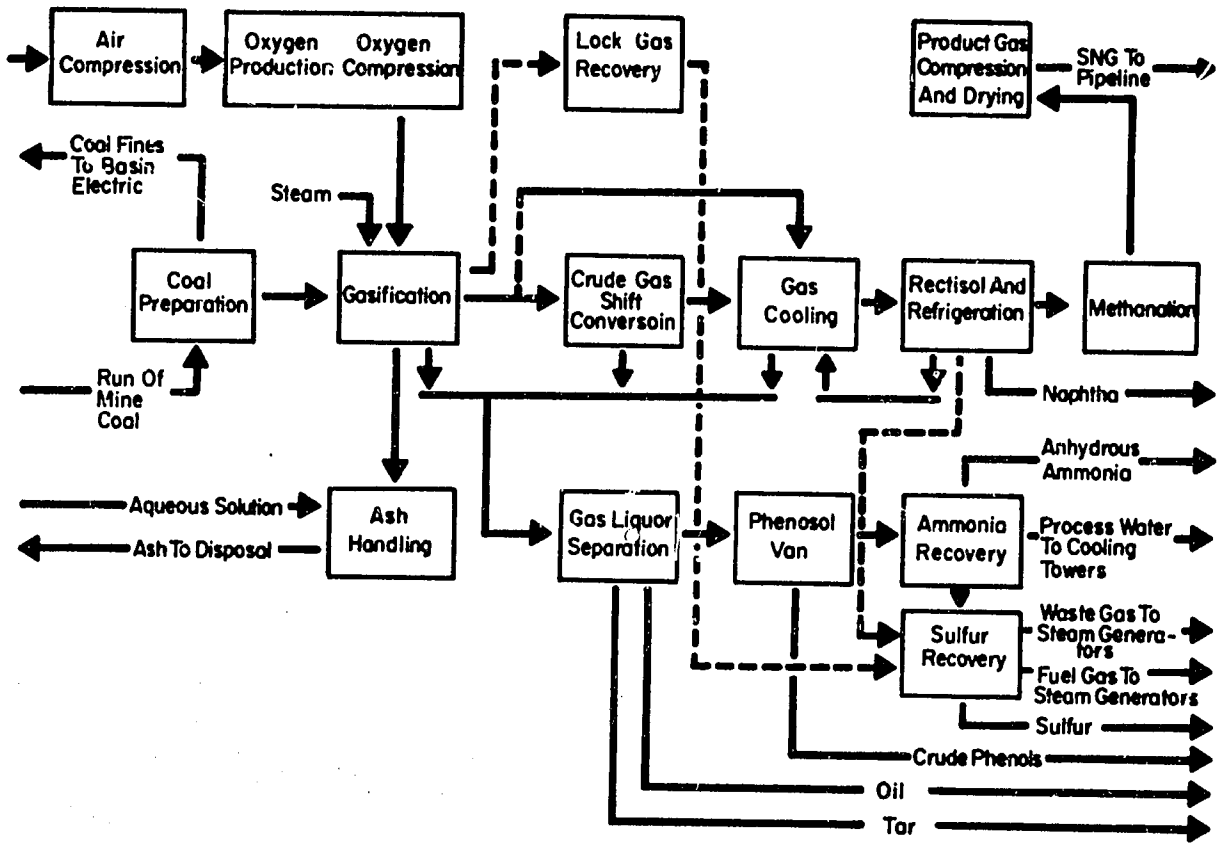


Fig. 10 – Process Scheme for the American National Resources Great Plains Coal Gasification Project

(Reference 12)

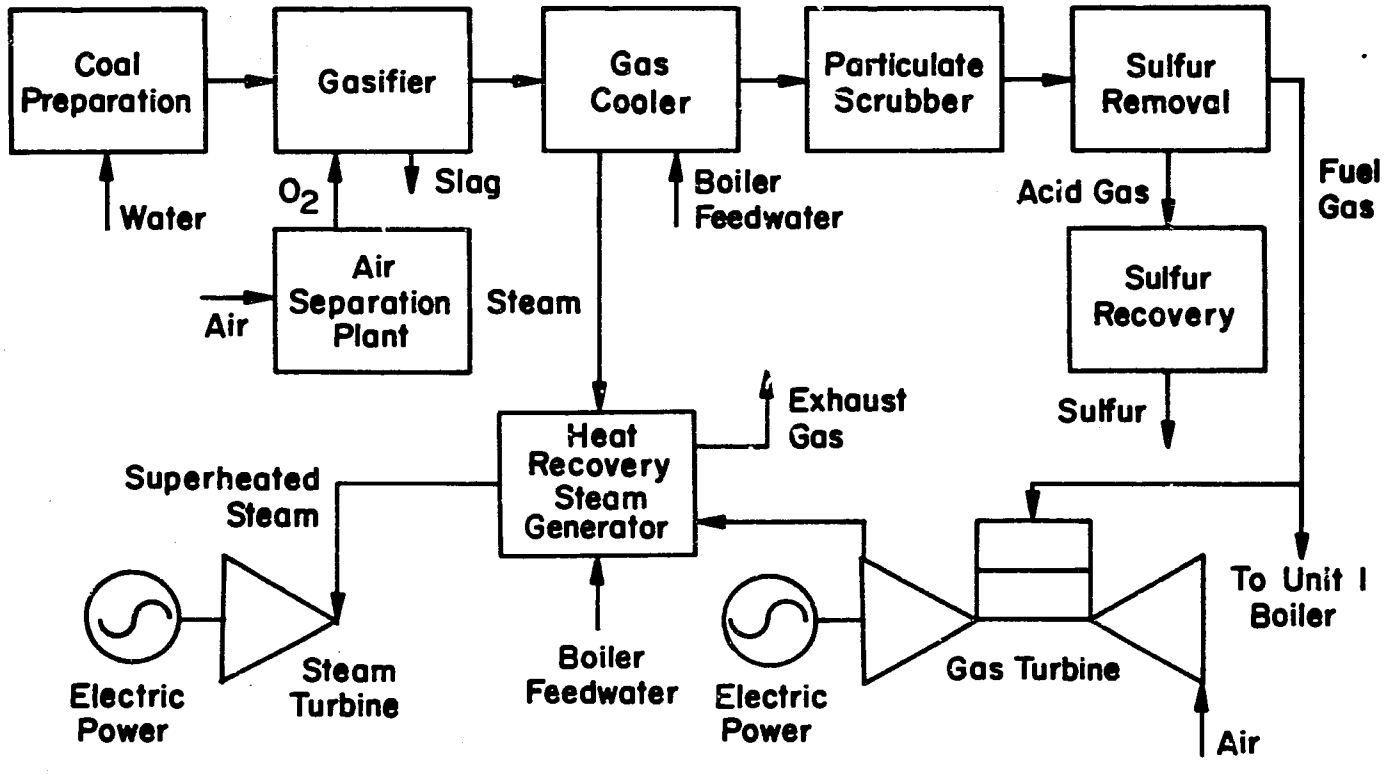


Fig. 11 – Process Scheme for The Southern California Edison's Texaco Coal Gasification Project
(Reference 4)

Insitu Coal Gasification Research In National Institute Of Geology And Mining - LIPI

Hariyanto Soetjijo

Abstract

Insitu or underground coal gasification has been simulated in the laboratory. The laboratory - scale combustion reactors together with auxiliary equipment have been designed and operated. These reactors were designed to measure all of the parameters. The data have been collected and they will be used to refine technique before going to the field.

Introduction

Insitu coal gasification has several advantages over the conventional mining operations - whether open cast or underground. The process can mitigate many environmental and mining problems associated with coal development.

Coal can be gasified insitu by burning coal insitu and then blowing air, or oxygen and steam - through the seam.

The results of the laboratory experiments can be used as the basis to further develop the techniques before going to the field. We also realize that those data cannot substitute entirely for experimental field data. However, these data can be used to interpret the behaviour of reactions, variables and parameters of the process, and will be very useful in designing large insitu coal gasification fields.

Reactors

Our first laboratory scale insitu coal gasification project was undertaken to understand the thermodynamic and kinetic aspects used to determine operational parameters. Due to limits in simulating all of the natural conditions which may be found on the field, the gasification reactors cannot represent perfectly all field conditions.

There are three insitu coal gasification reactors. The first one is the rectangular reactor, length: 80cm, width: 30cm and height: 20cm. This reactor has a 2.5 inch diameter burning hole, a 0.5 inch diameter hole for input gas and a 2.5 inch hole for output gas.

The second reactor is a tube, with diameter: 30cm and length: 2m.

The third reactor is also a tube, with diameter: 30cm and length 4m.

These reactors are made of steel. In the experiments these reactors were buried by soil for reducing the heat loss during the process. Auxiliary equipments included flowmeter, heater, compressor, a tube for cleaning the acid gas product, valves to remove the char and water, etc. The system has been completed now by a schruber.

An Orsat gas analyser is being used to analyse the gas product and for the next experiment, a gas chromatograph will also be used.

In the reactor, coal gasification takes place in the upper part leaving an empty column link in the bottom. With this arrangement of the coal in the reactor, we hope that the link will locate in the bottom of the coal seam and the coal will burn from the bottom upward eventually consuming the entire seam. However, if the link is formed near the top of the seam, gasification is inhibited in the downward direction because of ash slagging and liquid flow.

The volume of coal that can be gasified in the reactor will be increased by increasing the sum of the surfaces of coal burning. Since the seam is placed near the bottom of the seam, the gasification undermines the coal above, and fresh coal continually falls into the hot reaction zone.

If the natural permeability of the coal seam is too low for successful gasification, then seam permeability must be increased. In the field, the seam permeability can be changed and increased by fracturing the coal with high pressure air or explosives. In the laboratory this is difficult or impossible to do. To eliminate this factor, the coal which will be gasified, is first fractured to a size below 3cm in diameter.

Results

We have performed numerous insitu coal gasification experiments with these reactors. The data have been collected, covering the temperature profiles, caloric value; gas composition, volume of input air etc.

In the figures 1, 2, 3, and 4, we can see a part of those data. Generally, the calorific value of gas product is not constant ranging from 300 - 800 Kcal/Nm^3.

- temperature of the reaction varies according to the movement of reaction zones in reactor, the highest temperature is 900C.

- the volume of input is 70 - 110 litre/minute.

TABLE 1

Rembang Coal Quality Data

	Bereng kong %	Bereng kong %	Bereng kong %	Wido-daren %	Wido-daren %
1. Proximate analysis					
Inherent moisture	19.88	19.83	20.21	8.70	4.08
Ash	7.29	10.79	8.30	8.65	7.94
Volatile Matter	40.45	39.38	41.76	49.96	44.47
Fixed Carbon	32.38	30.00	29.73	32.69	43.51
2. Ultimate Analysis					
Carbon	47.50	48.12	50.25	60.52	-
Hydrogen	3.83	2.35	3.14	7.20	-
Oxygen	20.95	18.43	17.76	-	-
Nitrogen	0.55	0.48	0.46	0.53	0.28
Sulphur	1.71	1.64	1.61	-	-
3. Ash Analysis					
SiO_2				58.0	
Fe_2O_3				14.85	
Al_2O_3				14.95	
CaO				8.80	
MgO				3.46	
Calorific Value				6140	5785

TABLE 2

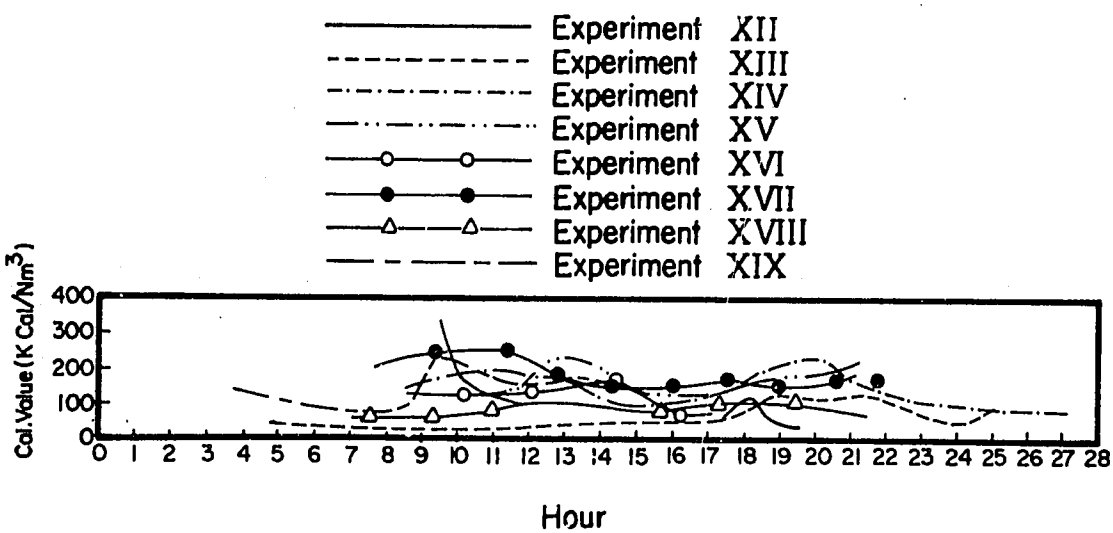
Analysis Of Gas Product Experiment XXII

Nomor contoh gas	Komposisi gas (%)								Nilai kalori (^oC, 76CmHg) (Kcal/Nm^3)
	CO_2	C_nH_m	O_2	CO	H_2	C_3H_8	CH_4	N_2	
1	6.2	0.2	11.1	14.9	2.9	0.8	2.1	61.7	855.79
2	10.2	0.2	7.4	9.2	3.6	0.8	2.0	66.6	726.53
3	11.0	0.4	6.2	5.8	3.0	1.0	2.0	70.6	656.89
4	11.8	0.4	4.2	4.6	4.8	1.2	1.8	71.2	701.47
5	12.8	0.2	3.0	7.2	3.6	0.6	2.4	70.2	660.48
6	13.8	0.2	3.4	6.6	3.0	1.0	2.0	70.0	679.75
7	14.4	0.4	2.4	6.8	2.4	0.4	1.8	71.4	515.49
8	14.2	0.2	2.4	3.6	1.6	0.2	1.6	76.2	338.02
9	13.4	0.2	4.0	6.0	1.4	0.2	1.0	73.8	364.84
10	14.0	0.2	3.4	5.2	2.2	0.2	1.0	73.8	347.08
11	12.8	0.2	3.4	4.2	2.0	0.2	1.2	76.0	330.73
12	11.8	0.0	4.2	14.2	1.6	0.1	1.4	66.7	492.57
13	11.8	0.0	2.2	10.4	2.0	0.2	0.8	72.6	471.95
14	10.0	0.0	4.4	9.0	1.8	0.2	1.0	73.6	444.15
15	10.4	0.0	2.2	9.4	0.8	0.0	0.6	76.6	345.81
16	9.8	0.0	3.0	11.0	1.0	0.2	0.8	74.2	460.20
17	8.2	0.0	2.0	12.8	1.0	0.0	0.4	75.6	430.77
18	9.0	0.0	3.6	13.0	0.6	0.2	0.6	73.0	487.82
19	8.6	0.0	2.4	13.0	0.4	0.0	0.6	75.0	437.16
rata-rata	11.3	0.15	3.94	8.78	2.09	0.39	1.32	72.04	512.08

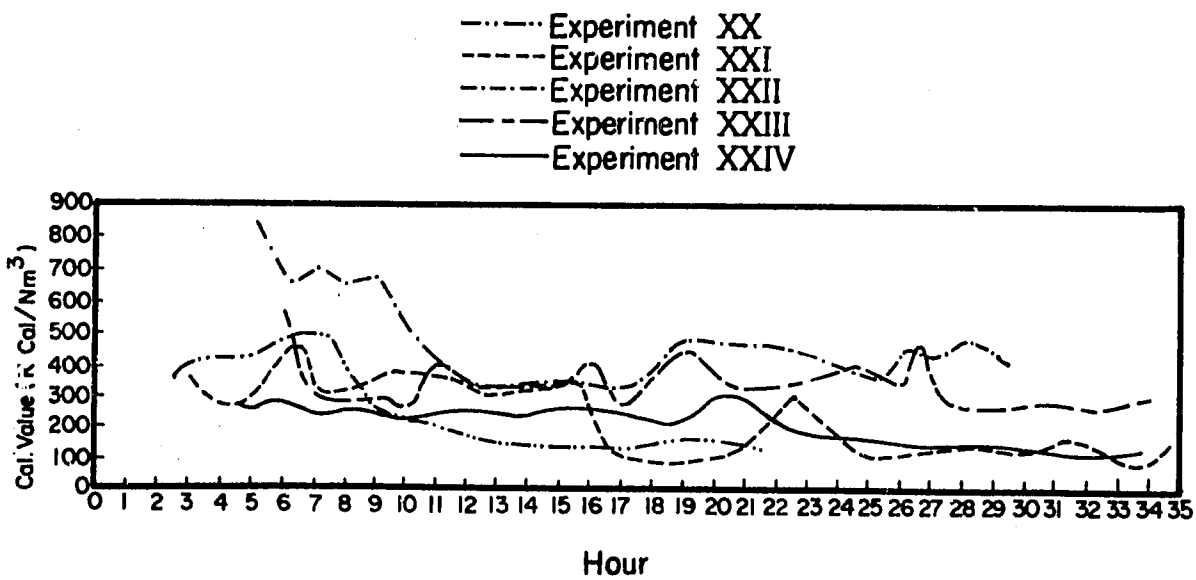
TABLE 3

Analysis Of Gas Product Experiment XXIII

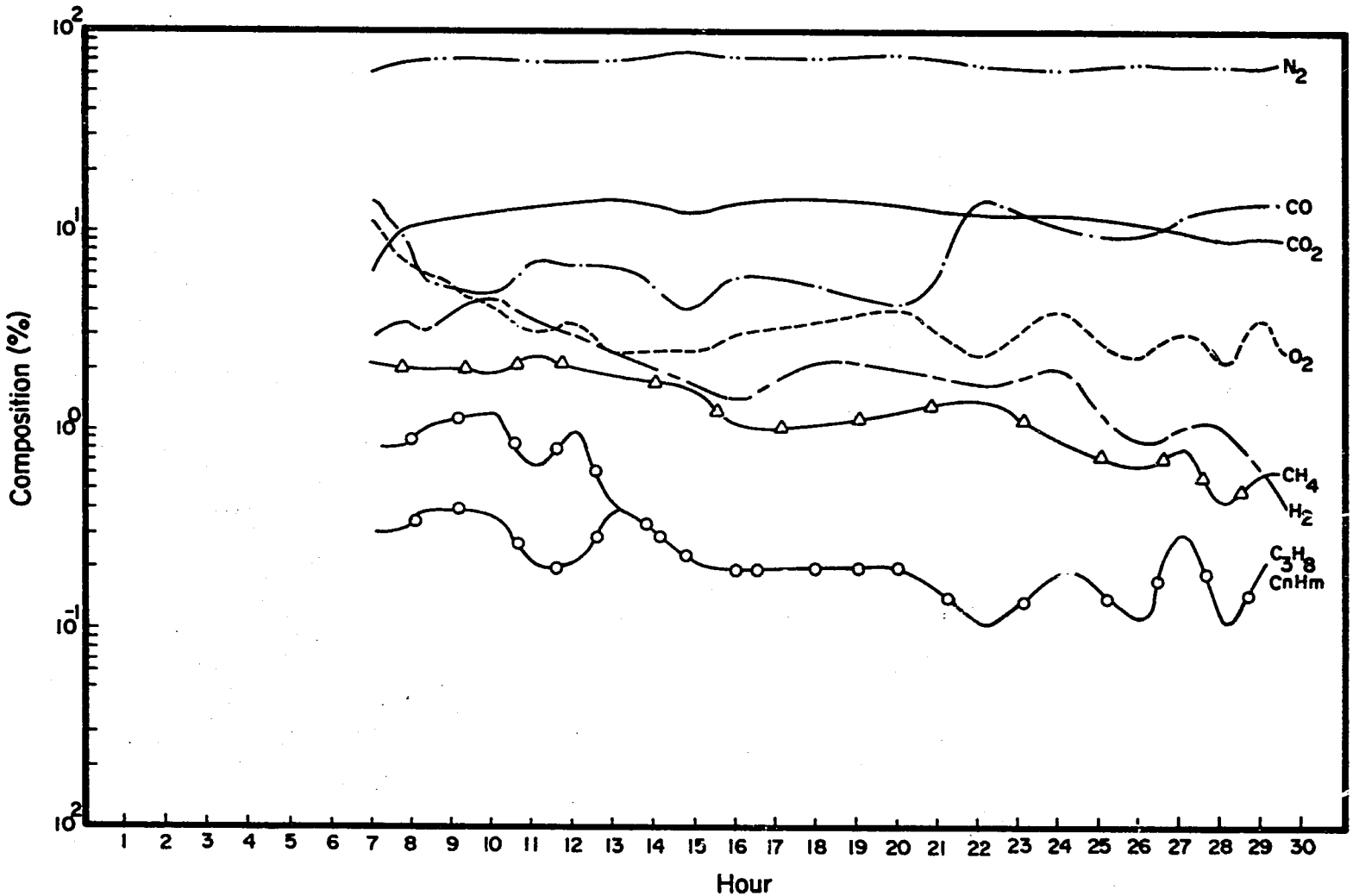
Nomor contoh gas	Komposisi gas (%)								Nilai kalori (^oC, 76CmHg) ($Kcal/Nm^3$)
	CO_2	C_nH_m	O_2	CO	H_2	C_3H_8	CH_4	N_2	
1	7.2	0.2	2.0	13.6	1.8	0.2	1.2	73.8	593.57
2	7.0	0.0	11.6	2.4	2.0	0.2	1.4	75.4	297.30
3	7.6	0.1	10.8	2.6	1.6	0.3	1.2	75.8	295.95
4	8.0	0.0	10.6	3.4	0.8	0.2	1.0	76.0	255.18
5	9.8	0.0	9.2	6.0	0.8	0.1	2.1	72.0	406.07
6	11.6	0.0	6.2	5.0	1.0	0.2	1.2	74.8	324.70
7	12.0	0.0	5.8	4.2	1.2	0.2	1.4	75.2	325.61
8	12.6	0.2	4.0	3.0	1.3	0.3	2.0	76.6	370.64
9	12.4	0.0	4.8	3.6	1.2	0.2	1.8	76.0	344.46
10	11.8	0.1	5.2	5.4	2.8	0.4	1.0	73.3	415.02
11	12.2	0.0	5.0	4.0	1.2	0.1	1.0	76.5	261.45
12	12.2	0.0	5.0	3.7	1.2	0.2	1.8	75.9	347.32
13	12.4	0.0	4.2	3.6	1.6	0.4	2.4	75.4	454.91
14	12.6	0.0	4.4	3.8	1.4	0.4	1.4	76.0	364.84
15	17.2	0.0	4.6	3.8	3.6	0.2	0.8	69.8	329.53
16	12.8	0.2	4.4	3.8	2.8	0.2	1.1	74.7	333.41
17	11.8	0.0	4.4	4.8	2.6	0.1	1.3	75.0	351.78
18	13.4	0.0	4.0	3.6	2.0	0.1	1.2	75.7	406.59
19	13.0	0.0	3.5	4.0	2.7	0.2	1.0	75.6	327.24
20	11.2	0.0	1.8	10.4	2.4	0.0	1.0	73.2	456.62
21	13.8	0.0	3.8	4.2	1.0	0.2	1.0	76.0	283.83
22	13.0	0.0	3.8	3.6	1.4	0.2	0.8	77.2	260.24
23	13.2	0.0	3.9	3.9	1.4	0.2	1.0	76.4	286.81
24	13.4	0.0	4.4	3.0	1.4	0.2	0.8	76.8	243.08
25	13.8	0.0	3.2	4.6	2.6	0.0	0.9	74.9	287.76
rata-rata	11.8	0.03	5.22	4.56	1.75	0.20	1.27	75.12	344.96



Experiments XII - XIX



Experiments XX - XXIV



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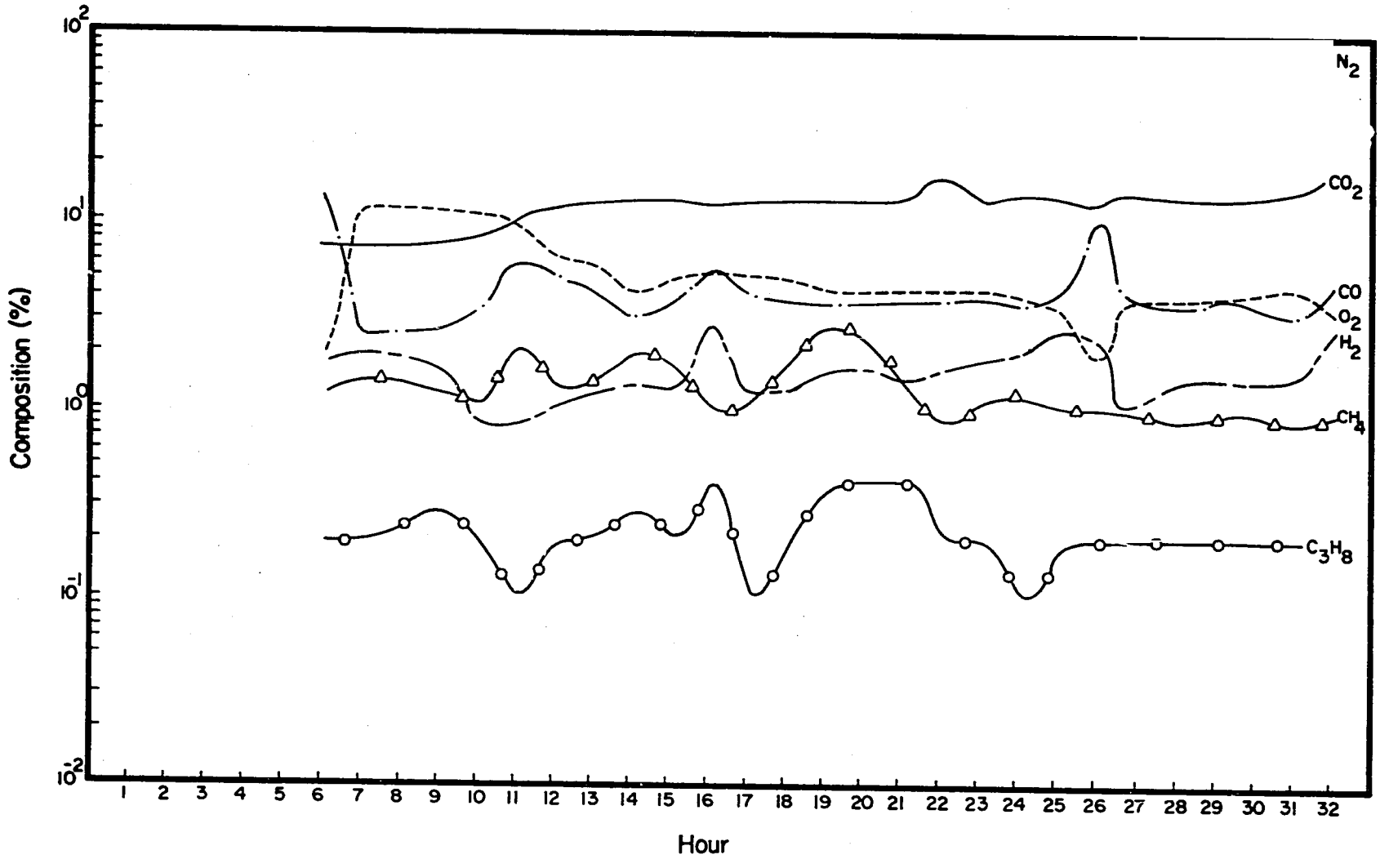
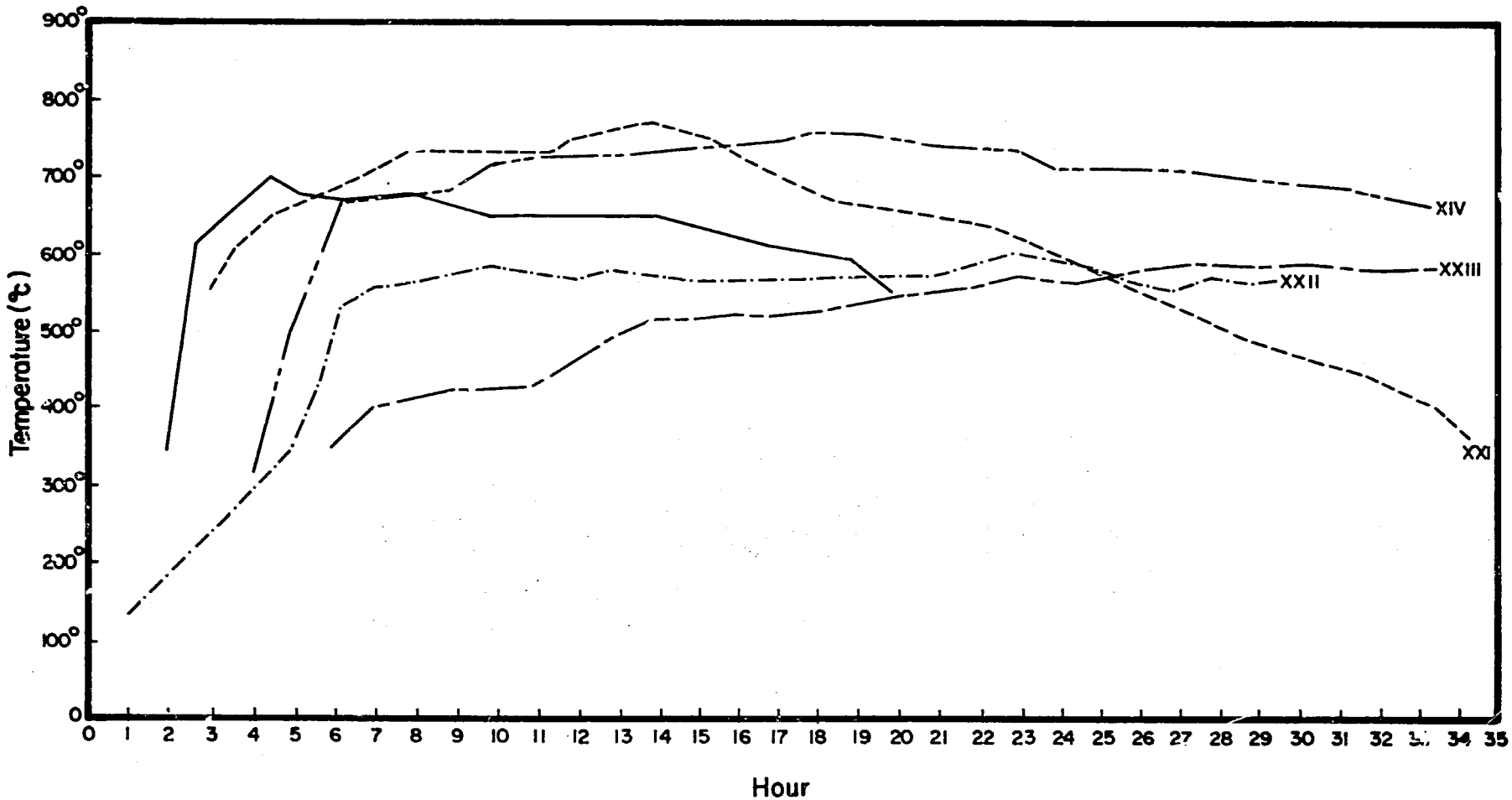


Experiment XXIII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800°
700°
600°
500°
400°
300°
200°
100°
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Hour
XIV
XXIII
XXII
XXI

Research and Development into Lignite Energy Conversion Process by the Department of Chemical Engineering Chulalongkorn University

Piyasan Praserthdam
Department of Chemical Engineering
Chulalongkorn University
Bangkok

Introduction

Thailand has a proven lignite reserve of 120 million tons at Mae Moh, Lampang province and a smaller reserve of some 50 and 30 million tons at Lee, Lampoon province and Bang Poo Dum, Krabi provinces, respectively. The approximate analysis of the Mae Moh lignite can be seen in Table 1.

The lignite produced at Mae Moh is at the present being used to generate electricity at Mae Moh (225 MW, 3 units) and at Krabi. A pulverized bed combustion process is currently employed. This process has two disadvantages. The ash produced is in the slag form and the flue gas has a high content of SO_2 and NO_x. A fluidized bed combustion (FBC) process has been proposed to replace the earlier process. A great deal of attention has recently been focused on this process (see Table 2). Research into fluidized bed combustion processes for lignite by the Department of Chemical Engineering, Chulalongkorn University is sponsored by the Electricity Generating Authority of Thailand (EGAT). This direct utilisation of solid fuel has also been complemented by research in gasification and liquefaction conversion processes for lignite.

Fluidized Bed Combustion

This research project has already obtained a research grant of $30,000 this year. The project leader is Assistant Professor, Dr. Sutham Vanichseni.

The laboratory-Scale fluidized bed combustor (see Fig.1) is 22.9 cm. (9 inc.) in diameter, refractory-lined cylindrical vessel. The bed section is 61 cm. (24 in.) high. The expanded freeboard section is 76.2 cm. (30 in.) high. The combustor is equipped with two heat exchangers. One is submerged in the bed, the other locates in the freeboard section. The air distributor plate is a cone perforated plate. Lignite from the hopper is fed directly into the bed by a screw feeder and a pneumatic conveyor. Limestone is fed directly into the top of the bed through a screw feeder with Ca: S ratio 2 to 3:1. The expanded bed height can be controlled by a drain pipe which locates at the bottom of the bed through the air distributor plate and by an overflow tube which penetrates through the side wall. Primary cyclone is used to collect the flyash in the flue gas. This flyash is reinjected into the combustor. The flue gas is passed through a secondary cyclone and a bag house before release to the atmosphere.

Tentative Experimental Program

One experimental approach is to set a specific set of operating conditions as a base and then to vary one parameter at a time.

The operating conditions of this FBC system are summarized and tabulated in Table 3. The range of bed temperature is chosen at the range 700-900°C. The bed diameter has been fixed at 22.9 cm (9 in.), this diameter in turn limits the variation of bed height which is in the range of 10-30 cm. A range of superficial velocity of 1-3 m/s will be used for study in this experiment. Lignite feeding rate has been fixed at 50 to 130 kg/hr. The particle size of 1-5 mm. will be used in this experimentation.

Gasification

1. Experimental Method

The 10 cm fixed bed gasifier of the down draft type is shown in

figure 2. The gasifier is made of stainless steel tube 10.5 cm. in diameter and 145 cm. long with a perforated plate just above an ash removing valve which is situated right at the bottom of the gasifier. The feed lignite to be processed is collected in the hopper connecting to the top part of the gasifier. The feed air inlet from reciprocating compressor is at 110 cm above the perforated plate. The producer gas obtained can be received at the bottom part, the gas is then passed through the cooling water jacket and to gas meter to measure the flow rate, then to the ORSAT gas analyser to work out its composition. To start the process the burning lignite is fed into the gasifier close to the feed air inlet, the top hopper is then filled with lignite until it is nearly full, the lid is then closed tightly. There are two sizes of lignite particles that have been used as feeds in this experiment with varying air flow rates of 1.8-17.7 Nm^3/hr.

2. Results and Discussion

The experimental results with two different particle sizes of 1.12 cm. and 0.65 cm. can be seen in Tables 4 and 5, respectively. Since an ORSAT gas analyser is being used to measure the volumes of different gases, the amount of CO_2 measured will include other acidic gases(1) such as SO_2, H_2S and NO_x for example (KOH is being used to absorb the CO_2 gas). Figure 3 shows the effects of air flow rate towards the amount of CO and CO_2 produced. For the particle size of 1.12 cm, with low flow rates of approximately 50-100 Nft^3/hr, the amount of CO produced is small and almost constant at 4-6%. However, if the flow rate exceeds 100 Nft^3/hr the amount of CO increases rapidly with a concommittant reduction in CO_2. On the contrary, Figure 4 shows that for a smaller particle size of 0.65 cm., when the air flow rate increases from 3 to 20 Nm^3/hr, the CO quantity slowly increases while the amount of CO_2 slowly decreases at the same time. The effect of the size of lignite particles provides evidence that for large particle sizes of 1.12 cm. or greater air flow rate asserts a greater effect on the amount of CO arising from combustion than is the case for small particle sizes.

3. Liquefaction

The proposed 3 year research project of lignite conversion into liquid fuel is now awaiting government approval. The project, if approved, would commence in the 1983 fiscal year with a total cost of around $100,000. We expect a decision in October, 1982.

The liquefaction process will be based upon the Fischer Tropsch process (2) starting from:

1. Incomplete burning of lignite with O_2 and water. The resulting gas is a synthesis gas with H_2S and COS as the unwanted by products. (These gases may poison the catalysts in the Fishcher Tropsch processes).

2. Removal of H_2S and COS.

3. Shift the H_2:CO ratio to obtain desired level.

4. Start Fishcer Tropsch Synthesis by exposing gas to catalysts.

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1. Chemistry of Coal Utilisation Supplement volume, H. H. Lowry, John Wiley & Sons, Inc, New York, London, 1963.

2. P. H. Groggins, "Unit Process in Organic Synthesis", 5th edition, McGraw-Hill Kogakusha, Ltd., 1958.

TABLE 1

Mae Moh Lignite Proximate Analysis Reported By Electricity Generating Authority Of Thailand (Analysis in 11 March 1981)

Moisture	35.2
Ash	16.4
Volatile Matter	36.7
Fixed Carbon	11.7
Sulphur	0.28
Calorific Value, Btu/lb	5021
Cal/gm	2789

TABLE 3

Operating Condition Of The FBC Of Lignite

Parameter	Range
Bed temperature, ^{o}C	700-900
Bed height, cm (in)	10-30 (4-12)
Superficial velocity, m/s	1-3
Lignite feedrate, Kg/hr	50-130
Ca: S ratio	2-3 : 1
Particle Size, mm	1-5

TABLE 2

Fluidized-Bed Combustion Facilities

Organization	Combustion Regenarator Size	Pressure atm	Gas Velocity, lps	Temperature, °F	
National Coal Board (NCB) and British Coal Utilization Research Association (BCURA)	6" diam, 12" x 12"	1	2-3	1240-1680	62-73/Combustion
	36" x 18"	1	2-8	1420-1680	
	40" x 24" (36" x 24")	5	2	1470-1745	
	27" diam	1	6-14	1420-1680	
Pope, Evans & Robbins (PER)	12" x 16" (FBC)	1	8-14	1450-2000	66-85/Combustion and regeneration, development plant
	20" x 6' (FBM)	1	12-15	1600-2050	
	20" x 20" (CBC)	1	12-15	1450-2000	
	20' 8.2" x 12'	1	9-12	1550	
U.S. Bureau of Mines	18" diam	1	2-3	1450-1650	66-72/Combustion heat transfer
Consolidation Coal	4" diam	1.5	2-3	1700-1900	68-70/Combustion and regeneration
CSIRO	9" diam	1	2-7	750-1850	67-68/Combustion
Argonne National Lab.	6" diam	1	3-7	1400-1700	68-75/Combustion, regeneration
	3" and 6" diam	8	2-5	1450-1650	
EXXON R&D	3" diam	1	2-4	1500-2000	68-75/Combustion, regeneration
	3" diam	10	5	1500-2000	
	12.5" and 5" diam	10	5-10	1700-2000	
Foster-Wheeler	18" diam	1	----	----	Operating/Combustion cold flow model
	6' x 6'; 5" x 21"	1	4-12	70	
Combustion Power	20" diam	1	4-10	1400-1800	73-75/Combustion (adiabatic)
	7' diam	4	5-10	1400-1800	
Bargbau-Forschung	16" x 31"	1	4-8	1470-1560	74-75/Combustion
Lurgi	5" diam	1	>10	2000-2200	62-70/Fast bed combustion of oil for Al_2O_3 production
	40" diam	1	>10	2000-2200	
	12' 5" diam	1	>10	2000-2200	
Battelle-Columbus Laboratories	6" diam	1	1-5	1400-2500	49/Bloating
	24" diam	1	2-10	1400-1700	60-75/Combustion
	6" diam	1	3-30	1400-1700	74-75/Combustion
	24" diam	8	10	2100	75/Combustion (gasification)

TABLE 4

Experimental Results With Particle Size Of 1.12 cm

F Nft^3/hr	F Nm^3/hr	CO_2 %	O_2 %	CO %
65.85	1.86	18.4	0.2	5.0
80.48	2.28	19.2	-	4.8
93.35	2.64	19.2	-	5.2
100.47	2.84	19.4	0.2	6.4
109.87	3.11	17.6	-	10.6
113.17	3.20	12.4	-	13.6
121.19	3.43	7	-	20.6

TABLE 5

Experimental results With Particle Size Of 0.65 cm

F Nm^3/hr	CO_2 %	O_2 %	CO %
2.93	18.4	-	2.0
4.23	17.0	0.4	5.6
4.56	17.0	-	6.6
6.19	16.4	-	9.0
7.46	15.0	-	10.2
7.61	15.2	-	10.0
10.11	12.4	-	14.6
11.88	12.4	-	15.0
15.66	11.4	-	17.6
17.73	10.4	-	19.4

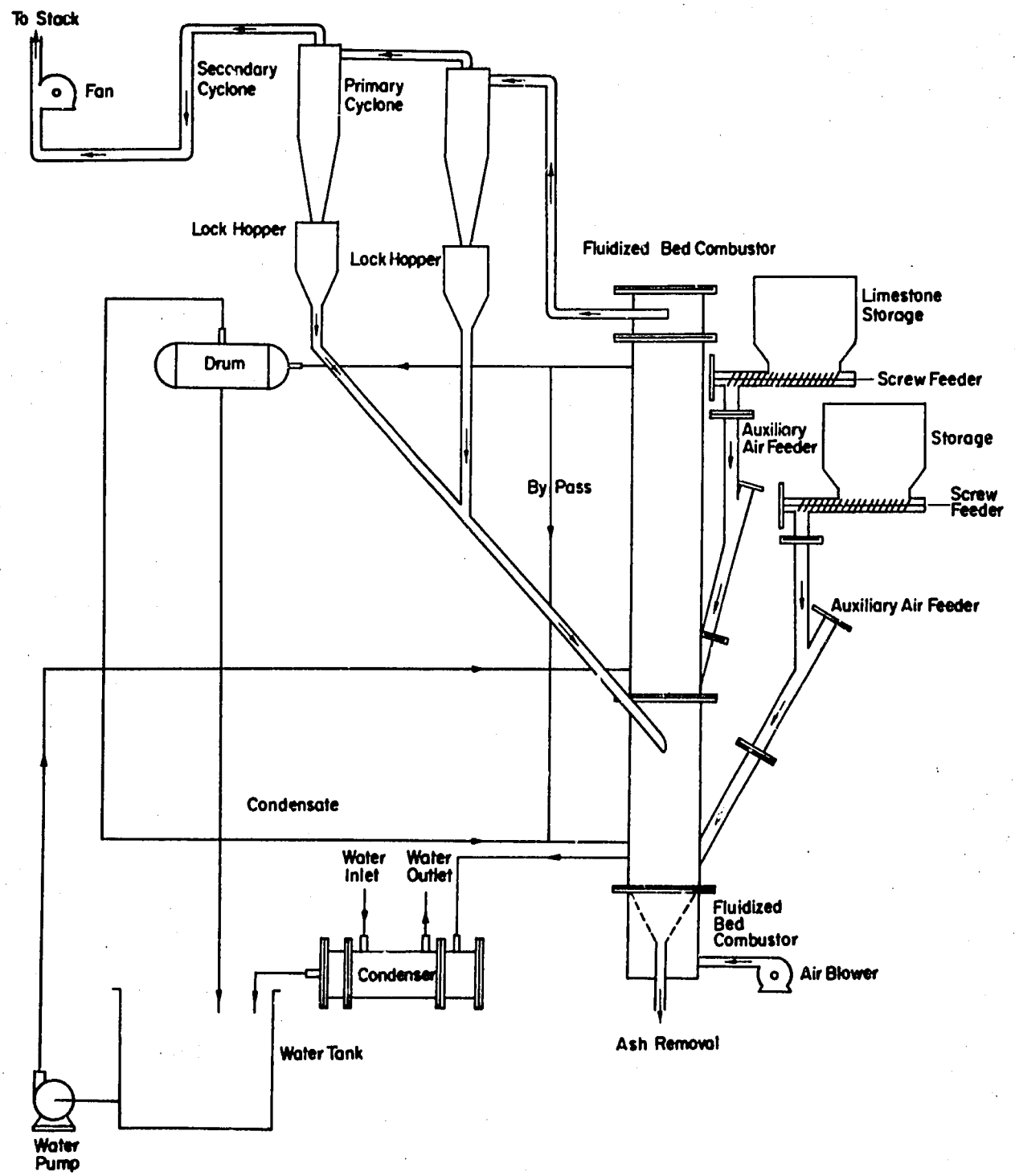

Fig. 1 – A 9 In. Fluidized Bed Combustion System

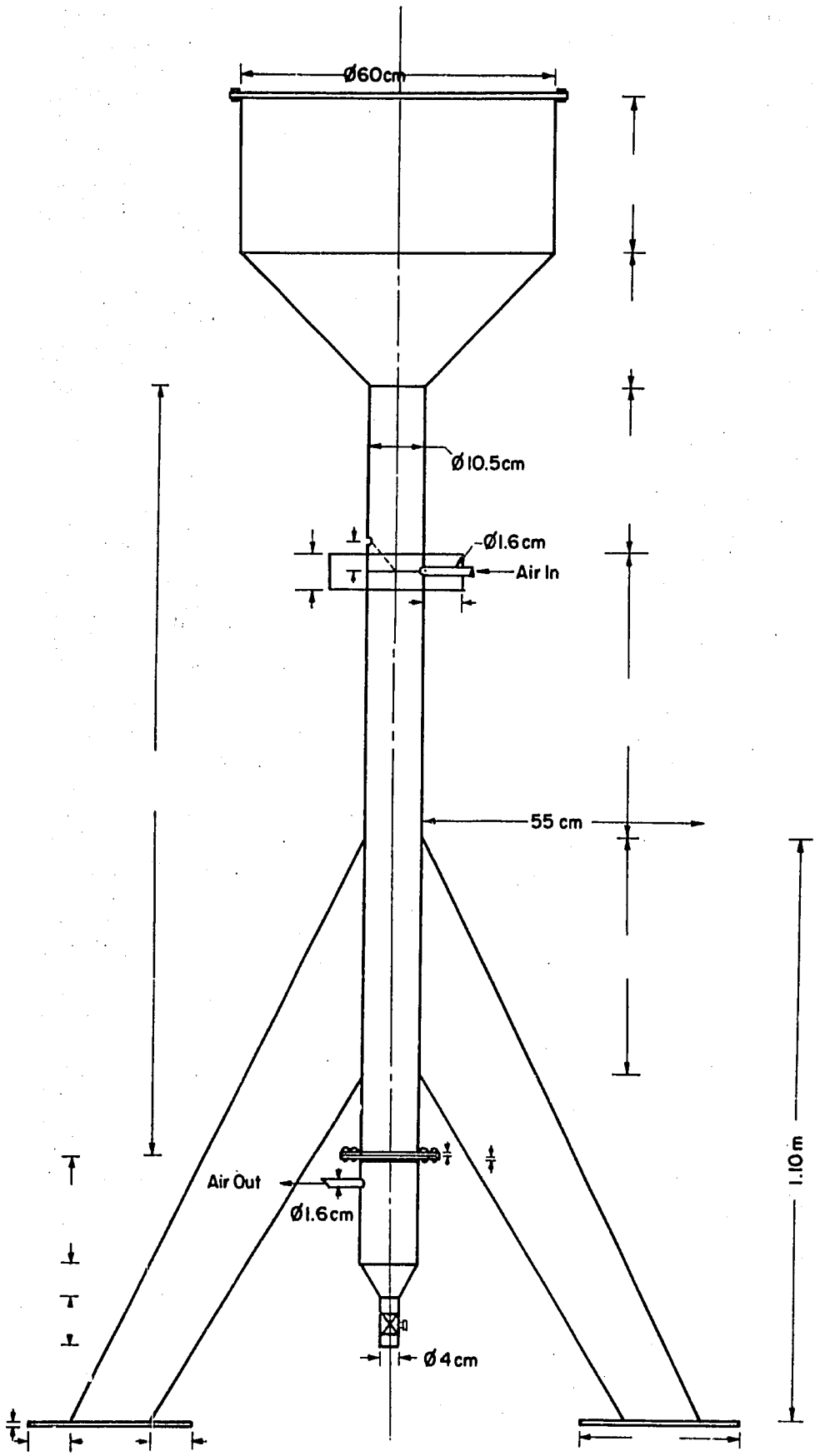

Fig. 2 – A 10 cm Lignite Gasifier

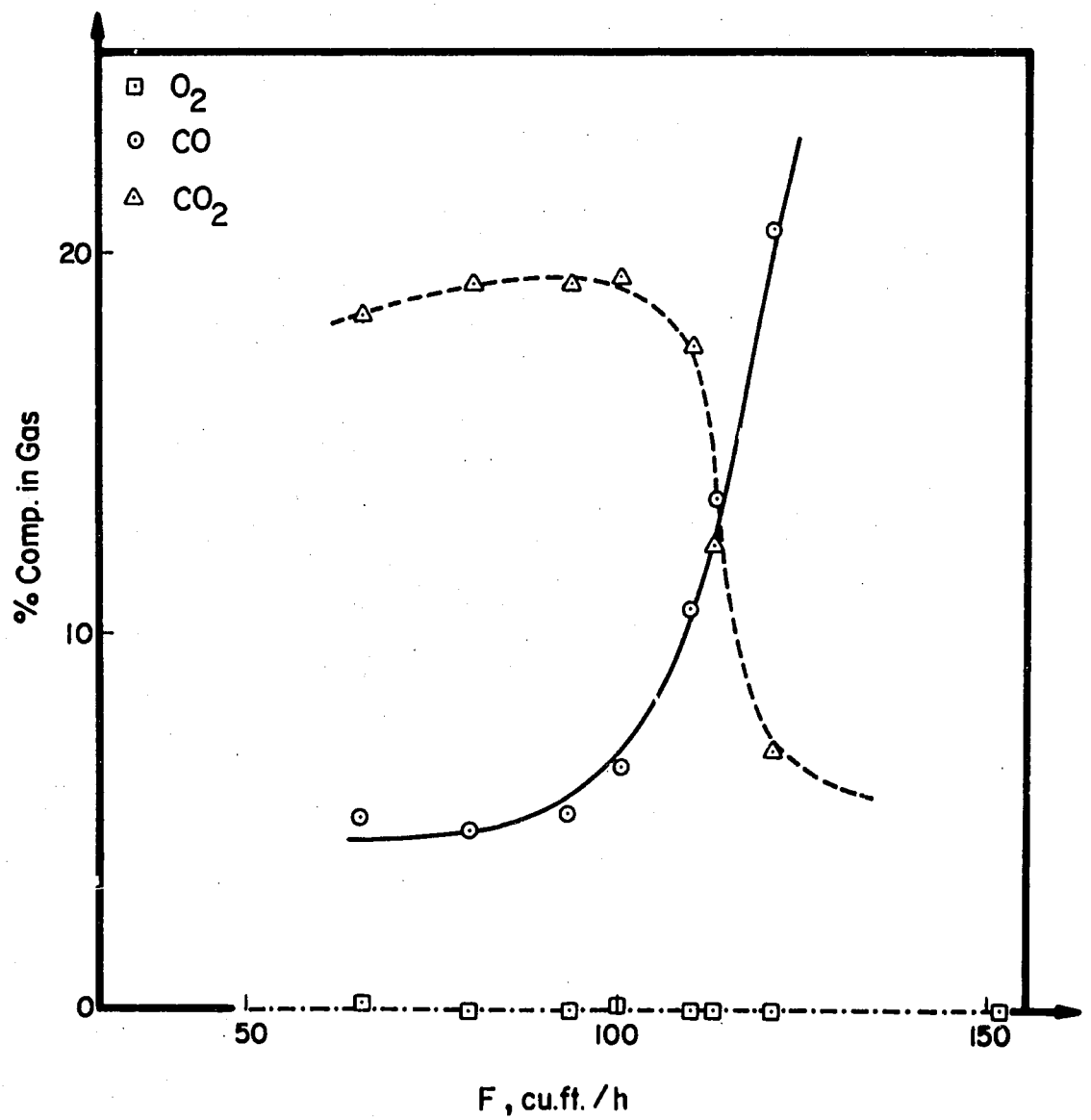

Fig. 3 – Correlation between Air-Flowrate and Producer Gas Composition for Lignite Size 1.12 mm

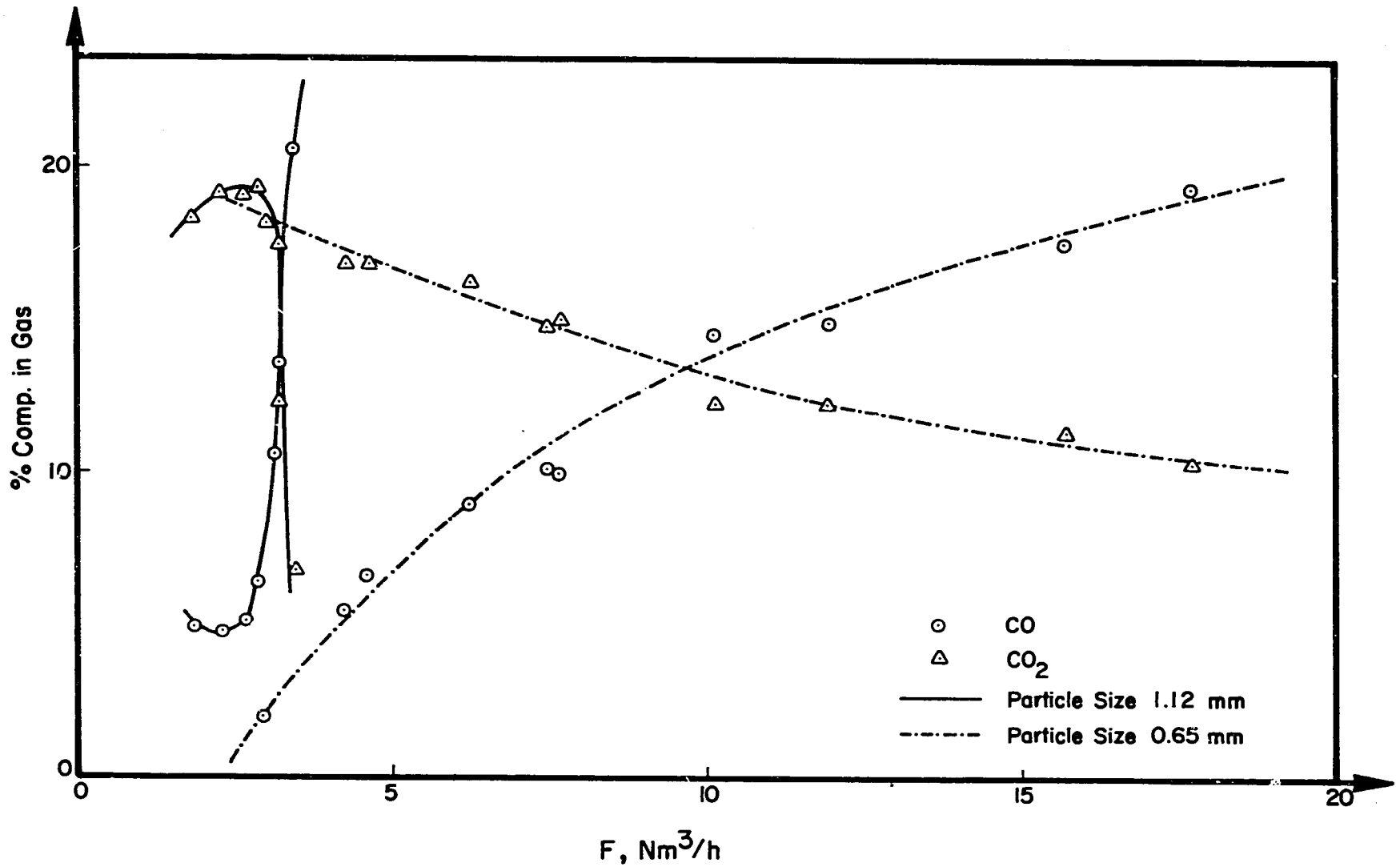

Fig. 4 – The Effect of Particle Size and Air-Flowrate on Gas Composition

General Energy Policy and Coal Development in Indonesia

Endro Utomo Notodisuryo

The Energy-Situation in Indonesia

As a consequence of the economic development and the population growth, the demand for energy is rising steadily from year to year. For example, energy consumption in 1963 was 7 million tons of coal equivalent (TCE), rising to 25 million TCE in 1978 and 34 million TCE in 1980. (Figure 1).

The energy consumption as seen in Figure 1 refers only to commercial energy, primarily petroleum, natural gas hydro-power and, to a small extent, of coal. So far, most of the energy consumed originates from petroleum which accounts for more than 80% of the total consumption of commercial energy. The role of the other energy sources is less than 20%. Commercial energy accounts for somewhat more than half of overall national consumption of energy. The consumption of non-commercial energy primarily fire-wood, accounts for almost half of total energy consumption.

The proportionate consumption of non-commercial energy falls from year to year but only slightly. In the face of rapidly rising commercial energy supplies, we infer a sharp increase in non-commercial energy as well. An important impact of increased consumption of firewood is environmental damage as the result of excessive tree felling.

Since petroleum accounts for the majority of foreign exchange earnings for Indonesia, increasing domestic consumption may reduce exports and thus development spending. In view of this, the Government has adopted a General Policy on Energy.

General Policy on Energy

The policy on energy constitutes an integral part of the national development viewed comprehensively, because of the close links between economic growth, population growth and energy supply.

Viewed from a world perspective, some already feel that the problem of the demand for and supply of energy, primarily petroleum may disturb economic growth, especially in the developing countries.

At the present time, many countries in the world are trying to reduce their dependence on petroleum. The increase in the demand for energy from year to year has obligated countries to make the use of energy more effective and efficient, to reduce the import of energy, petroleum in particular, and try to find and develop other domestic sources of energy, both conventional and non-conventional.

Efforts are continually made in oil and gas production to meet not only the steadily increasing domestic demand, but also to assure that oil export levels can be preserved. To assure continued exports such alternative sources as biomass, coal, hydro power, geothermal energy, nuclear energy, solar and wind energy, need to be developed.

The objectives of the National Energy Policy are as follows :

a. Procurement of energy for domestic purposes
b. Procurement of energy for export purposes
c. Economization in the use of petroleum as fuel material
d. Development of other energy sources
e. Environmental conservation
f. Increasing the national resilience.

In this Third Five Year National Development targets have been set for reducing the role of petroleum by increasing the role of other

energy sources for meeting the demand for energy. The role of petroleum was reduced from 83.7% in 1978/1979 to 77.48% in 1983/1984, while the role of the other energy sources was raised from 16.30% to 22.52% of the national energy consumption.

The following is a specification of the role of the respective energy sources in 1978/1979, and their role as expected in 1983/1984.

Year	1978/79	1983/84
Oil	83.70%	77.48%
Natural gas	11.95%	16.47%
Coal	0.68%	1.58%
Hydro power	3.67%	4.41%
Geothermal-power	0%	present
	100.00%	100.00%*

* This total is the equivalent of 251 million barrels of mineral oil (BOE) or of 50 million tons coal (TCE).

In order to achieve the energy supply targets, the Government has pursued the following four policy measures:

a. Intensification

b. Diversification

c. Conservation

d. Indexation

The coal situation and development of its production in Indonesia

1. Coal potential, production and consumption in Indonesia

Of all the various non-oil energy sources found in Indonesia, coal is the closest substitute for oil.

Fossil energy world-reserves

Coal	88%	10795 x 10^9 TCE
Oil	4%	480 x " "
Natural gas	3%	355 x " "
Oil shales	4%	510 x " "
Tar sands	1%	175 x " "

The above figures of reserves are an estimate of the world-reserves. Several countries are bestowed with coal or mineral oil only or both coal and oil, but there are countries having none of either of the two in significant quantities.

In this matter Indonesia is fortunate enough to have both mineral oil and coal in its territory; each being available in significant quantities.

Major coal reserves are found in the islands of Sumatra and Kalimantan, Irian Jaya. Coal is also found in Java, but it is scattered in small deposits (Fig. 2)

The main coal potential in Indonesia can be seen from Table 3. It shows that there is a large reserve of (15 billion tons) of lignite in the area around Banko, South Sumatra.

Most of the deposits in South Sumatra are found near the surface, making mining easy. West Sumatran and Kalimantan deposits are deep-seated ones, and may be mined only by the underground method.

The data on coal reserves in Indonesia as collected by Mr. Hardjono (1980) can be summarized in Table 4. A summary of the qualities of Indonesia coal (primarily those found in Sumatra and Kalimantan) is given in Table 5.

Of the available resources in Indonesia, now in production are the Ombilin Mine in West Sumatra and the Bukit Asam Mine in South Sumatra.

The pre-war coal output in Indonesia was 2 million tons. About one third of the output was exported, and the remainder was used for domestic consumption, primarily for shipping, railway and industry. After the war, the demand for coal steadily went down as oil consumption increased. The annual coal production is shown in Table 6.

Principal coal mines were located in Ombilin, Bukit Asam and Mahakam in Kalimantan. The latter is no longer in production. In 1973, the two mines still in operation, the Ombilin and Bukit Asam Mines, were already being considered for shutdown. Production at that time stood only at 150,000 tons a year. With the energy crisis in the industrialized countries in 1973, the future of coal became bright again. Since that year, production has gradually increased, and in 1980 output reached 300,000 tons.

To satisfy the plan goals, Indonesia must be able to greatly increase its coal output.

Year	Cement Factories	Steam Power	Others	Total
1980	60,000	-	140,000	200,000
1985	2016,000	2920,000	237,000	5173,000
1990	2156,000	13190,000	547,000	15893,000

From this coal consumption estimate can be seen our coal needs, primarily in the form of coal for producing steam.

To meet the needs of the State Electric Power Enterprise (PLN) for power plants for Java island in the year 2000, only 23 million tons of coal will be needed.

It has indeed become the determination of the Indonesian Government that in constructing power plants and cement factories coal must be used as the primary fuel whenever possible. Thus, within the next

10 years (1981-1990), the demand for coal will significantly increase.

In 1980 there was not yet any demand for coal for electric power generating stations, while the demand in 1985 is estimated at 2,920,000 tons, rising to 13,190,000 tons in 1990. In 1980, the coal demand of the cement industry was 60,000 tons. While in 1985, demand will be 2,016,000 tons, an increase of almost 34 times within a period of five years.

2. Efforts for increasing coal output

In order to be able to meet the steadily and rapidly increasing demand for coal, it is necessary to make serious efforts, such as increasing the production capacity of the mines now in production.

In boosting production, the Indonesian government has formed another company, PT. TABA, next to the already existing PN. Batubara (State Enterprise). The task of PT. TABA is to develop the Bukit Asam mine in South Sumatra which is presently designed to meet the coal demand of the Steam Power Plants at Suralaya, Banten, West Java, currently under construction with capacities of 4 x 400 MW and 2 x 600 MW, respectively. Suralaya I, with a capacity of 400 MW will be in operation in 1984 consuming 1.25 million tons of coal a year. When all the six stages of the construction of the PLTU have been completed, by 1990, consumption of coal will rise to 9 million tons a year (see Table 7). The upgrading of the Ombilin coal mine is aimed at making it able to meet the coal demand of the cement industry and is being handled by PN. Batubara.

Within the framework of increasing coal explorations and development of coal-production, the Indonesian Government has made a beginning by having foreign companies participating as at this stage carried out in East and South Kalimantan. By increasing the output of the Ombilin and Bukit Asam Mines, the demand for 2.5 million tons of coal will be met by 1985, rising to 5.4 million tons by 1990. In view of the rapid increase of consumption, it is estimated that in 1985 there will be a shortage of approximately 2.5 million tons and almost 5 million tons in 1990.

TABLE 1

Primary Energy Consumption Pattern (1978-1980)

Primary energy	1978		1979		1980	
	BOE (x 10^3)	%	BOE (x 10^3)	%	BOE (x 10^3)	%
Petroleum	24,760	84.5	27,212	80.8	29,945	80.2
Natural gas + L P G	4,090	13.9	5,156	15.3	6,069	16.3
C o a l	164	0.6	162	0.5	191	0.5
Hydro	300	1.0	1,148	3.4	1,113	3.0
Total	29,314	100.0	33,678	100.0	37,318	100.0

TABLE 2

Energy Consumption Pattern by Sector (1978-1980)

Sectors	1978		1979		1980	
	BOE (x 10^3)	%	BOE (x 10^3)	%	BOE (x 10^3)	%
Household sector	43,869	27.8	46,605	26.9	49,534	27.1
Transportation sector	47,667	30.3	52,496	30.3	48,682	26.6
Industrial sector	55,727	35.4	62,180	35.9	66,333	36.6
Electric Power sector	10,331	6.5	11,754	6.9	17,792	9.7
Total	157,594	100.0	173,062	100.0		100.0

TABLE 3

Coal Potential in Indonesia

Region	in million metric tons	
1. West & Control Sumatra (Ombilin, Logas, Sinamar, etc.)	200 to 300	
2. South Sumatra (Bukit Asam, Banko, Bukit kendil, etc.)	200 to 250	in excess of 15,000
3. Northeastern Kalimantan	100 to 150	a few billion tons
4. East Kalimantan	100 to 150	
5. Southeastern Kalimantan (incl. Pulau Laut)	150 to 200	

TABLE 4

Coal Reserves in Indonesia

(A Summary)

Location	Measured	Indicated	Inferred
1. Ombilin Mine, W Sumatra	92,291,400	9,944,500	85,000,000
2. Sinamar area, Jambi	-	106,000,000	-
3. Bukit Asam Mine S. Sumatra, (1978)	101,170,041	48,687,486	13,287,537 1)
4. Banko area, S. Sumatra	435,000,000	-	-
5. Arahan area	-	-	220,000,000
6. Air selero area	-	-	15,000,000
7. Air Lawai area (North) 2)	-	-	66,000,000
8. Suban Jeriji area	-	-	485,000,000
9. Loa Kulu	-	34,910,000	-
10. Loa Haur E. Kalimantan	-	14,760,000	-
11. Prangat area	-	193,380,000	-
12. Sungup-Selaro area NW part of P. Laut	-	11,000,000	-

Compiled by Hardjono, 1980

1) Exploration after 1978 has found additional measured reserves, exact figures not yet reported.

2) Coal prospect area surrounding Bukit Asam Mine Figures are given in cubic meters.

TABLE 5

Summary of Indonesian Coal Quality Data

ANALYSIS AND TESTING	SUMATERA					EAST KALIMANTAN			JAVA
	Ombilin	Air Laya	Suban	Banko (South Sumatera)	Sinamar (Jambi)	Mahakam	Berau-Bulungan	Paris Pulo Balang	Penang
	adb	mf	adb	mf	adb	mf	adb	adb	adb
1. PROXIMATE ANALYSIS, %									
Total Moisture	-	12.80-24.00	-	28.00-32.00	-	-	-	-	-
Free Moisture	1.18- 2.79	-	2.06- 3.93	-	-	-	4.50-15.70	-	-
Inherent Moist.	5.59- 6.36	3.80-11.30	1.65- 2.24	7.00-18.00	13.30-16.40	3.30- 9.80	7.10-10.30	2.60-20.80	14.00-28.33
Ash	1.98- 6.37	3.70-10.60	1.59- 5.73	4.10-11.80	1.50- 7.40	1.10-11.00	0.40- 6.80	1.20- 5.20	1.39- 7.39
Volatile Matter	35.59-37.97	37.67-41.80	8.18-16.78	42.60-47.90	35.40-36.90	41.00-50.80	40.50-46.10	36.40-47.40	32.16-43.64
Fixed Carbon	34.45-54.29	43.40-48.40	79.52-84.44	43.90-49.40	42.40-46.70	43.00-49.20	39.70-48.90	38.50-50.20	22.80-49.85
Total Sulphur	0.31- 0.58	0.20- 1.24	0.67- 1.14	0.15- 1.46	0.40- 3.10	2.80- 3.37	0.16- 0.95	0.10- 1.90	2.02- 3.86
2. ULTIMATE ANALYSIS, %									
Carbon	68.74-74.67	62.11-70.02	83.67-88.93	58.30-60.90				66.60-78.30	
Hydrogen	5.12- 5.59	4.33- 5.10	1.73- 3.09	5.00- 5.95				4.70- 6.00	
Oxygen	17.88-24.43	23.74-32.68	6.52-13.41	15.10-19.78				8.40-19.80	
Nitrogen	1.25- 1.42	0.88- 1.14	1.19- 1.46	1.00- 1.36				1.50- 1.90	

Continuous TABLE 5

ANALYSIS AND TESTING	SUMATERA					EAST KALIMANTAN			JAVA
	Ombilin	Air Laya	Suban	Banko (South Sumatera)	Sinamar (Jambi)	Mahakam	Berau-Bulungan	Pasir Pulo Balang	Penang
	adb	mf	adb	mf	adb	mf	adb	adb	adb
3. ASH ANALYSIS, %									
Sio_2	24.40-79.44	42.40-79.00		11.30-43.50					
Al_2O_3	6.70-22.87	6.50-37.00		21.70-36.50					
Fe_2O_3	8.34-32.96	1.40- 5.70		3.00-16.20					
TiO_2	0.39- 1.23	0.40- 1.20		1.20- 1.40					
MgO	0.63- 3.49	0.50- 3.70		0.90- 2.70					
CaO	1.99- 7.96	0.70- 6.'0		9.60-28.90					
Na_2O	2.49- 3.14	0.50- 5.10		0.50- 5.80					
K_2O		0.20- 0.60		0.20- 3.30					
P_2O_5	0.14- 0.22	0.07- 0.60		0.03- 0.60					
4. ASH FUSION POINT, °C									
Initial Deformation (ISO-A)	1,380->1,450	1,110-1,400		1,200-1,335			1,250-1,450		
Hemisphere (ISO-B)		1,245- > 1,400		1,290-1,405					
Flow (ISO-C)		1,400-1,600		~1,355-1,475					

Continuous TABLE 5

ANALYSIS AND TESTING	SUMATERA					EAST KALIMANTAN			JAVA
	Ombilin	Air Laya	Suban	Banko (South Sumatera)	Sinamar (Jambi)	Mahakam	Berau-Bulungan	Paris Pulo Balang	Penang
	adb	mf	adb	mf	adb	mf	adb	adb	adb
5. TESTING									
Free Swelling Index	1.50- 2.00	0.00- 1.00		0.00- 0.50		1.00- 1.50	0.50		
Calorific Value (Kcal/kg)	6,783-7,437	6,716-7,215	7,972-8,396	6,580-7,035	5,460-5,980	6,550-6,600	6,260-6,960	5,190-7,900	4,362-5,413
Dilatation	contraction only								
Gray King Type	C	B	A	A					
Hardgrove Grin dability Index	48.30-57.80	59.40-64.20		48.60-61.50					
6. PETROGRAPHIC COMPOSITION, %									
Total Vitrinite	92.3-93.2	84.5	89.5	69.3-90.2		83.0-87.0			
Vitrinite		00.4	72.2	66.8-79.8					
Resin		4.2	17.3	2.5-10.4					
Total Liptinite									
Exinite	3.7- 5.1	8.5		3.2-12.7		6.0- 7.0			
Sporinite	1.9- 3.3	1.1		0.3- 1.5					
Cutinite	1.4	0.2		0.4- 1.0					
Resinite	0.4	1.8		0.2- 1.9					
Suberinite		4.2		0.9- 3.0					
Others		1.3		1.4- 5.3					

Continuous TABLE 5

ANALYSIS AND TESTING	SUMATERA					EAST KALIMANTAN			JAVA
	Ombilin	Air Laya	Suban	Banko (South Sumatera)	Sinamar (Jambi)	Mahakam	Berau-Bulungan	Paris Pulo Balang	Penang
	adb	mf	adb	mf	adb	mf	adb	adb	adb
Total Inner-tinite	3.5- 4.0	4.6	0.4	1.6-15.0					
Fusinite	-	-	-	-					
Semifusinite	0.3- 0.7	1.5	0.2	0.7-10.9					
Sclerotinite	-	2.3	0.2	0.4- 0.7					
Micrinite	3.2- 3.3	0.8	-	0.5- 3.4					
Total Mineral Matter	2	2.2	10.1	1.8- 9.5					
Quartz		-	1.0	-		1.0- 3.0			
Carbonate		-	0.6	-					
Clay Minerals		0.2	6.1	1.6- 4.8					
Sulphides		2.0	2.4	0.2- 4.7					
Altered Iron Oxides		-	-	-					

TABLE 6

Coal Production in Indonesia

(Tons)

YEAR	OMBILIN	COAL MINES BUKIT ASAM	OTHERS	TOTAL
1939	590,743	631,663	558,231	1,780,637
1940	577,616	847,835	575,229	2,000,680
1941	537,738	863,706	627,431	2,028,875
1966	100,655	185,040	34,288	319,983
1967	66,697	121,834	20,042	208,983
1968	68,253	91,407	16,356	176,016
1969	69,281	112,701	8,232	190,214
1970	77,285	90,985	4,082	172,352
1971	89,730	108,526	-	198,256
1972	87,971	91,269	-	179,240
1973	81,841	66,985	-	148,826
1974	78,804	77,349	-	156,153
1975	76,095	130,295	-	206,390
1976	60,151	132,759	-	192,910
1977	81,020	149,607	-	230,627
1978	87,115	177,065	-	264,180
1979	92,318	186,271	-	278,589

TABLE 7

Production of Bukit Asam Coal Consumption
for Suralaya I,II,III,IV,V and VI Power Plants

(million tons)

TAHUN	I 400 MW	II 400 MW	III 400 MW	IV 400 MW	V 600 MW	VI 600 MW	Total 2800 MW
1982	-	-	-	-	-	-	-
1983	180	-	-	-	-	-	180
1984	1,250	180	-	-	-	-	1,430
1985	1,250	1,250	-	-	-	-	2,500
1986	1,250	1,250	-	-	-	-	2,500
1987	1,250	1,250	180	-	-	-	2,680
1988	1,250	1,250	1,250	180	-	-	3,930
1989	1,250	1,250	1,250	1,250	250	-	5,250
1990	1,250	1,250	1,250	1,250	1,875	250	7,125
1991	1,250	1,250	1,250	1,250	1,875	1,875	8,750
1992	1,250	1,250	1,250	1,250	1,875	1,875	8,750
1993	1,250	1,250	1,250	1,250	1,875	1,875	8,750
1994	1,250	1,250	1,250	1,250	1,875	1,875	8,750

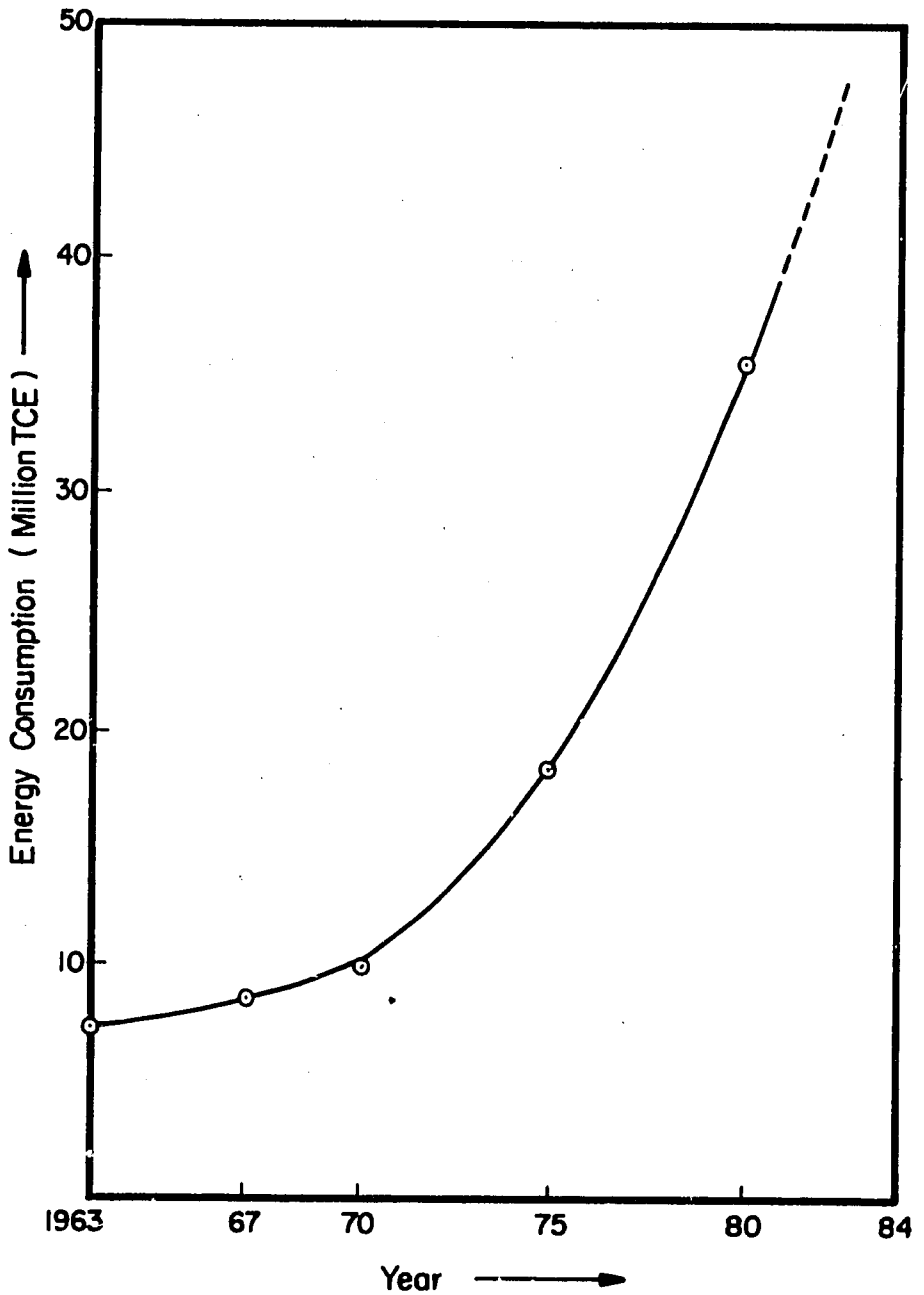

Fig. 1 – Energy Consumption , 1963 - 1980

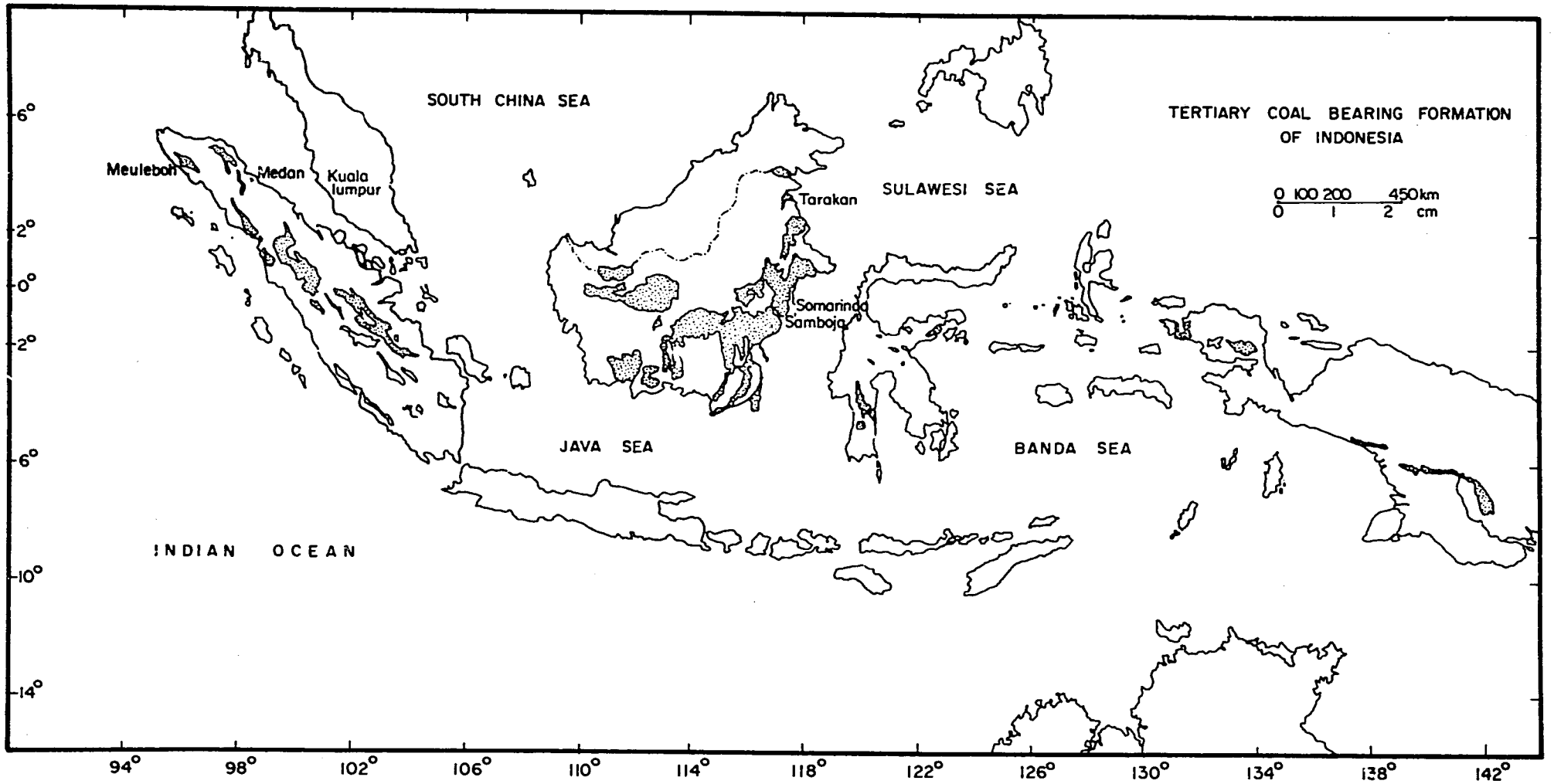
TERTIARY COAL BEARING FORMATION
OF INDONESIA
0 100 200 450km
0 1 2 cm
SOUTH CHINA SEA
SULAWESI SEA
JAVA SEA
BANDA SEA
INDIAN OCEAN
Meuleboh
Medan
Kuala
lumpur
Tarakan
Samarinda
Samboja
6°
2°
0°
2°
6°
10°
14°
94°
98°
102°
106°
110°
114°
118°
122°
126°
130°
134°
138°
142°

Fig. 2

Utilization of Coal and Lignite For the Generation of Electricity in Thailand

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Abstract

In Thailand, lignite deposits are found principally in the basins of Tertiary rock units. More than 20 lignite occurences are reported in widespread distribution all over the country. However, only 4 lignite fields are classified as commercial mines, and three of them are located in the North of the country while the other one lies in the South.

Most lignite in Thailand is used for direct burning. Research and development on dressing and upgrading of lignite is underway but no fruitful results could be publicised at present. About 80 - 90% of the mined-lignite is used in electricity generation. The rest is shared among small tobacco curing plants, cement kilns, iron smelting factories, lime production and some other small industrial applications. The main drawbacks of lignite which prevent it from wide spread use are its high ash content (11 - 34%), high moisture (15 - 33%), high volatile matter (18 - 40%) and low heat value (of about 1,750 - 4,250 Kcal/Kg.). Other demerits of lignite includes high pollution output and its high self-ignition quality which lead to unsafe and uneconomic transport, especially over long distances.

Introduction

Since the energy crisis in late 1973, Thailand, like all other countries depending seriously on imported fuel oil, has accelerated her exploration and development program of indigeneous and alternative sources of energy. Coal, specifically lignite, is one of the most promising available resources in the country.

In 1980, about 72% of energy needed was imported as petroleum products. Among the remainder, lignite contributed just 2.9%. As exploration and drilling are intensified, it is expected that the supply of lignite at the Mae Moh mine in the north of the country will alone be sufficient for the electricity generation of a 1,125 MW power plant through its life span. The net energy generation of those power plants will constitute 8.2% of the country's energy supply pattern which means a considerable relief from the nation's dependence on imported fuel oil.

Coal Resources and Reserves in Thailand

In Thailand, lignite deposits are found principally in the basins of Tertiary rock units (about 50-70 million years ago). More than 20 lignite occurrences are reported throughout the country. Its quality varies from place to place. However, lignite can be classified in general, as a low rank, brownish to black coal with a large percentage of ash, moisture, volatiles and a heating value of less than 8,300 Btu/lb. Most lignite is soft, friable and contains pieces of wood material.

Based on stage of production and development of individual deposits, coal resources in Thailand can be summarized in the following categories.

1. Commercially or minable coal resources

There are 4 lignite fields which can be considered commercial. Three of them are located in the North while the fourth lies in the South.

1.1 Mae Moh Mine

Of these mines mentioned, Mae Moh mine, which belongs to EGAT, is the largest one with a proven reserve of about 150 million tons. It is situated 30 kilometers in the east of Lampang Province, or about 603 kilometers by rail from Bangkok. The approximate area of this mine is 1.7 square kilometers. The results of analysis indicate that lignite from this mine has a rather high percentage of sulfur (4.5%), ash (11-34%) and moisture (15-23%). (For more detail see Table 1)

Previously, lignite from this mine was used either for electricity generation or for feedstock to a chemical fertilizer plant at the mine-mouth. At present, the fertilizer plant is closed and lignite is used solely for the power plants. Lignite consumption is about 1.5 million tons per annum which is sufficient for 3 units each of 75 MW capacity. A Mine Master Plan is now under study for the mine. This Master Plan will provide information to help cope with additional power plant. A total capacity of 1,725 MW is expected to be installed near the surface mine.

1.2 Li Mine

Li mine is in the north of the country, 14 kilometers from Amphoe Li, Lampoon province. In general, the properties of coal in this area are very good, and can be classified as high volatile C bituminous coal. The quality of coal is shown in Table I.

The mine has been in operation since 1965 by the government agency, NEA (the National Energy Administration). The minable reserve is about 19 million tons making it number two in the country. Most of the mined-lignite is used for non-electric uses i.e. tobacco curing, cement process, lime production and other small industries in the north. The annual production of Li mine is about 200,000 tons.

1.3 Krabi Mine

This mine is located in the area of Bang Pudum, about 25 kilometers

southeast of Krabi. An analysis of lignite from this source has been performed and shows that the heating value is slightly higher than Mae Moh lignite (see Table I).

This mine belongs to EGAT which use the coal mainly for electricity generation. The mine and 3 x 20 MW power plant were started in 1964. The annual production of this mine is about 450,000 tons. More detailed geological and drilling has been undertaken at Klong Wai Lek, Tambon Klong Khanan as well and at the existing mine at Bang Pudum. This investigation, if sucessful, would enable EGAT to plan an additional plant or otherwise prolong the life of the mine, the only one in the South.

1.4 Mae Teeb Mine

This mine belongs to a private-owner-franchisee. Neither exact reserves nor tonnage production is available. However, it is expected as high quality of lignite available on commercial scale with a heat content of 4,000 - 6,000 Kcal/Kg. (For more detail see Table I). Most of this lignite is used in tobacco curring plants in the north. Together with some higher grade lignite, it is transported to a small iron smelting plant in the capital.

2. Coal Resources under development

The following coal deposits are categorized as under development since drilling is in progress to quantify the minable reserves.

2.1 Ban Hang deposits, Amphoe Ngao, Lampang Province.

Minable reserve	N.A.
Probable reserve	23 Million Tons
Analysis	N.A.

2.2 Chae Khon deposits, Amphoe Chae Hom, Lampange Province.

Minable reserve	N.A.
Minable reserve	N.A.
Probable reserve	35 Million Tons
Analysis	See Table I

2.3 Muang deposits, Chiang Mai province.

Minable reserve	N.A.
Probable reserve	10 Million Tons
Analysis	N.A.

3. Other potential deposits

There are other lignite deposit areas which are now under serious investigation by the government agencies e.g. the Department of Mineral Resources (DMR) and the National Energy Administration (NEA). However, as no recent data are available, they are considered as potential deposits. They are found scattered and extended in more than 7 provinces, mostly in the north, i.e. Lampang, Pha Yao, Tak and Nan Province.

Research and Development of Lignite in Thailand

As already mentioned earlier, lignite in Thailand is used mainly for direct burning processes. And as far as lignite analysis is concerned, lignite in Thailand could be ranked as a low-grade coal. It has many drawbacks which prevent it from being widely used. Urgent research and development is needed to alleviate problems ranging across different stages i.e.

Exploration - to determine the feasible geophysical method for delineating the coal seams or to estimate the probable reserve within an accuracy allowance in a short time.

Development - to dress or upgrade lignite in order to lessen the moisture and ash contents.

Transportation - to control and transport lignite in a safe and low risk manner because of its self-ignition property.

Utilization - to study whether fluidized bed combustion may be erected on a commercial scale. To find developing processes for briquetting, cooking, carbonization and gasification etc.

Conclusions

Coal or lignite is considered a key element in national energy and economic development. Despite its low quality, lignite shoulders, with Thailand's other natural resources, a responsibility to save foreign currency exchange and also reduce the operating cost of energy production caused by continuous increases in imported fuel oil prices.

The research and development of any energy resource usually requires a long lead time, a large amount of funds and advanced technologies. Financial and technical aid from developed countries are of help and may increase in the future. These aids, when coupled with the promotion of efficient energy production and use, will solve the problem effectively.

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2. Annual Report of EGAT. 1978, 1979, 1980.

3. "The Energy situation in Thailand", 1969, National Energy Authority, Ministry of National Development.

TABLE 1

Analysis \ Location	Chae Khon	Mae Moh	Krabi		Li	Mae Teeb
			Klong Wai Lek	Bang Pu Dum		
Approximate (As-received)						
Moisture	11.43-20.25	15-23	14.6-41.8	28.7-34.2	20.69	18.69
Volatile Matter	26.92-29.64	18-20	47.07	31.7	33.92	35.05
Ash	27.42-38.44	11-34	15.9-44.63	16.5-23.1	8.13	6.21
Fixed Carbon	23.29-28.10	6-36	41.2	21.6	37.25	40.52
Dry Basis						
Heating Value	6,156-9,007	3,150-7.650	10,657-9,502	7,430-9,502	12,810	11,938
Ultimate Analysis						
C %	31.9	70			67.5	63.8
H %	3.4	5			5	6.9
O %	14.8	18.2			18.6	18.9
N %	0.91	2.3			0.7	2.0
S %	5.6	4.5			4	6.51

CAPACITY ADDITION

1981 - 1993

(MW)

		1981 - 1987	1988 - 1993
1.	Gas - Fired*	1,920	
2.	Lignite - Fired	975	600
3.	Hydroelectric	1,978	128
4.	Oil - Fired	75	360
5.	Other	---	2,400

* Excluding 900 MW gas conversion at South Bangkok

ESTIMATED % SHARE OF ENERGY SUPPLY

		1980	1983	1985	1988
1.	Energy Petroleum	72.0	62.3	47.9	41.4
2.	Natural Gas & Condensate	----	12.2	23.3	25.9
3.	Lignite	2.9	3.5	5.6	8.2
4.	Hydroelectric	5.8	5.5	6.5	7.1
5.	Fuelwood & Charcoal	13.7	12.3	11.2	10.0
6.	Bagasse	4.6	4.0	3.5	3.0
7.	Paddy Husk	1.0	0.2	0.5	0.6
8.	Other			1.5	3.8
	TOTAL	100.0	100.0	100.0	100.0

ESTIMATED % SHARE OF PRIMARY ENERGY SUPPLY TO THE POWER SECTOR

		1981	1983	1985	1987
1.	Natural Gas	----	28.8	58.5	52.5
2.	Lignite	8.9	7.6	13.4	20.0
3.	Energy Petroleum	75.2	46.0	7.3	7.2
4.	Hydroelectric	11.2	13.0	16.0	16.7
5.	Other	4.7	4.6	4.8	3.6
	TOTAL	100.0	100.0	100.0	100.0

TABLE 2

Lignite Consumption for Mae Moh Power Plant

Unit No.	Capacity (MW)	Commissioning Date	Annual Lignite Comsumption (10^6 ton)											
			1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	75	Apr. 78	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623
2	75	Dec. 78	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623
3	75	Feb. 81	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623
4	150	May. 84			0.639	1.019	1.019	1.019	1.019	1.019	1.019	1.019	1.019	1.019
5	150	Nov. 84			0.128	1.019	1.019	1.019	1.019	1.019	1.019	1.019	1.019	1.019
6	150	Sep. 85				0.293	1.019	1.019	1.019	1.019	1.019	1.019	1.019	1.019
7	150	Mar. 86					0.880	1.019	1.019	1.019	1.019	1.019	1.019	1.019
8	300	Aug. 87						0.742	2.006	2.006	2.006	2.006	2.006	2.006
9	300	May. 89										0.412	2.006	2.006
10	300	Apr. 92											1.566	2.006
Total Lignite Consumption (10^6 ton)			1.869	1.869	2.636	4.200	5.806	6.687	7.951	7.951	7.951	8.363	11.523	11.963
Total Heat Consumption (10^{12} Kcal)			4.671	4.671	6.591	7.324	11.338	13.541	16.701	16.701	16.701	17.731	25.630	26.729
Maximum Daily Consumption (ton)			5.119	5.119	10.750	13.498	16.291	21.785	21.785	21.785	21.785	27.250	32.775	32.775
Total Ash Disposal (10^6 ton)			0.404	0.404	0.569	0.907	1.254	1.444	1.717	1.717	1.717	1.806	2.489	2.584
(10^6 m^3)			0.404	0.404	0.569	0.907	1.254	1.444	1.717	1.717	1.717	1.806	2.489	2.584

Note: 1. Plant Factor 75%
2. Heating value 2,500 Kcal/kg
3. Average net Heat Rate
75 MW Plant : 3,160 Kcal/KWh
150 MW Plant : 2,586 "
300 MW Plant : 2.544 "
4. Average Ash Content: 21.6%
5. Specific Gravity of Net Ash 1 ton/m^3

Energy Technology Dep.
19 June, 1981

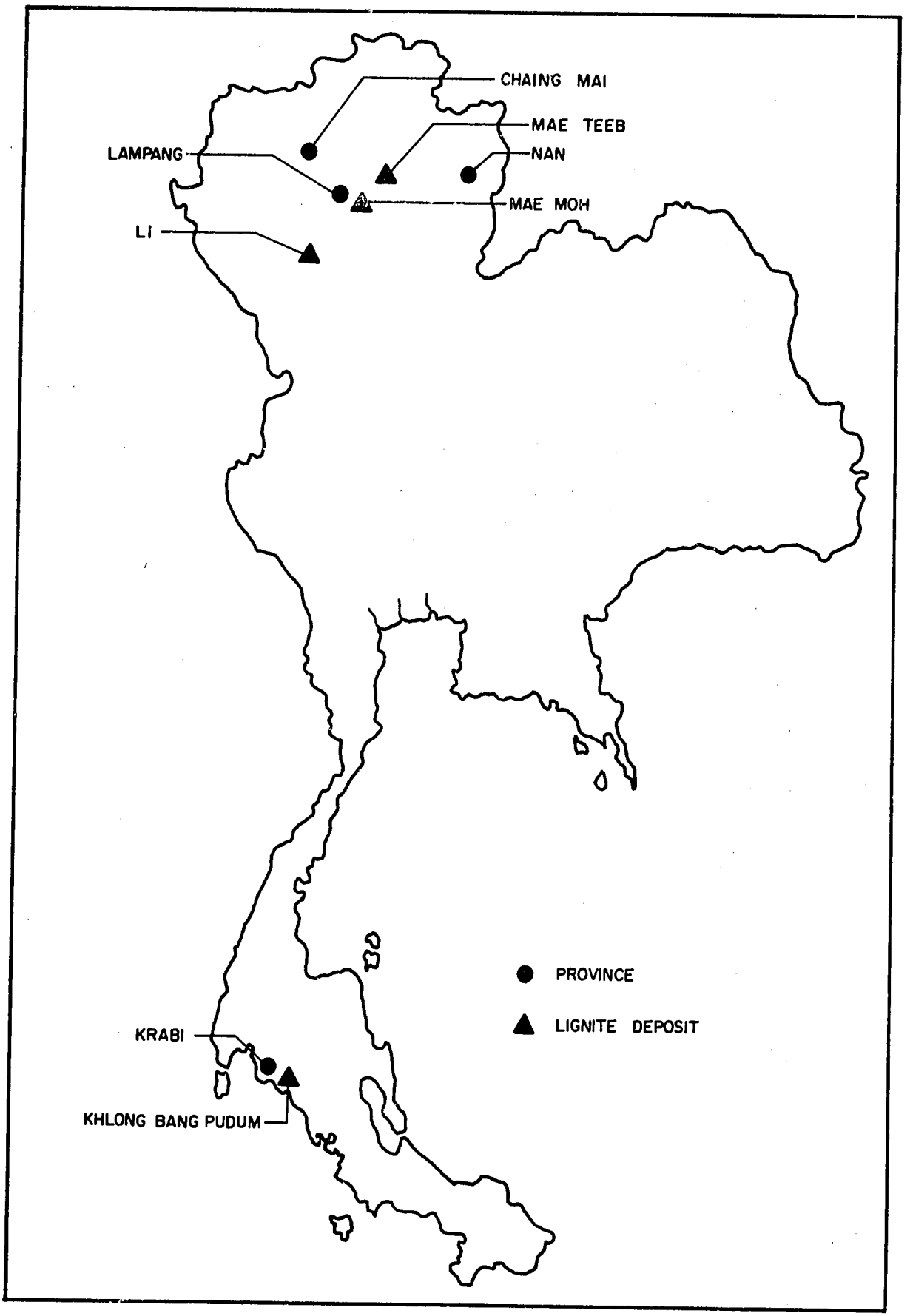
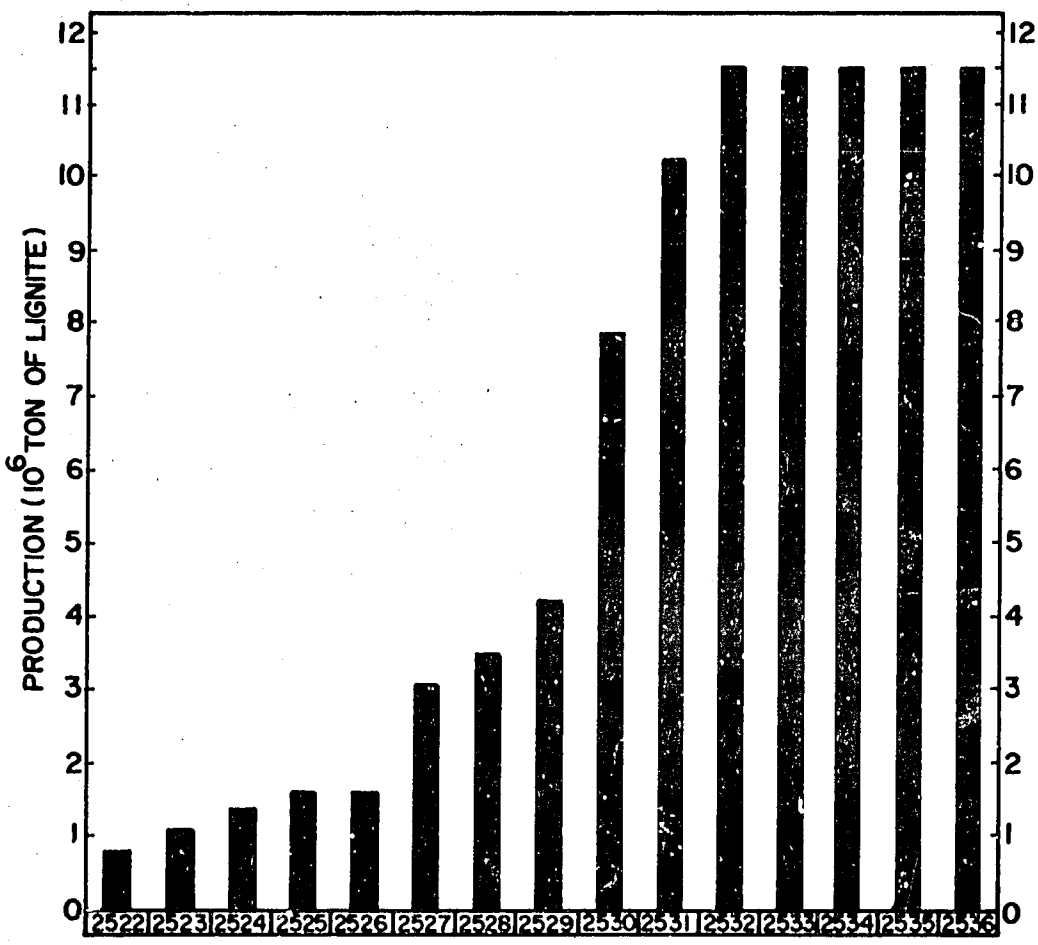


Fig. I – Lignite Deposits in Thailand



Production Plan of Mae Moh Mine

A New Testing Method to Determine The Performance of Thermal Solar Collectors

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Introduction

The thermal solar collector manufacturing industries is a rapidly growing business, not only in such developed countries as USA, Japan, France, and Isreal but also in developing countries where numerous locally designed manufactured collectors are put on the market. As a consequence, many developing countries are presently contemplating setting up national standards for testing solar collectors and for assessing their performances. Several testing methods including BSE[1], AFNOR[2], CEC[3] exists and are similar to the well known ASHRAE method described in the ASHRAE Standard 93-77[4].

Those methods are relatively recent and suffer several drawbacks. Most of those drawbacks are linked with the fact that the above mentioned methods suggest using the following regression equation for interpreting the experimental measurements of the collector efficiency:

$$\eta = \eta_o - U_1 x - U_2 x^2$$

where U_1 and U_2 are constants (except in BSE method where U_2 is linearly proportional to the intercepted solar radiation) and x is the ratio of the difference between the mean fluid temperature and the ambient temperature to the intercepted solar radiation.

Such a way of analysing experimental data increases the uncertainty associated with the resulting performance curve since some physical causes of the scattering of the experimental data about the fitting curve, as the dependence of η upon the solar radiation [95-6, 19] and the wind speed, are ignored and considered on the same footing as purely unavoidable experimental errors.

As a consequence, to secure reproducibility of the efficiency curves, those methods recommend performing test runs at a very well defined steady state which, in turn, leads to time consuming outdoor test runs or to costly indoor tests conducted under expensive sun simulators.

In an attempt to reduce the required test time and to improve the reproducibility of collector tests results the German Bundesverbond Solar Energie (BSE) Working Group suggested, in May 1978, guidelines for testing solar collectors whereby

- the thermal losses characteristics are determined under indoor conditions and,

- the optical efficiency η_o is evaluated through outdoor tests during which the collector experiences negligible heat loss.

As pointed out by Jenking and Hill[7], the basic concept of the BSE method, that is: constructing collector instantaneous efficiency curves from the recorded outdoor and indoor data has been explored by many researchers [8 to 12] but "there has been a reluctance to adopt such a technique because of the uncertainty associated with indoor determined thermal losses accurately reflecting collector thermal losses experienced outdoors".

In fact, the two above mentioned authors[7] have concluded that the BSE method leads to less uncertainty than the ASHRAE procedure and improves replicability.

It seems possible to reduce further the uncertainty associated to the collector performance equation by devising a model which leads to expressions for the coefficients U_1 and U_2 which are explicitely dependent on the wind velocity.

A model which also gives U_1 and U_2 in terms of the infrared envir-

onmental irradiance has been described elsewhere[14,15]. Nevertheless, the current study, rather than being a purely academic exercise, intends to be a modest contribution in the search for an easy way to conduct yet accurate solar collector testing procedure. To this end it is felt that a simpler model is more appropriate in that framework. Such a model is described later on in this paper.

Further reduction of uncertainty can also be achieved by minimizing the dependence of testing upon heat carrier flow rate and temperature difference measurements which are a major source of experimental errors. This can be done by monitoring outdoor stagnation tests during which the useful energy gain is zero instead of measuring that gain at various inlet heat carrier fluid temperatures.

During stagnation tests only three parameters need to be monitored, namely, solar radiation, wind speed and the difference between the fluid and ambiant temperatures. A time dependent regression analysis of these parameters, along with those recorded during indoor cooling tests, gives not only the optical efficiency and the heat loss characteristics of the collector but its heat capacitance as well.

A rather complicated two-node capacitance time dependent analysis of the solar collector useful energy gain has been given elsewhere[16] but a much simpler one-node capacitance analysis based on formula given in this paper, is felt to be more appropriate and is actually investigated at AIT[17].

A similar investigation is also conducted at Sophia-Antipolis[18] where the analysis of data is made in the framework of a one-node capacitance linear model.

Obviously, a simplified one-node capacitance analysis of time dependent collector stagnation temperature must be limited to the regression analysis of data recorded during periods which are "significantly away" from those periods during which solar radiation exhibits a "very large" logarithmic derivative with respect to time.

Although the meanings of "significantly away" and "very large" should be made more precise, there is no doubt that these periods will happen much more often than periods during which "the heat carrier fluid temperature should remain constant with ±0.5°C and the solar radiation input greater than 630 W/m^2 for, at least, 15 minutes prior measurement" as recommended by ASHRAE standard.

The Simplified Non Linear Saunier Model

A two-node capacitance model has been fully described [16] previously but it seems, for the time being, a too much complicated model for interpreting performance data recorded during solar collector tests. Up to this date, only a very crude, simple steady state model has been used for that purpose by testing centers and manufacturers. Therefore, a simpler one-node capacitance model is described here.

1. One-node capacitance non linear model of thermal solar collector

Let us consider a one-node capacitance non linear model to describe the heat transfer between an element of the collector's absorber and the surrounding atmosphere. (see figure 1)

Note that in previous papers the back heat losses through heat conductance, K_B, have been explicitely taken into account, but later on it has been found that the experimental evaluation of K_B is very difficult. Since that conductance is rather small in most cases it has been decided to lump it with the linear conductance between the fluid and the front cover.

See Fig. 1, where T_f = heat carrier fluid temperature

T_{fc} = front cover temperature

T_a = ambient temperature

$\theta = T_f - T_{fc}$

L = Total length of the collector which is assumed to have a uniform cross section

G = heat carrier fluid flow rate per unit of collector area

η_o = optical efficiency

I_s = global solar radiation intercepted by a unit area of collector

K_1 = linear heat transfer coefficient between the fluid and the front cover (corrected for the back heat losses)

K_2 = quadratic heat transfer coefficient between the fluid and the front cover.

Let us assume that the ambient temperature is quasi-constant and that the front cover has a effective heat capacitance equal to zero since its actual heat capacitance has been lumped with the absorber and fluid capacitance. The heat balance of the fluid mass per unit of collector area is given by:

$$M_e C_P \frac{\partial \omega}{\partial \omega} f + LGC_P \frac{\partial \omega}{\partial y} f = \eta_o I_s - K_1 \Theta - K_2 \Theta^2 \qquad (2)$$

$$K_1 \Theta + K_2 \Theta^2 = (A + BV)\ (T_{fc} - T_a) \qquad (3)$$

where $\omega_f = T_f - T_a$

C_p = specific heat of the near carrier fluid

M_e = effective lumped heat capacitance of the various components of the collector and the fluid measured in terms of water equivalent mass.

Note that the flow rate effect on the heat transfer coefficient between the fluid and the absorber could be taken into account[19] but this leads to a significantly more complicated formula. For the sake of simplicity and since the error is insignificant for the usual value of flow rate recommended by manufacturers (which, in general, is $GC_p > 60 \times J\ K^{-1}\ m^{-2}$) it is assumed hereafter that the heat transfer resistance between the fluid and the absorber is negligible, which is consistant with the one-node capacitance model assumption.

By expanding T_{fc} in Taylor series, we get:

$$T_{fc} - T_a = a\,\omega_f + b\,\omega_f^2 \tag{4}$$

then

$$\Theta = T_f - T_{fc} = (1-a)\,\omega_f - b\,\omega_f^2 \tag{5}$$

After substituting eq. 4 and 5 in eq. 3 we obtain

$$a = K_1 / (K_1 + A + BV) \tag{6a}$$

$$b = K_2\,(A + BV)^2 / (K_1 + A + BV)^3 \tag{6b}$$

After substituting eq. 6 in eq. 5 and eq. 5 in eq. 2, it follows:

$$M_e C_P \frac{\partial \omega_f}{\partial t} + LGC_P \frac{\partial \omega_f}{\partial y} = \eta_o I_s - U_1 \omega_f - U_2 \omega_f^2 \tag{7}$$

where the overall linear and quadratic thermal conductance are given by:

$$U_1 = \{K_1^{-1} + (A + BV)^{-1}\}^{-1} \tag{8a}$$

$$U_2 = K_2\,(A + BV)^3 / (K_1 + A + BV)^3 \tag{8b}$$

Eq. 7 is a partial differential equation which describes the time and space dependence of the fluid temperature. It simplifies greatly

at stagnation state where G = O. If we call Z, the stagnation temperature, eq. 7 gives:

$$M_e C_P \frac{dZ}{dt} = \eta_o I_s - U_1 Z - U_2 Z^2 \tag{9}$$

Let us call Z_o <u>the zero capacitance stagnation temperature</u> which is a solution of:

$$\eta_o I_s - U_1 Z_o - U_2 Z_o^2 = 0 \tag{10}$$

we obtain:

$$Z_o = (U_o - U_1)/2 U_2 \tag{11}$$

$$U_o = (U_1^2 + 4 U_2 \eta_o I_s)^{\frac{1}{2}} \tag{12}$$

<u>Remark</u>: It should be pointed out that Z_o is also the steady state limit of Z since Z_o is also the solution of eq. 9 when dZ/dt = 0

2. <u>The steady State Equation of Performance</u>

At steady state $\frac{\partial \omega}{\partial t} = 0$ and eq. 7 becomes:

$$LGC_P \frac{d\omega}{dy} = \eta_o I_s - U_1 \omega_f - U_2 \omega_f^2 \tag{13}$$

Consider the following successive changes of variables:

$$\omega_f \rightarrow r_1 = \omega_f - Z_o$$

$$r_1 \rightarrow r_2 = r_1^{-1}$$

The solution of eq. 13 follows:

$$\omega_f (y) = \omega_i + \frac{(1 - e^{-U_o y/LGC_P}) (\eta_o I_s - U_1 \omega_i - U_2 \omega_i^2)}{U_o - U_2 (Z_o - \omega_i) (1 - e^{-U_o y/LGC_P})} \tag{14}$$

where $\omega_i = \omega_f\ (y = 0)$ = inlet relative temperature

The useful power gain at steady state is given by:

$$\dot{Q}_u = G\,C_p\,(\omega_o - \omega_i) = F_{R_2}\,(\eta_o\,I_s - U_1\,\omega_i - U_2\,\omega_i^{\,2}) \qquad (15)$$

where $\omega_o = \omega_f\ (y = L)$ = outlet relative temperature

F_{R_2} = quadratic heat removal factor.

$$= \frac{GC_p\,(1 - e^{-U_o/GC_p})}{U_o - U_2\,(Z_o - \omega_i)\,(1 - e^{-U_o/GC_p})} \qquad (16)$$

Remark: - If $U_2 = o$ we find, as expected, $F_{R_2} = F_R$ = linear heat removal factor[13]

- If $GC_p \gg U_o$ we have $F_{R_2} \to 1$

In such a case ω_o is not very different of ω_i and it can be shown (which also is obvious from physical point of view) that eq. 15 leads to:

$$Q_u = \eta_o\,I_s - U_1\,\bar{\omega} - U_2\,\bar{\omega}^{\,2} \qquad (17)$$

where $\bar{\omega} = (\omega_o + \omega_i)\,/\,2$ = mean heat carrier fluid relative temperature. (18)

- To find the useful power gain (negative) during indoor cooling test when feasible (that is when the heat extracting system of the collector is not a heat pipe) let us put $I_s = 0$ in eq. 15, eq. 16 and eq. 17.

The Indoor cooling performance equations follows:

$$\dot{Q}_u^{(o)} = -F_{R_2}^{(o)} (U_1 \omega_i + U_2 \omega_i^2) \tag{19}$$

$$\text{where } F_{R_2}^{(o)} = \frac{GC_p (1 - e^{-U_1/GC_p})}{U_1 + U_2 \omega_i (1 - e^{-U_1/GC_p})} \tag{20}$$

if $GC_p >> U_1$, we obtain:

$$\dot{Q}_u^{(o)} = -U_1 \bar{\omega} - U_2 \bar{\omega}^2 \tag{21}$$

3. The non-steady stagnation state temperature

In general the solution, Z(t), of eq. 9 can only be calculated numerically since eq. 9 is a non linear differential equation whose coefficient I_s, U_1 and U_2 are function of time.

Note that U_1 and U_2 are functions of time because they are function of the wind velocity. Nevertheless, we will assume hereafter that stagnation outdoor tests will be performed under artificial strong wind generated by electric fans during days when natural wind is not available. Therefore, U_1 and U_2 can be considered as constant during test periods.

In spite of that simplification, eq. 9 cannot be solved analytically since it still includes the time function coefficient, $I_s(t)$. An approximate solution can be found by perturbation methods. To do so, assume that:

$$Z(t) = Z(t_o) + Z_o(t) - Z_o(t_o) + z(t) \tag{22}$$

where t_o is the starting time of the test and z (t) is the difference between transient at time t and transient at time t_o which is assumed to be "small"

Substituting eq. 22 and eq. 10 in eq. 9 leads to:

$$\frac{dz}{dt} + \frac{1}{\tau} z = \frac{-dZ(t)}{dt^o} - 2\,\beta\, Z_o\,(t)\,\{Z\,(t_o) - Z_o\,(t_o)\}$$

$$-K\,(t_o) - \beta\,\{z^2 + 2z\,(Z_o(t) + Z\,(t_o) - Z_o(t_o))\} \quad (23)$$

where $K\,(t_o) = (Z(t_o) - Z_o\,(t_o))/\tau + \beta\,\{Z\,(t_o) - Z_o\,(t_o)\}^2$ (24)

$$\tau = Me\ Cp/u_1$$
$$\beta = U2/M_e\ Cp$$

Hereafter it is assumed that the absolute value of the fourth term of the right arm of eq. 23 is negligible vis-á-vis the absolute value of the sum of the three first terms.

The integration of eq. 23 is then straightforward and gives:

$$Z(t) = Z(t_o) - \{\tau K\,(t_o) + Z_o\,(t_o)\}\,\{1 - e^{-\frac{t - t_o}{\tau}}\}$$

$$+ \{\frac{1}{\tau} - 2\beta\,(Z\,(t_o) - Z_o\,(t_o))\}\int_{t_o}^{t} Z_o\,(t')\,e^{\frac{t'-t}{\tau}}\,dt' \quad (25)$$

To simplify the regression analysis of the experimental stagnation temperature data, the integral in eq. 25 can be evaluated by gaussian or other numerical integration methods. With gaussion methods the integration limits should be 1. Therefore, we define a new variable, x, such that

$$x = \{2\,t' - (t + t_o)\} / \{t - t_o\}$$

we obtain

$$Z\,(t) = Z(t_o) - \{\tau K\,(t_o) + Z_o\,(t_o)\}\,\{1-e^{-\frac{t - t_o}{\tau}}\}$$

$$+ (t-to)\,\{\frac{1}{2\tau} - \beta\,(Z\,(t_o) - Z_o\,(t_o))\}\sum_{i=1}^{n} W_i\ Z_o(t'_i)\,e^{\frac{t'_i - t}{\tau}} \quad (26)$$

where $t'_i = \frac{t - t_o}{2}\,x_i + \frac{t + t_o}{2}$

and x_i and W_i are given in the literature[20].

Method of Testing

The simplified NLS model and in particular eq. 21 and eq. 26 provide a framework to interpret the performance data recorded during three series of very simple tests, that are:

- a set of indoor steady state tests performed without wind (V = o)
- a set of indoor steady state tests performed when artificial constant winds are generated by electric fans
- a set of outdoor non steady stagnation state tests

Suggested experimental procedure:

1. Indoor test: The indoor test bench can be very simple as shown in Figure 2. A set of performance data can be obtained by switching on successively the various heating resistances and electric fans.

A typical set of experimental points obtained from a commercial solar collector is shown in Fig. 3.

2. Outdoor test: The outdoor test bench can be the bench which is used for indoor test but during outdoor stagnation tests the flow meter and the electric heater are bypassed. It is compulsory to circulate the fluid on closed loop to have a uniform stagnation temperature throughout the collector. The connecting pipe between inlet and outlet and the circulating pump should be well insulated. Ideally, the sum of the heat loss through that pipe plus the power of the pump should be equal to zero.

Outdoor tests must be run during a calm day and the electric fans must be always switched on to overcome any small natural breezes.

A typical set of experimental points at stagnation state are shown on upper part of Fig. 3 (steady state) and on Fig. 4 (transient state).

3. Interpretation of experimental data: Characteristic parameters of the collector that are η_o, K_1, K_2, M_e are calculated by nonlinear regression analysis.

Typical estimates of initial values to start the nonlinear regression procedure are:

$$\eta_o = 0.7$$

$$K_1 = 5\ W/m^{2o}C$$

$$K_2 = 0$$

$$M_e = 1.5\ kg.\ of\ water/m^2$$

The present one-node capacitance model is limited by not taking into account the differences between the fluid temperature and the absorber temperature. These differences can be significant immediately after a large change in the solar radiation. We feel that we should reject data recorded immediately after a sudden change of solar radiation or when the solar radiation oscillates significantly around its average value with a period of 10 minutes or less.

An investigation to determine precise guidelines in selecting "good" data is currently in progress[21]. For the time being, we have only analysed experiments conducted both indoors and outdoors under natural quasi-steady state solar radiation. The radiation levels are abruptly decreased (or increased) by interposing (or removing) semi-transparent plastic sheets between the sun and the collector under test.

Preliminary results obtained with a well known commercial solar collector are summarized in Fig. 2 to Fig. 4.

The regression performance parameter values are:

$$\eta_o = 0.69$$

K_1 = 6.93 $W/m^{2o}C$

K_2 = 0.06

B = 1.13

M_e = 1.1 kg. of water/m^2

The neglected heat transfer coefficient between the fluid and the tube leads to a slightly different value for the collector effective heat capacitance when we take all data into account for the regression analysis. As an alternative, we discard the data recorded during the 10 minutes which follow the radiation step change.

The heat capacitance value obtained by the second procedure (that is M_e = 1.1 kg.) leads to a better fit since, in that case, the standard deviation is only 0.4% of the average stagnation temperature recorded during the test, while the standard deviation is equal to 1.0% for the first procedure.

Fig. 5 shows that the actual method, at least when it is conducted at steady state leads to performance curves which are in excellent agreement with performance curves obtained by ASHRAE method of testing[22].

Conclusion

A new method of testing to determine the thermal performance of solar collectors is presently under development at AIT.

The main feature of that method is that the parameters of the non-linear SAUNIER model of solar collectors are evaluated from data obtained during cooling indoor tests and outdoor stagnation tests not necessarily conducted at steady state.

Both of those tests can be performed quickly with inexpensive devices to measure temperatures. Further results will be reported soon.

Acknowledgement

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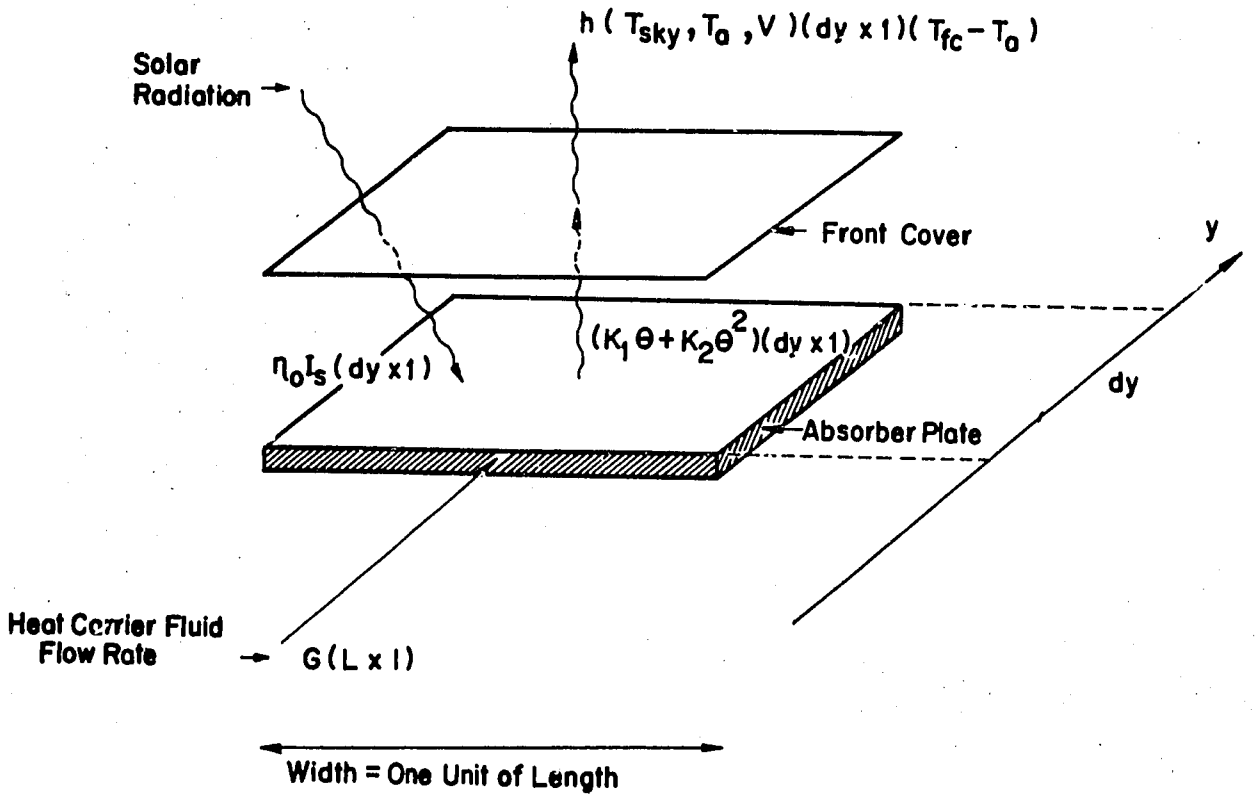

Fig. 1 – Solar Collector Heat Transfer Model

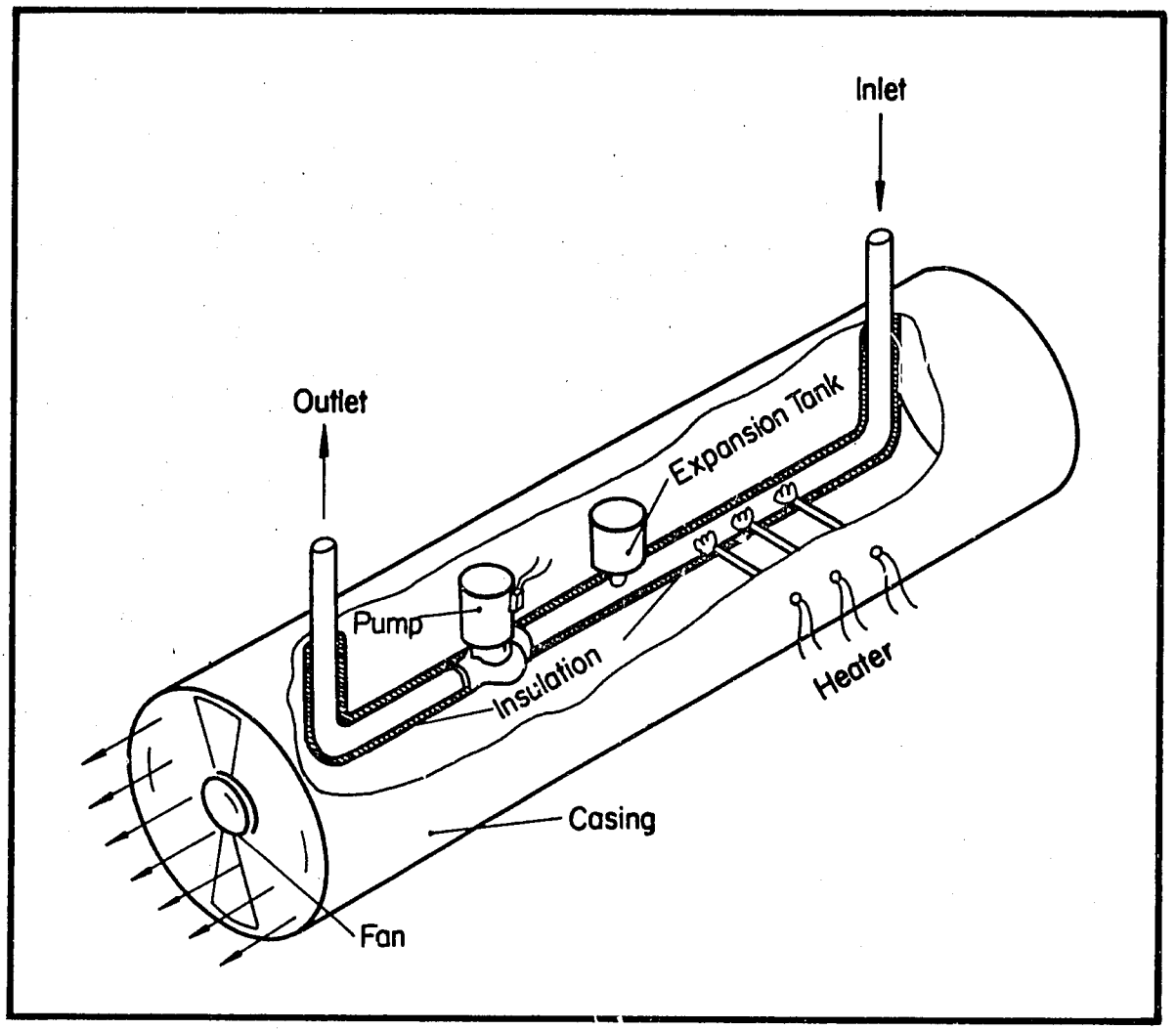

Fig. 2 – Heat Carrier Fluid Circulating Unit

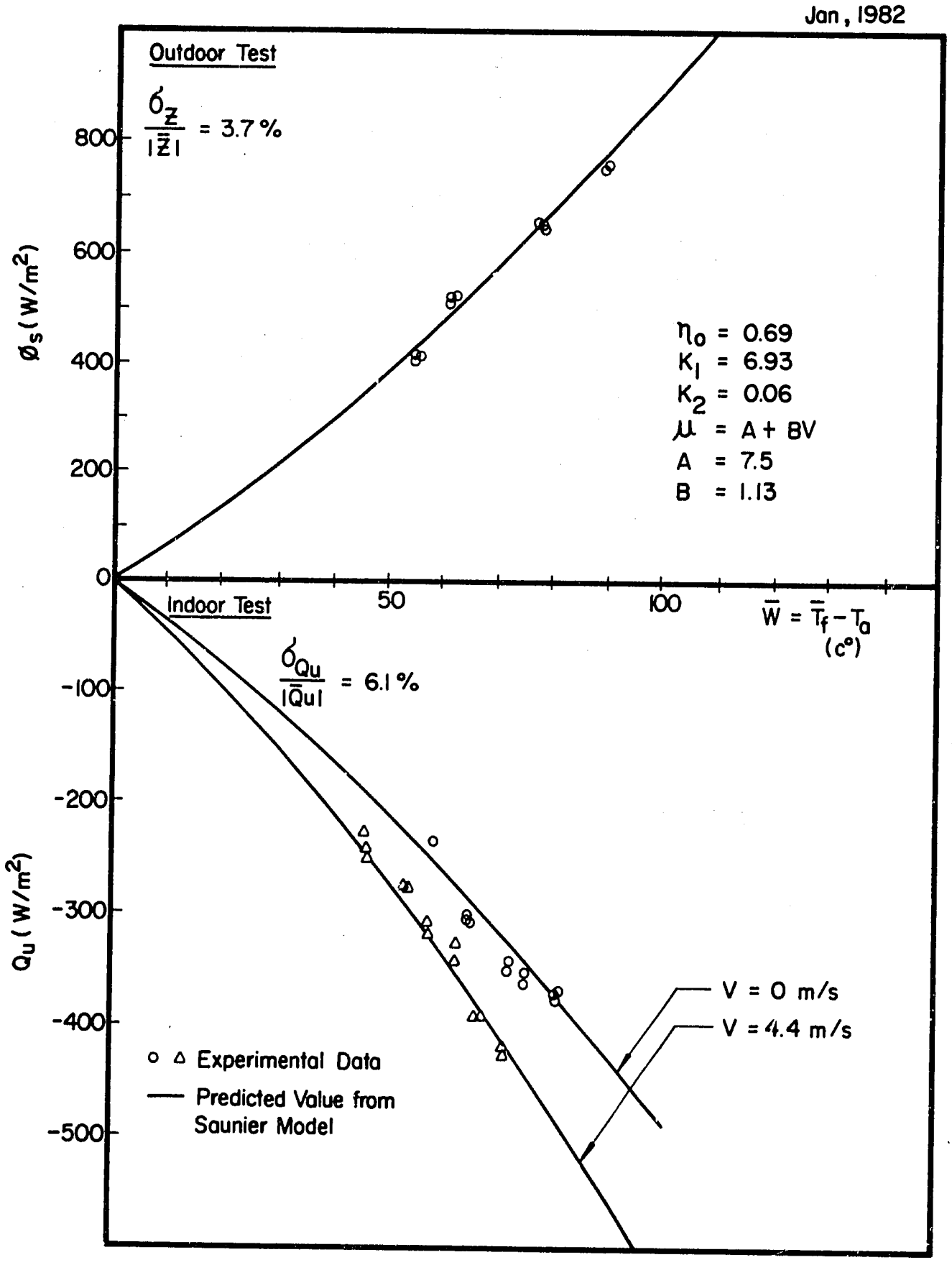

Fig. 3 – Stagnation Temperature (Upper Part) and Indoor Cooling Data (Lower Part)

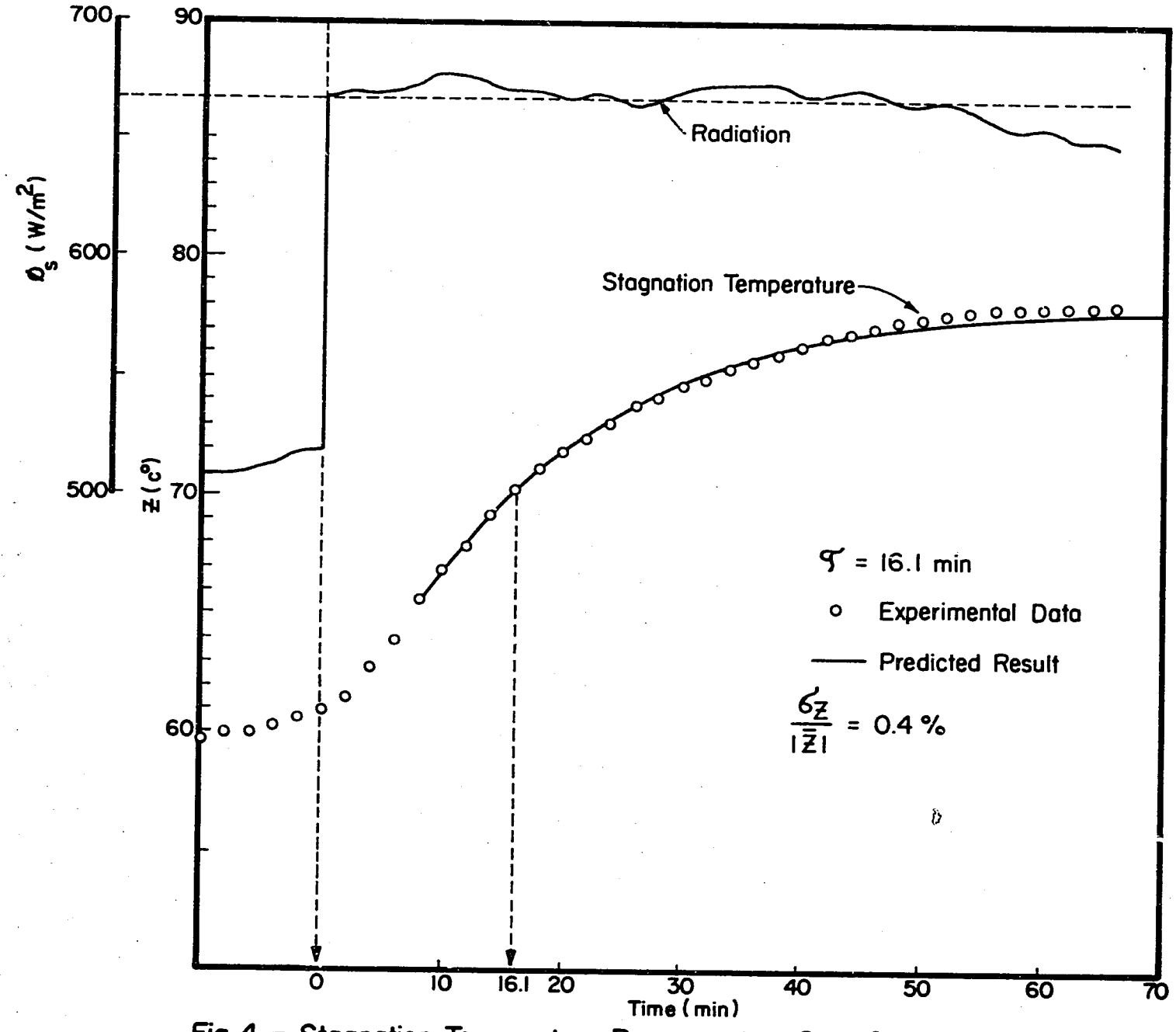

Fig. 4 – Stagnation Temperature Response to a Step Change of Insolation

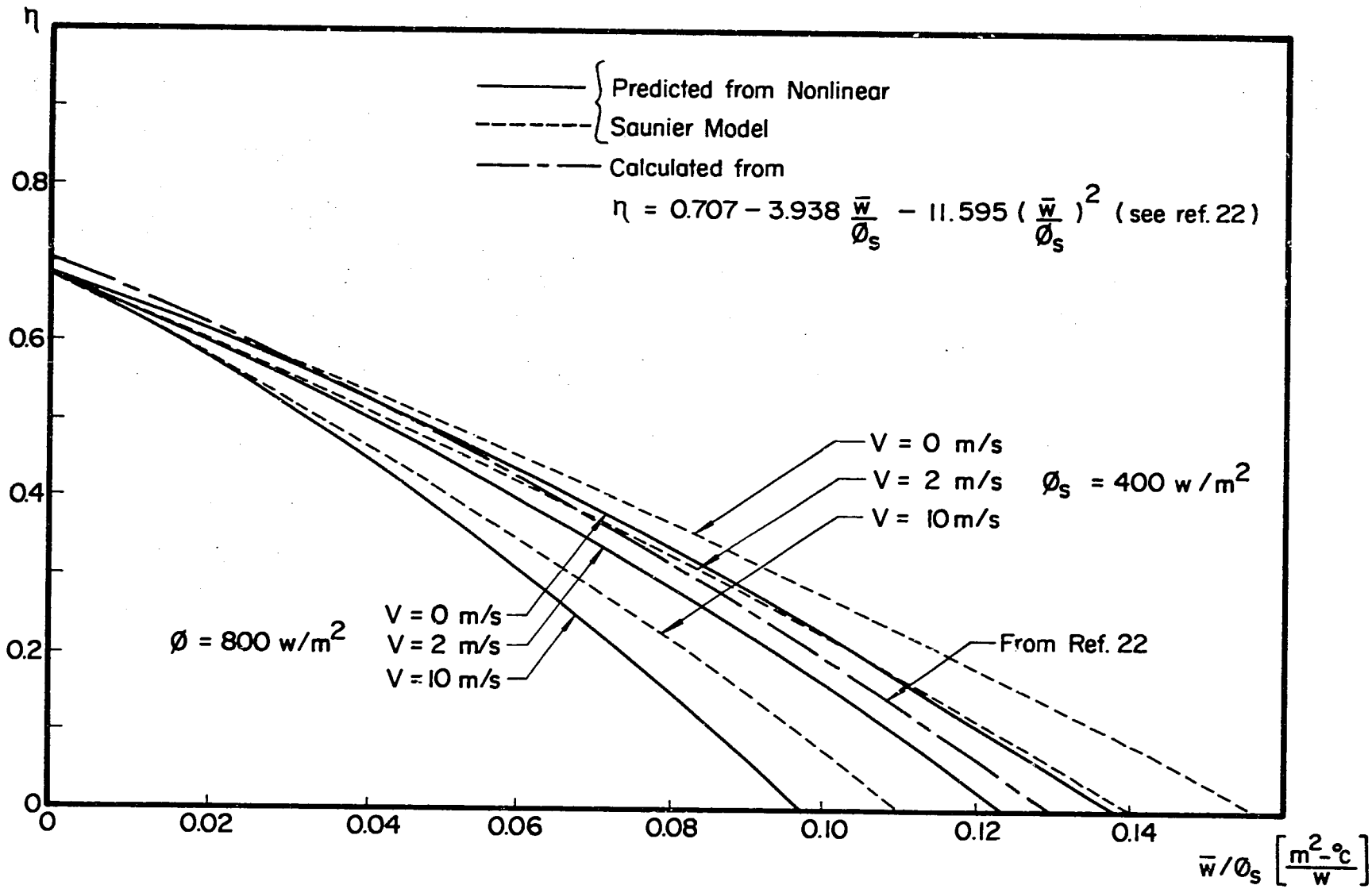

Fig. 5 – Comparison between Predicted Performance from the Saunier Model and Those Given by ASRHAE Method

Wind Resource Assessment

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Wind energy is created globally by the differential heating of the earth's surface. It is affected locally by the mesoscale effects such as local terrain features, existance of large bodies of water, surface cover, etc.

To conduct the most effective national planning for wind energy use, two different levels of efforts have to be adopted:

1. National Effort: (Global Scale Wind Resource Assessment)

The national effort in this area should assist various institutions to identify the local resource on a global scale. Such an effort requires collecting and analysing all available meteorological data.

Maps at a national scale should be used to identify the potential of large scale areas and cannot substitute for these more accurate on site data monitoring and analysis.

2. On-site resource analysis:

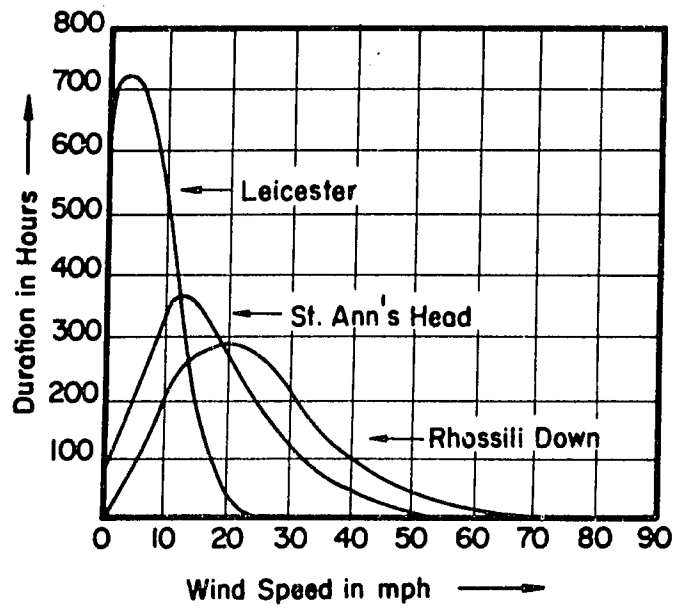
This effort should be carried out by prospective users, local utilities and project planners. The large scale global maps should assist in identifying the most promising areas for WECS installations. After a large scale area has been identified, on site data analysis needs to be performed.

The length and frequency of on-site observations are dependent on the size and type of the application. The large electricity producing WECS require a more accurate resource assessments than small electric WECS or water pumpers.

Sampling Frequency and Wind Speed Distribution:

The most accurate representation of wind speed is a continuous infinitely long duration of data collection, but in practice this may be prohibitively expensive.

Figure 1: shows the probability densities for two minutes, 1 hour, and 3 hours sampling rate.
The smoothness of probability density curve is severely degraded as the sampling rate decreases, although the general shape remains approximately the same.
The importance of the probability density curve to power performance evaluation will be discussed in next lecture.



The Weibull Distribution

The Weibull distribution for wind speed (V) is expressed by the probability density function (wind speed frequency curve)

$$P(V)dV = (k/c)(V/c)^{k-1} \exp\{-(v/c)^k\}$$

where c is the scale factor (units of speed) and k is the shape factor (dimensionless) for the Weibull distribution. The equivalent cumulative probability function (wind speed duration curve) is

$$P(V) = \int_0^V (k/c)\ (V/C)^{k-1} \exp\{-(v/c)^k\}\ dV$$

The next table shows the various instruments that can be used in a wind resource assessment. There are other recording instruments on the market that samples data once every two seconds and provide statistics on diurnal, monthly, hourly averages and deviations.

Site data adjustments

The most frequently used theoretical distribution that describes the wind resource is the Weibull distribution. The graph gives Weibull distributions at various sites and discusses the effects of C & K.

The two most frequently used methods to determine the Weibull parameters that produce a distribution that easily produce the actual observed distribution is the least square fit.

The question arises, why use a theoretical distribution as actual observed data is available? This is due to the fact that there are models that can project the distribution parameters with height, of the wind speed distribution is required at another level.

If only the average wind speed and standard deviation are available, then the second method can be used. There is also another method that uses the average wind speed and an indication of the wind variability.

Methods for Weibull Parameter Estimation

There are several methods which can be used to estimate the Weibull parameters c and k, depending on which wind statistics are available and what level of sophistication in data analysis one wishes to employ.

Least-Squares Fit to Observed Distribution - Method 1. If the observed wind speeds are divided into n speed intervals $0 - V_1$, $V_1 - V_2, \ldots,$ $V_{n-1} - V_n$, having frequencies of occurrences $f_1, f_2, \ldots, f_n$ and cumulative frequencies $P_1 = f_1 + f_2, \ldots, P_n = P_{n-1} + f_n$, then Eq. 2-2 transforms to the linear form $y = a + bx$ by the relations

$$X_i = \ln V_i \ ,$$

$$Y_i = \ln\{- \ln(1 - P_i)\} \ .$$

Best-fit linear coefficient values a and b can be found by either an unweighted or frequency-of-occurrence-weighted least-squares process. The Weibull parameters c and k are related to the linear coefficients a and b by

$$c = \exp\ (- a/b) \ ,$$

$$k = b \ .$$

Mean Wind Speed and Standard Deviation - Method 3. If only the mean wind speed $\bar{V}$ and standard deviation σ are available (where $\sigma^2 = \langle (V - \bar{V})^2 \rangle$, and the angle brackets denote an average), then c and k can be estimated from

$$\bar{V} = c\Gamma(1 + 1/k) \ ,$$

$$(\sigma/\bar{V})^2 = \{\Gamma(1 + 2/k)/\Gamma^2(1 + 1/k)\} - 1 \ ,$$

where Γ is the usual gamma function and $\sigma/\bar{V}$ is the coefficient of variation. The c and k values can best be found by using the approximate relation for Eq. 2-10; i.e.:

$$k = (\sigma/\bar{V})^{-1.086} \ ,$$

and the inverse of Eq. 2-9 is

$$c = \bar{V}/\Gamma\ (1 + 1/k) \ ,$$

where rms errors are the square root of the mean of the square of the devia-

tion from observed and theoretical distributions. Table 2-11 illustrates these relationships numerically.

Height Extrapolation of Wind Data

When wind data is recorded on site, it is usually recorded at 10m level (WMO standard). This data then has to be extrapolated to the hub height of the wind machine to be installed.

The problem of height extrapolation can be divided to two main problems. Extrapolation of long-term averages and short-term (instantaneous) speeds.

Long-Term Data Extrapolation

$$\bar{V}(Z) = \bar{V}_a \ (Z/Z_z)^{\alpha} ,$$

where Z_a is anemometer height in meters and $\bar{V}_a$ in m/s, α is given by

$$\alpha = \{0.37 - 0.088 \ln \bar{V}_a\}/\{1 - 0.088 \ln(Z_a/10)\} .$$

Then, the necessary form of the exponent of the Weibull parameters to be projected to a height Z from a height Z_a given that Eq. 2-28 applies to all individual speeds is

$$\frac{C}{C_a} = \left(\frac{Z}{Z_a}\right)^{\alpha} ,$$

where c_a is the Weibull parameter c determined from data at anemometer height Z_a, and C is the corresponding Weibull parameter at height Z. Eq. 2-29 gives α. The Weibull shape parameter k varies according to

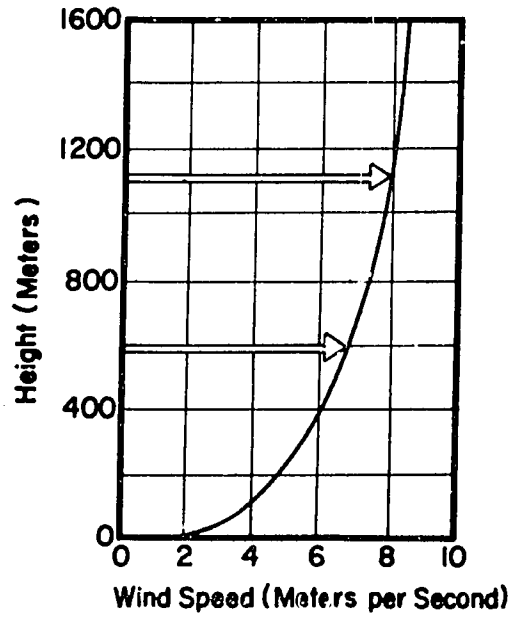
$$\frac{k}{k_a} = \{1 - 0.088 \ln (Z_a/10)\}/\{1 - 0.088 \ln (Z/10)\} ,$$

where Z and Z_a are in meters.

Short-Term Data Extrapolation (Instantaneous):

The term "Instantaneous" indicates wind speed averaged over a short period. The instantaneous wind speed variation with height is influenced mainly by the transfer of momentum form the top of the boundary layer to the ground the momentum transfer is in turn influenced by atmospheric stability, ground cover and topography. The most successful theory to explain the vertical wind speed profiles in relatively flat terrain is the Monin-Obukov Similarity Theory.

A sample formula based on the Monin-Obukov Similarity Theory and resulting from analysis of various tower data was developed.



Modified Power Law Model. The modified power law model given by Mikhail and Justus (1979) is

$$\bar{V} = \bar{V}_a \ (Z/Z_a)^{\alpha_P} \quad ,$$

where $\bar{V}$ (m/s) is the instantaneous average wind speed (over short period) at height Z, $\bar{V}_a$ (m/s) is the instantaneous average wind speed (over short period) at anemometer height Z_a (m), and α_P is given by

$$\alpha_P = 1/\ln\ (Z_g/Z_o) - \{0.088/(1 - 0.088 \ln\ (Z_a/10))\} \ln\ (\bar{V}_a/6) \quad ,$$

where Z_g (m) is the geometric mean height between anemometer and extrapolation heights given by

$$Z_g = (Z \cdot Z_a)^{0.5} ,$$

and Z_o is the estimated surface roughness length of the site.

The surface roughness length represents the physical impedence to the wind flow resulting from surface cover.

The following table gives an estimate of surface roughness length for various types of surface cover. Other methods are outlined in my report for Z_o estimation.

Other models are also used to extrapolate instantaneous wind speed such as ½ power law, logarithmic law, ... etc.

Modeling and Horizontal Extrapolation:

In the case of absence of on-site data and a preliminary analysis needs to be conducted then data from nearby can be used to estimate the candidate site resource.

If a few stations are available in a mesoscale area, and the potential of the whole region needs to be assessed, then various atmospheric models can be used to assess the resource. The various models in existence fall among these 3 categories:

* Primitive Equation Models
  fundamental equations that explains atm. motion.
* Physical Models
  Using scaled models
* Objective Analysis Models
  Uses amplified equations of motion, while still retaining the basic physical principles.

Unfortunately, these models have not been effective in describing the complex phenomonon of wind variability in various conditions.

Commercially Available Wind Sensors and Recording Equipment

System Number	Description	Parameters	Cost ($)	Estimated Error
1	3 cup anemometer and wind vane. No recording equipment		150	±3%
2	Hand held pressure tube anemometer and wind speed meter	wind speed	10	5%-10%
3	Pressure tube anemometer with weather vane, wind speed meter (wind direction estimated visually)	wind speed & direction	35	5%-10%
4	Anemometer and weather vane with wind speed and direction meters	wind speed & direction	298	±3%
5	Anemometer and weather vane with a wind speed and direction chart		850	±3%
6	Tension rate system--kite	speed & direction		±5%-10%
7	Anemometer and weather vane with a wind speed and wind energy accumulator (totalizer)	cumulative wind speed & power	500	
8	Anemometer and weather vane with a wind speed frequency by direction compilator (4 bins for 8 direction sectors of 2 or 4 second sampling note)	wind speed frequency by direction sectors	1650	±3%
9	Anemometer and weather vane and a microprocessor with the average and standard deviation for different averaging periods of wind speed and direction and maximum gust (under development)	wind speed & direction & maximum gust	1600	±5%
10	10-m Mast (12 in.)		200-500	

Different Surface Roughnesses

Type of Surface	Z_o (m)
Mud flats, ice	$10^{-5} - 3 \times 10^{-5}$
Smooth sea	$2 \times 10^{-4} - 3 \times 10^{-4}$
Sand	$10^{-4} - 10^{-3}$
Plain, snow covered	4.9×10^{-3}
Grassy surface	0.017
Mown grass	$10^{-3} - 0.01$
Low grass, steppe	0.032
Flat country	0.021
High grass	0.039
Wheat	0.045
Beets	0.064
Palmetto	0.1 - 0.3
Low woods	0.05 - 0.1
High woods	0.2 - 0.9
Suburbia	1 - 2
City	1 - 4

Roughness Lengths Associated
With Different Crops

Crop	Z_o (m)
Plain, snow covered	0.0049
Grassy surface	0.0173
Flat country	0.0214
Low grass	0.032
High grass	0.0394
Wheat	0.045
Beets	0.064

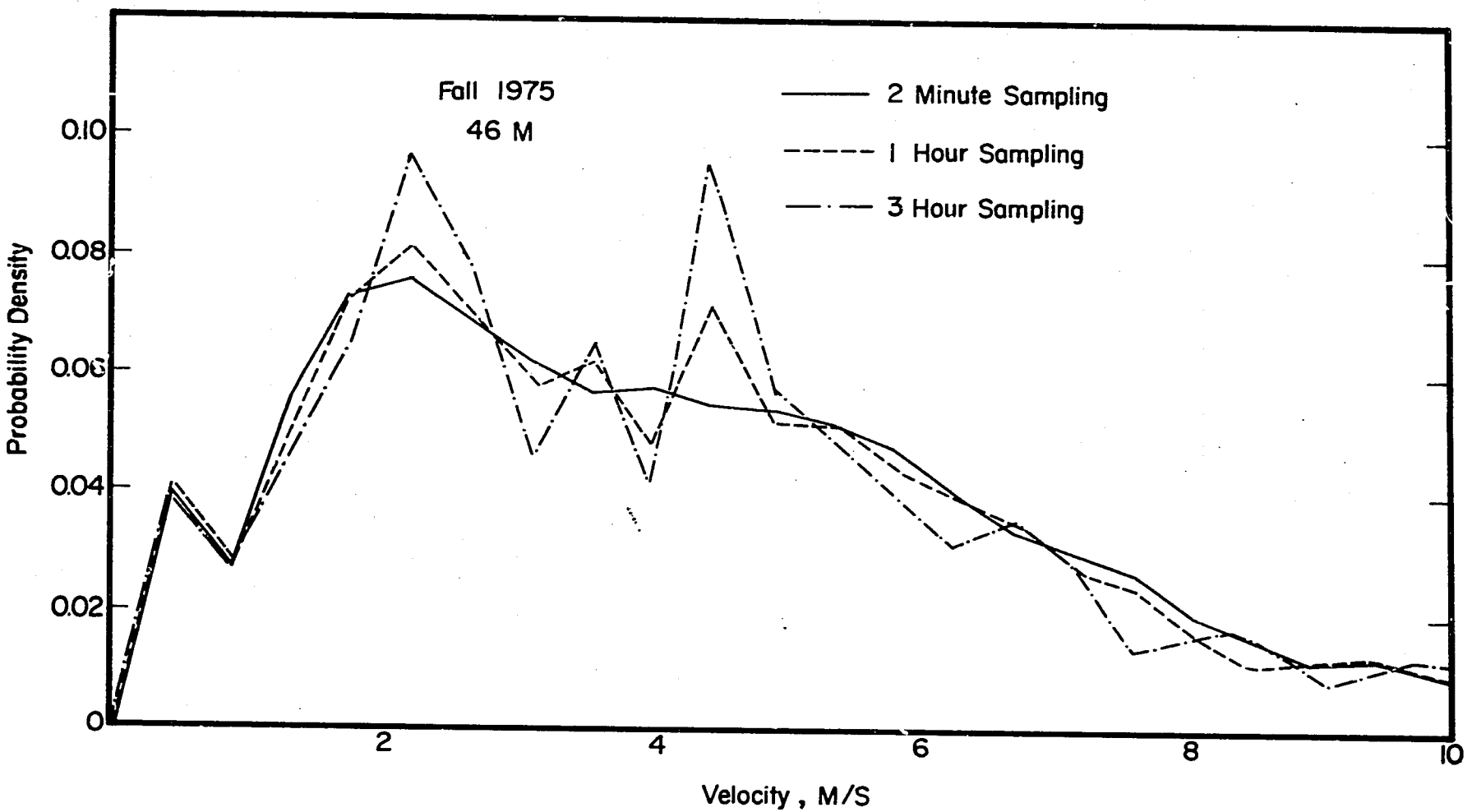
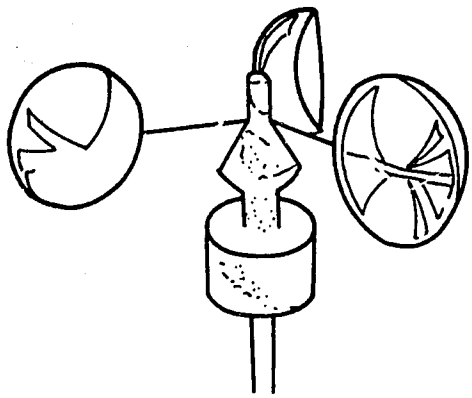
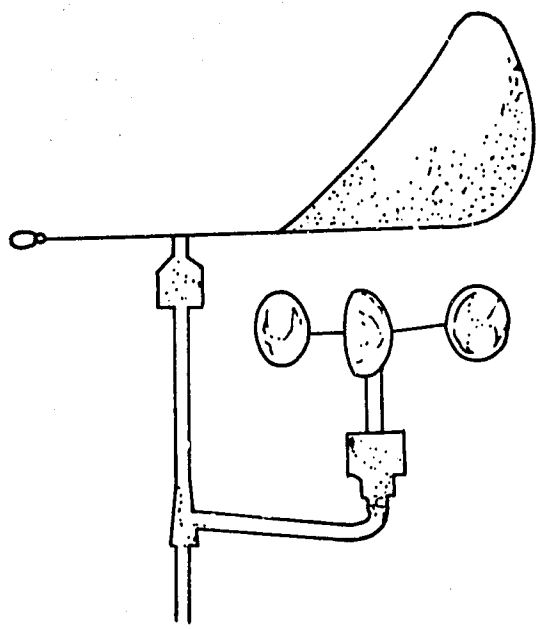


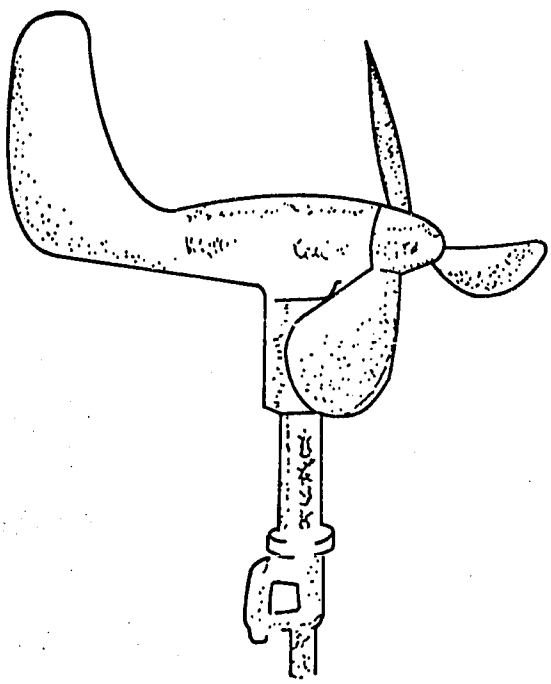
Fig. 1 – Velocity Probability Densities for Two-minute, One-hour and Three-hour Sampling Periods, Fall 1975



Wind Cup Anemometer

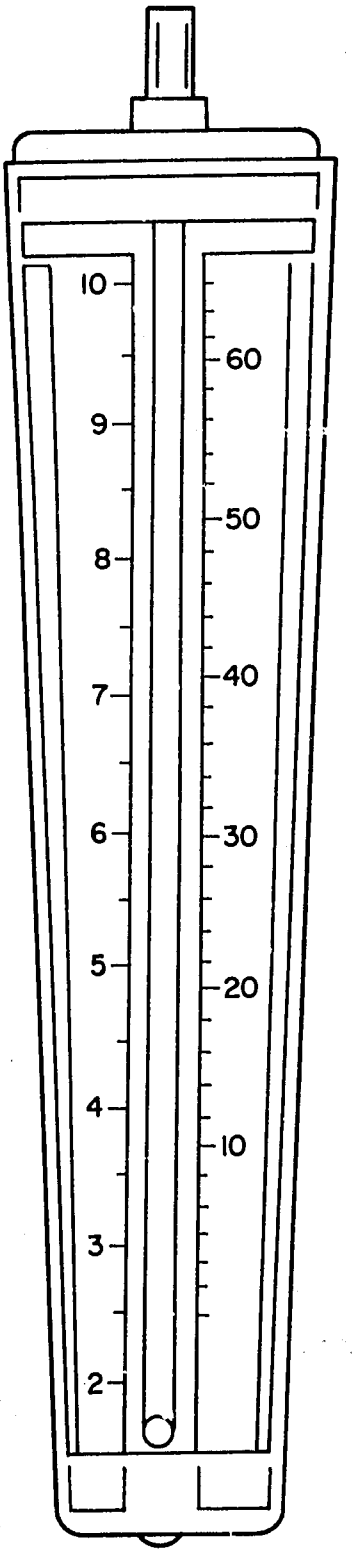


Wind Cup Anemometer
with Wind Vane



Propeller – Type Wind Anemometer

Wind Speed and Direction Sensors



Hand - Held Anemometer

Assessing the Availability Of Wind Energy in Thailand

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Introduction

Thailand lies in the region of the Asian monsoon climate in which the prevailing surface winds are south-west in summer (July) and north-east in winter (January). Since, however, Thailand lies in the area over which the tropical convergence zone passes twice a year, winds are light. The country is not affected by typhoons.

Three types of locally constructed horizontal axis windmills have been used for lifting water in Thailand for many years. Slow speed sail windmills with six or eight triangular sails have their axes fixed in the direction of the prevailing winds. They are used for pumping sea water in the salt farms on the coast. They start pumping at a wind speed of 2.2 m/s and have optimum performance at 3.6 m/s.

High speed wooden windmills with two or four blades are used for irrigating rice fields near the coast. The axis of the rotor, which can be turned manually to face the wind, is 5 m above the ground. They need a wind speed of 3 m/s to operate, and must be started manually.

Multiblade metal wind pumps are becoming increasingly popular due to the enterprise of a local manufacturer. They are self-starting at a low wind speed, but are rated at 8 m/s, and have a rotor 12 to 15 m above the ground where the wind speed is much greater than near the surface.

Some years ago a study by Heronemus (1) made rough estimates of the availability of wind energy in Thailand at several stations in the central

plain and the north-eastern region. More recently studies at AIT (2,3) have provided a fairly complete survey of the wind over the country using published meteorological data. Thailand is fortunate in having a considerable amount of readily available wind observations made by the Meteorological Department. It is the purpose of this lecture to show how this data has been put into useful forms for wind energy studies.

The data actually employed included a rather old, but good, report summarising surface wind observations at 48 stations over a ten-year period (4). The data consist of monthly frequencies of occurrence of observations divided into five wind speed classes and sixteen wind directions. In addition unpublished hourly observations of wind speed and direction at four stations over one year were obtained from the Meteorological Department for more detailed investigations. A summary of climatological data for Thailand over 25 years was also used (5).

The Energy in the Wind

The power due to the kinetic energy of a wind stream of density ρ with constant speed V passing through an area A is $\frac{1}{2}\rho AV^3$. Aerodynamic theory shows that the maximum power that can be extracted by a wind machine is 59% of this amount, but practical windmills have power coefficients in the range of 15% to 47% (6).

If the wind is unsteady the average power in the wind is proportional to the time average of V^3, which we shall denote by $Av(V^3)$. Published meteorological data normally quote the time average Av(V) of V, which is insufficient to determine $Av(V^3)$ without a knowledge of the statistical fluctuations in the wind. Therefore our objective in wind energy assessment is to determine (among other things) the frequency distribution of wind speeds.

Let F(V) be the (cumulative) distribution function giving the probability that the wind at any time has a speed less than V. A graph of V versus 1 - F(V) is called a velocity duration curve (Fig. 1).

The frequency function f(V), whose integral from V_1 to V_2 denotes the probability that the wind speed lies between V_1 and V_2 is obtained by differentiating F(V) thus:

$$F(V) = dF(V)/dV$$

A graph of f(V) versus V is called a velocity frequency curve (Fig. 2). The average wind speed is given by:

$$Av(V) = \int_0^\infty Vf(V)dV$$

and the average of V^3 is given by:

$$Av(V^3) = \int_0^\infty V^3 f(V)dV$$

Another useful diagram is the power duration curve (Fig. 3) in which V^3 is plotted versus $1 - F((V^3)^{1/3})$. If the horizontal scale of the power duration curve is multiplied by the duration of the period under consideration, and if the vertical scale is multiplied by the area swept by the windmill rotor and by the power coefficient of the windmill, then the resulting diagram (Fig. 4) represents the power available to the rotor. The shaded area, determined by the practical design of the windmill, represents the total energy output of the machine during the period.

The Weibull Distribution

Experience shows that the Weibull function

$$F(V) = 1 - \exp(-(V/c)^k)$$

where c and k are parameters, is generally a good representation of wind speed distributions (7). The dimensionless exponent k determine the shape of the distribution function, and the scale factor c is close to the average wind speed given by $Av(V) = c\,\Gamma(1 + 1/k)$, where Γ is the gamma function. Examples of Weibull distributions are given in Fig. 5.

The equation

$$\ln(-\ln(1 - F(V))) = k \ln V - k \ln c$$

which is equivalent to (4), shows that the parameters c and k representing an observed wind speed distribution can be found by plotting the observed values of $\ln(-\ln(1 - F(V)))$ versus $\ln V$. If a Weibull distribution fits the observations, then a straight line is obtained with slope k and intersect $-\ln c$ on the vertical axis.

Variation of Wind with Height

Drag on the wind at the surface of the earth causes the wind speed to increase with height z. The standard height for anemometers maintained by meteorological stations is 10 m, but the actual heights of the instruments are usually different from this and a correction to 10 m height is necessary for comparison purposes. Observations show that V is proportional to Z^n, where n depends on the surface roughness, ranging from 0.16 over open water to 0.4 over cities (6).

In the study for Thailand the value n = 0.2 was used for the reduction of all wind speeds to 10 m height (Fig. 6). Under this assumption, the power in the wind only 3 m above the ground is one-half of the power at height 10 m and the power at height 20 m is 50% greater than at 10 m.

Wind Speed Distributions in Thailand

First we present the wind speed distributions obtained from unpublished hourly wind data supplied by the Meteorological Department for two well exposed sites in Thailand: Ubon inland in the north-east, and Haadyai on the peninsula in the south. Observations for one year (1974) were used. The year was divided into four three-month seasons: February-April, May-July, August-October, and November-January. For each station and for each season the occurrences of each reported wind speed were counted to determine the wind speed distribution. When the values of $\ln(-\ln(1 - F(V)))$ were

plotted versus ln V a curve was obtained showing that a Weibull function does not fit the raw data. However, when the observations of calm were omitted from the counting, the graph became straight and a good fit using the Weibull distribution was obtained. Figures 7 and 8 show one example.

We may therefore conclude that to specify the hourly wind speed distribution one needs to state (a) the percentage of time the air is calm, and (b) the parameters c and k of the Weibull functions fitting the non-calm observations.

Table 1 summarises the results obtained and shows that Haadyai on the peninsula has higher average wind speed but more calms than Ubon inland. The table also shows that the wind speed distributions at Haadyai with k close to 2 are peaked near the average speed, but at Ubon with k close to 1.2 the distributions decrease steadily from high frequencies at low wind speeds to lower frequencies as the wind speed increases (see Fig. 5).

Much labour was needed to process the hourly wind data as described above. It would have been impracticable to use the same method to find the wind speed distributions at many stations. However, the data in reference 4 give enough information to find the Weibull distribution parameters over the whole of Thailand. The data published consist of the monthly wind observation frequencies divided into the wind speed classes: calm, below 4 knots, 4-16 knots, 17-27 knots, and over 27 knots. Forty-five stations were selected for the study.

Since observations of wind speeds over 27 knots were rare, the frequencies in the two highest classes were added together and the cumulative frequencies $F(V_1)$ and $F(V_2)$, where V_1 = 4 knots and V_2 = 16 knots, were found (calms being excluded) in each three-month season at each station. The values of k and c were then calculated with the help of the equations

$$k = (N_1 - N_2)/(\ln V_1 - \ln V_2),$$

$$c = \exp\left(\left(N_1 \ln V_2 - N_2 \ln V_1\right)/(N_1 - N_2)\right),$$

where

$$N_1 = \ln(-\ln F(V_1)), \quad N_2 = \ln(-\ln F(V_2)).$$

This is equivalent to finding the straight line giving k and c described above using only two points. Although this method is crude, the parameters obtained are reliable because the data represent ten-year averages.

The results have all been published in reference 3, but Table 2 shows the values of k and c found for Ubon and Songkhla. Songkhla, a station on the coast near Haadyai, has been included for comparison since the station at Haadyai had not been set up when reference 4 was written. Don Muang airport, a few kilometres north of Bangkok, is also included.

Diurnal Variation of Wind Speed

It is a common experience that surface wind speeds are greater during the day than during the night. This is caused by convective mixing of the lower layers by the heating of the surface in the day and the stabilization of the lower layers at night by the cooling of the surface.

To study these effects, the diurnal variation of mean wind speed was determined at Ubon and Haadyai from the hourly wind observations. For this purpose, the day was divided into three-hour periods. At each station in each three-month season the mean wind speed was calculated from the observations in each three-hour period. The percentage of observations of calm in each three-hour period was also noted.

Representative results are shown in Fig. 9 and Table 3. At Ubon there is a contrast between the summer and winter seasons. During the south-west monsoon in summer, the wind speed is less than during the winter when the prevailing wind is from the north-east and the wind speed is only slightly reduced at night. At Haadyai the seasonal contrast does not exist although the prevailing wind is from the west in summer and the east in winter. On the other hand there is a strong contrast between the high mean wind speed in the daytime and the nearly calm conditions at night.

Wind Directions

Since some types of windmill have horizontal axes whose orientation is fixed, it is of interest to study seasonal wind directions. They are represented by two parameters: the bearing Θ of the average direction (measured eastwards from north) from which the wind blows, and a parameter r representing the constancy of direction. They were calculated from the percentage frequencies of the eight main directions N, NE, E, ..., NW without reference to the wind speeds by the following method.

The eight directions are represented by eight equally spaced points on the circumference of the unit circle with polar coordinate angles Θ_i, and each point is weighted by the frequency of occurrence f_1. Then the centroid (r, Θ) of these weighted points is found by means of the equations

$$X = \sum_{i=1}^{8} f_i \cos \Theta_i / \sum_{i=1}^{8} f_i,$$

$$Y = \sum_{i=1}^{8} f_i \sin \Theta_i / \sum_{i=1}^{8} f_i,$$

$$r^2 = X^2 + Y^2, \quad \cos \Theta = X/r, \quad \sin \Theta = Y/r.$$

Large values of r, which lies between 0 and 1, represent winds with a relatively constant direction, and small values represent wind with a more variable direction. Table 2 shows some typical results and Fig. 10 shows the distribution of average wind directions over Thailand in summer and winter, together with the values of the Weibull scale parameter c.

Discussion

The wind speeds over Thailand depend more on geographical location than on seasonal changes. Winds are very light in the north and much of north-east Thailand with average speeds in the Weibull distributions less than 2 m/s. As one moves southwards the winds become stronger and reach average speeds in the Weibull distributions over 4 m/s at exposed locations near the coast. The most promising areas for the development of

wind energy are the southern provinces on the peninsula, the part of the central plain near the Gulf of Thailand, and a broad band stretching across the north-eastern region.

The data used here were all taken from ordinary synoptic weather stations. Windmills whose sites are especially chosen with regard to the surrounding terrain could extract more energy from the wind than the results of this study indicate. Clearly there are many places in Thailand where a potential for the use of simple windmills, such as those mentioned at the beginning of this lecture, exist.

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TABLE 1

Weibull Distribution Parameters

Station	Season	% calm	c (m/s)	k	Av(V) (m/s)
Ubon	Feb - Apr	30	2.44	1.07	2.38
	May - Jul	24	2.20	1.21	2.07
	Aug - Oct	34	2.38	1.21	2.24
	Nov - Jan	26	3.74	1.23	3.50
Haadyai	Feb - Apr	48	4.35	1.96	3.86
	May - Jul	50	3.60	1.79	3.20
	Aug - Oct	49	3.82	1.78	3.40
	Nov - Jan	50	3.61	1.88	3.20

TABLE 2

Parameters for Distributions of Wind Speed and Wind Directions

(see text)

Station	Season	% calm	c (m/s)	k	θ (deg)	r
Ubon	Feb - Apr	51	2.3	1.1	70	0.1
	May - Jul	52	2.4	1.3	220	0.5
	Aug - Oct	48	2.8	1.3	300	0.2
	Nov - Jan	35	3.6	1.4	30	0.8
Don Muang	Feb - Apr	6	3.6	1.6	160	0.6
	May - Jul	8	3.4	1.6	200	0.6
	Aug - Oct	12	3.0	1.6	230	0.3
	Nov - Jan	15	2.5	1.5	20	0.4
Songkhla	Feb - Apr	19	5.5	1.9	90	0.7
	May - Jul	34	3.7	1.7	230	0.4
	Aug - Oct	33	4.2	1.7	240	0.4
	Nov - Jan	14	6.7	1.8	80	0.7

TABLE 3

Diuranl Variation of Frequency of Calm (%)

Station	hours of the day							
	2-4	5-7	8-10	11-13	14-16	17-19	20-22	23-1
Ubon								
May - Jul	29	34	13	13	18	18	28	26
Nov - Jan	33	40	20	20	20	22	24	27
Hatyai								
May - Jul	85	83	42	15	6	18	63	85
Nov - Jan	86	84	44	8	1	23	67	81

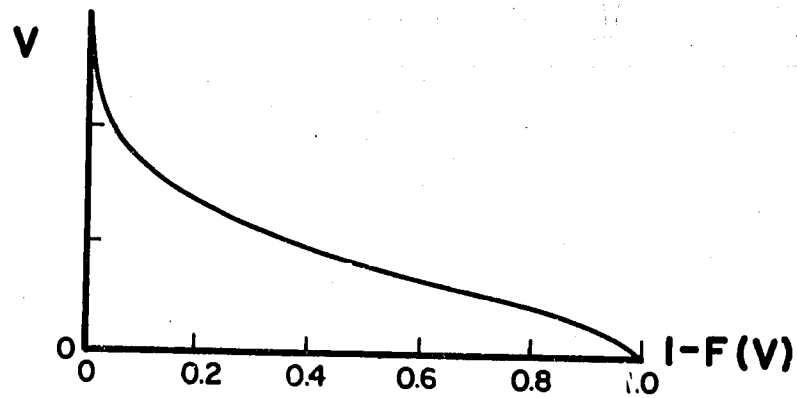

Fig. 1 – Velocity duration curve.

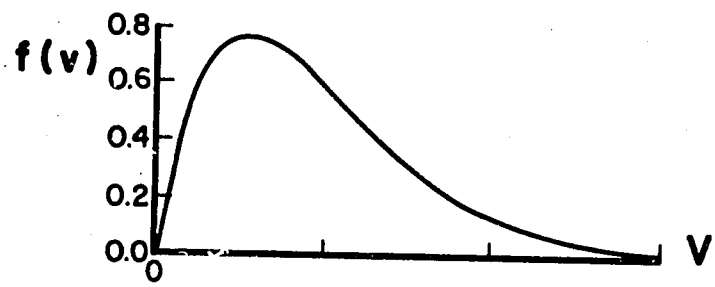

Fig. 2 – Velocity frequency curve.

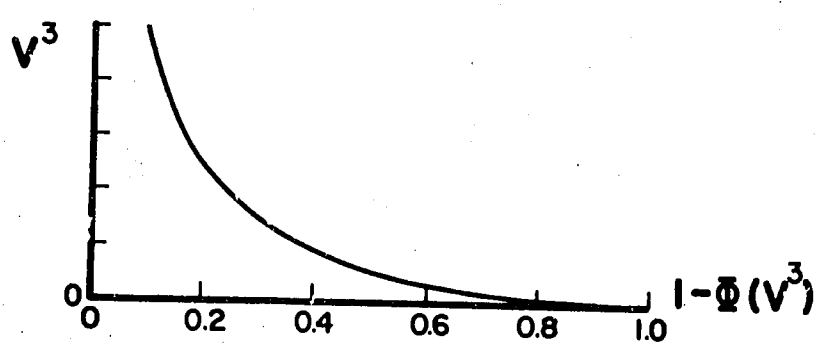

Fig. 3 – Power duration curve.

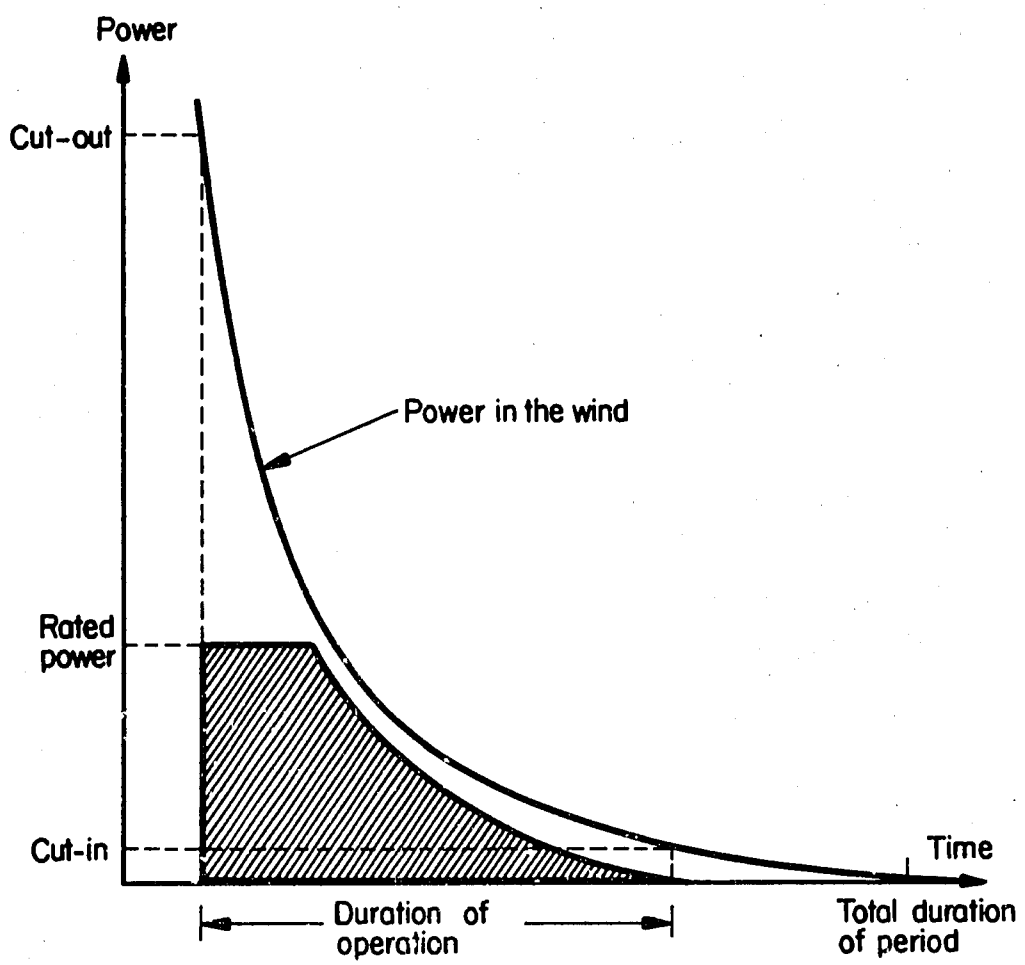

Fig. 4 – Total Energy Output of a Windmill during Period (Shaded Area)

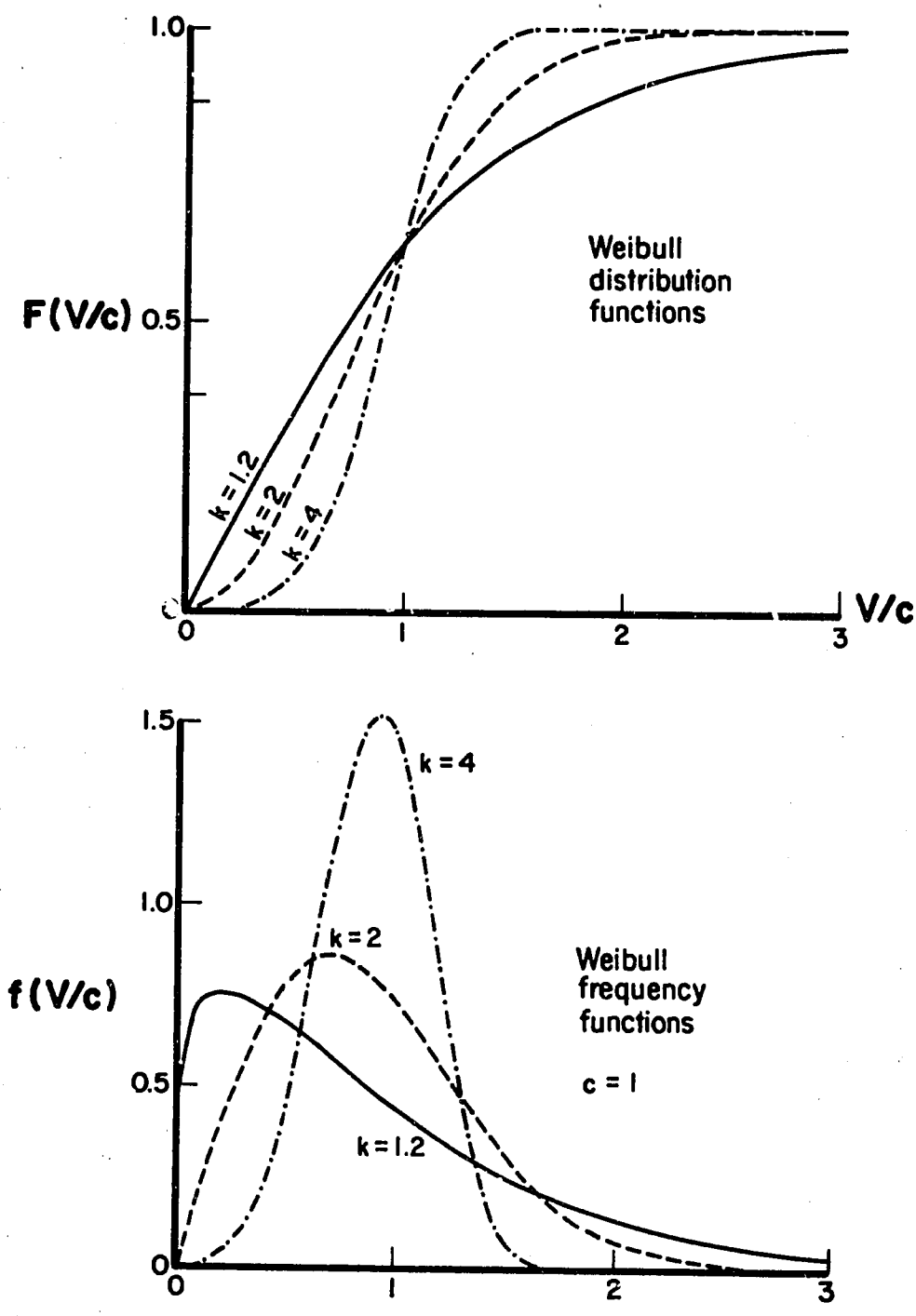

Fig. 5 – The Weibull Distribution.

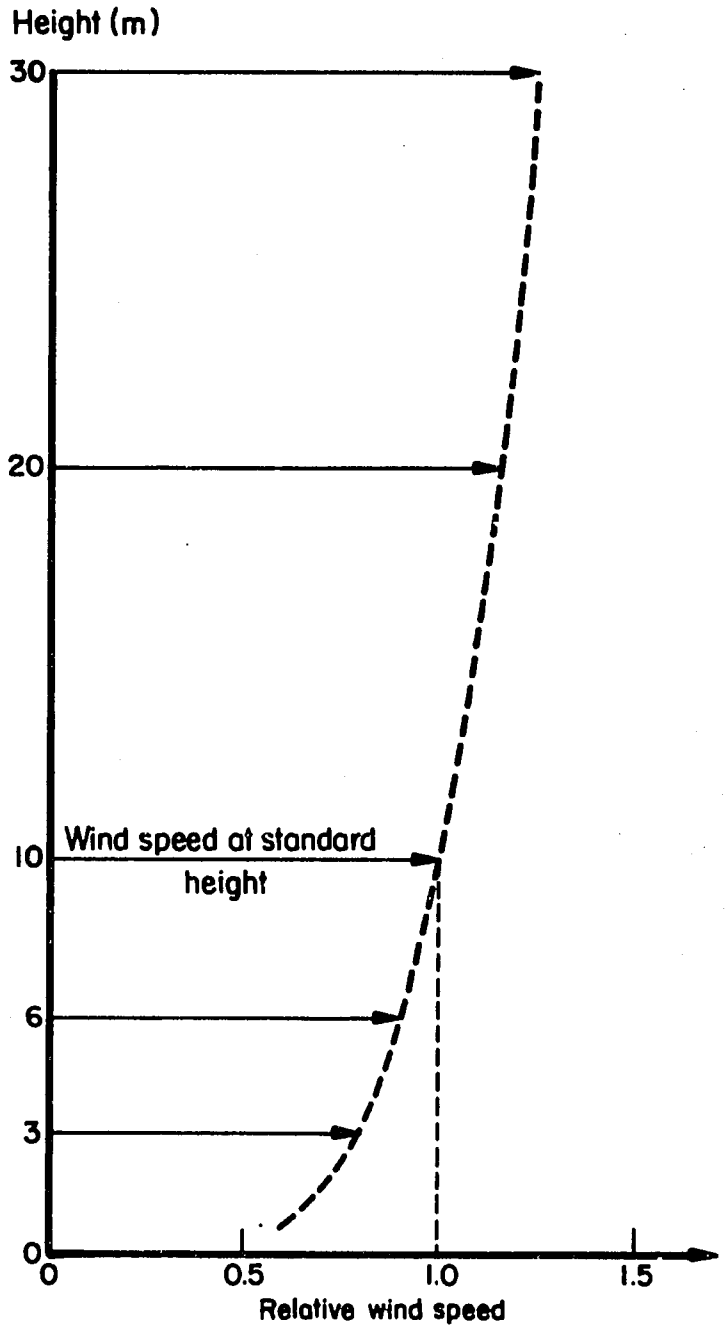

Fig. 6 – Assumed Dependence of Wind Speed on Height

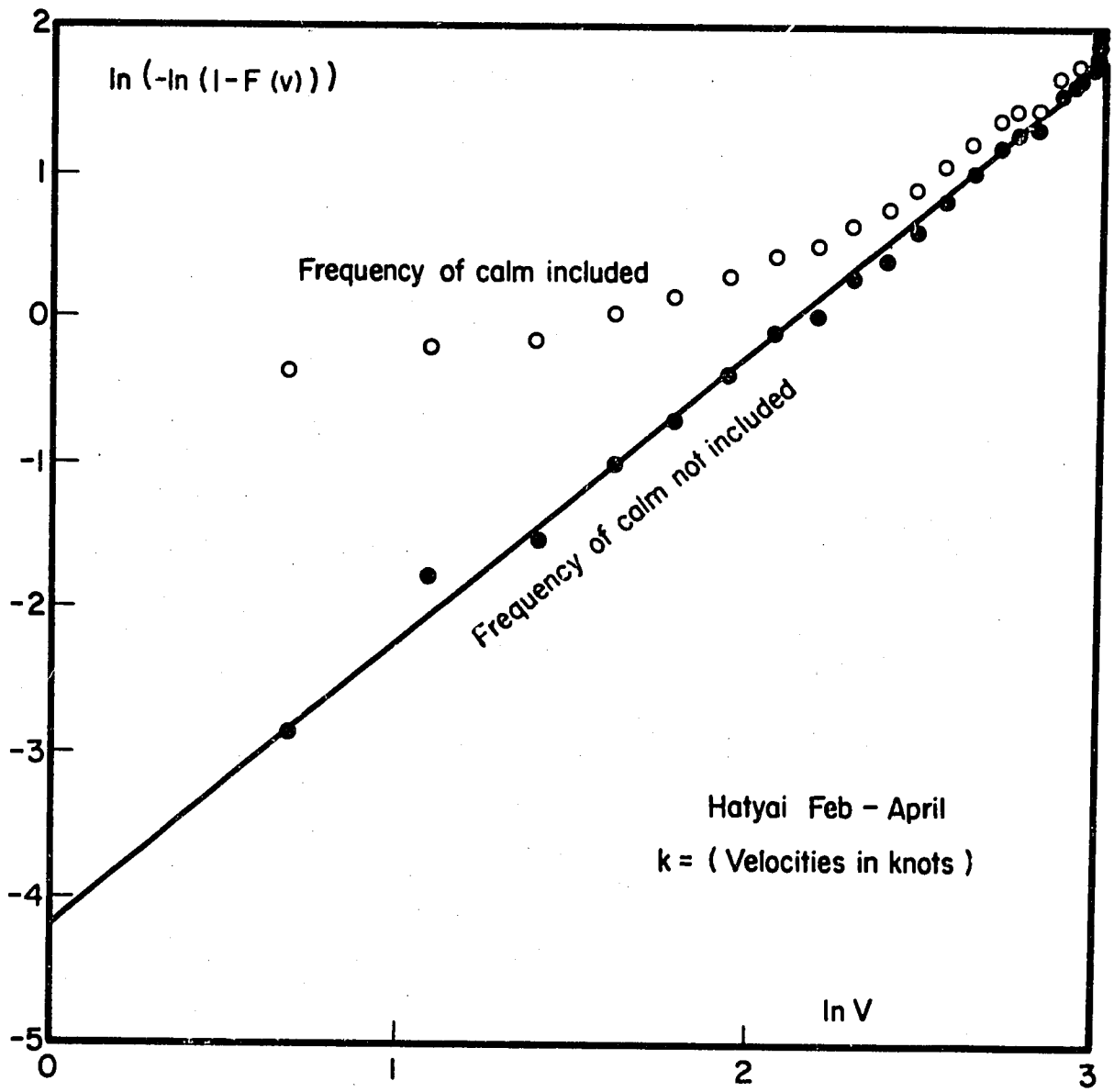

Fig. 7 - Plot for Determining Weibull Parameters

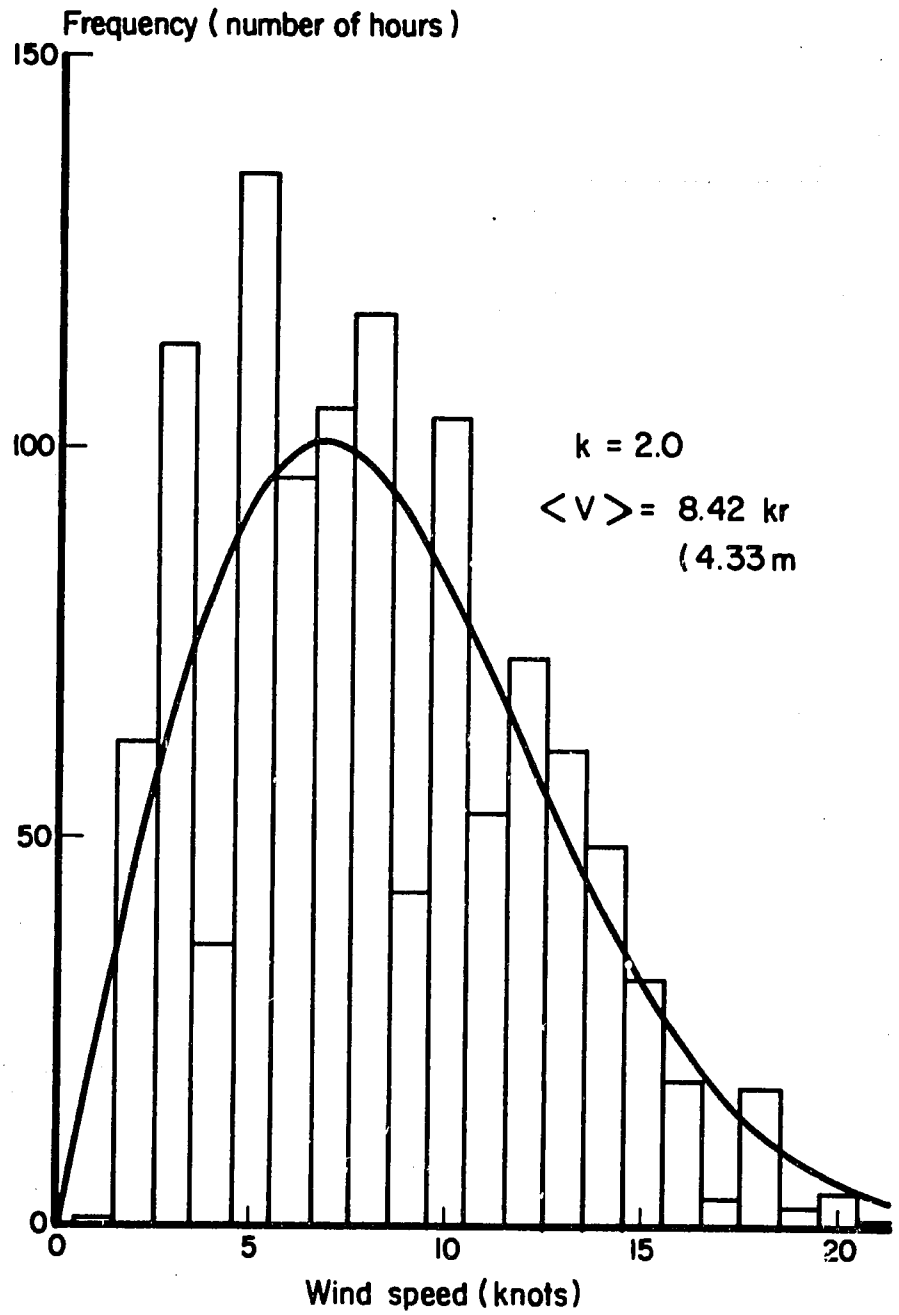

Fig.8 – Velocity Frequencies at Hatyai (February-April)
Histrogram Shows Observed Frequencies.
Curve Shows Weibull Function.

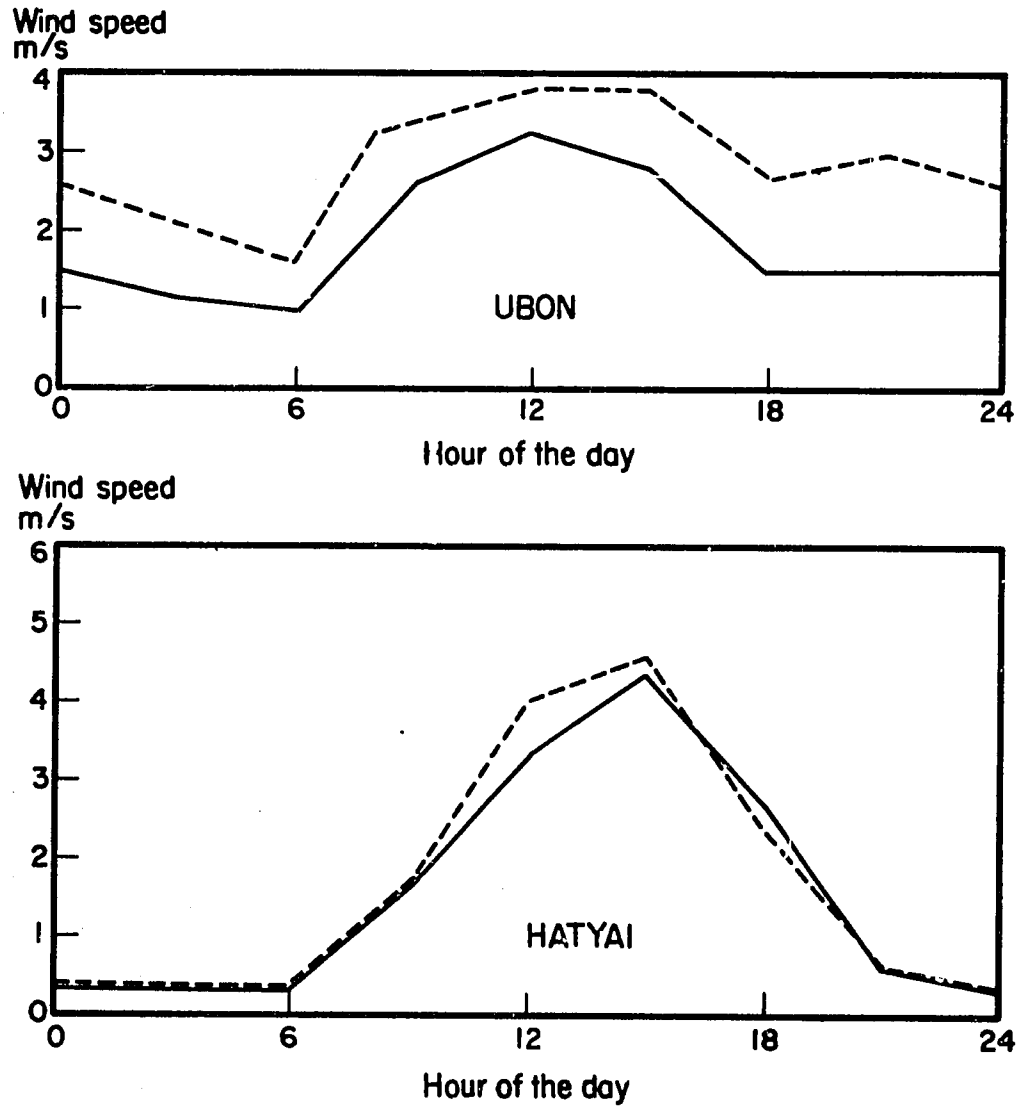

Fig. 9 – Diurnal Variation of Mean Wind Speed at Ubon and Hatyai in Summer (Full Line) and Winter (Dashed Line)

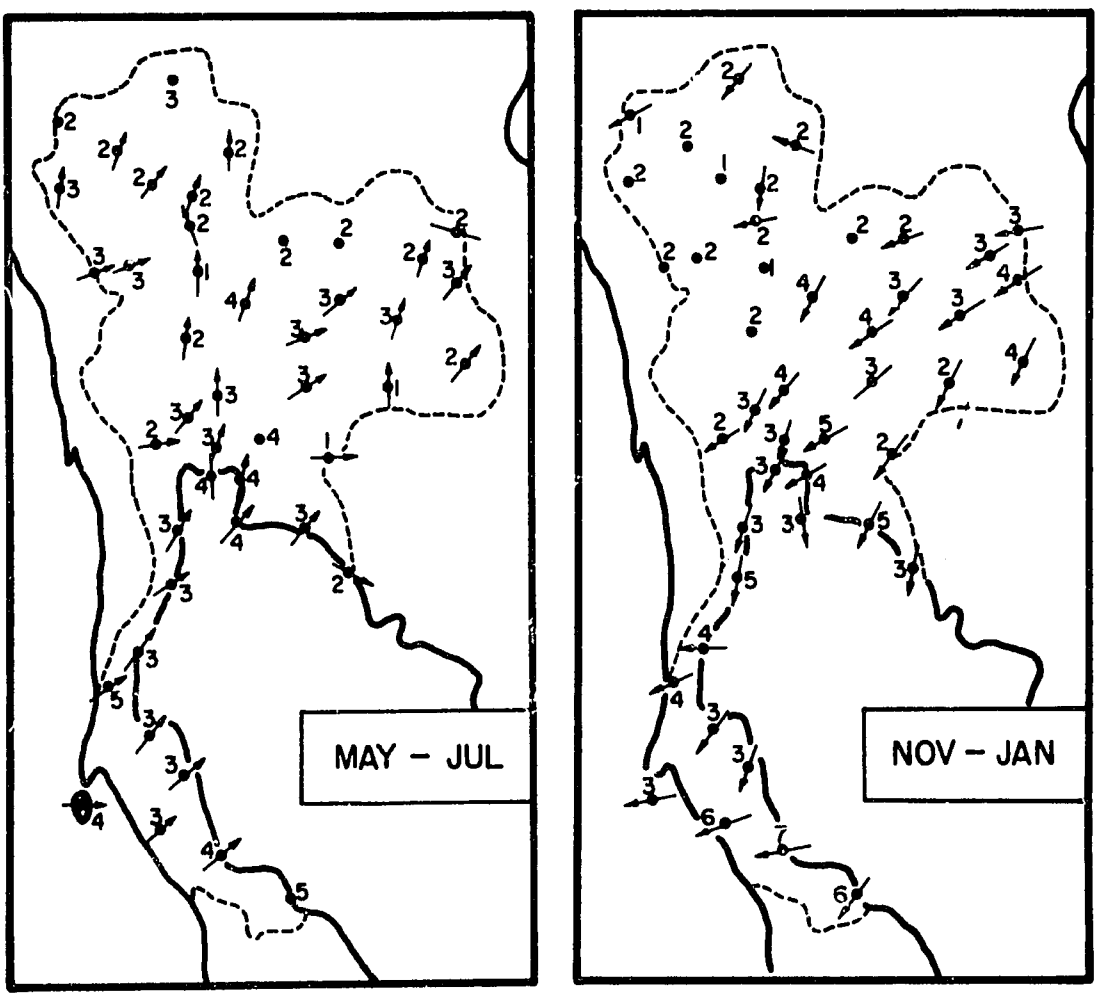

Fig. 10 – Summer and Winter Winds. Numbers Show Approximate Weibull Parameter c (m/s) Arrows Show Mean Wind Direction θ When r ≥ 0.3

An Experience With Photovoltaic Modules Under Low Concentration And An A.C. Pump

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Abstract

The design criteria for application of photovoltaic modules under low concentration to operate on a 100 watt, 220 v, 50 Hz (1Φ) water pump are discussed.

These considerations for seizing the total number of photovoltaic modules required, include the microclimate, the low concentrator, the pump characteristics, the inverter and the back-up battery system. A typical over-all system efficiency is given.

Further work using a microcomputer control is indicated.

Introduction

The aim of this work is to study the utilization of solar energy in water pumping using photovoltaic modules with low concentration of sunlight and a back-up battery subsystem during adverse weather. The back-up battery is recharged during period of high solar radiation. The over-all system consists of the following:

1. A realistic assessment of the microclimate in which the system is to function.

2. The low concentration subsystem.

3. The inverter.

4. The pump characteristics/the well characteristics and water demand.

5. The back-up battery.

These components are represented in the block diagram in Figure 1.

Assessment of the microclimate

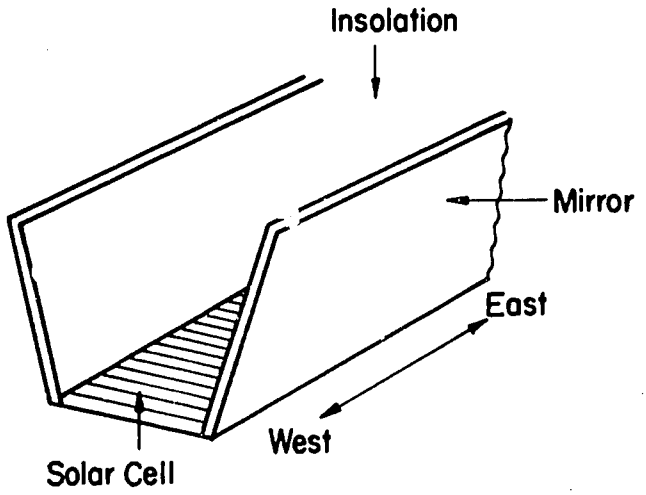
Quantitative mean value and stochastic values of solar radiation namely, global, diffuse and direct should be available for initial sizing of a photovoltaic water pumping system. Works for obtaining these data for Peninsular Malaysia are now available (1-4). The monthly distribution of the mean global solar radiation is shown in Figure 2 for Penang. Generally, the peak period is during the first quarter of the year with the lows in July-September. Typical hourly values of the mean global and direct radiations for the months of May and June are tabulated in Table 1 and Table 2. These typical hourly values could be used for seizing the power input to the photovoltaic modules. The results could then be checked with actual measured values.

The Low Concentrator

Normal silicon cells can be used with concentration factors of 1-4 without tracking and cooling as indicated by Palz [5]. Teoh, et al [6] indicated an optimum concentration factor of 2 at a normal operating cell temperature not exceeding 45°C. This result is shown in Figure 3, where the efficiency is plotted against temperature for illumination intensities varying from 80 $mWcm^2$ to 350 $mWcm^2$.

A simple concentrator to meet the above requirements is a trapezoidal groove shown in Figure 4. Light is focused onto the solar cell mounted between the mirrors and the resulting concentrator is installed with its axis in the East-West direction. Some diffuse light is also collected by

the concentrator. The dimensions and inclination of the mirror to achieve an approximate concentration factor of 2, based on one reflection, may be obtained as follows:



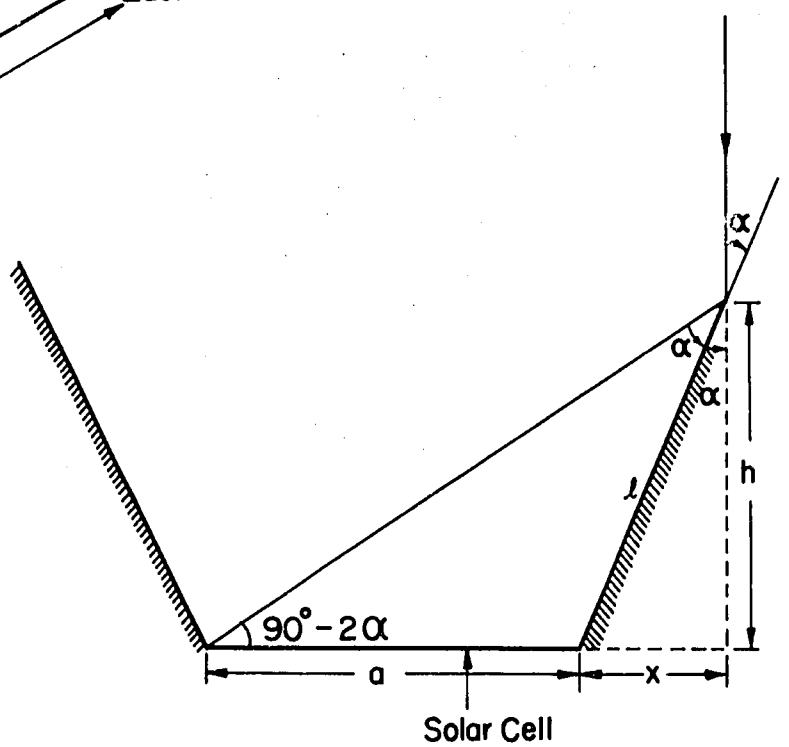


Fig. 4 – A Trapezoidal Concentrator

For a concentration factor of 2, $x = \frac{a}{2}$ (see Figure 4).

$$\frac{a}{2\ell} = \sin \alpha \tag{1}$$

$$\frac{a}{\sin} = \frac{\ell}{\sin\ (90-2\alpha)} = \frac{\ell}{\cos\ 2\alpha} \tag{2}$$

From (1) and (2)

$$\cos\ 2\alpha = \frac{1}{2} \rightarrow 2\alpha = 60^{\circ} \rightarrow \alpha = 30^{\circ}$$

and from (1),

$$\ell = a.$$

For the present system,

$$a = 38.8 \text{ cm}$$
$$\ell = 38.8 \text{ cm}$$

Using the dimensions for $a = \ell = 38.8$ cm, two mirrors, each of length equal to the length of a module, were fixed to the PV module. Figure 5 shows two modules fitted with such mirrors and two modules without them. The I-V characteristics of these modules were measured and compared with the manufacturer's specifications as given in Figure 6 and Figure 7.

The solar radiation indicated on the I-V curves was measured global solar radiation (G) for 6th and 9th June, 1980. On the latter date the weather was cloudy/raining with intermittent break-out of sunshine. The hourly measured direct solar radiation (I) for 6th June and twice the hourly values (2I) are tabulated in Table 3 with the global solar radiation data (G). The total solar radiation falling on the module surface should be $(G-I) + 2I = G + I$, where $G-I = D$ (diffuse component). This value and the approximate concentration ratio (C.R. = $\frac{G + I}{G}$) are also tabulated in Table 3.

The concentration ratio varies between 1.50 - 2.00 depending on the availability of the direct component and to within the expectation of the preceeding calculation.

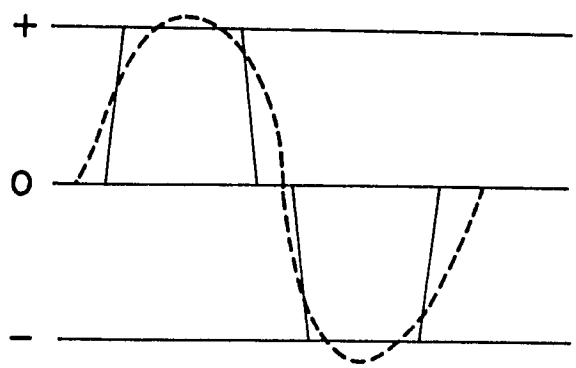
Referring to Figure 6, generally, the current output of the modules with concentration is higher than that of the manufacturer's specifications at 100 mW cm^2 (60^oC) and 50 mW cm^2 (60^oC). This comparison is in general agreement with the higher total solar radiations expected to fall onto the silicon cells arising from the low concentrators.

For 9th June 1980, though there was a general absence of direct solar radiation (from record of other climatological data) except for intermittent sunshine, the module output current was significant, ranging from about (0.5 - 1.0) ampere.

These results indicate that a low concentrator collects both direct and diffuse solar radiations [7].

The inverter and pump characteristics (or well characteristics)

Since the output current from the module is direct current, an inverter is used to convert this output to A.C. input for the pump. The output waveform is a modified sine wave as shown in Figure 8.



Specifications

Input VDC :	12
Output VAC :	115-230
Watt :	500
Frequency :	50 Hz

Fig. 8 – Waveform of Inverter

The efficiency varies from 45% to 80% depending on the power factor of the load. As the inverter interfaces between the module and the pump it is necessary to determine the working points of the inverter on the I-V curves of the PV module.

Normally the pump is chosen on the basis of the well's characteristics (static and dynamic head, and the water demand per day). However, in this case, in the absence of sufficient fund to meet the characteristics of the shallowest known well, a small A.C. pump was used to simulate the pumping system. The characteristics of the pump are as follows: AC 100W 0.7A, 220V, 50 Hz (1ϕ), 2.5 cm diameter, 21.1 gpm at 5.5 m. The pump was placed

at 4.3 m from a tank to which water was lifted (Figure 9). The pumping rate with a 2.5 cm diameter tube was measured as 8 gpm.

With two 12 volt batteries connected to the input of the inverter and the output to the A.C. pump, the input voltage was varied in step of 2 volt until 12 volt, the corresponding input current, the output voltage and current were recorded. These values are tabulated in Table 4.

The input current-voltage data to the inverter-pump system were plotted on the I-V characteristics of the module in Figure 10. The resultant current-voltage curve is nearly vertical in the region of the module I-V curves. In the absence of a DC/DC power conditioner, the operating point (on the module I-V curves) that limits the proportionality of the current to the variation of light intensity is at 12V. At this point, for an intensity of 200 mW cm^2 the optimum current is about 3.8A. Thus, to be able to start the pump at 21A, the number of modules would be $21/3.8 = 5.5 \simeq 6$. However, one would have to examine the microclimate data to allow for the lowest reasonable solar radiation so as to enable the pump to start at this period. Considering the I-V curve at 100 mW cm^2, where the optimum current and voltage are 2.0A and 12.0V, this would require 10 modules. With a concentration factor of 2, the base requirement of solar radiation is 50 mW cm^2, which from previous solar radiation data (Figure 1 and Figure 2) could be between 9.00 a.m. - 3.00 p.m. but a little less initially. In view of this, fourteen modules (based on 1.5A, 80 mW cm^2 in Figure 10) with concentrators could suffice quite comfortably. This means, once the pump is started, there will be excess current (provided the weather continues to be good) and this excess current should be stored in storage battery for starting/operating the pump during adverse weather conditions. Thus, a back-up battery subsystem should be incorporated to take care of the fluctuation of the solar radiation so that it could operate the pump during periods of insufficient insolation and being trickle-charged or recharged when there is excess output current (during good insolation period). This is being discussed further under the microcomputer control subsystem.

With respect to the efficiency, if we take the module efficiency at $45^{o}C$ (Figure 3) as 8.5%, the inverter efficiency as 74% and the pump efficiency as 65%, the overall system efficiency is 0.085 x 0.74 x 0.65 = 0.041 or approximately 4%. It is hoped to improve on this efficiency by investigating the optimization of each part of the system.

Back-up battery subsystem with microcomputer control

The control system for this project is still being investigated with a SDK-85 microcomputer. The aim of this control is to ensure continuous operation of the pump during the required duration each day with minimum possible usage of the battery and to allow the battery to be charged whenever possible.

A simplified flow-chart indicating the control and parameters to be monitored is shown in Figure 11. If the available current, I_c, from the panel is less than the operating current, I_o, the microcomputer switches on the PV modules (now called "battery charger") to charge the battery. On the other hand, if the available current, I_c, exceeds the operating current I_o, the microcomputer is programmed to check this value against the starting current of the pump, I_s. Depending upon the actual value of I_s, either the pump can be operated purely from the modules if I_c exceeds or equals I_s or the pump can be operated with the battery for an initial starting and switches over to the modules if I_c is less than I_s but exceeds I_o. For the latter two cases, the difference in current between initial starting current and the operating current with the pump running can be considered as excess available current, I_x, to be used for charging the battery. It is important to regularly check the available current, I_c, so that the pump does not stop during the operation.

With this back-up battery subsystem, the number of PV modules could be reduced from 14 to 10 for start-up on battery and operation on the PV modules thereafter.

Conclusion

It is feasible to use photovoltaic modules under low concentration in a given microclimate to operate an A.C. pump. A clear understanding of the characteristics of the microclimate data is essential to the sizing of the power requirements of the system. A microcomputer to control the operation of the back-up battery subsystem is being studied as a means of stabilising the continuous operation of the pump without allowing the battery to be completely discharged.

Acknowledgement

We thank the AIT, Bangkok, for the opportunity to present this paper, the Universiti Sains Malaysia for the short-term research grant, the National Electricity Board of Malaysia for partial financial support, the French Government for the donation of the BPX 47c photovoltaic modules and the Water Authority, Penang for the loan of the inverter.

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TABLE 1

Mean Global solar Radiation (mWhr cm^{-2}) (1975-80)

Penang (Lat. = 5° 18'N, Long.= 100° 16'E, Ht.= 3m above MSL)

HOURLY	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6
MAY	3.75	19.60	35.96	50.70	58.97	63.3	68.92	64.94	55.18	41.90	24.60	9.61
JUNE	3.15	17.49	34.05	48.76	57.59	63.78	66.88	63.98	53.92	41.48	24.46	10.31

TABLE 2

Mean Direct Solar Radiation (mWhr cm^{-2}) (1980)

Penang (Lat.= 5° 18'N, Long.= 100° 16'E, Ht.= 3m above MSL)

HOURLY	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6
MAY	22.91	29.18	30.02	28.12	25.28	26.61	29.98	27.78	21.97	15.30
JUNE	12.35	20.12	29.95	26.79	24.75	19.70	22.69	21.81	21.78	13.84

TABLE 3

6th June 1980: Solar Radiation Data (mWhr cm^{-2})

HOURLY	G	I	2I	G + I	$\frac{G + I}{G}$ = C.R.
10.00 a.m.	49.84	36.27	72.54	85.81	1.72
12.00 noon	79.89	43.28	86.56	123.17	1.54
2.00 p.m.	33.67	16.63	35.74	52.78	1.57
4.00 p.m.	32.00	32.00	64.00	64.00	2.00

TABLE 4

Input/Output Current-Voltage Data for Inverter

INPUT (DC)		OUTPUT (AC)		
V	A	V	A	
2.1	0.04	-	-	
4.2	0.095	-	-	
6.4	0.15	-	-	
7.6	15.3	100	0.8	
9.5	19.0	135	0.99	
12.0	21.0	250	1.20	STARTING
11.0	16.2	185	0.75	OPERATING

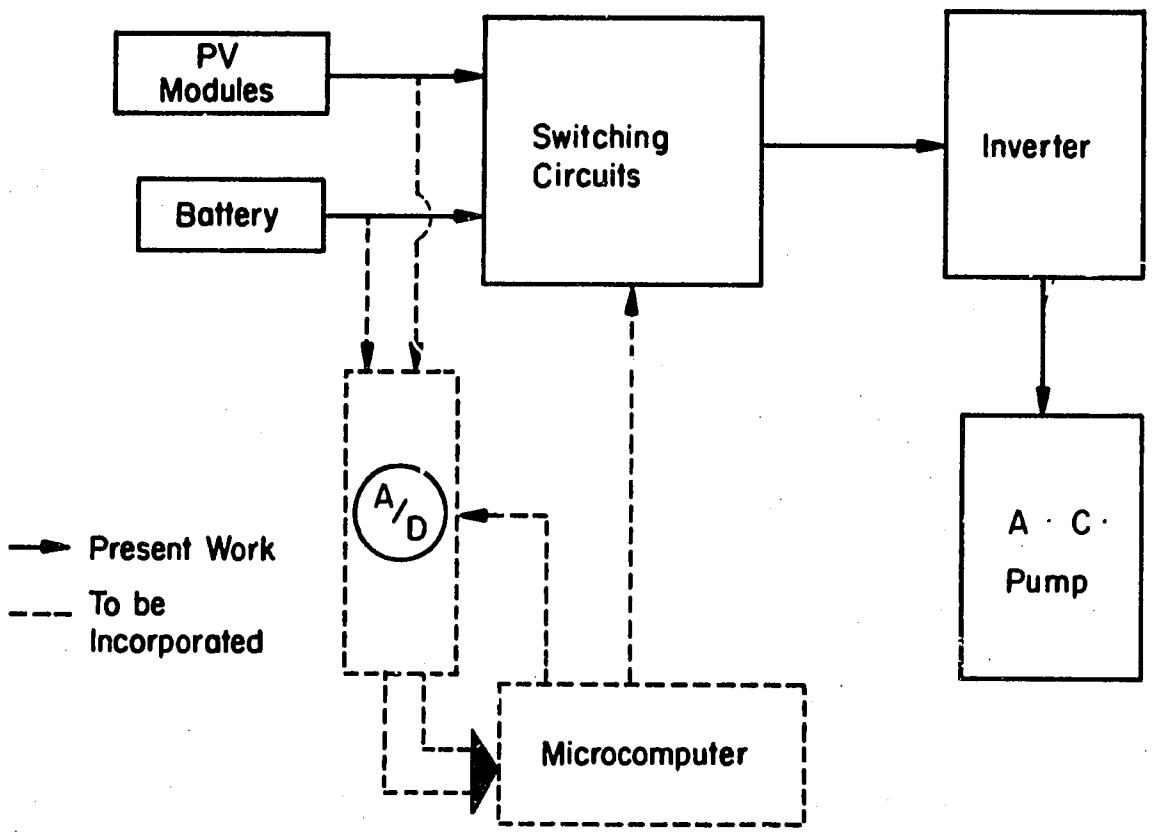


Fig. I – Pumping System

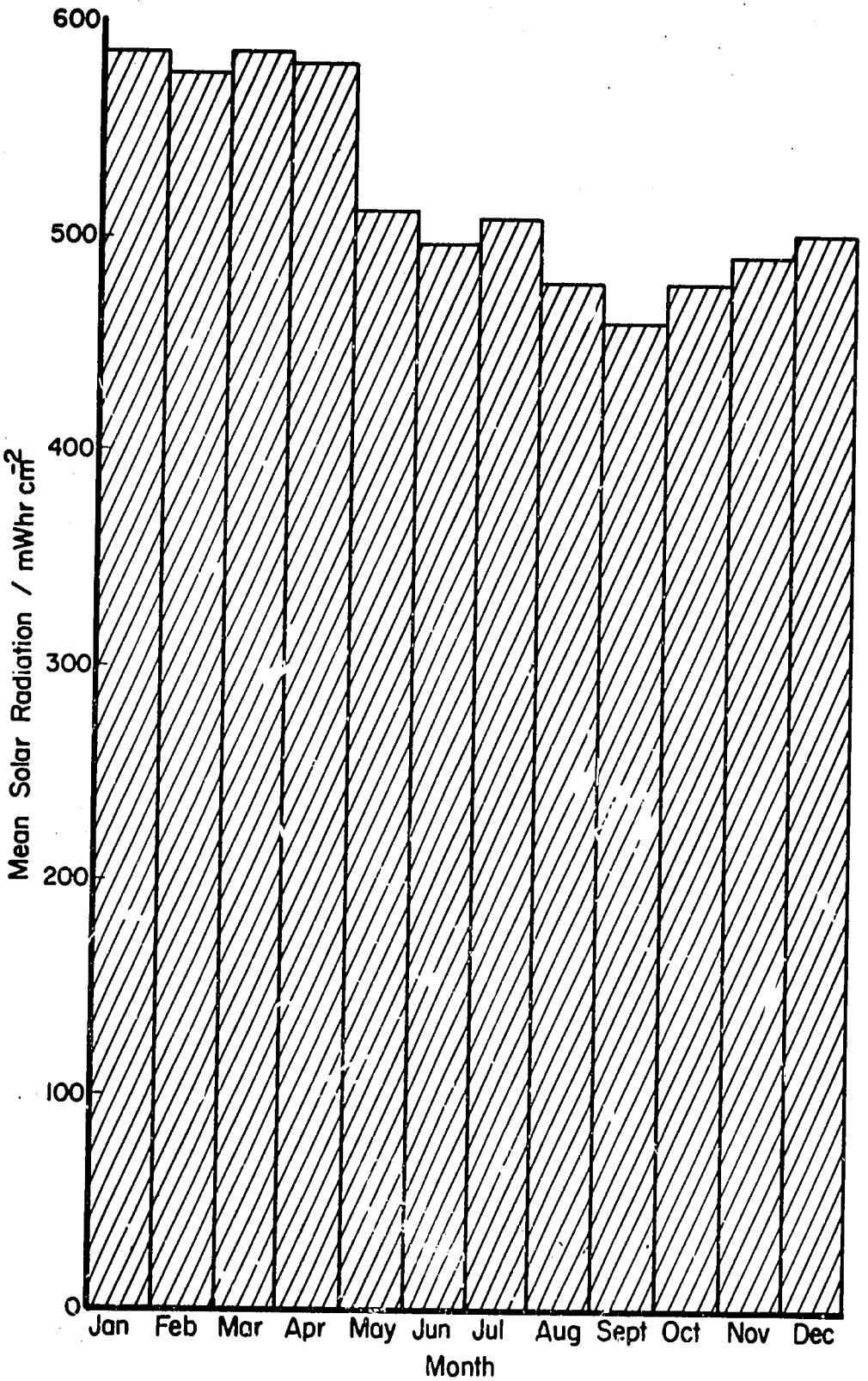
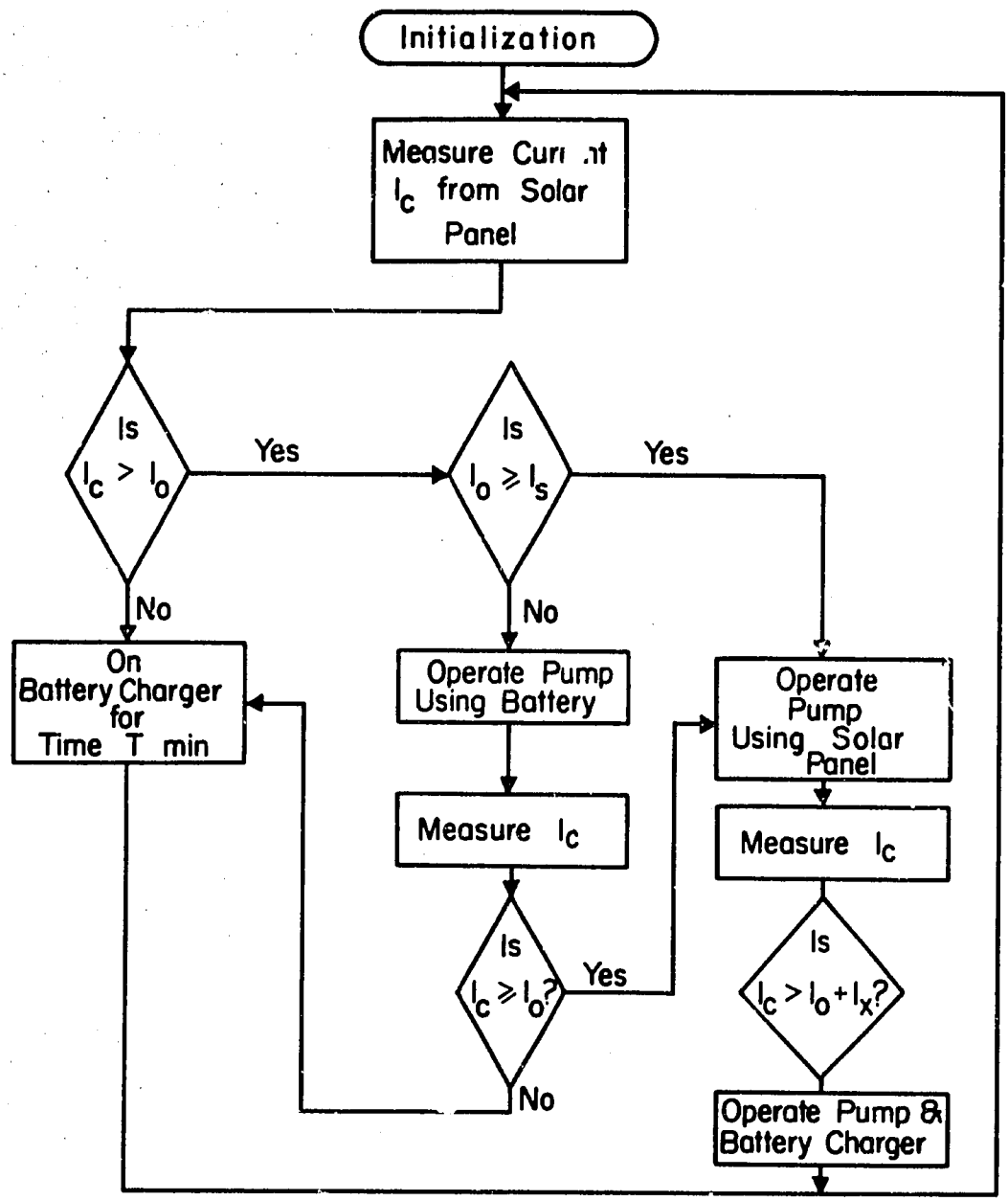


Fig. 2 – Mean Global Solar Radiation for Penang
(1975 - 1978)



I_s = Starting Current for Pump

I_o = Operating Current for Pump

I_c = Current from Solar Panels

I_x = Excess Current

Fig. 2 – Simplified Flow-Chart

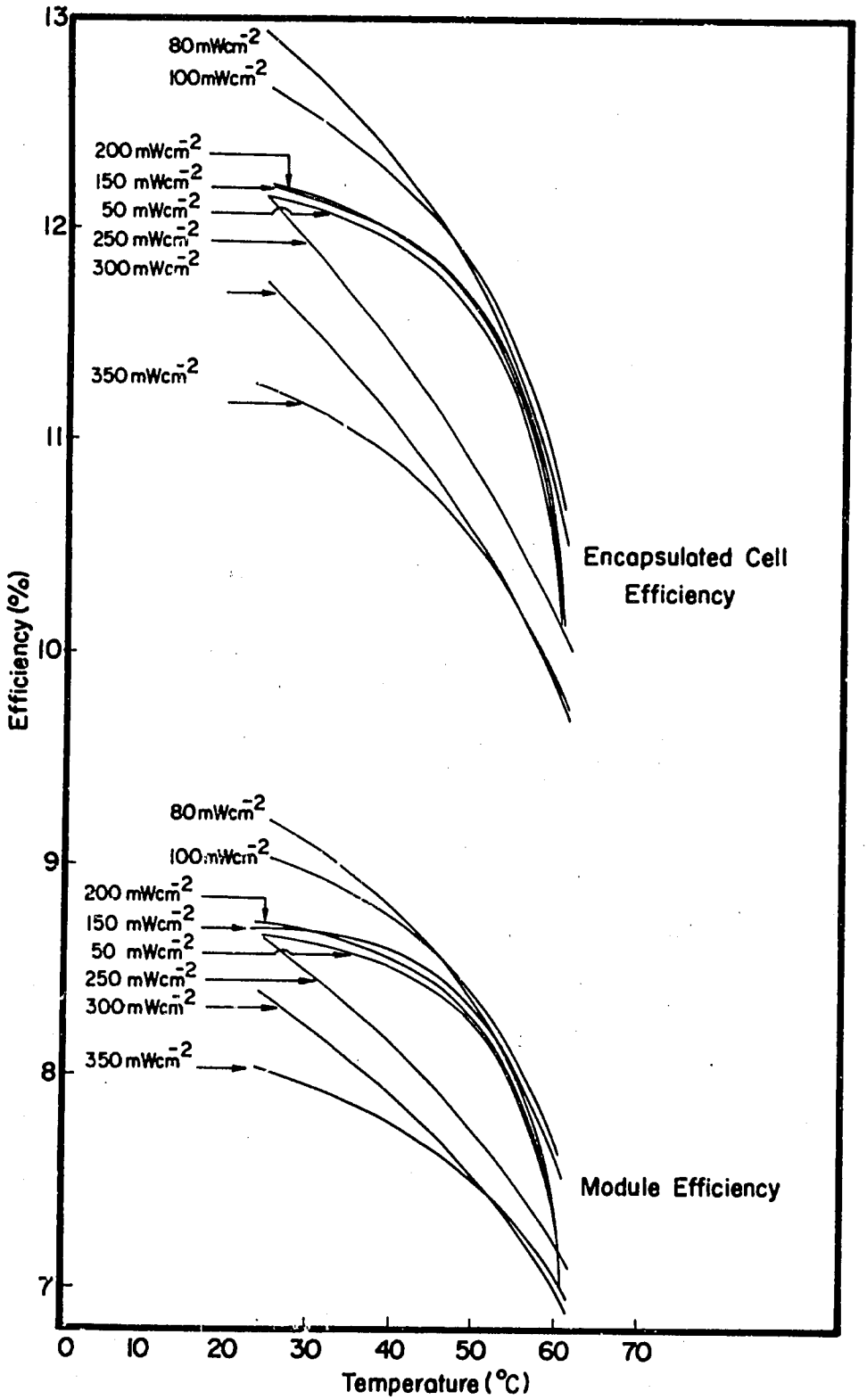
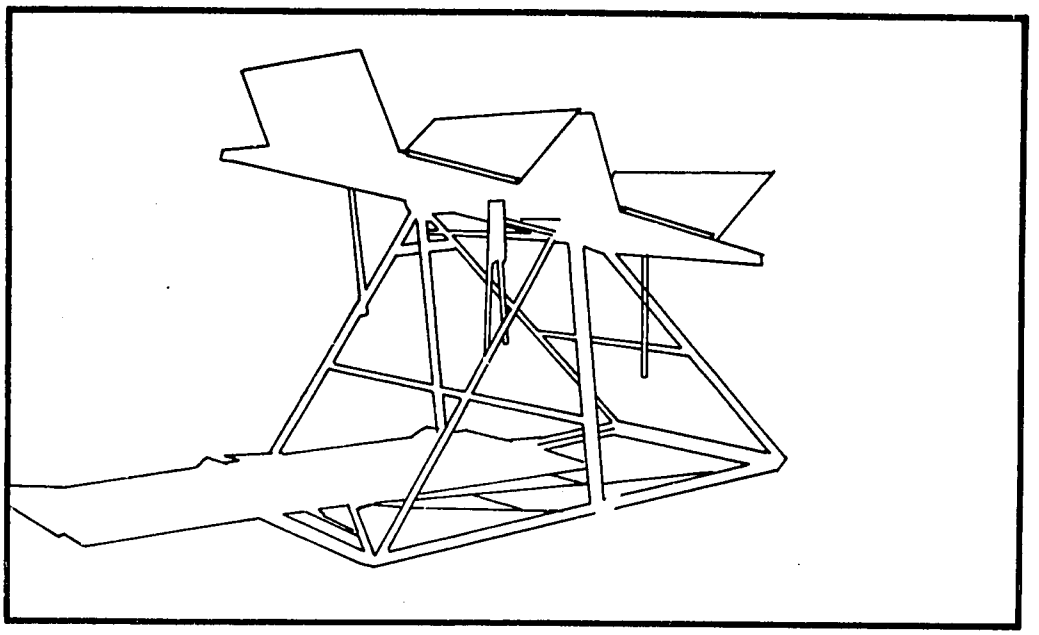
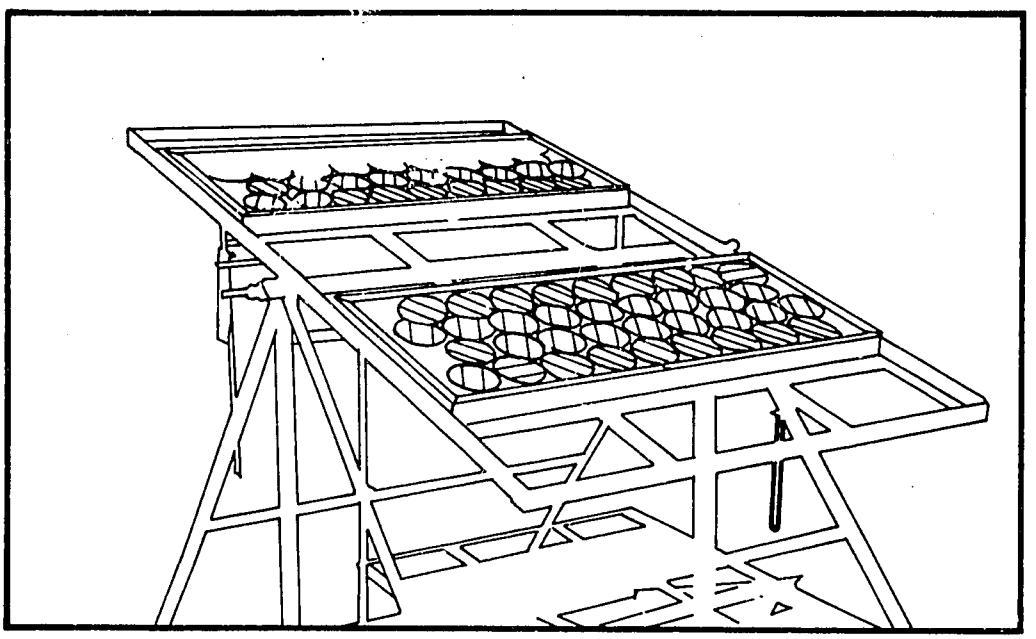


Fig. 3 – Efficiency vs Temperature



(a)



(b)

Fig. 5 (a) – PV Modules with Concentrators
(b) – PV Modules

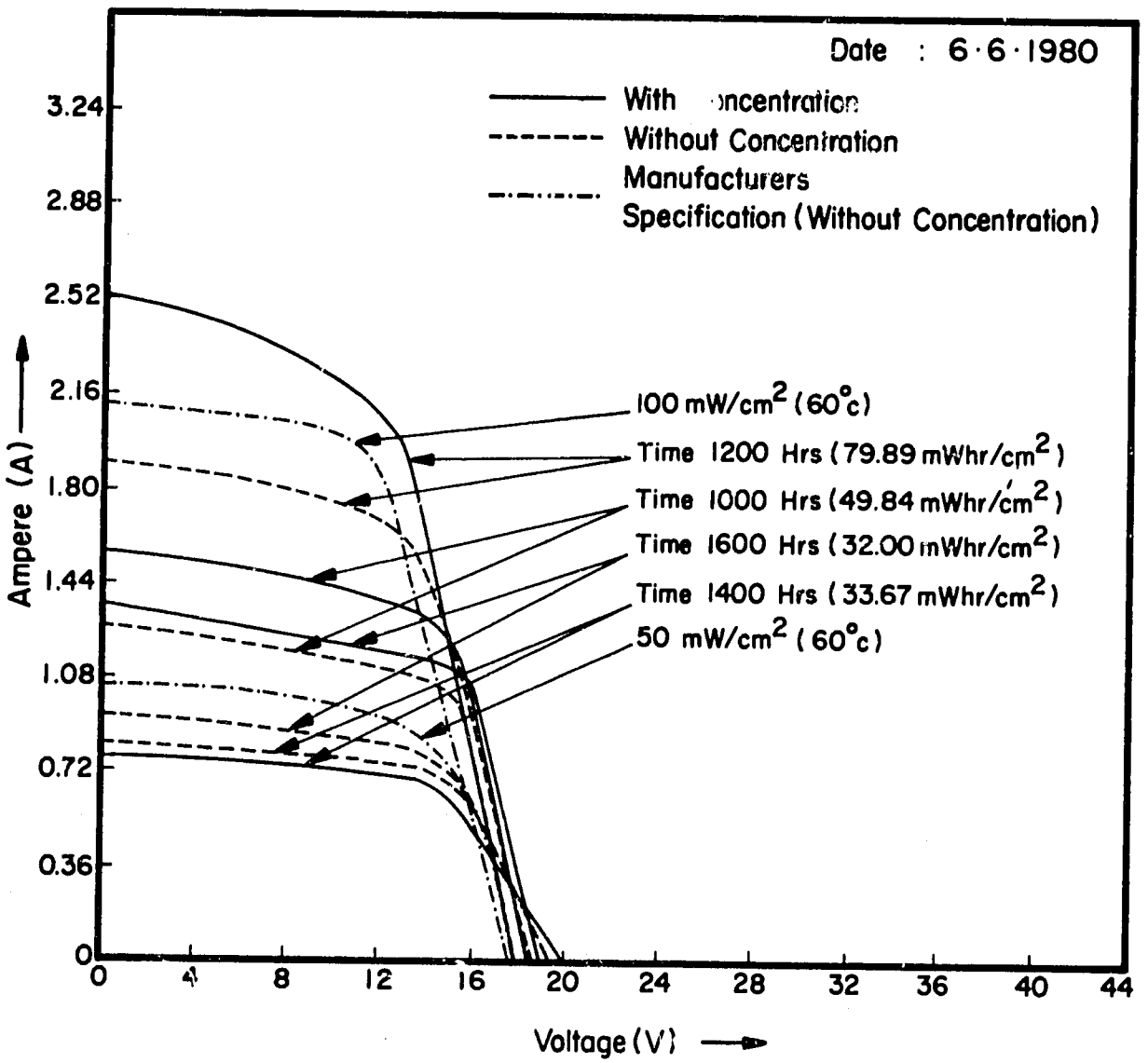


Fig. 6 – Current – Voltage Characteristic

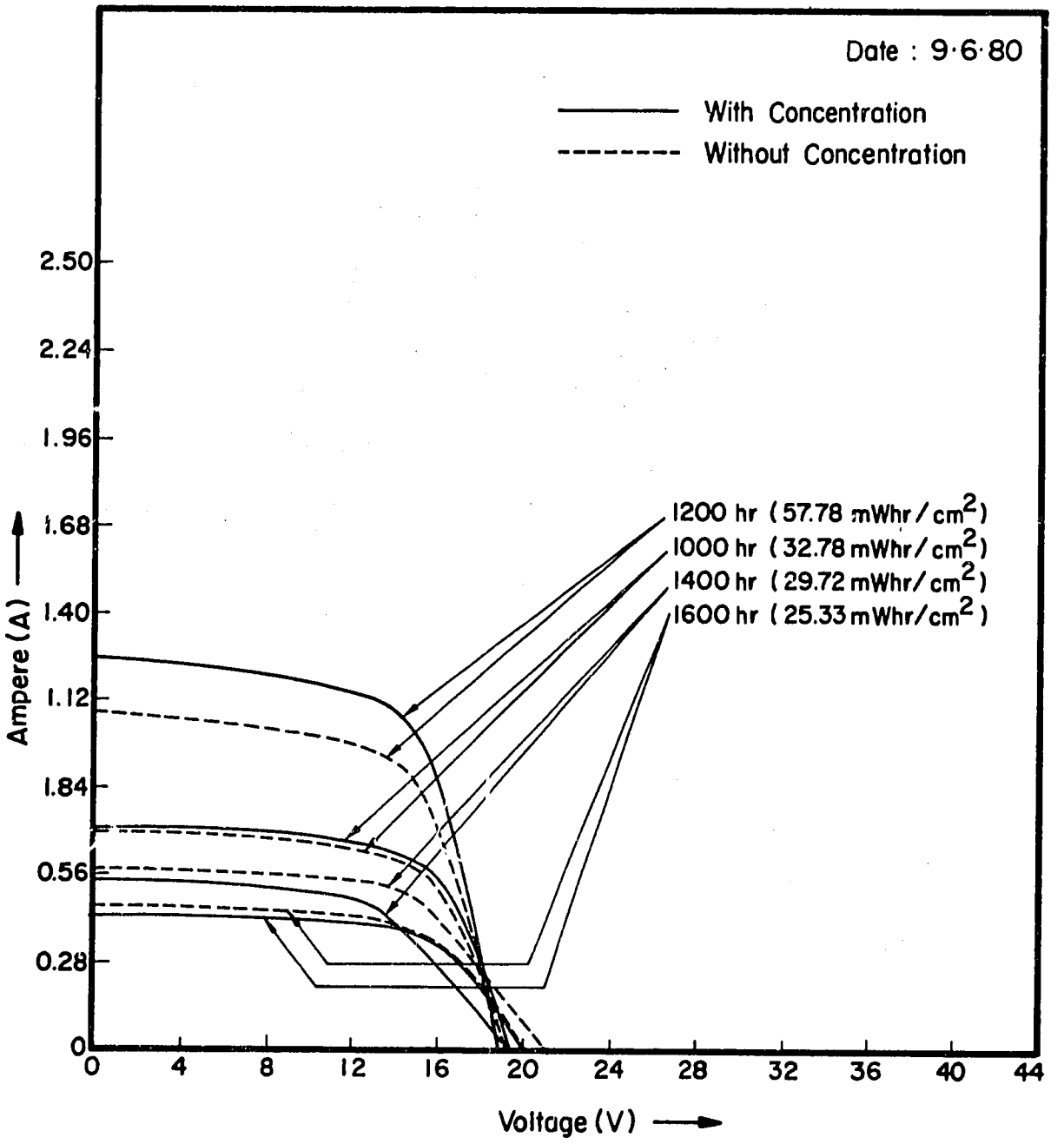


Fig.7 – Current - Voltage Characteristic

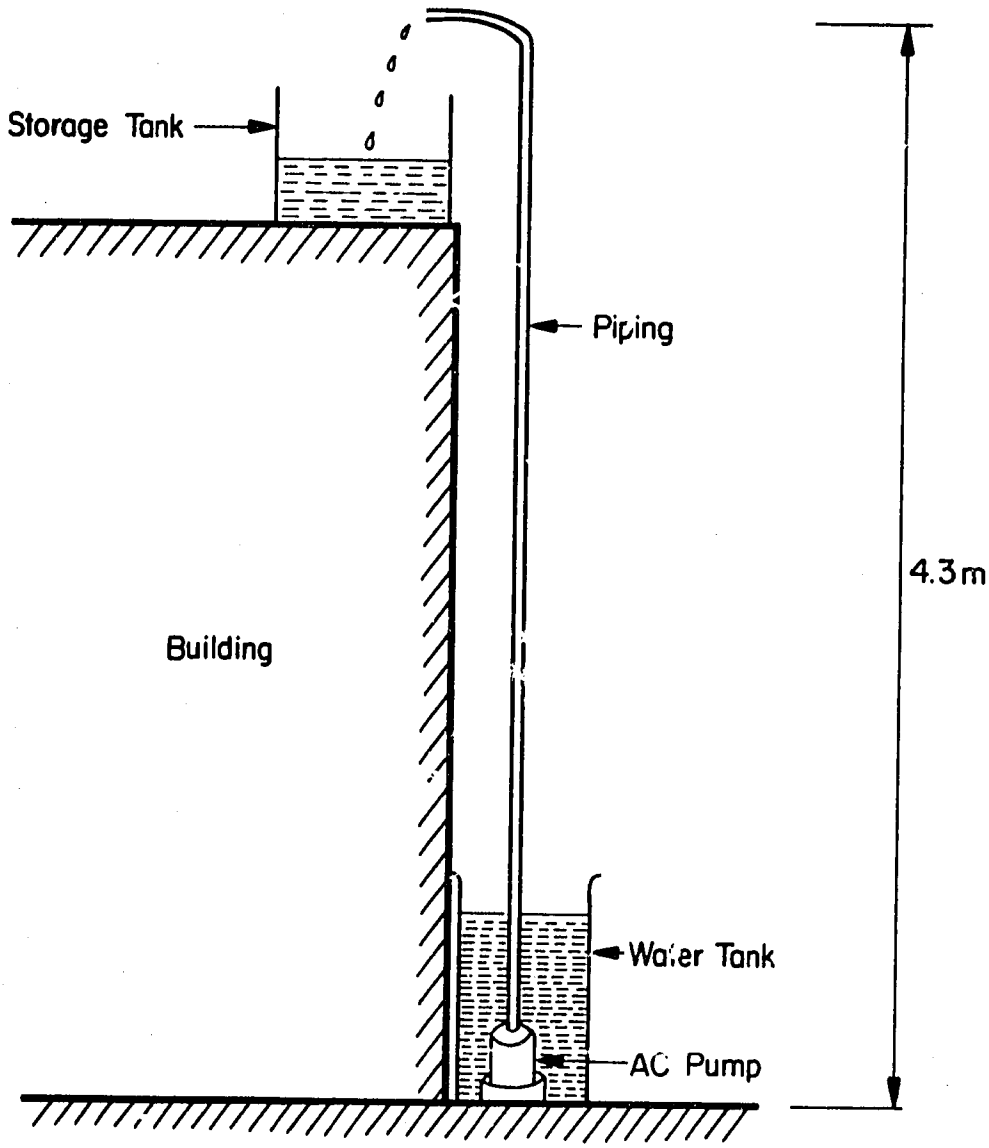


Fig.9 – Demonstration Set-up of Pumping System

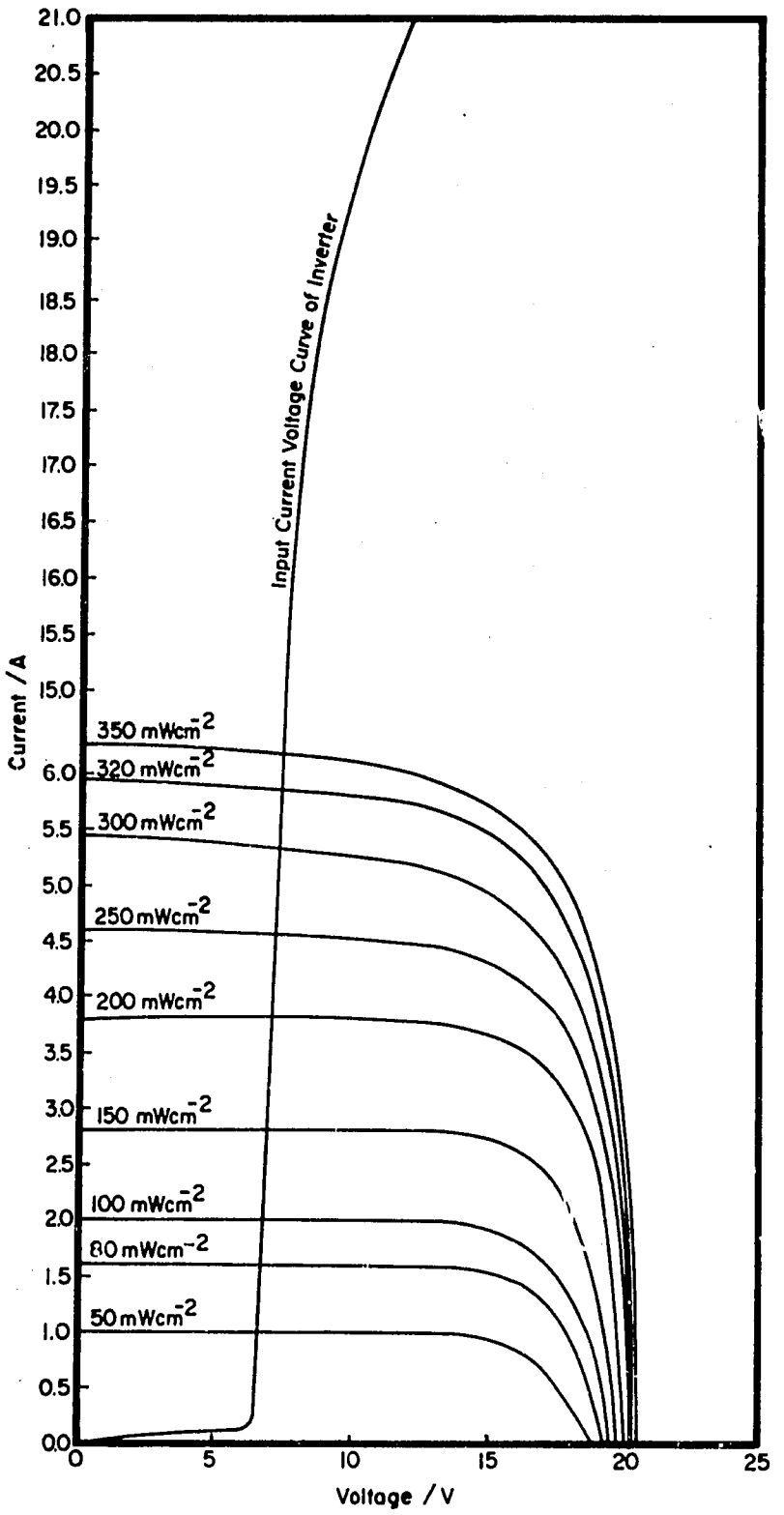


Fig. 10 - Current Versus Voltage at 45°C

Solar Photovoltaic Water Pumping

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Abstract

Water pumping, for both irrigation and drinking purposes, is potentially the single most important area of large-scale applications of Solar Photovoltaic Systems in the developing countries. The present state of art of Photovoltaic water pumping is reviewed on the basis of the UNDP project (GLO/78/004) and Indian experience. A methodology is proposed to compare the cost-effectiveness of various options of the Solar Photovoltaic Systems (SPPS) on the basis of break even cost calculation with diesel pumps. The important role of the Balance of Systems (BOS) costs on the design and deployment of solar photovoltaic has been emphasised. The variation of allowable module cost/peak watt with variation in (a) the head of water and (b) cost of non-area related BOS has been investigated. The direction of further work in SPPS is indicated.

Introduction

Water Pumping, for both drinking and irrigation purposes, has been identified as one of the most important areas in most of the developing countries for satisfying the basic needs of food and water. The high growth rate of population coupled with the facts that (a) more than 50% of the population of these countries lives in the villages where the facilities for using electric utilities are limited and (b) the cost of diesel is rising very fast making it imperative for the Government of these countries to study the alternative means for water pumping in the rural sector.

Presently, hand operated tube wells and bore wells are extensively used for pumping water used for drinking purpose. Diesel pumps and electric pumps are the two common types that are used extensively for irrigation purpose. But the costs and hazards of using diesel pumps are increasing everyday affecting the national economy. Since electric pumps cannot be operated in most villages, an intensive search has been started for finding suitable alternatives for these pumps. Wind, Photovoltaic, Solar Thermal, and Biogas pumps have been developed and demonstrated by various organisations over the last few years in many countries. It is not the purpose of this paper to study and compare all these possible alternatives. Rather, we shall concentrate solely on the photovoltaic water pumping and try to analyse its technological and economic aspects as far as possible. We shall further restrict our analysis to the case of water pumping for irrigation where diesel pumps are used and shall not consider water pumping for drinking, a use normally met by hand operated pumps.

Description

Solar Photovoltaic Water Pumping has been a subject of intensive study for the last few years and a UNDP project was executed by the World Bank in collaboration with the governments of several developing countries (1). In addition, a number of demonstration projects were carried out in Asia and Africa by photovoltaic companies, particularly from USA and France (2-4).

The schematic diagram of a Solar Photovoltaic Pumping System (SPPS) is shown in Fig. 1. It is interesting to note that there are various options of SPPS depending upon the inclusions of the Battery and the Maximum Power Point Tracker (MPPT) in the system. The efficiency and cost impacts of these options vary depending on a number of parameters including available insolation, and head of water. A trade off among cost, efficiency and reliability is important to identify the most suitable systems in particular locations. In order to carry this out, we had to find the break even cost of the basic SPPS vis-à-vis the diesel pump system.

Break-even Cost Calculation

The assessment of the economic viability of a solar energy system for a particular application can be made through a break even cost calculation with the conventional energy system. The break even cost can be calculated by finding the present value of the average yearly savings between the solar energy system and the conventional energy system. Alternatively, in the case of micro-irrigation, it can also be determine in terms of unit cost of water discharge by the pump set. This approach is followed in this paper. The costs of the diesel pump sets have been calculated following the method of J. Parikh (5).

The capacity of the diesel pump sets for this analysis has been chosen to be 5 H.P. It is interesting to note that in the Indian market diesel pump sets with capacities less than 5 H.P. are not generally available. Private discussions with manufacturers and users of diesel pump sets in India indicate that efforts to introduce diesel pumps of capacity 3 H.P. or less have encountered both technical and economic problems. To irrigate a plot of about 1 hectare (10,000 square meter), a typical agricultural land holding under Indian conditions, 5 H.P. diesel pumps are universally used, though there has been a tendency to under utilise the engines. The 5 H.P. diesel pump has been taken as the basis for comparison with SPPS although we recognise that the effective capacity required for this purpose is much less.

Usually, diesel pump sets of this capacity can pump 20 m^3 of water per hour. One hectare farm generally requires about 10,000 m^3 of water per year for the cultivation of 3 crops in a year in India. The operating hour of the diesel pump set has thus been taken as 500 hrs/year. The fuel consumption has been taken as 1 litre/hr. The present price of the diesel is taken as $400/ton (1980) including the cost of transportation. The cost of the pump set is $600 (approx.) and the maintenance cost is $50/year. The life is expected to be 10 years and the resale value of the diesel pump

set is assumed to be negligible. The total discounted cost of the diesel pump over a period (T) of 10 years has been calculated, by considering 10% annual increase in diesel price as:

$$C = \sum_{\eta=1}^{T/c} (K + \sum_{t=i}^{\ell} (\frac{O(t)}{(1 + d)^{t-1}}) (\frac{1}{(1 + d)^{n-1}}) \quad (1)$$

where C is the discounted cost of installed capacity,

K is the capital cost,

O = m + f, where m is maintenance cost and f is fuel cost,

l = life time of the diesel pump set (= 10 years),

d = discount rate (= 10%)

The present discounted cost, thus calculated for a diesel pump set with 10 years of life, is \$400. This pump set can discharge 10^5 m^3 of water for 10 years of operation. Thus, the water cost comes to \$0.041/m^3. It is interesting to note that in a recent UNDP project on small scale irrigation the water cost has been assumed to be 5 cents/m^3 (1979 prices)[1].

To make the solar photovoltaic pump set cost-effective, the water cost should be in a similar cost bracket to pump 10^4 m^3 of water annually. The levelised annual cost thus will be \$410. Assuming a highly conservative levelised annual maintenance cost to be \$50/year for the entire PEPS, the levelised annual capital cost must not exceed \$360 to keep the cost within the target. Thus, with 10 years of life, negligible resale value and 10% discount rate, the maximum acceptable discounted capital cost of the solar pump set is \$2,212 in order to achieve delivered water cost at \$0.041/m^3.

BOS Costs

The overall cost of a SPPS depends both on the cost of the solar cell modules and the cost of Balance of Systems (BOS) which can be broadly divided into two components, (a) area-related costs such as costs of array structure and site preparation, module interconnections, installation and

other costs including module testing, packaging etc. and (b) non-area related costs such as costs of storage, power conditioning (which include regulating circuits, controllers, maximum power point trackers etc.), field-wiring etc. So far more attention has been paid to reduce the solar cell panel costs to meet the DOE target of US $700 per peak Kilowatt by 1986. Only recently has some attention been paid to the analysis of BOS costs which may eventually dominate the Photovoltaic Systems costs. Once these costs are known, one may determine the cell efficiencies and costs that can be allowed to make photovoltaics economically viable (6-7). The BOS costs in more developed countries are rather high - the DOE target for the area related BOS costs (A-R-BOS) is US $60/m^2 (1980). Consequently, the cells having conversion efficiency less than 10-14% are not considered to be economically viable in those places (8). But the nature of BOS cost is such that country to country variations could depend upon a number of socio-economic factors. It is necessary to analyse the BOS costs in some detail for arriving at a realistic estimation of the SPPS costs in a particular place. An exercise has been made in this respect for a number of small scale photovoltaic systems. Their BOS costs/peak watt under Indian conditions have been estimated, and then compared to the NASA BOS cost/peak watt, as shown in Fig. 2 (9). One can see that the considerable difference of BOS cost/peak watt in these two different countries.

The large variation of BOS costs for Photovoltaic Pumps can be appreciated from an interesting example of the recent quotations (May, 1982) from two well-established Photovoltaic companies of the developed countries, as shown in Table 1. All the costs are exclusive of taxes but include packaging and freight. One can see that there is considerable variation in the concept of BOS itself as well as in the BOS cost per watt and peak watt between these two systems. It appears necessary to have a closer look at the BOS part of SPPS and its impacts on the design and deployment of SPPS.

Allowable costs

As described in Section 2, a SPPS may have different variations of BOS depending upon the choice of the vendor and the user. These are no definite critiria, so far as the knowledge of the authors goes, which enable the user to choose the correct option for his application. The World Bank project report (1) has indicated some guidelines on the undesirability of the use of storage batteries and maximum power point trackers for use with SPPS. In many technical papers and reports, however, there are claims for enhanced efficiency and output through the use of these optional units. In order to solve this riddle, we shall follow the approach indicated in reference 6.

The overall cost of the Photovoltaic system (PSC) including storage, power conditioning and installation, may be calculated as:

$$PSC = (AC/A)AA + \frac{PSP}{1000} (PMC\ SGC + PC) \qquad (2)$$

where AA = Array area

AC/A = Area related cost/unit area

PSP = Photovoltaic panel output in watts peak

SGC = Storage cost/peak Kilowatt

PC = Power conditioning cost/peak Kilowatt

PMC = Pump-Motor unit cost/peak Kilowatt

The power conditioning in SPPS also includes any improved version of motor-pump unit that is developed specifically for this application. The area of the photovoltaic array is given by:

$$AA = PSP/(\eta_c \times 1000)m^2 \qquad (3)$$

$$\frac{AC}{A} = \frac{CC}{} + (\frac{SC}{A} + \frac{WC}{A} + \frac{INSC}{A}) = \frac{CC}{A} + \frac{C_{Ar}}{A} \qquad (4)$$

where η_c = AM1 module conversion efficiency

$\frac{CC}{A}$ = Cell cost/unit area

$\frac{SC}{A}$ = Structure cost/unit area

$\frac{WC}{A}$ = Wiring cost/unit area

$\frac{INSC}{A}$ = Installation cost/unit area

C_{Ar} = (Structure + Wiring + Installation) cost which is basically Area-related BOS costs.

It is now necessary to estimate the size of the Photovoltaic panel for this particular application.

The peak power output for pumping is given by:

$$PSP = \frac{V_D \, H \, \eta_c}{\eta_{system} \, E_{in}} \times 2.72 \text{ peak watt} \qquad (5)$$

where V_D = Average daily/water pumping requirement (m^3/day)

H = Average total water head (m)

η_{system} = Overall system efficiency including the pump-motor unit

E_{in} = Average daily global insolation per unit area (Kw /m^2)

Combining, equations (2) through (5), we set,

$$PSC = \frac{V_D \, H(2.72 \times 10^{-3})}{\eta_{system} \, E_{in}} \left\{ \frac{\left(\frac{CC}{A} + \frac{C_{Ar}}{A}\right)}{\eta_c \, (PMC + PC + SGC)} \right\} \qquad (6)$$

For the typical application, considered previously, with an annual volume of pumped water of 10,000 m^3 and assuming a 250 days of operation, average daily water pumped is 40 m^3/day. Incidentally, this conforms exactly with the parameters selected in the World Bank project. The best nominal module efficiency at 28°C as reported by World Bank project is 9.7% so that at the nominal operating cell temperature (NOCT) of about 52°C, the module efficiency would be derated to 8.5%. Introduction of all these values reduces Eq. (6) to:

$$PSC = \frac{0.109\ H}{\eta_{system}\ E_{in}} \left\{ \frac{CC}{A} + \frac{C_{Ar}}{A} + 0.085\ (PMC + PC + SGC) \right\} \quad (7)$$

PSC for this application has been estimated from the break even cost calculation indicated in section 3. The allowable cell cost per unit area for different BOS costs or, conversely, the allowable BOS cost for a specified cell cost per unit area can be obtained from equation (7) if the system efficiency, head of water and daily average insolation are known.

System Efficiency

The overall system efficiency in Eq.(7) is a complex function of the head of water, incident solar radiation (E_{in}), and the different configurations of SPPS. Fig. 3 shows the variation of overall system efficiency with different heads of water for a directly coupled system with MPPT subsystem as reported by the World Bank Project. Fig. 4 shows similar results for two different heads of water with varying insolation as measured at A.I.T. Table 2 shows the variation of the η_{system} with and without storage battery in the SPPS as measured in the Charsarati project at Kalyani, India. It is rather difficult to make any comparisons of allowable cost estimates of the various options of SPPS since so many parameters are interrelated and variable. Nevertheless, we were able to obtain some interesting results by combining equation (7) with Fig. 3.

Allowable PV Module Cost

The break even cost for a typical SPPS required for pumping 10,000 m^3 of water annually for cultivating 1 ha of land, has been estimated in Section 3 to be US $2,212 (1980). The average daily insolation can be assumed to be the mean value of standard clear hazy day radiations which amounts to 5.32 Kwh/m^2, as indicated in Fig. 5. The area-related BOS cost per unit area (C_{Ar}/A) may be estimated at about $40/$m^2$, in developing coun-

tries, just half of the value presently reported in more advanced countries. The cost of the motor-pump unit has been taken as $550 for a 250 peak watt installation in accordance with reference 1 so that the price is $2,200 per peak KW. PC has been chosen to be about $800 per peak KW. Use of battery storage option could not be considered here since its effects on overall system efficiency for different water heads are not yet known. SGC has been ignored. Using these parametric values, Fig. 3 and assuming PSC to be equal to $2,212 for economic competitiveness with diesel pumps, the allowable solar cell module cost per unit area and hence module cost peak watt (assuming η_c = 8.5%) can be computed for various values of heads of water for both directly coupled system and that with MPPT. The results of these computations are shown in Fig. 6. Similarly, assuming a fixed head of water, the effect of overall system efficiency on the allowable module cost per peak watt has been computed for various values of non-area related BOS cost including (PMC, PC & SGC). These results are shown in Fig. 7.

Conclusions

Fig. 6 indicates that under existing conditions with $\eta_{system} < 3.5\%$, little benefit can be expected from the inclusion of MPPT unless the head is less than 3.5 meters. On the other hand, when the head is less than 3.5 meters, the effect of MPPT on the allowable module cost is significant.

Fig. 7 brings out a very important point that if the overall system efficiency can be increased to 4.6% as projected by the World Bank, the allowable module cost becomes much more realistic and a considerably higher value of non-area-related BOS costs can be tolerated. Thus, the inclusion of MPPT and/or storage battery can be justified if the overall efficiency sigficiantly improves from its value with the directly coupled option. Controlled experiments should be performanced with various options and the results analysed to explore this possibility. On the other hand, the overall system efficiency is principally limited by the PV module efficiency can be raised significantly over the present best value of 8.5%. Therefore, considerable effort should be exercised to raise the efficien-

ies of pumping units from the present range of 40-50% to 70% or more. Alternatively, the cost of PV modules should be reduced to 3-4 $/peak watt. This would make the SPPS economically competitive with diesel pump systems for the cultivation of relatively small land-holdings and shallow water depth. Actual field survey in some parts of India and Thailand by the authors have indicated that favorable conditions for the exploitation of SPPS do exist in these countries.

Acknowledgements

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7. H. Saha, Solar Energy, 27 (1981), p. 103.

8. M. Wolf - Proc. 3rd EC Photovoltaic Solar Energy Conf. Cannes, 27-31 Oct. 1980, p. 204.

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TABLE 1

Comparison BOS Costs Solar Photo-voltaic Pumping System (May, 1982)

COMPANY A

Rated Power Motor-Pump:	350 Watts
Peak Power of PV modules:	672 peak Watt
Approx. price of modules:	US $15/peak Watt
Total price of modules:	US $10,080

Balance of Systems

Array Structure	
6 Lead Calcium Batteries (12 V. each)	
1 D.C. Motor-Pump Unit	
1 SVR-Series Voltage Regulator	Approx. US $7,450
1 Pump - Controller, Solid State, Special design.	
Total cost of SPPS:	US $17,530
BOS COST PER WATT:	US $21.3/Watt
BOS COST PER PEAK WATT:	US $ 11.1/peak Watt

COMPANY B

Rated Power of Motor-Pump:	162 Watts
Peak Power of PV modules:	219 peak Watts
Approx. price of modules:	US $13/peak Watt
Total price of modules:	US $2,887

Cost of Balance of Systems

Movable Array Structure	
1 D.C. Pump-Motor Unit	Approx. US $3,059
Suction and Delivery Pipes	
Total cost of SPPS:	Approx. US $5,946
BOS COST PER WATT:	US $18.8/Watt
BOS COST PER PEAK WATT:	US $13.9/peak Watt

Performance with and without Storage Battery Head of Water 3 meters

Option	Daily Total Water Output	Motor-Pump Efficiency	Overall Efficiency (η_{system})
Without Battery	24	22%	1.48%
With Battery	27	33%	2.0%

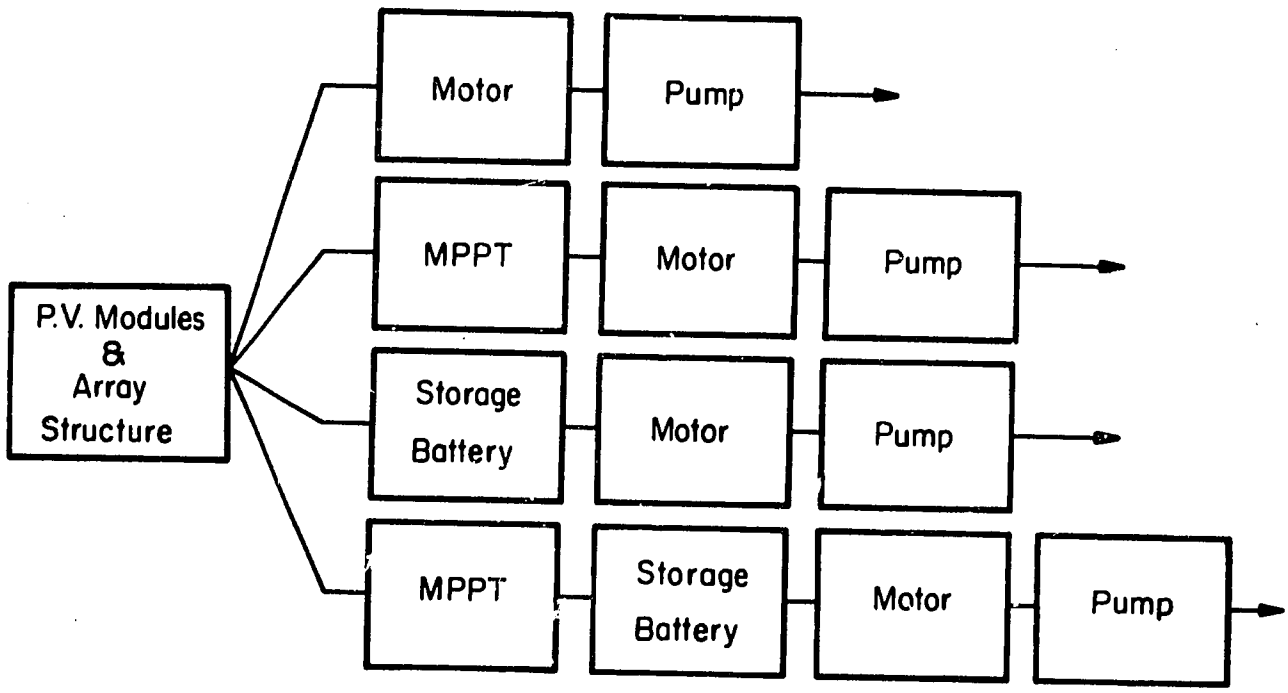


Fig. I – Various Options of Solar Photovoltaic Pumping System

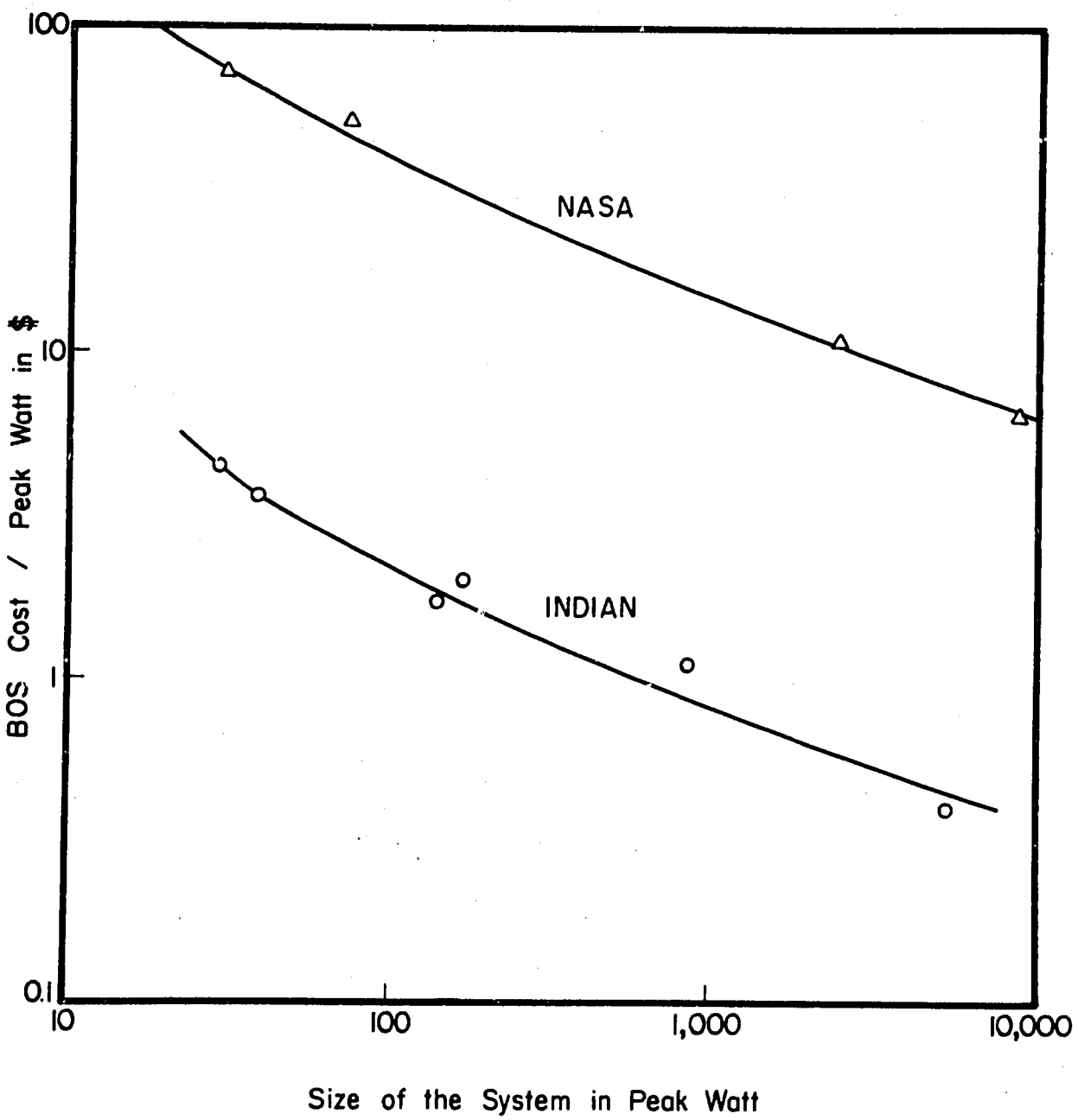


Fig. 2 - BOS Cost/Peak Watt from NASA & Indian Experiences

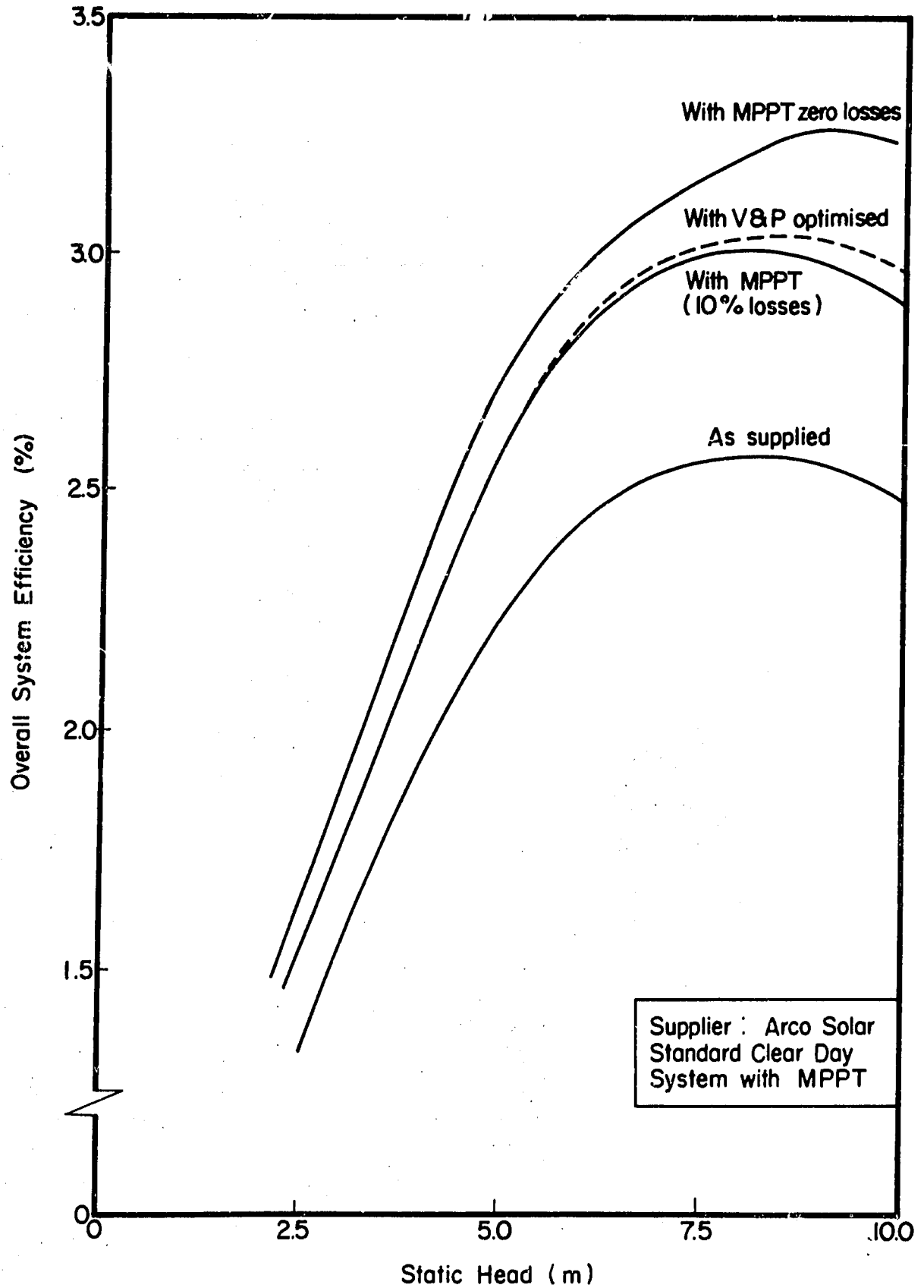
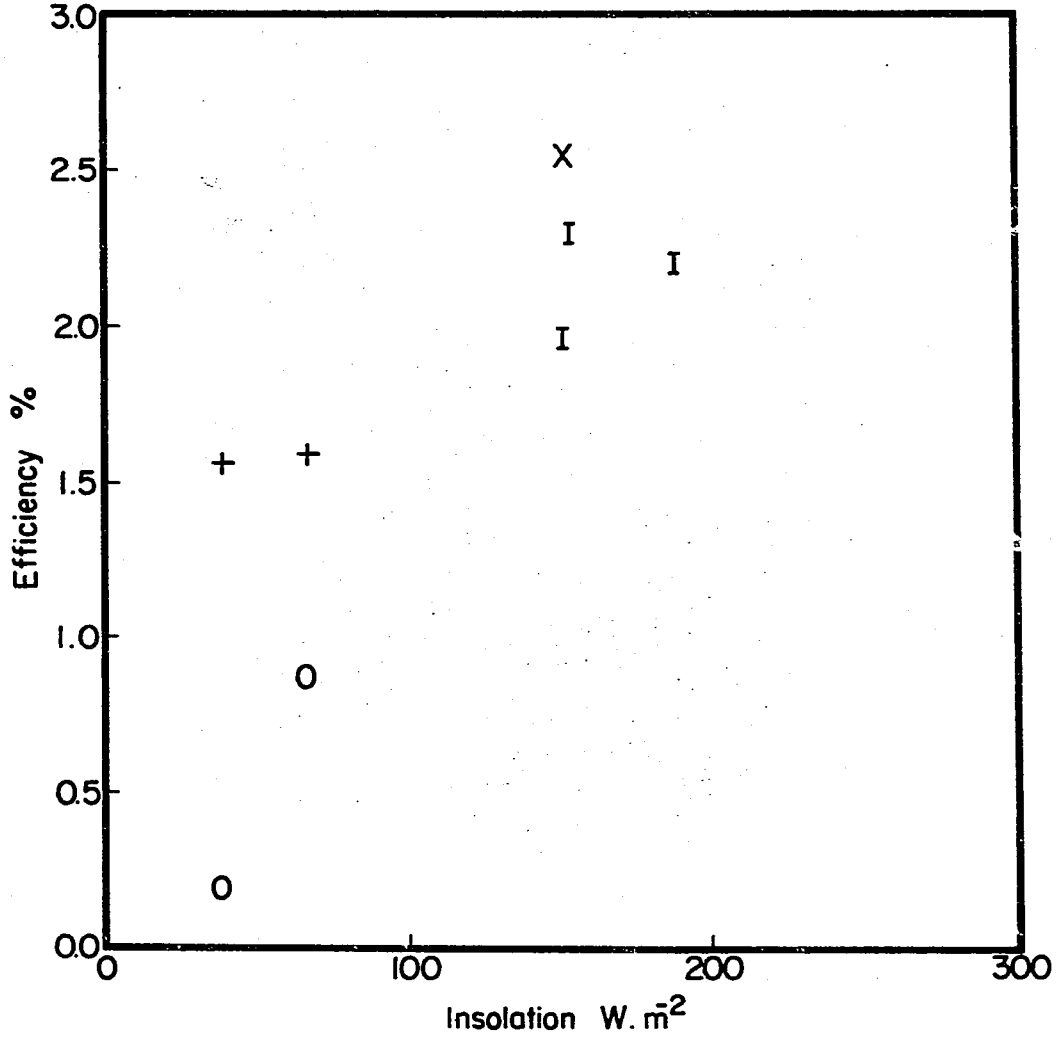


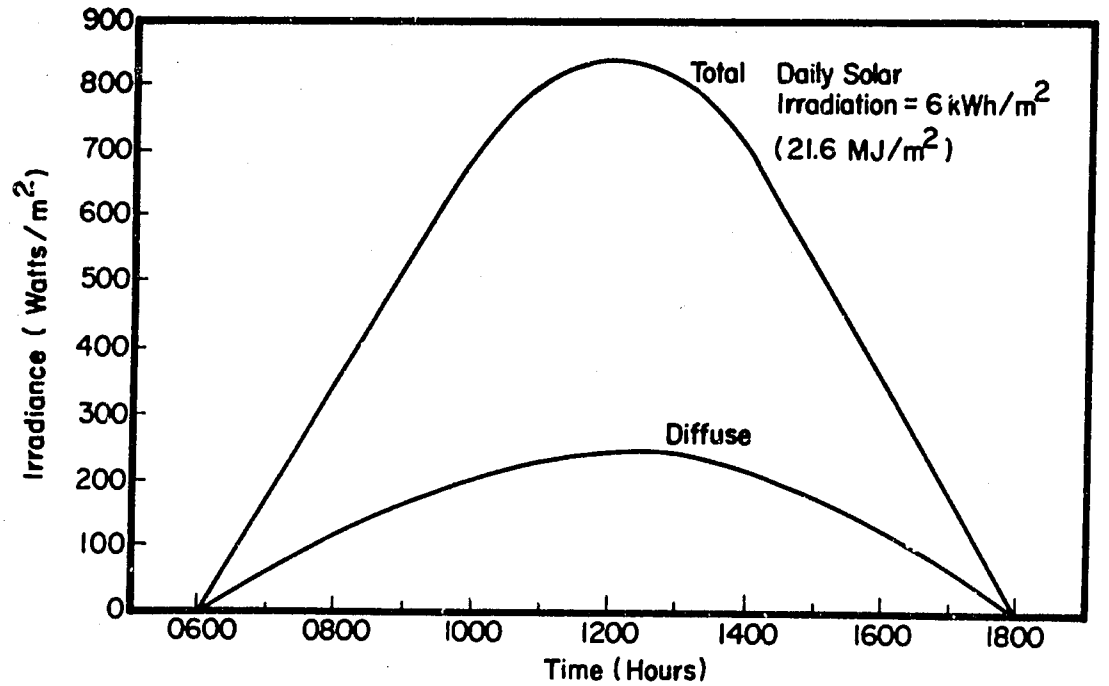
Fig. 3 – Variation of Daily Overall System Efficiency with Head for System with or without MPPT



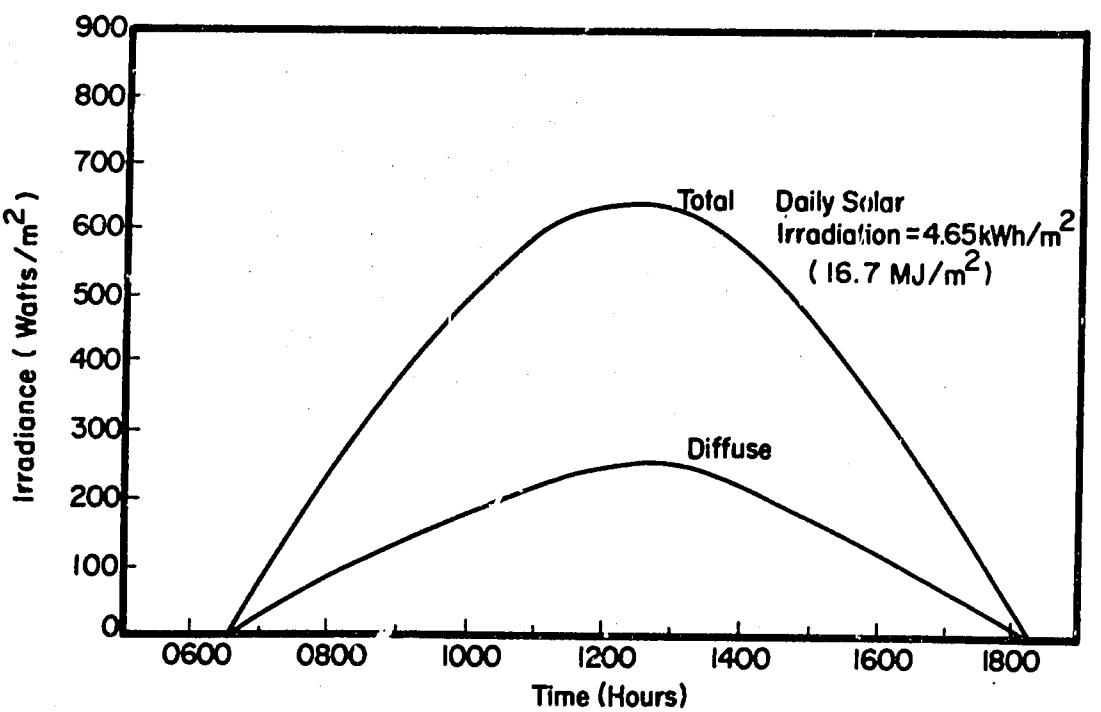
Head \ MPPT	Yes	No
0.46 m	+	O
1.07 m	X	I

Centrifugal Pump 187 Watt
8 Photovoltaic Modules : 33 Watt Each
MPPT : 0.85 Efficiency

Fig. 4 – Variations of Overall System Efficiency with Insolation for Different Heads



a) Clear Day



b) Hazy Day

Fig. 5 – Standard Solar Days - Clear and Hazy

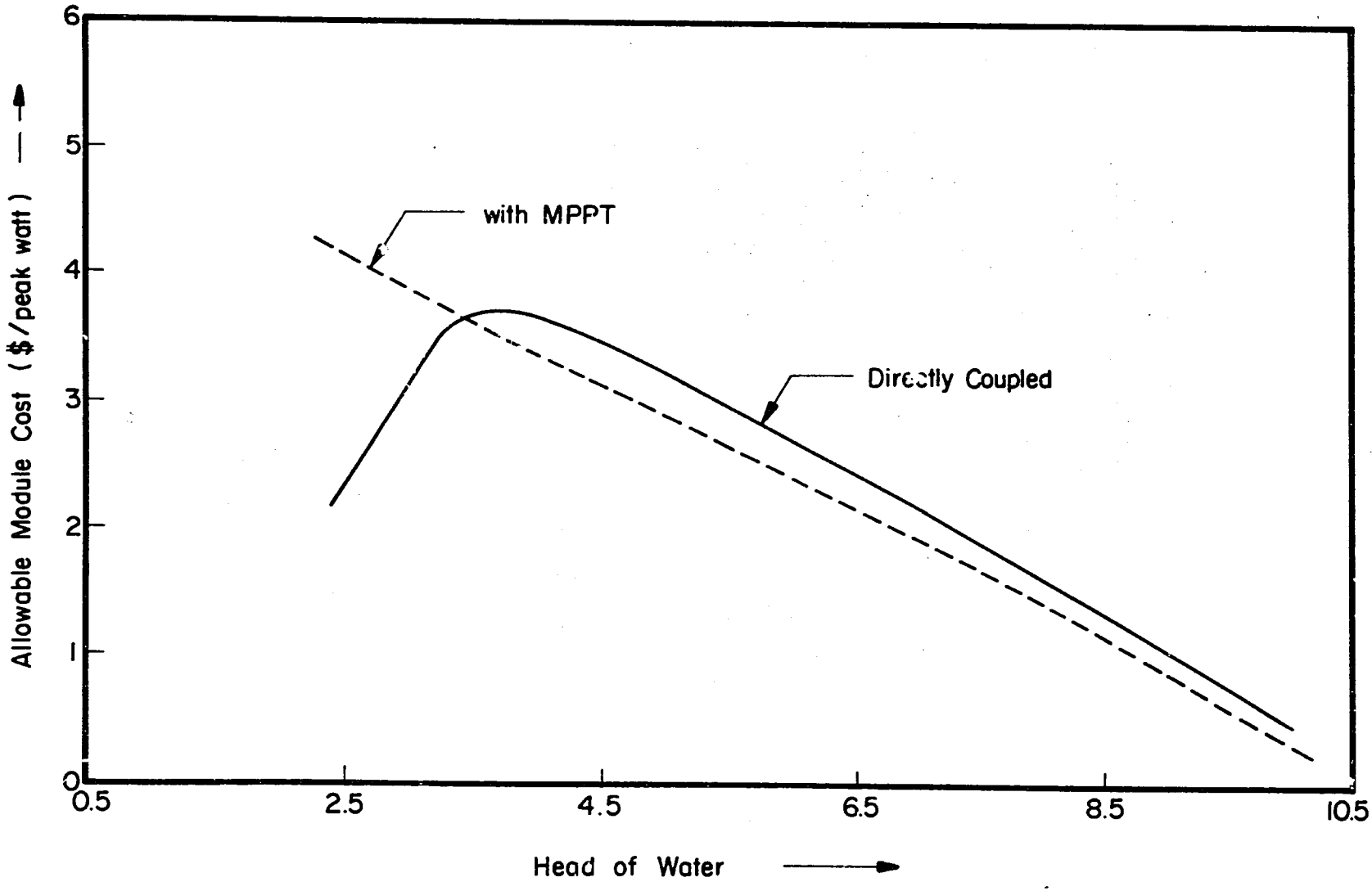


Fig. 6 - Variation of Allowable PV Module Cost / Peak Watt with Various Water Heads

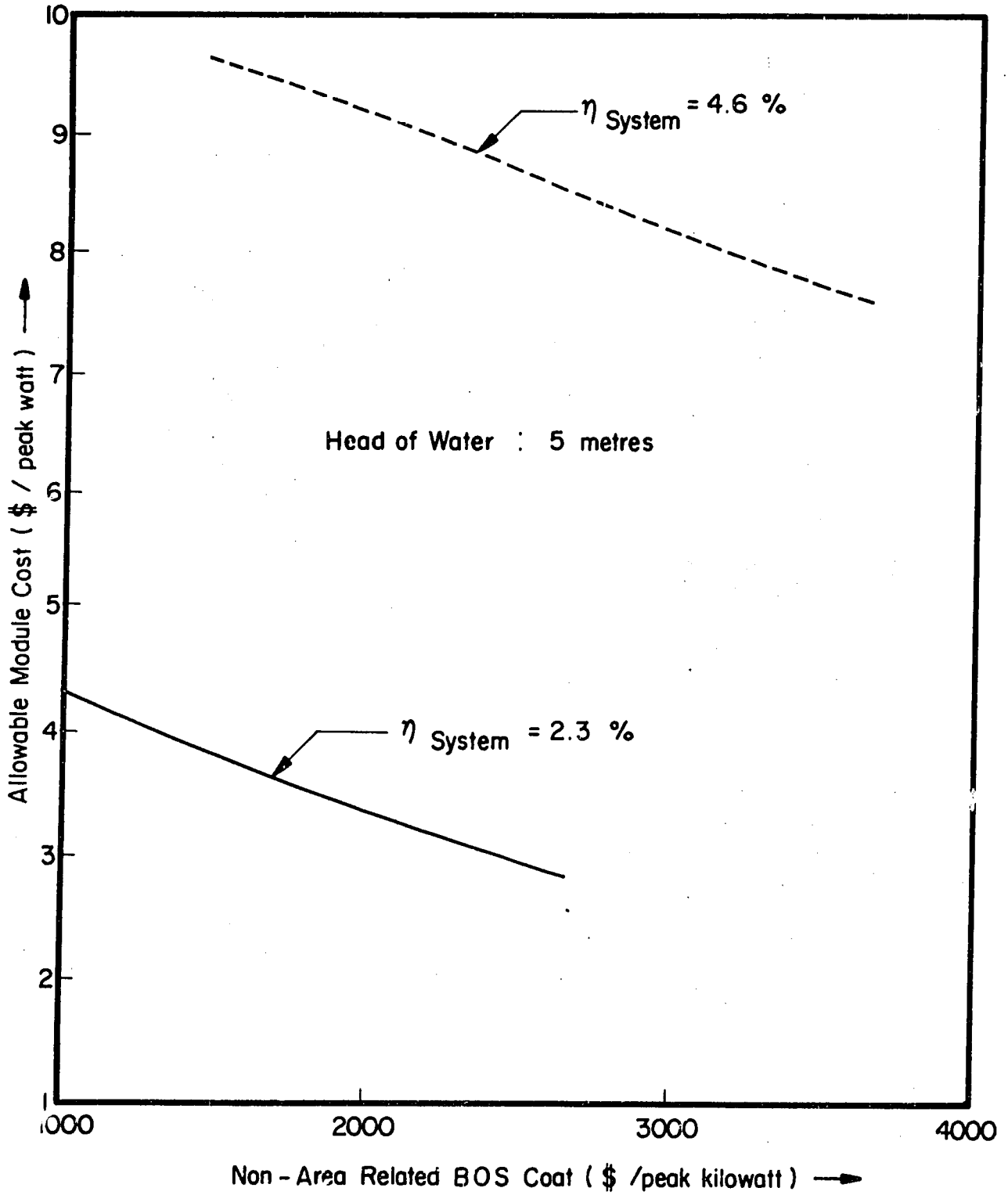


Fig. 7 - Variation of Allowable PV Module Cost / Peak Watt with Various Non - Area - Related BOS Cost

Small-Scale Solar-Powered Irrigation Pumps And Their Economic Prospects In The Philippines

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Introduction

As a result of the oil crises and the economic difficulties it has brought upon both developed and developing countries, worldwide efforts have been directed towards the development and exploitation of various alternative, renewable sources of energy such as solar, wind, and biomass. In particular, interest in utilizing solar energy to power pumps for crop irrigation have been greatly renewed. In recognition of these developments and of the importance of increased food production, the UNDP funded a project entitled "Small-Scale Solar-Powered Irrigation Pumping System", in which the principal aim was to provide direction to the development of solar pumps for use by marginal farmers of the third world. The project was executed by the World Bank with Sir William Halcrow and Partners Ltd., London as the project implementor. The project involved three major activities: a) demonstration and field testing of solar pumping systems; b) laboratory tests of system components, and c) system designs studies. The Philippines was among the three countries which hosted the field trials. The two other countries were Mali and Sudan. This paper discusses our experiences with the performance of the pumps in the field. Certain findings of the global project will be reported and attempts will be made to assess the economic potential of solar pumps in the Philippines.

The Solar Approach to Small-Scale Irrigation

It is recognized that all over the world, over 50 million of the world's poorest farmers subsist on fewer than 50 million hectares of the world's best land. This places the average size of land holdings which

are intensely cultivated by small or marginal farmers at less than one hectare per farm-family. For most of these areas, water is available from ground or surface sources for lifts of under 5 meters and the required hydraulic pump output will be in the range of 100 to 350 watts. Significantly, no engine has been designed and constructed specifically for this purpose. The smallest available diesel engine commonly used for small farm irrigation is rated at 3.5 HP. However, the economics of using the 3.5 HP diesel engine has been shown to become increasingly unfavorable as the farm size decreases (2). Appropriate fractional horsepower electric motors are available and are relatively cheap, but the cost of electric distribution system needed to irrigate scores of tiny plots, likewise, renders this alternative uneconomic. Small-scale solar-powered pumping systems now appear to provide an alternative, cost-effective technology for small farm irrigation.

A solar pumping system basically consists of three elements: a) a collector to trap solar energy and convert it into a more suitable form, b) a prime mover whose output is mechanical energy, and c) the pump. Figure 4 illustrates the numerous pumping system configurations resulting from a wide selection of system components and from the numerous ways these components can be put together to form complete systems. Many attempts have been made to build prototype thermal pumping systems. A review of these pumps and their principles has been made by Pahoja (3). Most of these pumps had hydraulic outputs of several watts and system efficiencies of about 1%.

For the scale of irrigation (0.5 to 2 has.) envisioned in the UNDP Project and in consideration of the related environmental, social, technical and economic criteria that had to be met in the selection of the appropriate pumping system, PV systems appear to have advantage over thermal systems. Comprehensive reviews of the technical aspects of small-scale PV pumping system components are found in the reports by Halcrow (4) and Matlin (5). Several important points emerge from these reports: a) silicon is the most developed solar cell material b) on the basis of

cost and efficiency, DC permanent motors are favored over DC wound and AC motors in the fractional horse power range, and c) centrifugal pumps appear superior to positive displacement pumps for high-volume, low-lift applications.

Field Tests of Solar Pumps

In the UNDP project, a total of 12 solar pumps (11 PV and one (1) thermal) were acquired for field testing. Four of these, namely, Omera, Segid (200 PW), Briau (600 pw), Pompes Guinard (600 pw) and Solar Electric International (SEI) (250 pw) were consigned to the Philippines. The SEI system employs a submersible electronic commutation pump which was coupled to the PV array via a Maximum Power Point Tracker (MPPT) unit. The test procedures and a partial report on the performances of some of these systems had been given earlier by Ibarra (6).

Insufficient data were then obtained for the Omera system because of array shading caused by trees around it. This system was subsequently relocated to a nearby site. At the new site, the motor/pump assembly was mounted on a platform beside a creek with the PV array some 10 m. away. Suction head was fixed to approximately 2.7 m. The total head was made variable for testing purposes, but was later fixed at 3.02 m. to maximize daily water output.

Poor performance of the Pompes Guinard System was also reported. The problem was attributed to cavitation caused by excessive suction head. The motor/pump unit was eventually lowered by about 1 m. resulting in a reduced suction head of about 4 m. Total head was maintained at 10.72 m. An improvement in the start up from 800 W/m^2 to 670 W/m^2 was noted. However, the overall system performance remained unsatisfactory. No attempt was made to lower the motor/pump unit further down the river bank because of the danger posed by heavy swelling of the river during the rainy months.

Figure 1, 2 and 3 are typical plots of time or irradiance - related system performance parameters derived from the field measurements made for

the Omera Segid system. The following observations are drawn from these plots:

a) Array temperature generally increases with increase in array irradiance. It should be noted, however, that the temperature points in the high irradiance region are obviously in error and that they should have been higher. This error was subsequently traced to improper use of the digital thermometer. The maximum temperature should be approximately 60°C.

b) Sub-system (motor-pump unit) efficiencies appear to be unaffected by changes in temperature and array irradiance except when array irradiance falls below 450 W/m^2 where the corresponding array output is 65 watts. Presumably, at motor-pump input power of over 65 watts, the pump achieved high enough specific speeds (no measurement was made) to flatten out the pump efficiency.

c) Array efficiency is clearly sensitive to both array temperature changes and to the degree of impedance matching between the array and the motor pump unit. At the same time, sufficient power is available to the motor-pump so that the motor rotates at high speed and hence presents itself to the array as a high and nearly constant impedance. In this regime, the temperature effect dominates the impedance effect, so that the general behavior of the efficiency plot resembles that which is attributed to temperature effects alone. The behavior is shown in the region to the left of the array efficiency peak. At some values of irradiance (750 watts/m^2), array power (110 watts) and temperature (42°C) combined temperature-impedance effects become a minimum, so that array efficiency becomes a maximum. At array irradiance of 750 watts/m^2 and below, a progressively lower impedance is experienced by the array due to a decrease in both the operating voltage and current. Nominal power is consumed resulting in lower array efficiency. At the same time, array efficiency should increase since array temperature continues to decrease. However, the array efficiency is observed to fall with decrease in irradiance. This indicates that impedance effects

dominates temperature effects in this region. In Fig. 3 the plot between cumulative flow and cumulative array irradiation is shown. This plot is characteristic of a particular pumping system and is indicative of the overall system performance. It is generally linear with slope expected to change with the seasons because of the seasonal variation of ambient or array temperature. The slope, denoted by R, could be used for a quick comparison of the performance of different but equivalent (in array rating) systems.

In Table 1, various system parameters are listed for the four systems. The ratio in percent of the measured array peak power to the rated peak power is shown to vary with the type of system. Three systems have ratios in the range from 60% to 70%. SEI with a ratio of 96% is the best matched system pressumably because of its MPPT unit. The peak power ratio should be a good measure of the overall system efficiency. Earlier, it was shown that array efficiency is not only dependent on the array temperature but also on the degree of impedance match. Since the overall system efficiency is a product of array, and subsystem efficiencies, the latter being typically 4 to 5 times bigger than the former, a change in the subsystem efficiency will have a greater effect on the overall system efficiency than an equivalent change in array efficiency.

The result of the system design studies (1) indicate that further improvements in the overall PV pumping system performance can be readily obtained by:

a) use of pumps whose efficiency changes as little as possible over the likely changes in the working head.

b) optimization in the series - parallel connection of all within the module. An improvement of 13% in overall efficiency was reported with one system.

c) the use of the MPPT unit. Daily water output was observed to increase by 15% on a clean day and by 25% on a hazy day.

d) reorientation of PV array twice daily. This results in collection of 95% of the irradiation available to a continuously tracking array.

If these improvements are successfully implemented, it should be feasible to produce small scale solar (PV) pumping systems having efficiencies approaching 5%.

Economic Performance of Solar and Diesel Pumps

How close is solar pumping to becoming a cost-effective alternative to diesel pumps for small farm irrigation in the Philippines? To get an idea of what the answer might be, let us consider the following case study.

A group of four farmers in Bulacan province use a 7.5 HP diesel pump to irrigate 4 hectares of riceland. Each farmer is assumed to own one hectare. The pump is used mainly during the dry season (November-January). After deduction of expenses incurred for capital charges, diesel fuel, maintenance, and fertilizers, the net income is ₱ 1,955 per ha.- season-farmer. This is equivalent to US $230 (₱ 8.5 = US $1) which is not much even by farm standards. The corresponding unit cost of water is ₱ 0.15/m^3 (see appendix for details of calculations). It is reasonable to assume that if this net income should fall further, the farmers will most likely forego planting a second crop during the dry season. The estimated unit cost of water that could be delivered (in 1981) by the best solar pump (overall system performance of 4.6%) designed to service 0.5 ha., is 11.4 ¢/m^3 (7). This is 6.5 times the economic cost of irrigation water in Bulacan. The capital cost for the required solar pump (1 ha.) is estimated to be $ 6400 (₱ 54,400) at silicon cell price of $ 7/pW. This is an enormous amount relative to what the prospective user-farmer could presently afford. From the Appendix, we note that the amount of money which the farmer could allocate for annualized capital charges, say, for investment in a solar pump with no consequent reduction in his net income, is ₱ 1,650. If financing is available at 12% interest, with 10 years to pay, the amount of money that he can afford to borrow would be ₱ 9,332

(US $ 1096). This is what he has for payment of a solar pump which is barely enough to pay for the cost of a DC motor.

Conclusion

Solar pumps are generally robust, simple to operate and maintain and have potentials for long and reliable operation. Their major draw-backs are inherently low system efficiency and high cost. At present the economic performance of small diesel pumps, in spite of escalating fuel costs remains overwhelmingly superior to solar pumps insofar as micro-irrigation in the Philippines is concerned. Little cost reduction in solar pumps is expected by way of further improvements in the overall system efficiency, unless breakthroughs occur in the basic photovoltaic technology which may then usher in cheaper and more efficient solar cell materials. Development of cheaper mass production techniques for solar cells coupled with expanded markets could alter and enhance the otherwise sluggish downward movement of solar cell prices.

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2. Smith, D.V., & Allison, S.V., "Micro-Irrigation with Photovoltaics," MIT, Massachussetts, 1978.

3. Pahoja, M.H., "A Review of Solar Pumps and their Principles," Proceedings of the International Solar Energy Society Congress. New Delhi, India, 1978.

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5. Matlin, R.W., "Technical Aspects of Solar Pumping Systems," A paper presented at the workshop on Solar Pumping in Developing Countries, Manila Philippines, June 1981.

6. Ibarra, R.H., "The Application of Solar Eelctrical Energy to Irrigation Pumping," Regional Asia and Pacific Workshop on the Applications of Solar Energy in Agricultural and Post Harvest Activities, Bandung, Indonesia, January, 1981.

7. UNDP/World Bank/Sir William Halcrow & Partners/Intermediate Technology Dev. Grp. Ltd., "Small-Scale Solar Powered Irrigation Pumping Systems Technical and Economic Review," London, September, 1981.

TABLE 1

Pump System Performances

PUMPS	BRIAU	POMPES GUINARD	SEI	OMERA SEGID
ARRAY AREA (M^2)	7.71	5.799	2.97	2.733
CELL AREA (m^2)	3.2	4.692	2.35	2.26
ARRAY RATED POWER (PEAK WATT)	600	600	250	200
MEASURED AVERAGE PEAK POWER (WATT)	410[a]	422	240	130
$\frac{\text{MEAS. PEAK POWER}}{\text{ARRAY RATED POWER}} \times 100\%$	68	70	96	65
OPTIMUM HEAD (m) (From Lab. Tests)	6	10	5	5
ACTUAL OPERATING HEAD, (m)	3.7-5	10.72	4.7	3.02
PEAK HYDRAULIC POWER (WATT)	102[a]	145	0.83	32
APPROX. START UP (W/m^2)	350-400	670	380	360
ARRAY EFFICIENCY (GROSS)	5.6 a,b	7.6(7.77[c])	8.04(8.18[c])	4.7(5.28[c])
SUB-SYSTEM EFFICIENCY	26 [a,b]	10.44(12.56[c])	27.73(346[c])	23.47(25.33[c])
OVERALL EFFICIENCY (GROSS)	2.4 [a,b]	0.797(.98[c])	2.23(2.77[c])	1.1(1.32[c])
MAX. TEMPERATURE INCREMENT (MEAS), (^oC)	23(97)	17(960)	15(785[c])	17(970[c])
WATER OUTPUT/ARRAY IRRADIATION ($M^3/MJ/m^2$)	2.03	0.48	1.58	1.0

Notes: a. average over many days

b. average max.

c. maximum

APPENDIX

A. Cost and Returns in irrigating 4 has. of paddy using a 7.5 HP diesel engine driven centrifugal pump i: 982.

Item	Total Cost (₱/4 ha.-4 farmers-season)	Unit Cost ₱/ha.-farmer-season
Pump/Prime Mover Accessories	₱ 7184 (1978)	₱ 1796
Amortization (10%, 7 years)	₱ 2,000	₱ 500
Diesel Fuel (7 barrels at ₱600/barrel)	₱ 4,200	₱ 1,050
Fertilizers (20 bags at 230/bag)	₱ 2,600	₱ 650
Operation & Maintenance	₱ 400	₱ 100
TOTAL	₱ 9,200	₱ 2,300
Water used (1100 m^3/ha.)	₱49,000 m^3	11,000 m^3
Unit cost of H_2O Yield	₱ 0.15/m^3 (US 1.84/m^3)	₱ 0.15/m^3
(230 cavans/4 has. at ₱74/cavan)	₱ 17020	₱ 4255
Net Income	₱7820/4 ha.-4 farmers-season	₱1955/ha.-farmer-season

B. Affordable Capital Investment for a Solar Pump by farmer

- Affordable annualized capital charges,

  Ca: ₱1650

- Loan terms; 12%, 10 years.

- Cost of required PV pumping System:

  2X $ 3193 = $ 6386

Baseline model

irrigation area	:	0.5 ha.
overall sys. eff.	:	4.6%
Silicon cells	:	$7/pW
Balance of System	:	$3/pW
Array rating	:	%319 p.W.

- Required Capital investment C:

  ₱9322 (US$ 1096)

  where $C = C_a \quad 1-(1+i)^{-t} \quad / \ i$

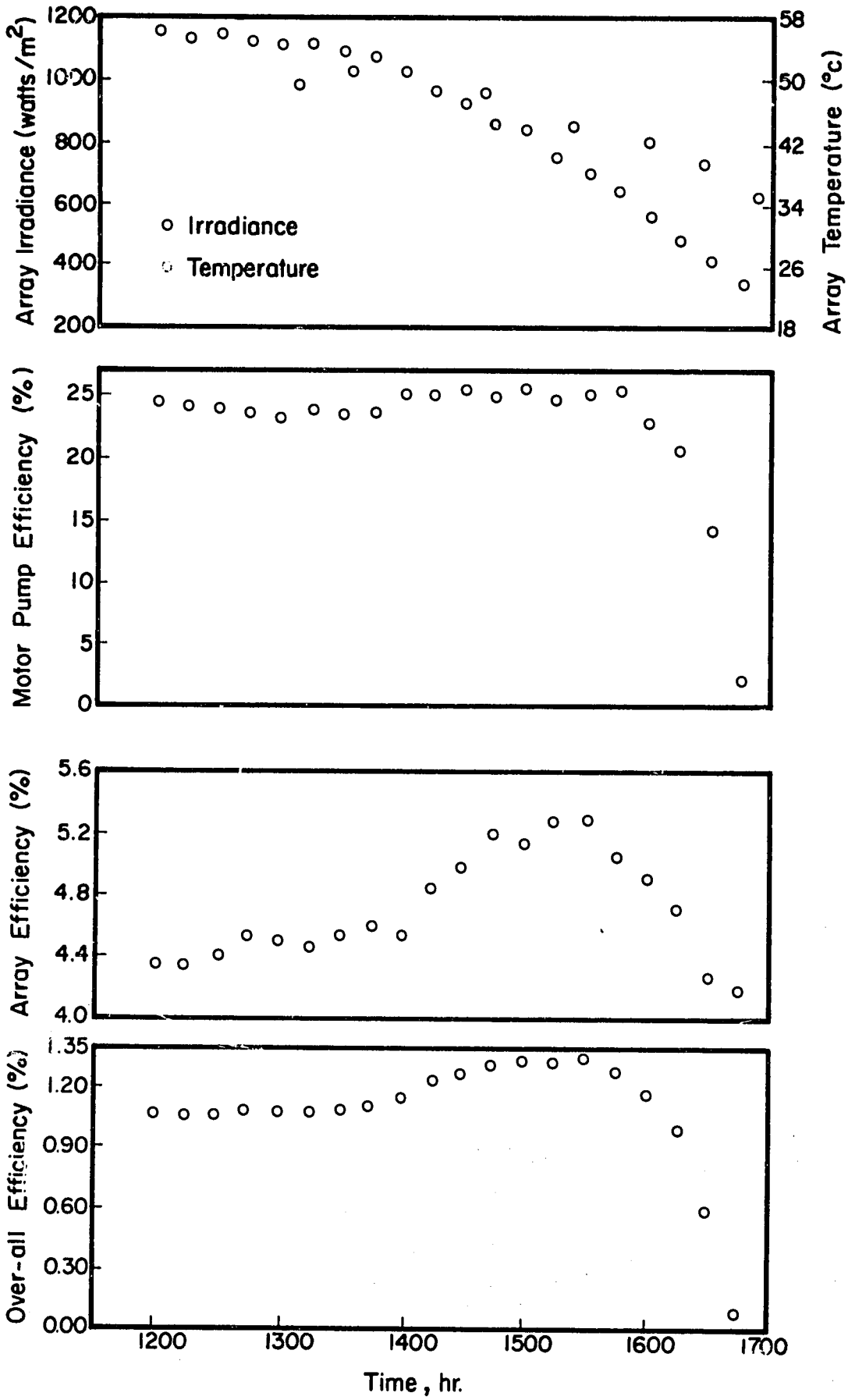


Fig. I — Field Performance of Omera Segid System

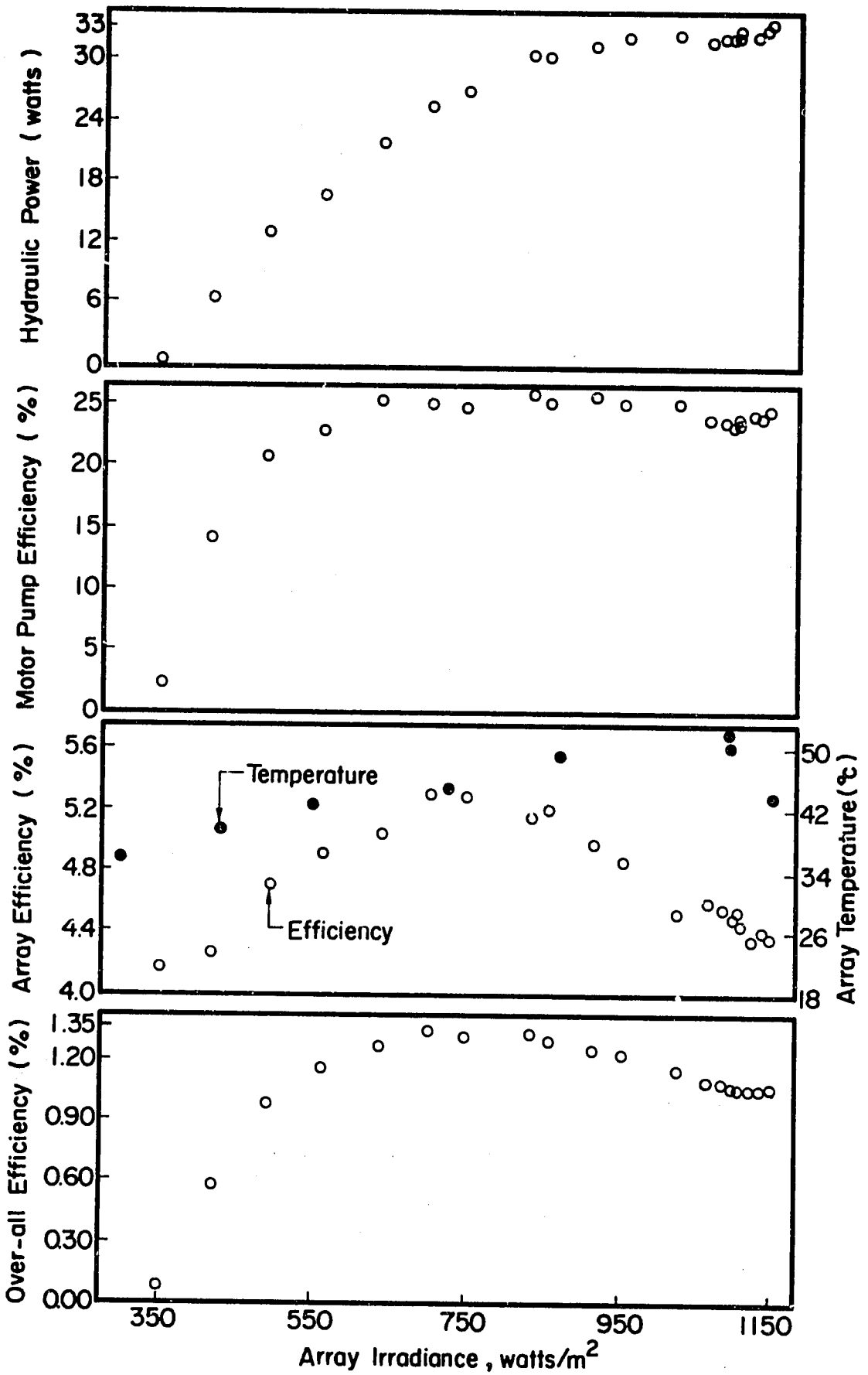
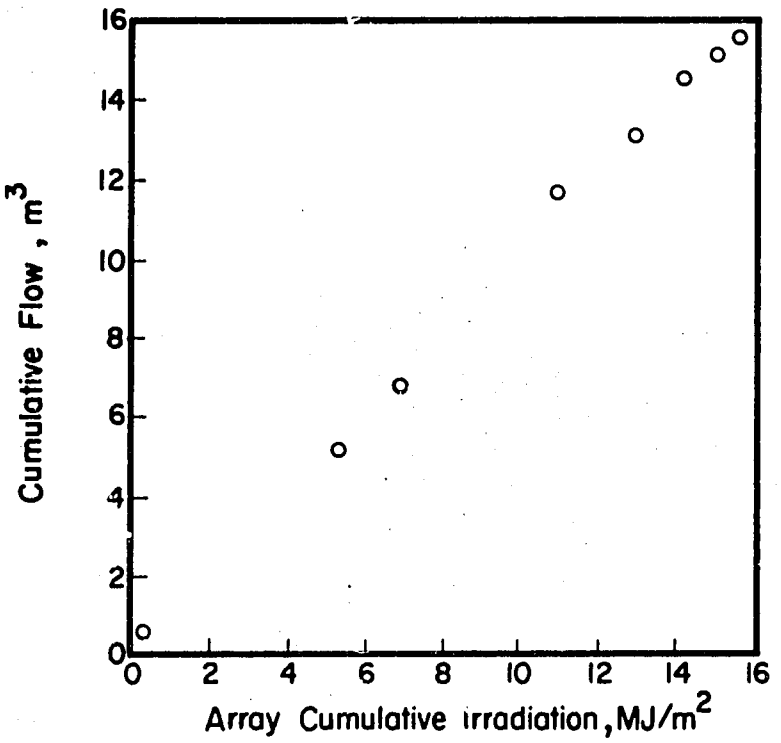


Fig. 2 – Field Performance of Omera Segid System



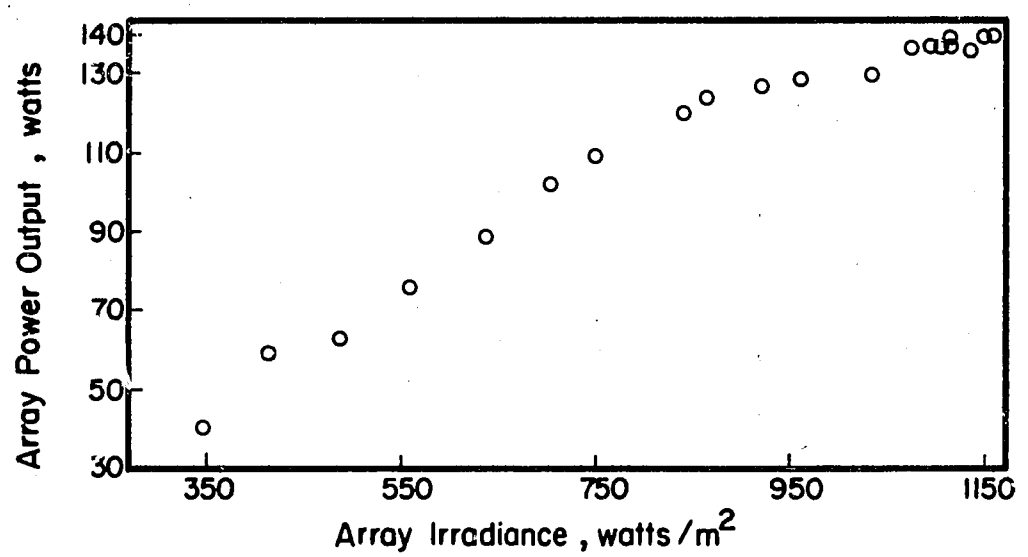


Fig. 3 – Field Performance of Omera Segid System

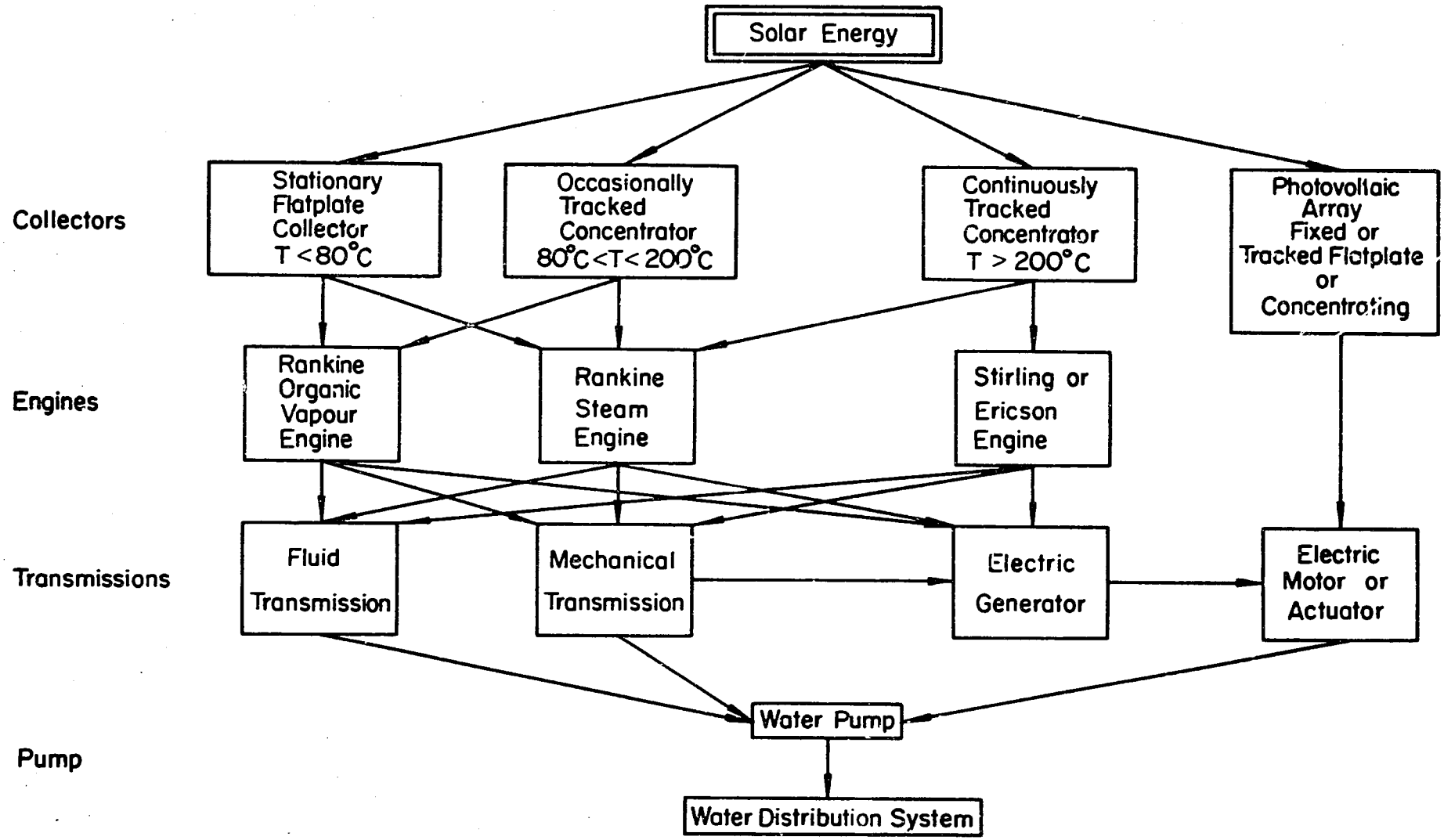


Fig. 4 — Feasible Options for Solar - Powered Pumping Systems

A Modest Program on Photovoltaic Power System

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The Electrotechnical Department of University of Indonesia was founded in the year 1964 and at present has two main streams: 1) Electric Power Engineering; 2) Electronic & Telecommunication Engineering. This department can be considered as a second generation of Electrotechnical Department in Indonesia, the first generation being the Bandung Institute of Technology established in 1949.

The Electric Power Engineering Stream has three specializing fields, called packages, viz.,

- The Package of Power System & Technology
- The Package of Service and Industry
- The Package of Energy Management

The Package of Power System & Technology will be promoted as a Graduate Program in Power System.

The department has a modest education program in Modern energy technology. The subject "Electrical and Electronic Engineering Materials" is a prerequisite for such fields as Power Electronics, Direct Energy Conversion and High Voltage. The Seminar on modern technology includes such topics as "Photovoltaic Power Generation and Systems". And it is possible for students to complete their studies with theses in some areas of Photovoltaics.

Photovoltaic Power System

We can divide Photovoltaic Power System into three levels:

- The Low Level System (1-10 kW)
- The Intermediate Level System (0.1-10 MW)
- The Central Power System or High Level System (50-5000 MW)

The Low Level System is already suitable and cost effective means providing electricity for remote areas or other special needs. Photovoltaics becomes progressively more attractive as a large scale, power generation method as the price of conventional electricity increases. Intermediate and High Level use of Photovoltaic Power System cannot be expected until capital costs are reduced by a factor about 50. To achieve cost competitiveness, it appears that an array price of US$ 100-500/kW_{peak} is required. In the United States it is predicted if this is achieved the price of photovoltaic electricity should be about 4.5-6.5/kWh, similar to the projected busbar energy cost for conventionally produced electric power in the United States during the period 1985-2000.

Education Program

THE PROGRAM

Based on the assumption of reduced costs, we have planned photovoltaic activities in the Electric Power Engineering Subdivision as a spin off from the conventional Electric Power Engineering Program.

Student interested in photovoltaics can follow a one semester seminar course in photovoltaics followed by a thesis in this area. Such an introduction to the area of this new technology is hoped, firstly, to enhance interest and awareness in alternative energy in general and photovoltaic energy specially. Secondly, we hope to develop skilled workers in this new area.

Course Outline: "Photovoltaic Power Generation and System"

- Basic theory of the Solar Cells
- Photovoltaic Power System
- Economic Assessment of Photovoltaic Power System

Major references:

- David Pulfrey, "Photovoltaic Power Generation", Van Nostrand Reinhold Company, 1975.
- Richard C. Neville, "Solar Energy Conversion", Elsevier Scientific

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- Some journals

RESEARCH & DEVELOPMENT PROGRAM

Photovoltaic activities began in 1979, but its background, solid state electronics, began one year earlier.

There are two objectives in these activities:

1. To support the education program in photovoltaics, i.e. to give strong research background for teaching courses related to that field.

2. To foster student amongst electric power engineering students a greater involvement in Photovoltaic Research & Development.

There are two areas to be selected in this field:

1. Photovoltaic Power System as an entity.

2. Solid State Electronics as a basis of Photovoltaic Device.

Conclusions

The photovoltaic program in our department is an attempt to transfer alternative energy technology and to contribute research and development in this field. We expect to encourage more intensive research and development in the future.

Performance of a Small-Scale Photovoltaic Array

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Introduction

In the present deliberations on the development of alternative energy sources, solar energy emerges foremost as the potential for the future supply of energy for heating and power generation. The utilization of solar energy for winter heating in temperate countries, for air-conditioning and for hot water supply is well developed. Generation of electrical power from solar energy can be achieved via two methods: directly, perhaps via concentrators, the energy from the sun can vaporize a low pressure liquid for driving a turbine which converts mechanical energy into electrical energy; the more direct method is via the photovoltaic effect. When sunlight of energy greater than the band gap energy strikes a semi-conductor, electrons are dislodged from their normal positions leaving positively charged holes in the valence band and negatively charged particles, electrons, in the conduction band. The holes and electrons are then available for the conduction of electricity. Such a transducer is capable of developing a voltage of 0.5 - 1.0 V and a current density of 20 - 40 mA per square centrimetre depending on the semi-conductor material and sunlight conditions.

Solar cells operating on this principle are available commercially. The connection of solar cells in series and in parallel and incorporation into a module provide a higher rated unit which can be interconnected with similar modules to form an array. In principle, electrical power of any given magnitude can thus be produced. Electricity from such arrays is being utilized in a variety of applications ranging from lighting beacons

and lighthouses to powering televisions, radio-telephone and water pumps in remote areas. Design and construction of large scale units, such as the 1 MW peak power installation in Southern Italy, are underway in other parts of the world.

Production of power on a large scale is still prohibitively expensive. In the period 1974-1976, the cost per peak watt was around S $20 per peak watt. This cost is expected to fall significantly as technology in the area improves. To this end, the goal set by the US Energy Research and Development Administration is US $0.50 per peak watt by 1986. They further project a cost of US $0.25 by 1990. At those prices, the solar cell holds great promise as an alternative energy supply in the future and it may surpass all other forms of solar energy utilization.

Studies into the performance and scope of applications under local conditions are at present still limited. The main objective of this study is to examine the performance and applications of a small scale solar cell array under local conditions. Another objective concerns the storage of electrical energy produced by the array. We anticipate that the electrical energy produced will have to be stored. Considerations will necessarily have to be given to charging batteries by the solar cells.

The photovoltaic array and energy storage system

The solar cell system under study consists of an eight-module array and four 6-V lead acid batteries. Figure 1 shows the array. Each module consists of 16 cells each of diameter 5.08 cm (2 inches) and is enclosed between two borosilicate glass covers.

Used in conjunction with four low self-discharge batteries, the system is claimed by the manufacturers to be self-regulating and capable of producing 10 ampere-hours per day everyday on an annual cycle.

The solar cell array was mounted on a stand, faced south and inclined at an angle of 10 degrees. The 10-degree inclination was selected mainly to facilitate self-cleaning action.

Equipment and instrumentation

1. Solar radiation intensity. Total solar radiation intensity on the array was measured using an Eppley pyranometer. Continuous monitoring over the period of the experiment was carried out using a strip chart recorder connected to the output of the pyranometer.

2. I-V characteristics of the array. As the main objective of the study concerned the performance of the panel, the I-V characteristics study was determined for the array rather than for each module. The objective of this part of the study was to investigate the current-voltage variations of the array under differing solar intensity levels.

Figure 2 shows the circuit diagram for determining the I-V characteristics. The basic features of the equipment are a volt meter to measure the voltage across the resistor and hence the current of the array. Three rheostats, each of range 156 ohms rated at 3 amperes, were used to vary the resistive load. The voltage signals, representing the array voltage and current, are connected to a x-y plotter.

In the determination of each I-V curve, the solar intensity level was observed on the strip chart recorder. When an approximately constant radiation level was observed, the rheostats were quickly and steadily increased from zero (short circuit current Isc flowing through the circuit) to the full range of 345 ohms (approximating open circuit voltage Voc of the array). The resultant current-voltage curve was traced out on the x-y recorder. This procedure was repeated for a range of intensity levels corresponding to three weather conditions namely: sunny, cloudly and cloudy-drizzling conditions.

3. Power measurements. A circuit as shown in Figure 3 was used to provide continuous recording of the power output of the array. The main feature of the circuit consists of the multiplier circuit of a TR 20 analog computer.

One input signal to the multiplier was the output voltage of the array.. The current of the array was converted into a voltage signal to the multiplier via the voltage drop across a standard resistor. After suitable calibration and amplification, the output of the multiplier, representing the charging power of the array, was displayed on a strip chart recorder. During the experiment, recording of the array output power was carried out simultaneously with the total solar radiation intensity incident on the array.

The simultaneous monitoring of the input and output power provided the means for determining the operating efficiency of the array under different solar intensity levels. At regular intervals during each test, the state of charge of the batteries was manually carried out by measuring the specific gravity of the battery electrolyte. A chart relating the ampere hour capacity to the specific gravity enabled a determination of the amount of energy delivered to the batteries. This aspect of the study provided the means for comparing the performance of the array at various states of charge of the batteries.

4. Load tests. Load tests on the array were carried out on three systems. In the first application, the array was used to drive a thermoelectric device. The thermoelectric device operates on the principle in which a voltage applied across the terminals of a semiconductor device causes a heat extraction from a system at low temperature and heat transfer to a system at a higher temperature. This is similar to the conventional vapour compression refrigeration unit except that the device involves no moving parts and operates on semiconductor principles. Preliminary tests indicated that cooling can be achieved when current at 12V was supplied to the devices terminals. Accordingly, an experiment on cooling of 3 kg of water was carried out as shown in Figure 4.

In the constant load tests, a 12-V DC fan and a filament light bulb were used to study the discharge characteristics of the batteries.

Results of the experimental studies

The results of the experimental studies on the photovoltaic array are presented in this section.

1. I-V characteristics, maximum power and efficiency. Traces of the current-voltage (I-V) variations of the array were obtained for a range of solar intensity levels and for the three weather conditions mentioned earlier. A sample of the I-V curves for radiation levels varying from 1023 to 230 W/m^2 on a sunny day, is shown in Figure 5.

The power output of the array for each radiation level varies according to the voltage across the load. A graphical method was employed to determine the maximum power point (Pmax) for each of the curves in Figure 5. The maximum efficiency of the array was then computed according to the following formula:

$$\text{maximum efficiency } E_{max} = \frac{P_{max}}{A\ I_n}$$

where A = total area of the 148 cells

In = solar intensity

To study the performance of the array, the variation of Emax with intensity levels was plotted and shown in Figure 6. Included in Figure 6 are the efficiencies obtained for the cloudy and cloudy-drizzling weather conditions.

Two other important parameters of the I-V curves are the short-circuit current Isc and the voltage circuit voltage Voc. Under ideal conditions, the maximum power of the array is given by Voc x Isc. The variations of Isc and Voc for different intensity levels and weather conditions are shown in Figures 7 and 8.

2. Charging characteristics of the array. Samples of the simultaneous recordings of the solar intensity level and charging power of the array are shown in Figure 9 and 10. Integration of the curves for the intensity level and charging power provided an analysis of the overall array

changing efficiency and power over an interval of time with respect to different intensity levels at different states of charge of the batteries. The results of the intepretation of the experimental data described above are shown in Figures 11 and 12. Figure 11 shows the charging power variations with solar intensity levels for four initial states of the batteries while Figure 12 shows the charging efficiency variations with intensity levels and states of charge of the batteries.

3. Results of the thermoelectric device and constant load applications. Figure 13 shows the cooling curve over a 4-hour period for the 3 kg of water in the insulated container. The coefficient of performance of the device as a refrigeration unit was computed based upon the mean power input and the heat extraction by the device. The results show coefficients of performance 1.15, 0.87, 0.66 and 0.54 at the end of the 1st, 2nd, 3rd and 4th hours of the experiment.

The DC fan and the filament bulb each drawing constant currents of 1.12 and 0.4 were run for 10 hours and 20 hours, respectively. The decreases in the ampere hour capacity of the batteries were found to be 12.25 Ah and 8.95 Ah, respectively.

5. Discussion

The I-V curves show that at each intensity level, the maximum power points vary with the array voltage. The voltages corresponding to the maximum power points decrease slightly with the intensity level. At a relatively low intensity level of 230 W/m, the array voltage at maximum power point was 12V and the highest intensity level of 1023 W/m, the corresponding voltage was about 9.8V. This characteristic of the array shows that under constant load conditions, it is not possible to operate the array optimally.

Figure 7 shows that the array short circuit current varies linearly with the intensity level. As expected, at higher intensity levels more photons are absorbed and more electrons are liberated to generate higher current. The open circuit plot for the array shows that at a low intensity level of 70 W/m, the open circuit voltage was 13.6V. This is higher

than the battery terminal voltage and indicates that charging the batteries is possible during low intensity levels of a cloudy-drizzling day.

The array efficiency variations in Figure 6 shows that the maximum values are much lower than the theoretical value of about 21% based on ambient conditions at Aml. The low value of about 10% is not unexpected and is attributed to both the material properties and present silicon cell technology. We observed from Figure 7 that the array efficiency, at a given intensity level, is lower for a sunny day than for a cloudy day. The cause for this is the poorer performance of the array as cell temperature increases.

The charging power for the given states of charge shown in Figure 11, increases linearly with the intensity level. This can be expected since with increased intensity levels coupled with small voltage changes, the current increases linearly as shown in Figure 7. Figure 12 shows, on the other hand, that the charging efficiency reduces with increased intensity levels for the four given states of charge of the batteries. Increased cell temperature at high intensity levels is the primary cause for this reduction in efficiency.

From Figure 12, it can be observed that for a fixed intensity level, the charging efficiency is higher at lower states of charge of the batteries. This is because at high states of charge, the battery terminal voltage is away from the maximum power point. As the state of charge reduces, the voltage moves nearer to the maximum power point resulting in higher power input and, hence, higher efficiency. This indicates that it is more efficient to drain the batteries to a lower state of charge before charging via the array. A compromise with battery life has to be made, since the number of charge and discharge cycles of batteries varies directly with the depth of discharge.

The experimental results for the thermoelectric device show that a satisfactory coefficient of performance was obtained for the first hour of cooling only. The reduced coefficients of performance for the third

and fourth hours of cooling are attributable to both the limitations in the capacity of the device as well as increased heat transfer from the surroundings at lower water temperatures.

The constant load studies show that the array under study is suitable for DC fan and filament bulb applications. Good discharge efficiencies of the batteries of about 90% were obtained for each case.

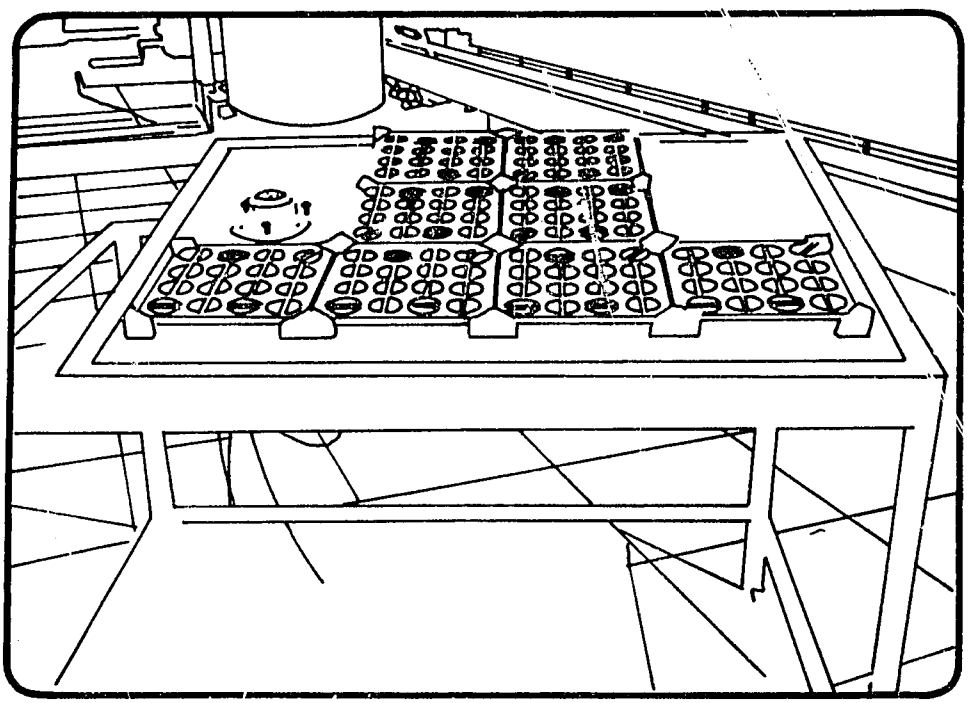

Fig. I – Photograph of Solar Cell Array

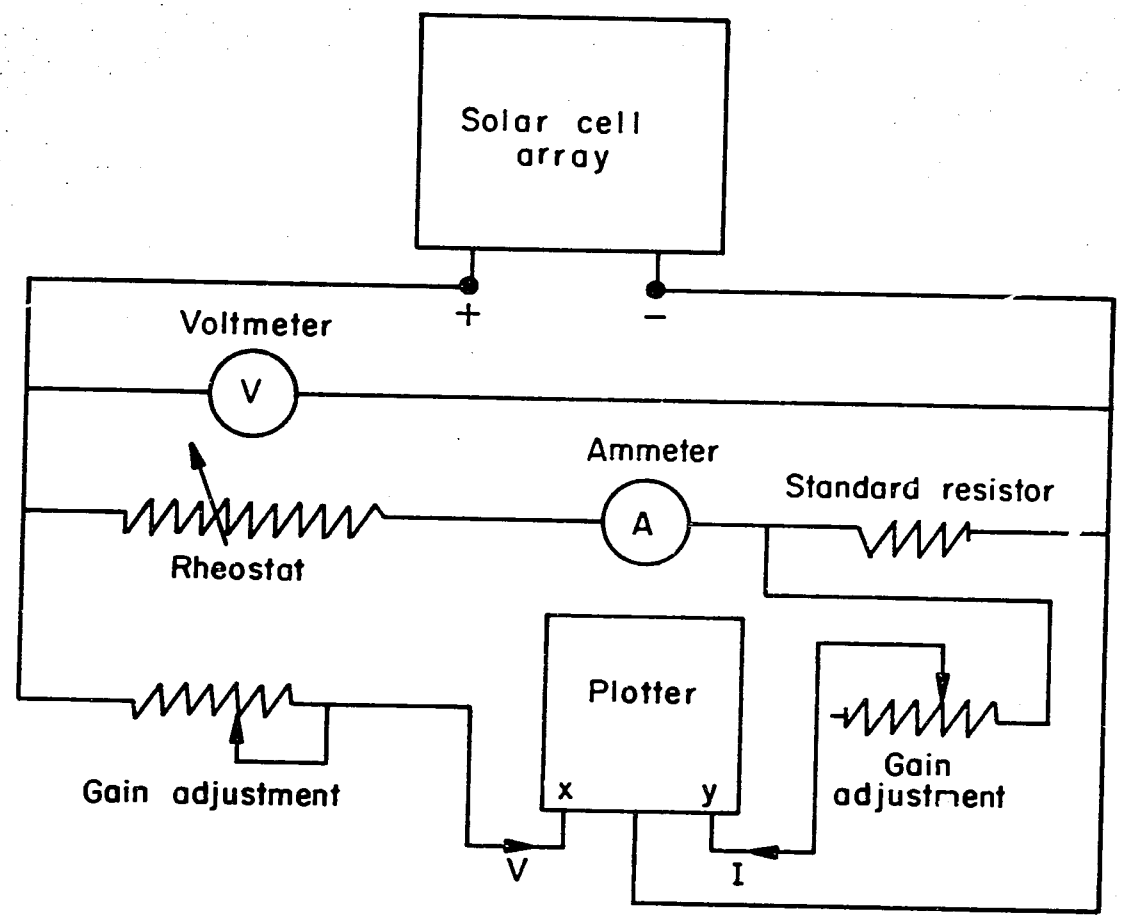

Fig. 2 – Circuit Diagram for I – V characteristics

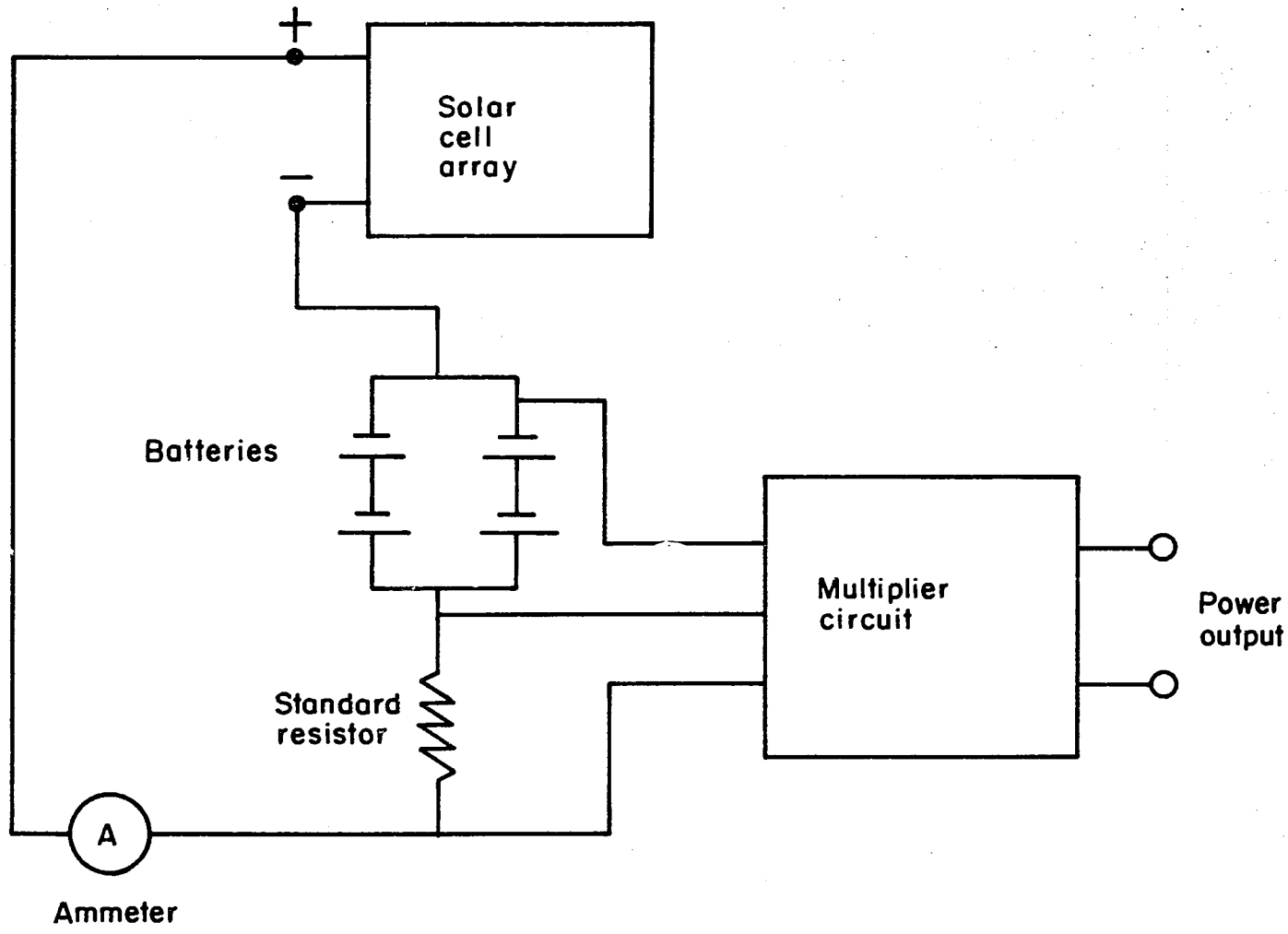

Fig. 3 - Power Measurement Circuit

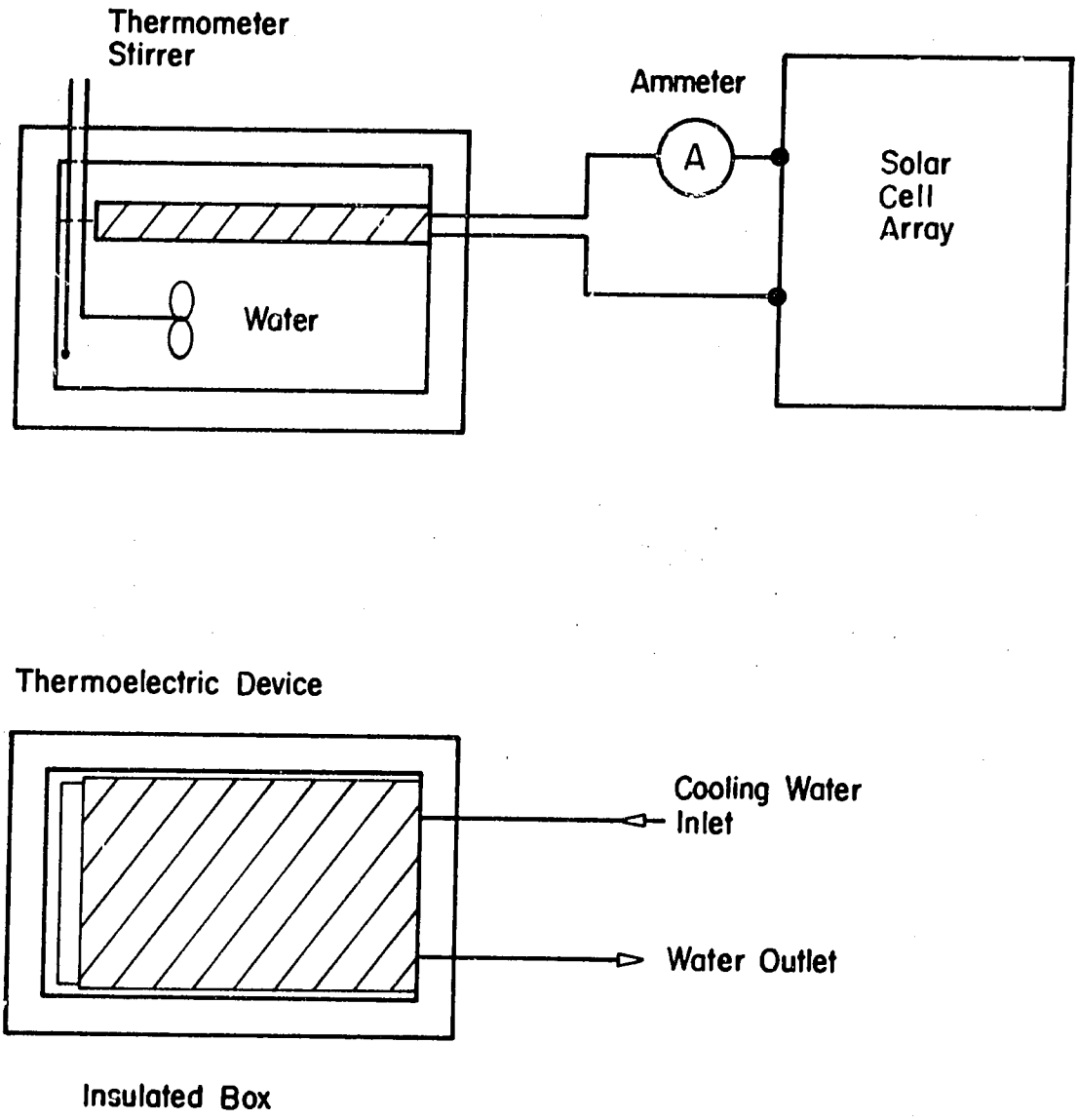

Fig. 4 – Cooling of Water by Thermoelectric Device

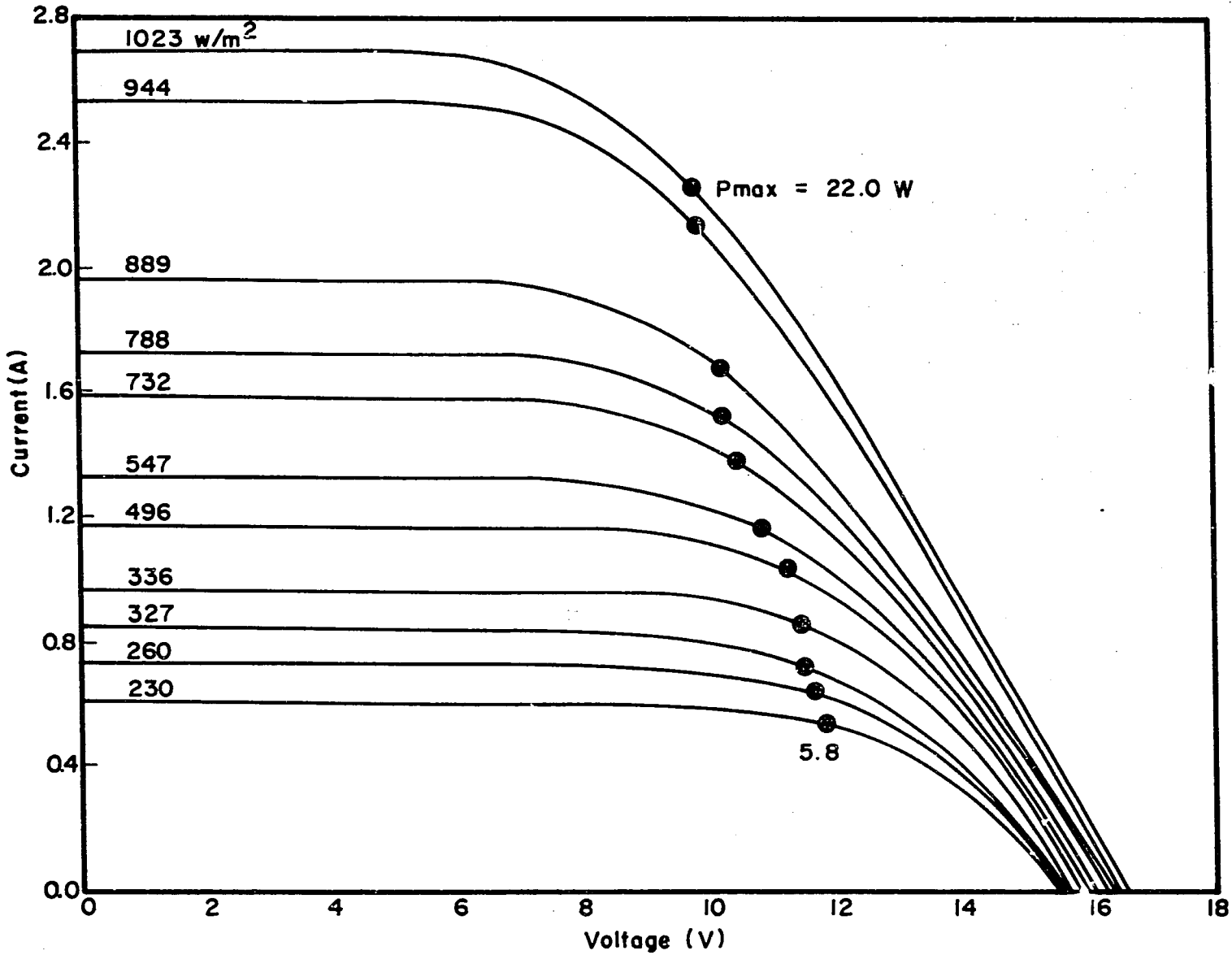

Fig. 5 – I-V Curves for a Sunny Day

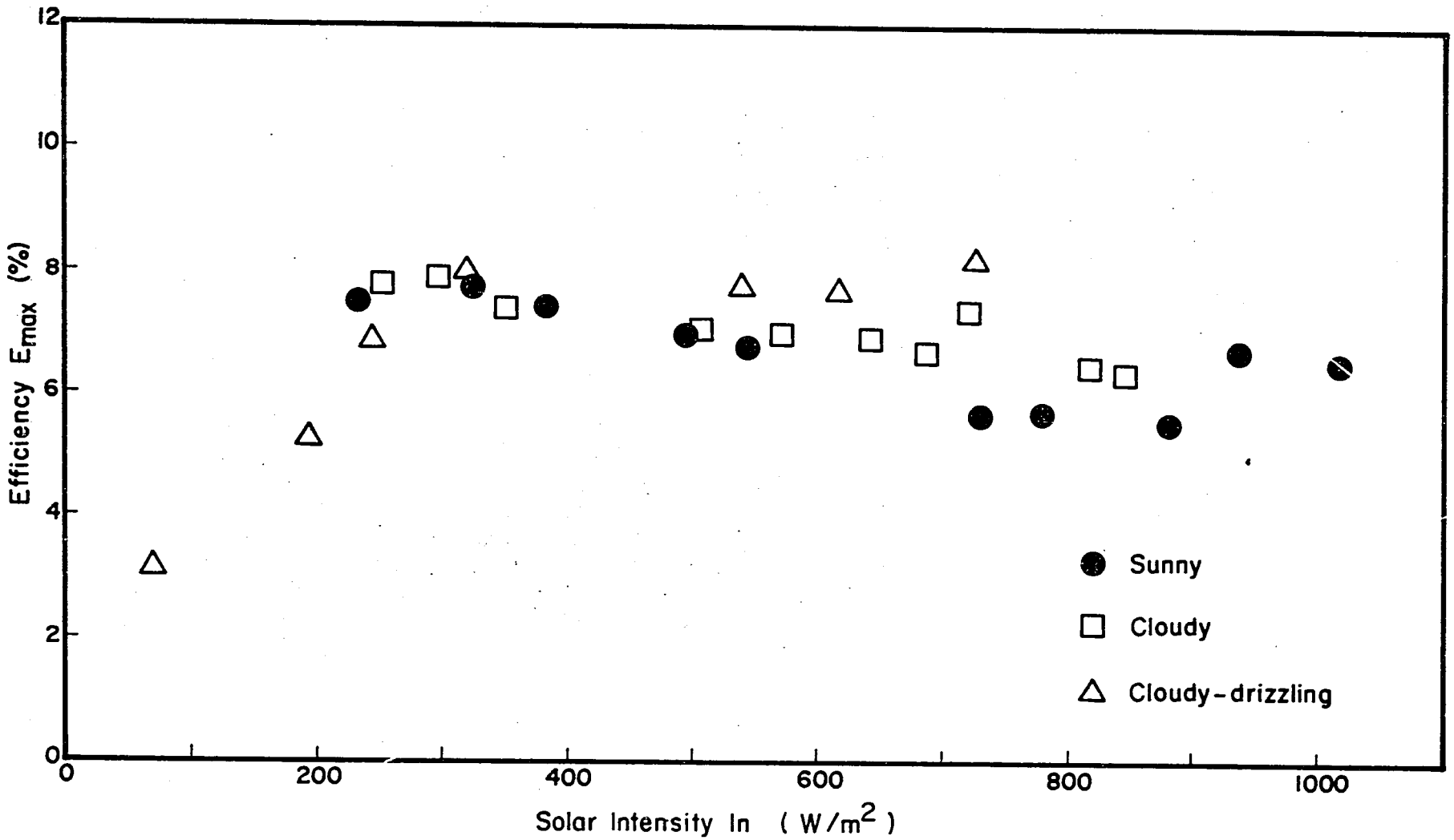

Fig. 6 - Variation of Maximum Efficiency with Solar Intensity

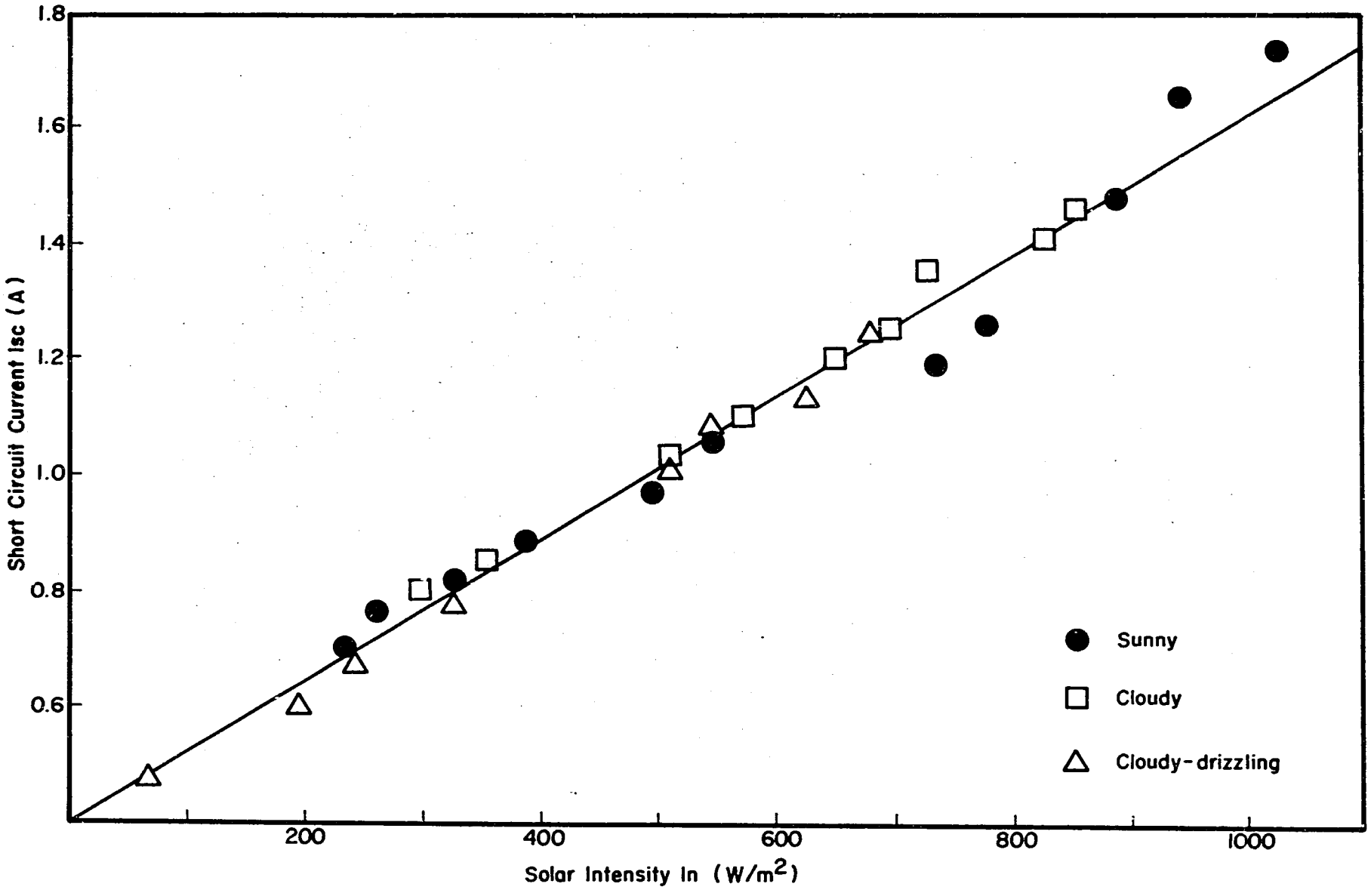

Fig. 7 – Variation of Short Circuit Current with Solar Intensity

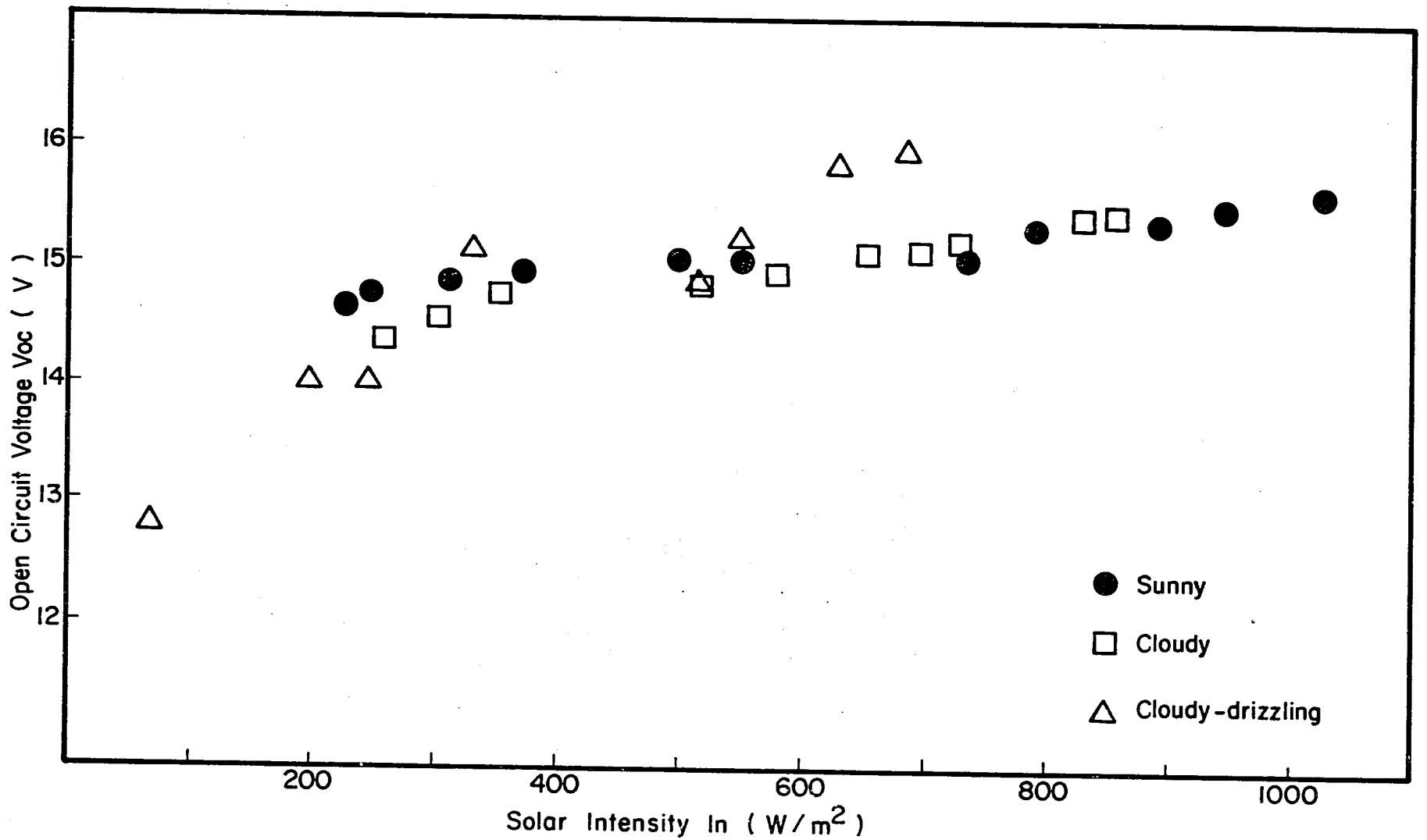

Fig. 8 – Variation of Open Circuit Voltage with Solar Intensity

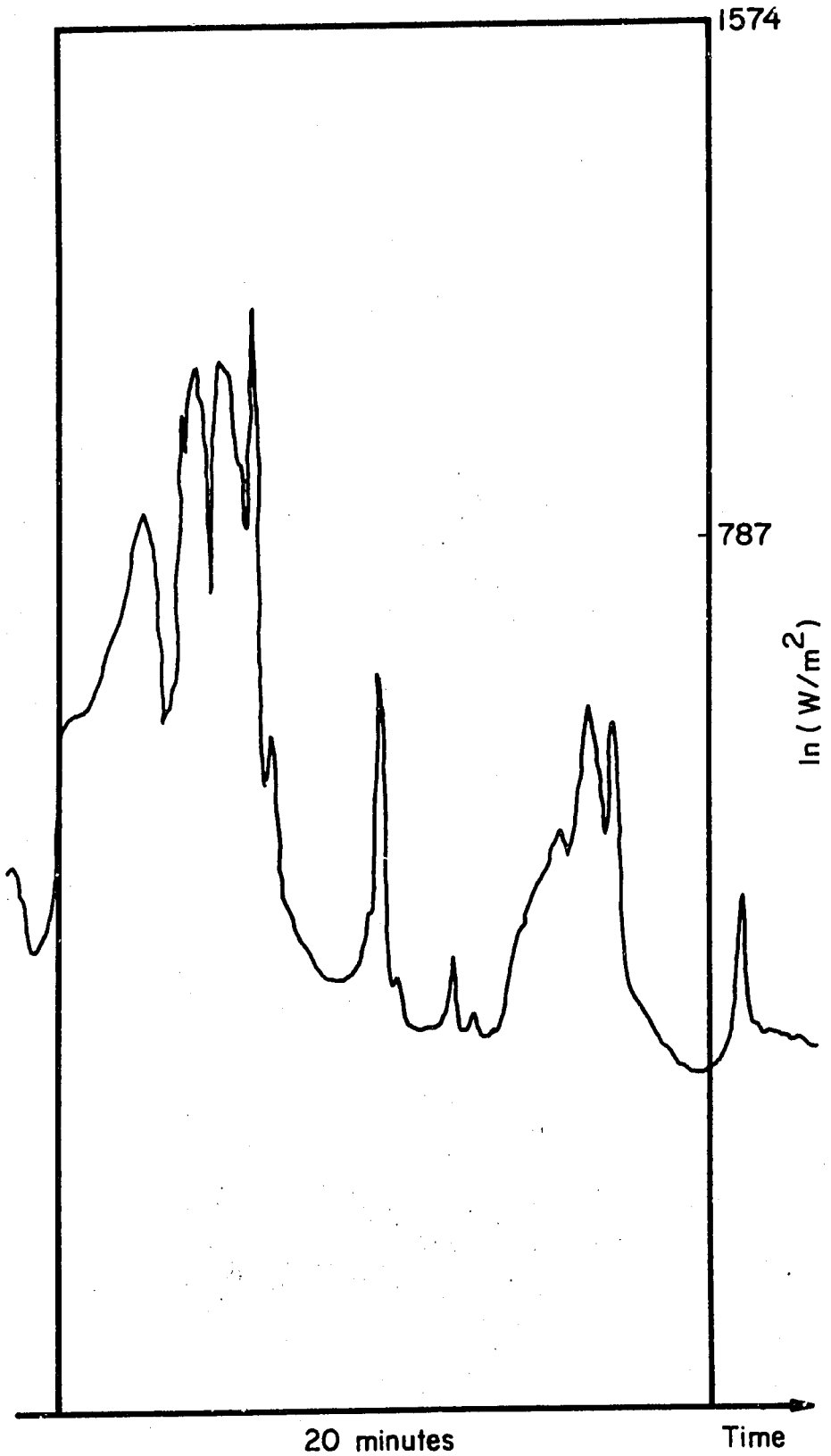

Fig. 9 – Solar Intensity Variation with Time

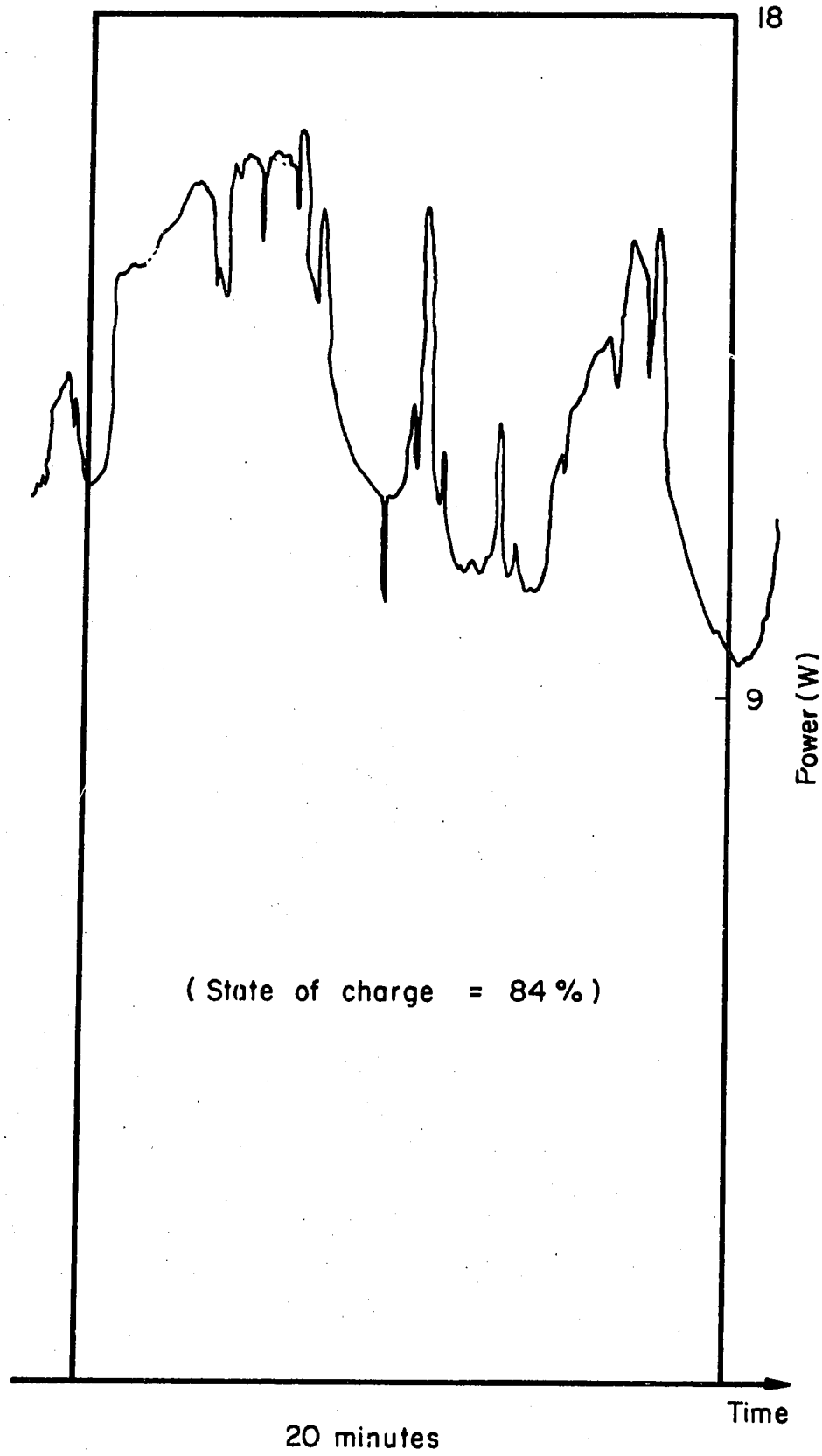

Fig. 10 – Charging Power Variation with Time

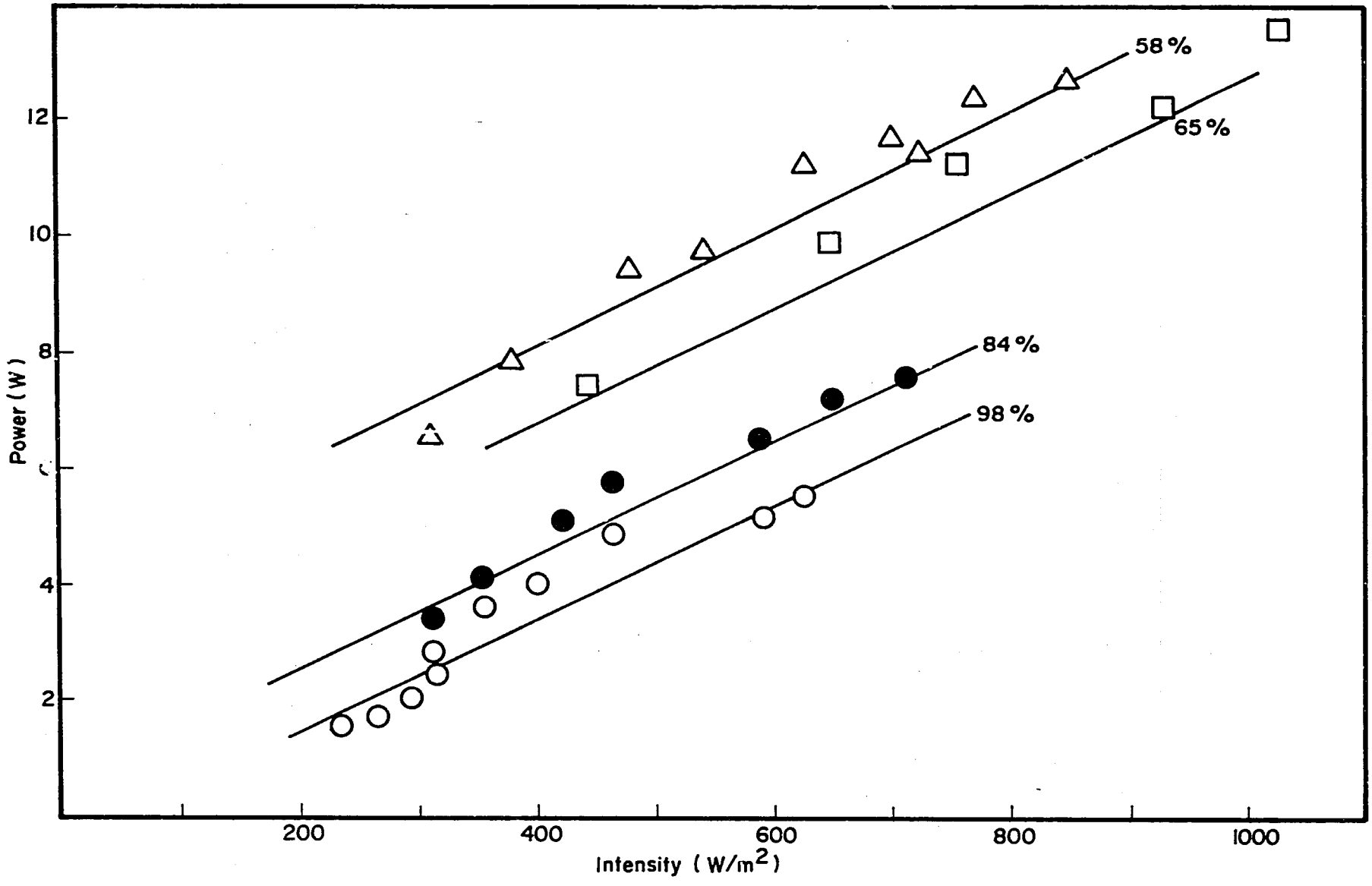

Fig. 11 – Charging Power Variation with Solar Intensity

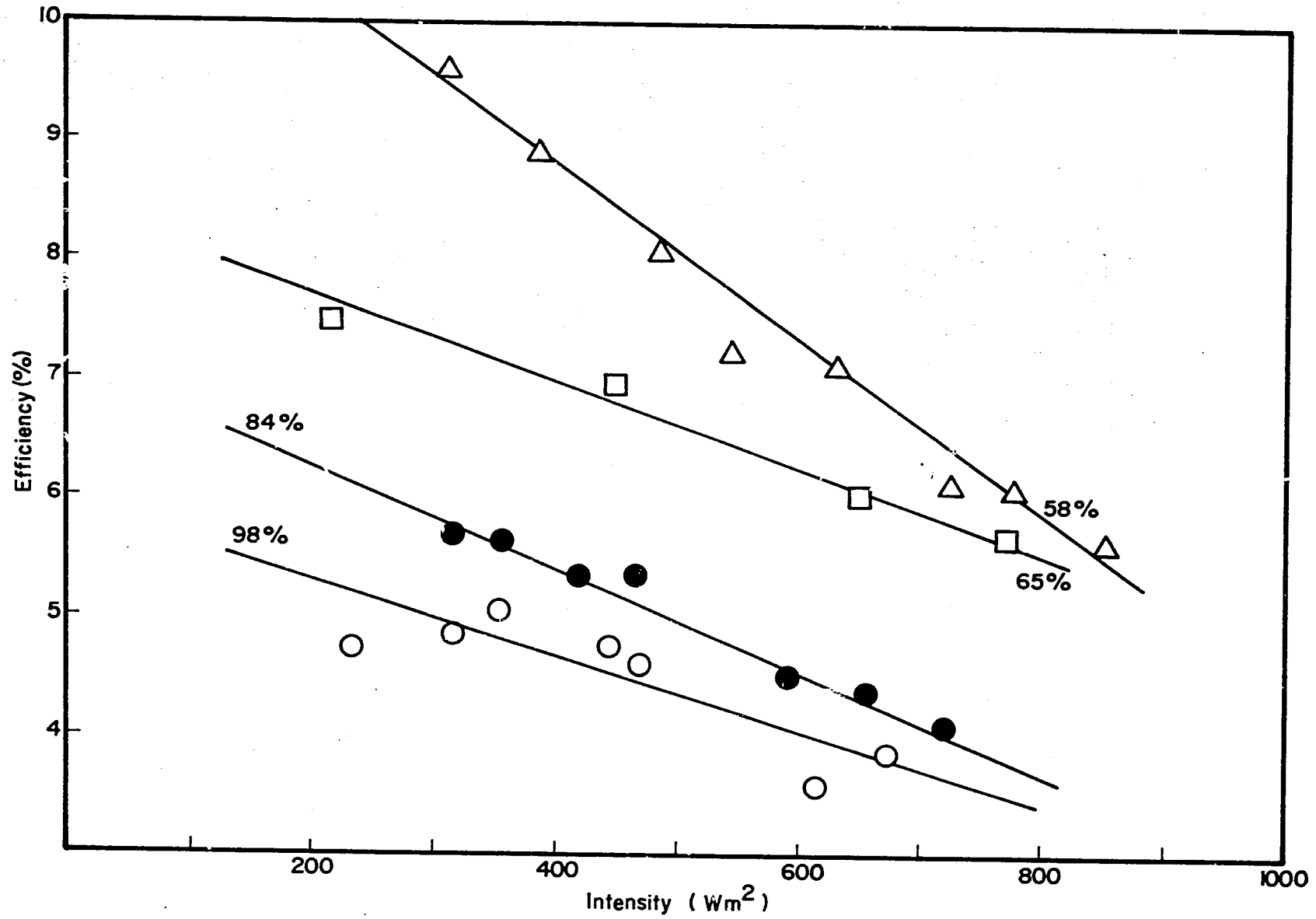

Fig. 12 – Charging Efficiency Variation with Solar Intensity

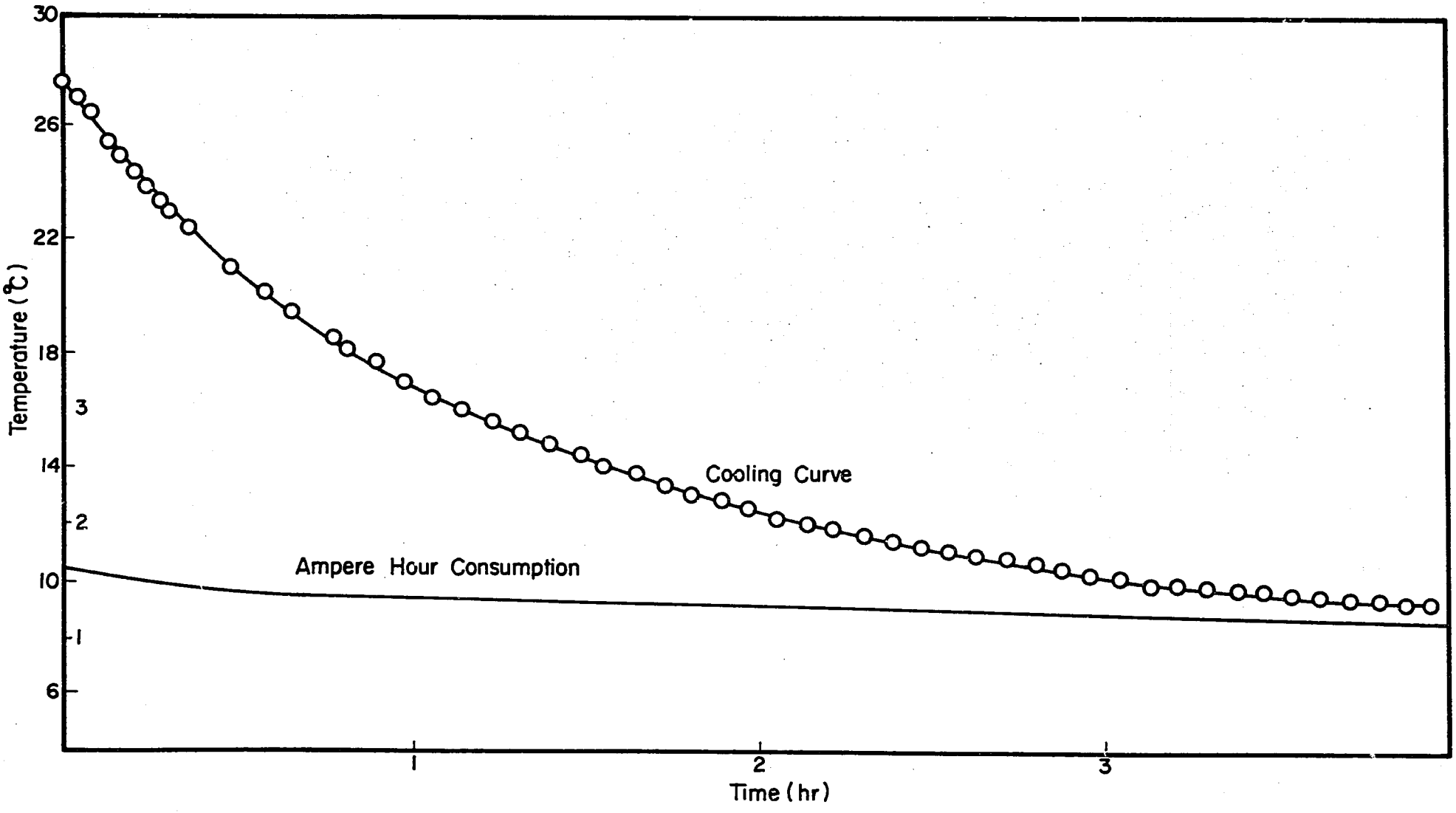

Fig. 13 – Cooling Curve for Thermoelectric Device

Status of Solar Energy Development in Thailand

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Abstract

Since the energy crisis of 1973, Thailand has shown a great interest in utilizing renewable sources of energy, especially solar energy. Several solar energy R & D projects have been carried out by researchers in universities, educational institutions, government agencies and private firms. These R & D projects encompass a wide range of technologies, from the very simple to the highly complex. The present course of R & D is aimed at developing low cost high efficiency solar devices for industrial process heat, agricultural and industrial drying, large-scale distillation, air-conditioning, refrigeration and electric power generation for remote areas.

On the demonstration and utilization aspect, only solar hot water heating application is presently at a commercial stage. There are approximately 10,000 square meters of flat plate collectors installed in hotels, hospitals, condominiums, barber shops, and private houses. The figure may increase by more than 30% by 1985 as the private sector has currently shown great interest. Additionally, the government plans to install more demonstration projects and to provide more incentives.

Introduction

Since the energy crisis of 1973, Thailand has encountered severe energy problems due to the country's heavy dependence upon imported oil. In 1981, energy consumption is expected to be equivalent to 18,724 million litres of crude oil, of which imported crude oil comprises approximately 76 percent. Since crude oil has to be imported at high prices, the country

has drained a large portion of the national export earnings. This creates large payment deficits, inflation and income distribution problems. As a result, the national economic and social development has deteriorated substantially.

The government of Thailand has been putting greater emphasis on the development of nonconventional energy. This fact is reflected in the present nonconventional energy development plan. The government has a policy to promote the utilization of nonconventional energy with emphasis on research and development, demonstration of a near-future economically viable projects, prefeasibility studies for technical and econo-social justification, and resource assessments.

With regard to the solar energy which is one of the most promising renewable sources, the government has set a target that in 1986 utilization of solar energy in the country will replace approximately 10 million litres of crude oil. The allocated budget to accomplish this during the five year plan is approximately 150 million baht.

Research and Development on Solar Energy

Several solar energy R & D activities have been carried out in Thailand during the past five years. These R & D projects encompass a wide range of technologies, from the very simple to the highly complex. The present trend of the activities is to develop a low cost high efficiency solar devices for applications fo solar water heating, industrial process heat, agricultural and industrial drying, distillation, refrigeration and air-conditioning, water pumping, and electric power generation for remote areas.

The organizations which actively deal with R & D activities in the field of solar energy are as follows:

- King Mongkut's Institute of Technology

- Chulalongkorn University
- University of Chiengmai
- Khonkaen University
- Prince of Songkhla University
- Kasetsat University
- National Research Council
- Electric Generating Authority of Thailand
- National Energy Administration

The National Research Council is primary a funding agency. In 1981, the total budget allocated for research and development was 11 million baht.

The National Energy Administration and the Electric Generating Authority of Thailand are oriented towards implementation. Several projects are jointly implemented with other agencies.

The following are highlights of the solar energy R & D activities during the past year.

1. Solar Radiation

Thailand lies between 5° - 21° north latitude, and 96° - 106° east longitude, covering an area of approximately 514,000 sq. km. Annual daily average solar insolation is reasonably high at about 16.7 MJ/m^2 - day with the fluctuation of the level of the insolation only $\pm$ 15 percent from the mean. The atmosphere in Thailand is slightly hazy with high levels of humidity, giving a comparatively high diffuse portion.

A study of solar radiation in Thailand was initiated by R.H.B. Exell and K. Saricali(1). The solar radiation map was produced. A simple linear regression equation was used to estimate total radiation from sunshine data. Later on K. Kirtikara et al (2) applied the linear multiple regression with

meteorological data of sunshine duration, cloudiness index, ambient temperature, relative humidity, wind velocity, and atmospheric pressure as input data, the results showed an improvement of the correlation coefficient. On the study of the interrelationships between the total radiation, the diffuse radiation and the direct radiation, K. Kirtikara et al (3) discovered that the measurement data from the meteorological station at Bangkok indicated a higher proportion of diffuse radiation when compared to the well-known standard relationship developed by Liu and Jordan.

2. Solar Water Heating

Several types of flat plate collectors suitable for heating water up to 60°C have been developed and tested. Experimental results of identical thermosyphon systems having different absorber materials show that the system with copper as an absorber material has the highest efficiency compared to those using aluminium or galvanized steel as an absorber material.

A solar water heater with latent heat storage has been studied (4). Three experimental units with different absorber materials have been constructed. Stearic acid was used as a working fluid. However, more effort will be needed as experimental results reveal that the overall system daily efficiency is rather poor at approximately 12 percent.

A reversed flat plate collector was developed from a flat plate collector with two transparent glass covers above the absorbing plate and one glass cover underneath (5). A half cyclindrical reflecting surface reflects sunlight to the bottom surface of the absorbing plate. The experimental results showed that the reversed flat plate collector gives higher thermal output than those of the conventional single glazed and double glazed flat plate collector.

Parabolic troughs have been designed and experimented at a number of institutions. The latest design has a unit equipped with an automatic tracking mechanism. The observed absorber surface temperature and working

fluid temperatures were 228°C and 180°C, respectively, at a solar radiation level of 780 watt/square meter (6).

An evacuated tube has been fabricated and tested at the King Mongkut's Institute of Technology at Thonburi (7). Test results showed that the system efficiency increases as the pressure inside the collector decreases. Below 584 mm H_g vacuum, only small increases in efficiencies were observed. The thermal losses from the receiver to ambient depend on vacuum pressure inside the annular and on the ratio of glass envelope to absorber tube.

A thermosyphon flow measuring equipment was constructed (8). The flow rate was determined from the time of flight of viscous oil droplets, having specific gravity nearly equal to that of water, between fixed distances along the flow using electronic timers.

Experimental thermal performance testing of a flat collector has been conducted at the National Energy Administration (9). The outdoor testing procedure employed four identical flat plate collectors connected in series. Experimental results showed that the time needed to complete one set of performance curves was only one day under clear sky condition. A second degree polynomial equation fitted the experimental data better than an exponential equation or a straight line equation. The coefficients of determination in all cases were better than 0.975.

3. Solar drying

Several types of a natural air-circulation solar box drying systems have been experimented upon (10). The effects of cover angle, the ratio of air-inlet area to the absorber area, and the cover materials have been investigated. The results from various sources reported that a box dryer having 14° - 18° cover angle has maximum thermal efficiency while the ratio of the inlet port to the absorber area should be at 11 - 13 percent. The drying rates and the efficiencies were 3.2 - 4.2 kg/m^2 -day and 48 - 64 percent, respectively.

Box dryers with separate air collectors have been studied and experimented with (11). Test results indicated that the air heater with glass cover and absorbing plate at the middle of the air gap gave the highest drying efficiency.

Several products such as rice, meat, tobacco, and fish have been tested with satisfactory results (12).

4. Solar Cooling

A solar absorption cooling system was recently designed and tested (13). Lithium Chloride and water solution was selected as the working solution. The coefficient of performance was found to be 0.2 - 0.35 at the chilled water temperature of 14° - $16^{o}C$ and at a generator hot water temperature of 65 - $75^{o}C$. Several modifications of the system are currently underway.

5. Solar distillation

Solar distillation has been extensively studied by the group of researchers at the King Mongkut's Institute of Technology at Thonburi (14). Several types of still such as a simple portable solar still, a simple stationary still with cement tray, a tilted-tray solar still, a regenerative solar still were experimented. The results revealed that the optimum angle for a still with a glass cover is 14 degrees facing south; and for a still with an acrylic plastic cover, the optimum angle is 24 - 40 degrees. Output of a still depends on absorber material and condensing cover material. It generally varied from 1.7 - 4.0 litres per square meter per day.

For a regenerative solar still in which the latent heat of condensation is partially recovered, it was discovered that only small improvement was achieved. The average production rate was 29.4 litres/m^2 - day compared to the rate of 29 litres/m^2 - day for an identical still without regeneration (15).

Application to alcohol distillation has been studied (16). For a starting volume with 10 percent concentration by volume, the average distilled volume was 0.5 litres/m^2 - day with final concentration of 48%.

6. Solar cells

Research and development of photovoltaic technology has increased recently in many institutions. A Schottky barrier silicon solar cell and a P - N junction single crystal solar cell, have been fabricated at Chulalongkorn University (17). Typical efficiencies of these solar cells were 3 and 11 percent, respectively. The present course of development at this institute is to develop an appropriate technology for solar cell fabrication.

Performance testing of a solar cell available in the market has been carried out by the Electric Generation Authority of Thailand.

7. Solar Thermal Electricity

The possibility of solar thermal electricity interested the Electric Generating Authority of Thailand. The organization has sponsored Chulalongkorn University to make a prefeasibility study of a solar central tower system of 1,000 KW thermal and to construct and experiment a prototype of 100 KW thermal. The organization has also sponsored the King Mongkut's Institute of Technology to make a prefeasibility study of a 100 KW thermal solar distribution system. The first phase of this project is expected to be completed by 1983.

Solar Energy Utilization

Utilization of solar hot water systems in Thailand is presently gaining a public interest. It is estimated that before 1979 there were less than 1,000 square meters of a solar collector installed while there are presently about 10,000 square meters of solar collectors installed for various applications in hotels, hospitals, private clinic, barber shops, condominiums, and private houses. A list of major solar water heating installation is given in Table 1.

As fossil fuel prices continue to increase there are signs that several hotels and hospitals will invest capital in solar hot water systems. The prospects for solar hot water systems seem to be promising for the near future.

It is hoped that more than 30,000 square meters of solar collector will have been installed by 1985 as the government plans to launch more demonstration projects and to provide more incentives.

The National Energy Administration which is a department in the Ministry of Science, Technology, and energy has been involved in the field of renewable energy since 1977. For solar energy, several demonstration projects have been installed; one solar air-conditioning system of 2 tons capacity in 1979, one solar hot water heating system at the Royal Grown Prince hospital at Nhongkai in 1981, two solar hot water systems for hospital in 1982, and technical service for a 504 m^2 solar hot water system at Rama hospital.

The department of science has installed at 100 m^2 solar still. It provides purified water for use in laboratories, and for drinking.

Conclusion

It is evident that solar hot water systems are considered economically viable and practical as means of conserving energy. Other applications such as solar drying, solar process heat, and solar distillation may gain social & economic acceptance as more research and development and demonstration efforts are made.

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TABLE 1

List of Major Solar Water Heating Installation

No.	Project Name	Collector Area (m^2)	Date of Completion	Note
1	Chakangrao Hotel, Kamphangpetch	96	March 1979	
2	Burapar Hotel, Petchabul	84	November 1979	
3	Taksin Hotel, Nakornsrithamaraj	67	1979	
4	Phanphit Court, Bangkok	72	October 1980	
5	National Energy Administration, Bangkok	52	February 1980	Solar Air-conditioning System
6	Indra Hotel, Bangkok	144	June 1980	
7	Piman Hotel Nakornsawan	150	1980	
8	Tipchang Hotel Lampang	285	1980	
9	Seaview Hotel Pattaya	162	1980	
10	Paradon Inn, Chumpon	109	February 1980	Thermosyphon System
11	Holiday Inn, Songkhla	96	August 1980	
12	Yala Rama Hotel, Yala	102	1980	
13	Tepnakorn Hotel, Pitsanuklok	250	June 1980	
14	Dyana Hotel, Pitsanuklok	22	December 1980	

Table 1 cont'

15	Nanchao Hotel, Pitsanuklok	200	March 1980	
16	Royal Garden Resort Hotel, Pattaya	42	July 1980	
17	Aurentel Hotel, Songkhla	82	June 1980	
18	Mandarin Hotel, Bangkok	600	July 1980	
19	Dhevaraj Hotel, Nan	288	January 1981	
20	Ocean Apartment, Bangkok	40	May 1981	
21	Royal Crown Prince Hospital, Nhongkai	40	November 1981	
22	Tropicana Hotel, Pattaya	322	January 1981	
23	Rose Inn Hotel, Pichit	144	January 1981	
24	Ramada Hotel, Bangkok	56	June 1981	
25	Rintr Guest House, Pattaya	22	February 1981	
26	Wiengtak Hotel, Tak	84	May 1981	
27	Meridian Hotel Pattaya	56	1981	
28	Rosukon Hotel, Khonkaen	120	February 1981	
29	King Hotel, Yala	42	1981	Thermosyphon System
30	Srichareon Hotel Yala	33	June 1981	Thermosyphon System
31	Hyatt Orchid Hotel, Chiengmai	360	April 1981	

Table 1 cont'

32	Rama Hospital, Bangkok	504	March 1982	
33	Asian Institute of Technology, Bangkok	52	March 1982	Solar Air-conditioning System
34	Srikrung Hotel, Bangkok	392	May 1982	
35	Phumipol Hospital, Bangkok	324	-	Under construction
36	Supak Hotel, Kalasin	60	-	Under construction
37	Royal Cliff Condominium, Pattaya	112	1982	
38	Wieng Inn Hotel, Chiengrai	238	1982	
39	Wiengtai Hotel, Bangkok	300	March 1982	
40	New Sluppy Massage, Pitsanuklok	80	January 1982	
41	Bangkok Palace Hotel, Bangkok	965	January 1982	
42	Grand Palace Hotel, Pattaya	960	-	Under construction
43	Royal Crown Prince Hospital, Petchabul	40	-	Under construction
44	Chiengmai Hospital, Chiengmai	288	-	Under construction

A Preliminary Evaluation on the Economic Feasibility Of the Application of Solar-Powered Refrigeration System in Small Scale Coastal Fishery Activity

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Introduction

The storage of fish at low temperature is an essential operation in the fishery activity. By that operation, fish can be delivered to the market fresh, even though there are some unavoidable time delays between catching and consuming the fish. Omission and the operation could result in heavy losses, because the fish deterioriate at higher temperatures for prolonged periods.

In small scale coastal fishery activity, ice is commonly used for low temperature storage of the fish.

In this paper, the possibility and the opportunity for economically utilizing solar-powered refrigeration/ice producing systems for the storage of fish for small scale coastal fishery activities is examined. The analysis is based on calculations and estimates using limited information on solar refrigeration systems and coastal fishery cost structures. Data come primarily from the fishery community around Tegal, Central Java. Therefore, the results described here should be considered preliminary.

Objective of the Study

The objective of the study presented in this paper was to evaluate the economic feasibility of applying solar-powered refrigeration systems in small scale coastal fishery activities.

Preliminary Evaluation of the Economic Feasibility of Utilizing Solar-Powered Refrigeration System in Coastal Fishery Activity

In evaluating the economic feasibility of utilizing solar-powered refrigeration systems in coastal fishery activities, we examined the gross profit margin of utilizing such a system.

At the first stage, the margin between the sales income from various levels of fish production, and the costs of producing the necessary ice required for the refrigeration of those levels of fish production is determined. To do that, the following relationships were developed and utilized:

a. The investment cost of a solar-powered refrigeration unit as a function of its capacity (expressed in terms of collector surface area) is given by the following equation:

$$I_x = I_5 \left(\frac{A_x}{A_5}\right) \qquad (1)$$

where I_x = investment cost, US $ of a system having a capacity equivalent to a collector surface area of x m^2

I_5 = idem, x = 5 m^2; used as a basis for calculation

A_x = collector surface area of x m^2 capacity

A_5 = idem, x = 5 m^2

n = constant; estimated to have a value of 0.7

This equation is plotted as a curve in the upper left quadrant of Figure 1. The development of this equation is described in Appendix 1.

b. The relationship between the collector surface area of the solar refrigeration system and its storage capacity for fish (tons of

fish stored per day), is established by utilizing the following basic relationship:

- 1 sq. meter of collector area will produce 5 kg. of ice per day
- 1 ton of fish stored per day requires 0.80 ton of ice per day (see Appendix 2 for further explanation)

The curve relating collector area to storage capacity in tons of fish stored per day is shown in the upper right quadrant of Figure 1.

With the help of the two curves, the investment cost for a solar-powered refrigeration system appropriate for a given storage capacity can be easily estimated.

c. The lower right quadrant in Figure 1 indicates the sales income as a function of the level of production capacity. The curve drawn as an illustration is based on a sales price of Rp. 100,000/ton of fish (US $ 156/ton).

d. Utilizing the three previous relationships, as described in (a), (b), and (c), a fourth relationship can be established in the lower left quadrant of Figure 1. This relationship indicates that for a certain level of production capacity (tons of fish per day) and at a given sales price of the fish, the appropriate refrigeration system would require an investment as indicated in the horizontal axis (investment cost), while the corresponding sales income would be as indicated in the downward vertical axis.

To clarify the use of Figure 1, the following illustration is given:

- For a fishery activity having a production capacity of 1 ton of fish per day, a solar refrigerator having a collector capacity of approximately 17 m^2 would be required

- Such a solar-powered refrigeration system would require an investment of approximately US $ 3,500

- At a sales price of US $ 156/ton of fish, the sales income would be US $ 47,000/year

The curve on the lower left quadrant of Figure 1 would provide the basis for determining the gross profit margin, if the investment for the solar refrigeration system is depreciated yearly.

The result of such calculation, using a depreciation scheme as described in Appendix 1 is presented in Figure 2; e.g. for an economic lifetime set at 5 years, and interest rate of 15% per annum.

It can be seen from Figure 2 that the gross profit margin of utilizing solar refrigeration with respect to the sales income is always positive, rising with the level of production.

The above measure, however, does not quite give a clear picture about the economic feasibility. To get a better picture, a different measure of gross profit margin will be examined.

Based on existing price of ice, and the amount of ice necessary to store the fish caught, the yearly operating expenditure for storage utilizing bought ice from the market is determined. This value is then compared to the yearly depreciation of investment cost for a solar powered ice producing system of the proper capacity.

Given two levels of ice prices, namely US $ 32/ton of ice and US $ 25/ton, and two economic lives of the refrigeration system, 5 and 7 years, comparisons of gross profit margins are shown in Figure 3.

It can be seen that for an economic lifetime of 5 years, and at the lower price of ice, the gross profit margin seems to be always negative.

Having equipment with a longer life time would make the solar-powered refrigeration system competitive if the fish production capacity is higher than 900 tons/year or 3 tons/day.

From Figure 1, the collector area corresponding to 3 tons/day of fish is approximately 50 m^2. Our conclusions change considerably if the ice price is US $ 32/ton. Then, a smaller system would be competitive.

The analysis shows that the system lifetime and the transport distance and subsequent costs of the ice with respect to the fishery are two important factors that determine the economic competitiveness of a solar-powered refrigeration system.

Summary and Conclusion

An approximate method for the evaluation of the economical utilization of solar-powered refrigeration system has long been described.

Application of the method to a typical fishery environment at Tegal, shows that the use of such a system is economically competitive only if the production/storage capacity to be supported by the ice producing unit is large, at least 3 tons of fish stored per day.

An installation with such capacity would only be appropriate if the fishing community collectively used the unit. The provision of ice from an on site solar-powered installation will have certain advantages in such a situation, namely:

- melting of ice during transport is practically eliminated
- the unit can be installed in remote locations where otherwise ice would be impossible to get; this would suppress losses due to deterioration of the fish

Further studies utilizing a wider set of data, perhaps complemented with a pilot project, are necessary for a better evaluation.

Acknowledgement

The authors would like to express their appreciation to LIPI and the Organizer of the ASEAN - US Energy Seminar for providing the opportunity to present this paper. To Ir. Rudy E. S. who has provided the essential information for this study, the authors express their sincere gratitude.

Appendix 1: The Investment Cost Of Solar Powered Refrigeration

The assessment of the investment cost of solar powered refrigeration is based on the following data:

- Ammonia generated (expressed in terms of collector surface area) is 2.0 - 2.5 kg. ammonia/sq. m collector per day based on solar radiation insolation at mid day of 600 - 810 W/m^2.
  Using evaporation heat efficiency of 0.6, the capacity of solar refrigerator expressed in term of ice produced is 5 kg. of ice/m^2 collector area per day.

- The calculations of the investment cost of a solar refrigerator (based on AIT Bangkok, solar refrigerator model) having 1 and 5 sq. m collector area gives investment values of Rp. 400,000 (US $625) and Rp. 960,000 (US $1500), respectively.

Based on the investment cost data and using the relationship in Equation 1, proper value of n was found to be 0.5. The value of n used for the calculation of investment cost of refrigerator having collector area greater than 5 sq. m in Equation 1, varies between 0.5 - 1. Therefore, for calculation purposes, a value of n-0.7 was chosen.

To calculate the investment cost of solar refrigerator, the following formula is used:

$$I_x = 1500 \left(\frac{A_x}{5}\right) 0.7$$

where I_x : investment cost, US $ of a system having a capacity equivalent to a collector surface area of x m^2

And to calculate the depreciation for the investment cost, the following formula is used:

$$D_x = I_x (1 + i)^y \left[\frac{i}{(1 + i)^y - 1}\right]$$

where y : solar refrigerator economic life time

i : inflation rate

Appendix 2: Ice required for storing 1 ton fish per day

The heat coming in to a container having $0^{o}C$ temperature from surroundings of $30^{o}C$ temperature, using containers with insulation of 0.0745 kcal/hr m C heat transfer conductivity coefficient, and thickness of 10 cm, was calculated to be 2682 kcal/day per m^3 of container volume. This heat loss requires 33.5 kg. of ice to maintain container temperature at $0^{o}C$.

If 1 m^3 of container volume is occupied by 0.6 ton of fish, then the amount of ice needed per ton fish stored is 60 kg.

Normally, ice needed for fish preservation in the fishery activity in Tegal varies between 60 - 100 kg. per ton of fish. Therefore, for calculation purposes, a value of 80 kg. ice per ton of fish stored was chosen.

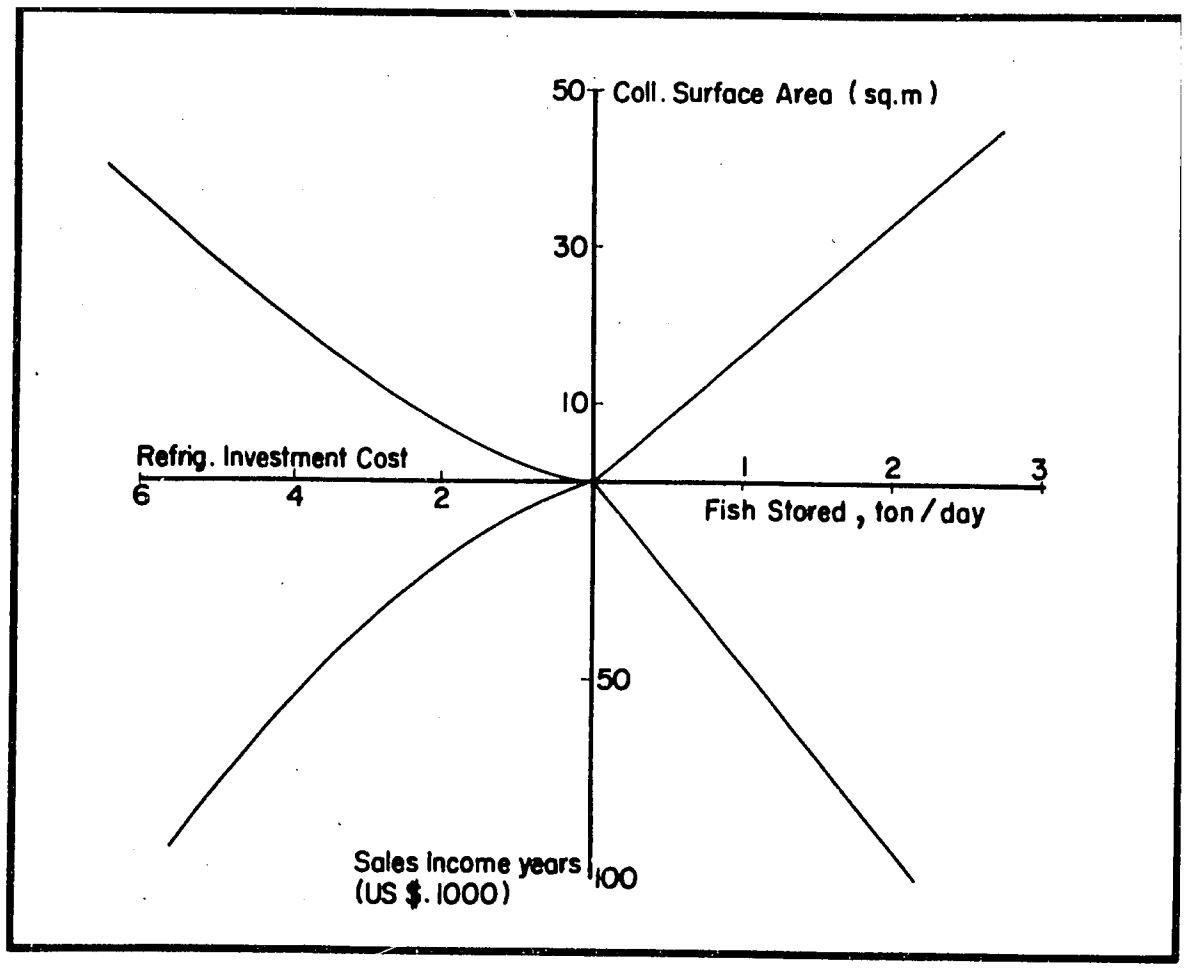

Fig. I - The Relationship of Coll. Area-Investment-Fish Stored-Sales Inc.

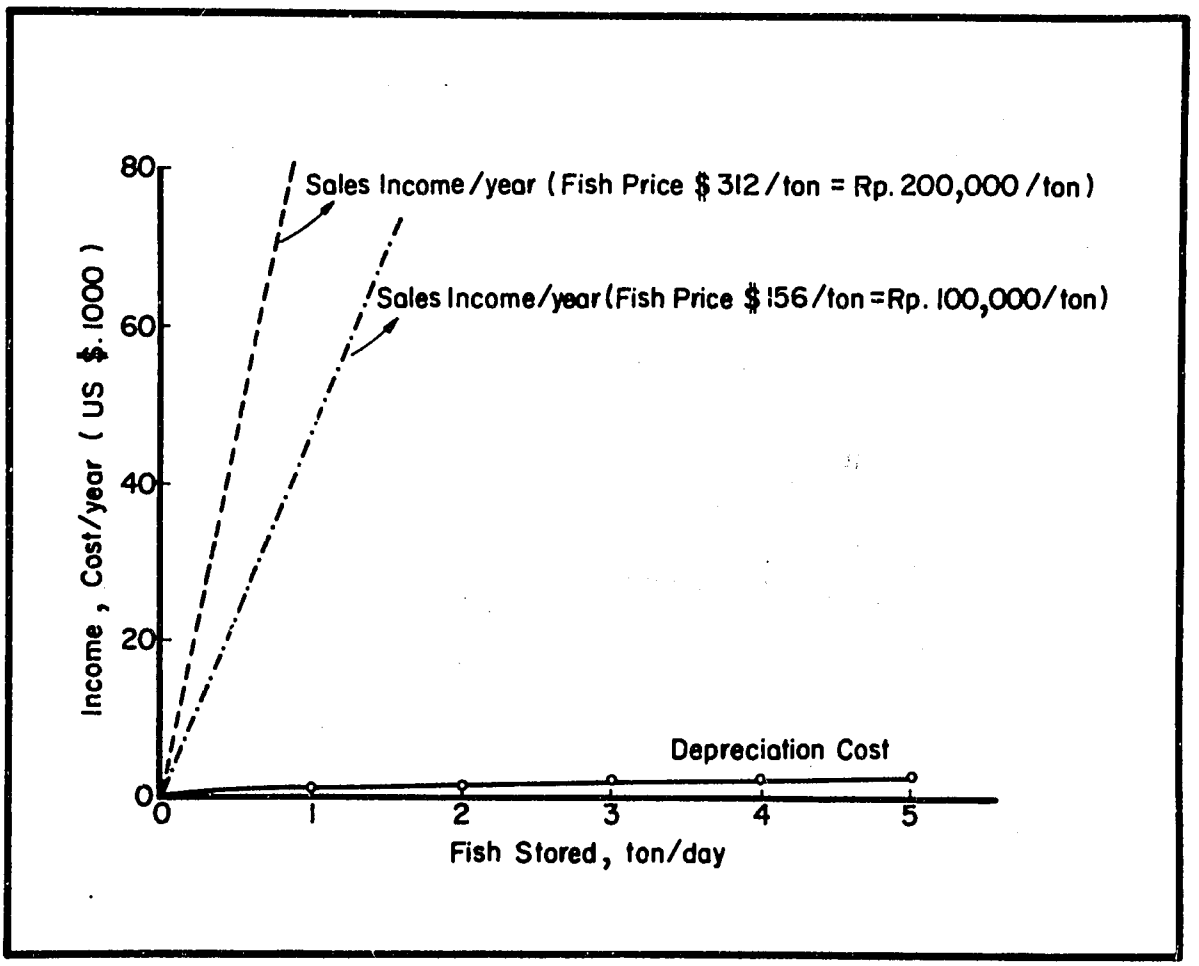

Fig. 2 – The Margin Value of Sales Income - Solar Refrig. Depreciation Cost at Various Fish Stored

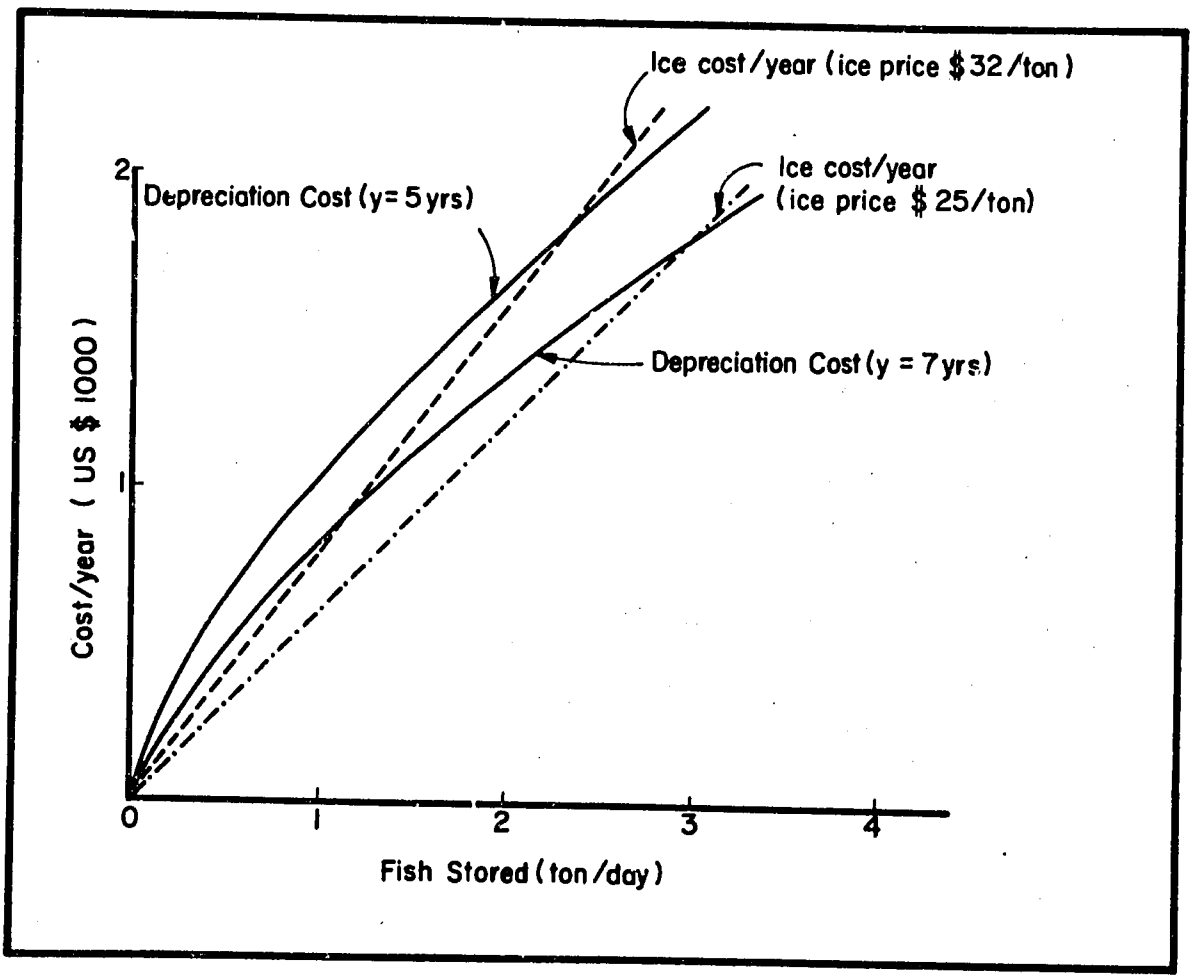

Fig. 3 - Ice Cost - Depreciation Cost for Solar Refrigerator at a Various Level of Fish Stored

Assessing the Availability Of Solar Energy in Thailand

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Introduction

The input to a solar energy collector is highly variable because of the change in the position of the sun with time of day and with time of year, and because of the diurnal and seasonal fluctuations in the amounts of cloud and atmospheric turbidity. The change in the position of the sun can easily be calculated accurately for any time and any location on the earth from astronomical data, but the effects of weather and climate must be treated statistically.

An excellent text on solar radiation is that by Robinson (1), particularly chapter 4 by Schuepp, which has been used as the basis for much of the solar radiation work done in A.I.T.

Theoretical studies of the operation of a solar energy device frequently require a numerical simulation of the solar radiation input data together with other meteorological elements such as wind and temperature. In developed countries complete data are often available and actual meteorological records can be used in the simulations. In developing countries such data are usually incomplete or not available at all, and some method of constructing a simulation model for solar radiation has to be invented.

Thailand is fortunate in having a complete five-year run of daily total solar radiation measurements at Bangkok (1968-72), and good, but incomplete, measurements of the hourly solar radiation at Bangkok and

Chiang Mai. Complete records of the daily duration of sunshine are also available for 18 stations spread throughout the Kingdom. By using these data relations between solar radiation and sunshine at Bangkok and Chiang Mai have been calculated, and the geographical distribution of solar radiation has been found from these relations and the sunshine records at the other stations. Seasonal effects were determined by making seperate studies for eight 1½ month periods of the year defined by standard solar declinations. In this lecture results for the summer solstice period have been selected to illustrate the methods of calculation; the complete results are available elsewhere 2,3 .

The term "solar radiation" as used in this lecture means the sum of direct are diffuse solar radiation on a horizontal surface.

Correlations Between Solar Radiation Measurements and Sunshine Records

Fig. 1 shows a scatter diagram for the relationship between daily records of total solar radiation H_d and the duration of sunshine S. The regressions are linear. The regression lines in the scatter diagrams for Bangkok and Chiang Mai were obtained by the method of least squares using a standard computer program and five years of data 2. The standard errors of estimate of H_d on S were also determined; they are shown in Fig. 1 by dashed lines on each side of the regression line. Regression equations of the form

$$H_d/H_c = a + bS/S_m$$

were then calculated, where H_c is the total daily solar radiation from a clear sky under standard atmospheric conditions and S_m is the maximum daily duration of sunshine recordable. Both H_c and S_m are functions of station latitude and solar declination.

The values of H_c were taken from reference 1 and the values of S_m were calculated from the time between sunrise and sunset. The parameters a and b vary with location and time of the year and have been the subject

of much discussion in the literature. A study of their values in India and Thailand shows that the parameters

$$a = 0.33, \qquad b = 0.52$$

may be recommended for use in the South-East Asian peninsula.

The regression equations were used to estimate the mean daily totals of solar radiation at the other stations where the mean duration of sunshine, but not the solar radiation, had been recorded. Mean cloud amount reports were also used to estimate the mean duration of sunshine at a further 26 stations and thus extend the network of solar radiation estimates. The latter part of the work required human judgement because of the irregularity of the relations between sunshine and cloudiness. Cloudiness is reported by meteorological stations in eights of the sky covered with cloud. Let C denote the mean cloudiness for one of the eight seasonal periods mentioned above. Then the ratio of the mean daily total solar radiation to the radiation from a clear sky can be estimated by the equation

$$H_d/H_c = 0.8 - 0.005\ c^2$$

This formula, obtained by examining the data for Thailand, gives H_d/H_c with an accuracy usually better than 10% when c is in the range 2 to 7 eights.

Fig. 2 shows the type of solar radiation map thus obtained. It is noteworthy that since the method of least squares makes the regression lines for H_d on S pass through the centroid of the points on the scatter diagram, and since mean values of H_d are being estimated from mean values of S, this method should give results with an accuracy greater than that suggested by the standard error of estimate of H_d and S.

Percentage Distributions of Daily Totals of Solar Radiation

Observed Distributions at Bangkok

The daily totals of solar radiation in the complete five-year run at Bangkok were divided into 14 classes, and the frequencies of occurrence of the classes during each 1½ month period of the year were counted. The result for the summer solstice period is shown as a percentage frequency histogram in Fig. 3.

Estimation of Distributions from Sunshine Data

It is possible to estimate the percentage distributions of daily totals of solar radiation from complete records of the daily duration of sunshine with the help of the regression relations and the standard errors of estimate of solar radiation on sunshine duration. The method of calculation is suggested by Fig. 1. If the daily durations of sunshine are known but the daily totals of solar radiation are not, then the individual points cannot be plotted on the diagram. But an examination of the data used for determining the regressions at Bangkok and Chiang Mai showed that the points have an approximately normal distribution about the regression line in the direction of the H_d axis. Consequently, the following method could be used to estimate the solar radiation distribution.

The recorded values of the daily duration of sunshine were divided into 13 classes each of width $1hd^{-1}$. Let $S(i)$ be the mid point and let $f_S(i)$ be the relative frequency of the i-th sunshine class. Quantities $n(i,j)$ were assigned to the 14 solar radiation classes j in such a way that the distribution with respect to j of these quantities (a) was normal, (b) had mean value $H_c(a + bS(i)/S_m)$, (c) had standard deviation equal to the standard error of estimate of H_d on S, and (d)

$$\Sigma_{j=1}^{14} n(i,j) = f_S(i).$$

The relative frequency $f_R(j)$ of the j-th radiation class is then given by

$$f_R(j) = \Sigma_{i=1}^{13} n(i,j)$$

In the actual study the known statistical regression parameters were used to estimate the percentage distributions of daily totals of solar radiation from complete records of duration of sunshine at four stations in Thailand. The length of this calculation lies on the boundary between what one can do by hand and what must be done by computer. It was actually done by hand. The results for the summer solstice period at Bangkok are shown in Fig.3. There is good agreement between the estimated and observed distributions, but the estimated distributions are smoother, an unavoidable effect produced by the method of estimation.

Time Series of Daily Totals of Solar Radiation

Observed Series at Bangkok

For this part of the study the daily totals of solar radiation were divided into three classes: A (over 500 cal cm^{-2} d^{-1}), B (from 300 to 500 cal cm^{-2} d^{-1}), and C (below 300 cal cm^{-2} d^{-1}). An example of the time series of radiation classes that occurred at Bangkok is shown in Fig. 4.

The simplest statistical model of the time series treats it as a purely random one requiring for its description only the probabilities of the three classes A, B, and C. A statistical test has shown that the actual series differs significantly from this model because of the tendency of meteorological conditions to persist for several days at a time. However, it has been found that the series can be adequately represented as a Markov chain with different initial probability distributions and transition probability matrices for each 1½ month periods of the year. Table 1 shows the observed initial probabilities a(A), a(B), and a(C), of the classes A, B, and C, and the Markov transition probabilities p(AA), p(AB), ..., p(CB), p(CC) of the transitions A to A, A to B, ..., C to B, C to C respectively.

Fig. 4 compares simulations by the purely random model and the Markov chain model with the observed series for the period March to September. It is hard to judge the simulations by eye, but the better representation by the second order theory of spells of fine weather in spring and spells of bad weather in autumn can be discussed.

Estimation of Transition Probabilities from Sunshine Data

The initial probability distributions and the transition probability matrices can be estimated from complete records of the daily duration of sunshine. The method of estimating the initial probabilities a(A), a(B), and a(C) is exactly the same as that described earlier for estimating the percentage distributions of daily solar radiation, but the estimation of the Markov transition probabilities p(AA), p(AB), ..., p(CB), p(CC) is more complicated. The calculation, which was done by automatic computer, proceeds as follows.

Given the initial and final durations of sunshine S_k and S_{k+1} for the consecutive pair of days k and k+1, one calculates from the regression parameters the initial and final probabilities $P_k(A)$, $P_{k+1}(A)$, $P_k(B)$, $P_{k+1}(B)$, $P_k(c)$, and $P_{k+1}(c)$ of the radiation classes A, B, and C respectively. These probabilities are then used to calculate the probabilities of the nine possible pairs of radiation classes for the pair of days k and k+1. For example, the probability that the transition AB occurred on this particular pair of days is $P_k(A)\ P_{k+1}(B)$. An estimate of the frequency of a specified pair of radiation classes in a particular 1½ month period is then obtained by adding together the probabilities of the specified pair of radiation classes for all the pairs of consecutive days in the period. For example, if the specified pair of radiation classes is AB, and the 1½ month period is N days long, then the estimated frequency f(AB) of this pair of radiation classes in the period is given by

$$f(AB) = \Sigma_{k=1}^{N} P_k(A) P_{k+1}(B)$$

Estimates of the Markov transition probabilities p(AA), p(AB), ..., p(C,B), and p(CC) in the 1½ month period are easily calculated from these frequencies. For example, p(AB) = f(AB)/Na(A).

Markov transition probabilities were estimated in this way for the eight 1½ month periods at four stations in Thailand. Table 1 shows the results for the summer solstice period at Bangkok. There is good agreement between the estimated and observed values.

Runs of Consecutive Days with Low Radiation at Bangkok

The frequencies of runs of consecutive days with solar radiation less than 300 cal cm^{-2} per day (class C), each run being immediately preceeded by and immediately followed by at least one day with solar radiation greater than 300 cal cm^{-2} per day (class A or B), have been determined by counting the occurences of these runs in the Bangkok radiation measurements.

The first row of Table 2 gives the observed annual frequencies of runs of different length. The second row of the table shows the expected annual frequencies of runs of class C days calculated on the assumption that the time series of daily totals of solar radiation is a first order random process. Here the expected number of runs of exactly n class c days immediately preceeded by and immediately followed by days of class A or B in a 1½ month period N days long is

$$N(1 - a(C))^2 \, a(C)^n$$

This number is calculated for each length of run (that is for each n) and for each 1½ month period, and the annual frequency for each n is obtained by adding together the expected numbers of runs of length n in the eight 1½ month periods.

The numbers in the third row of Table 2 have been calculated on the assumption that the time series is a Markov process. According to this

theory the expected number of runs of exactly n class C days is

$$Na(C)\ (1 - p(CC)/a(C))^2\ (p(CC)/a(C))^{n-1}$$

The table shows that second order theory predicts the frequency of runs of low radiation more accurately than first order theory, although first order theory is quite good.

Diurnal Variation of Solar Radiation

Although daily totals of solar radiation are useful for determining the general level of the solar energy input to a collector, a theoretical prediction of the actual operation of a solar powered system often requires a simulation of the fluctuating energy input hour by hour throughout the day. Since only incomplete records are currently available in Thailand, a study of the probabilities in this complicated random process is necessary.

Measurements of hourly totals of solar radiation at Bangkok and Chaing Mai are available. Table 3 gives the percentage frequency distributions of the hourly totals among radiation classes of width 10 cal cm^{-2} h^{-1} for the summer solstice period at Bangkok.

In order to use these data to construct a simulation model, it is necessary to make a conversion from zone mean time (ZMT), which is influenced by the difference in longitude between the observing station and the standard meridian and by the equation of time, to apparent solar time (AST). It is also necessary to find an adequate representation of the random process.

A disadvantage of this model is that a large number of percentage frequencies have to be recorded. Fig. 5 shows the frequency distributions throughout the day in one 1½ month period at Chiang Mai. The trouble with this model is that a large number of percentage frequencies have to be recorded because the distribution patterns are dominated by the hourly change of solar altitude.

Fortunately a more concise representation is possible. Let a factor K_h be defined by the equation

$$K_h = G_h/G_c$$

where G_h denotes the hourly global solar radiation and G_c denotes the hourly global solar radiation under a clear sky. Fig. 6 shows the distributions of K_h corresponding to the distributions of global solar radiation in Fig. 5. They are nearly the same throughout the whole day. Consequently, if the average of the distributions in Fig. 6 is used to represent the fluctuations in every hour interval only small errors will occur in the representation. This method has been used in the treatment of the Thai data, and for the construction of the simulation model. The detailed results are published (3). They have been used to construct a computer simulation model of solar radiation that will be discribed in the next lecture 4,5 .

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TABLE 1

Probabilities in the Markov Chain Model for the Time Series of Daily Solar Radiation Classes at Bangkok during the Period May 29 - Jul 15

Initial probabilities	observed	estimated
a(A)	.16	.15
a(B)	.62	.67
a(C)	.22	.18
Transition probabilities	**observed**	**estimated**
p(AA)	.29	.23
p(AB)	.60	.69
p(AC)	.11	.08
p(BA)	.11	.14
p(BB)	.68	.68
p(BC)	.21	.18
p(CA)	.20	.09
p(CB)	.51	.62
p(CC)	.29	.30

TABLE 2

Number of Runs per Year of Days having Solar Radiation in Class C at Bangkok

	Length of run (days)					
	1	2	3	4	5	6
Observed	32.0	9.4	3.4	1.8	0.8	0.0
First order Theory	43.8	9.2	2.2	0.6	0.2	0.0
Second order Theory	31.8	10.0	3.5	1.3	0.5	0.2

TABLE 3

Percentage Frequency Distributions of Hourly Solar Radiation Class at Bangkok during the Period May 29 - Jul 15

ZMT (h)	Radiation classes (cal cm^{-2} h^{-1})								
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90
5-6	100								
6-7	98	2							
7-8	19	57	23	1					
8-9	2	21	29	29	18				
9-10	1	6	11	26	26	27	4		
10-11	1	1	9	17	21	26	21	4	
11-12	1	2	5	16	12	29	16	17	2
12-13	2	4	9	12	16	24	15	16	2
13-14	2	4	10	16	18	24	14	9	2
14-15	2	11	12	19	27	14	14	1	
15-16	8	14	24	22	24	7	1		
16-17	19	28	36	16	1				
17-18	73	26	1						
18-19	100								

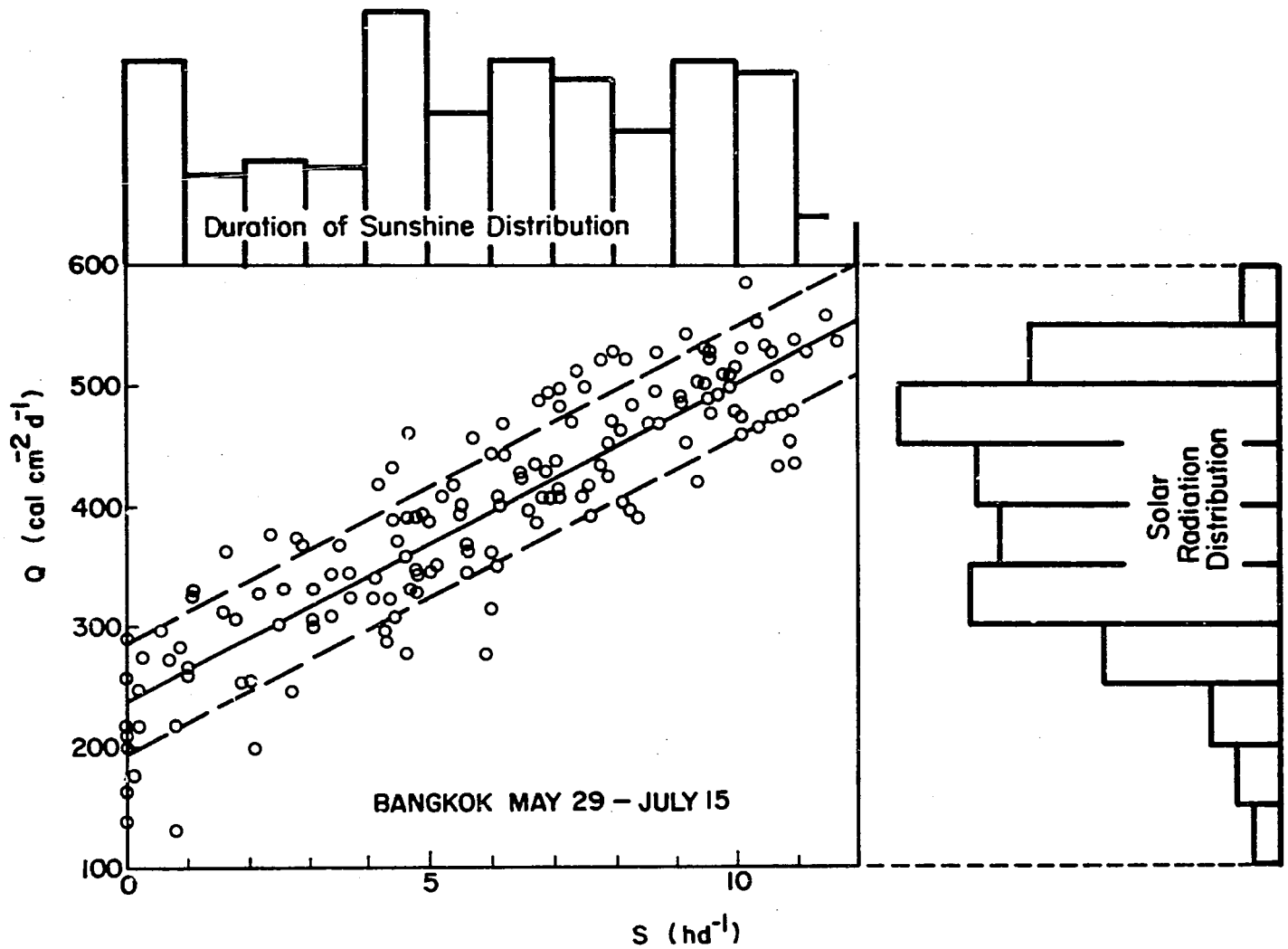

Fig. 1 – Scatter Diagram for Radiation – Sunshine Relation

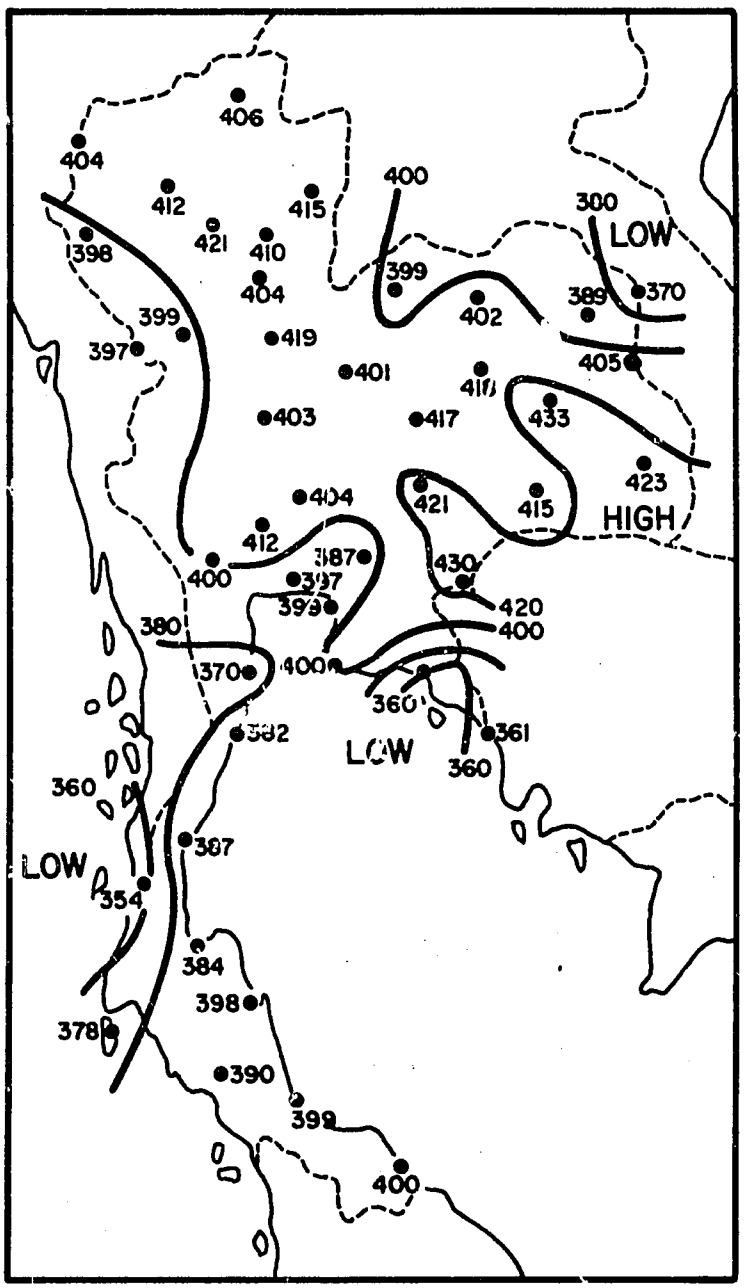

Fig. 2 – Solar Radiation (cal cm^{-2} d^{-1})
May 29 – Jul 15

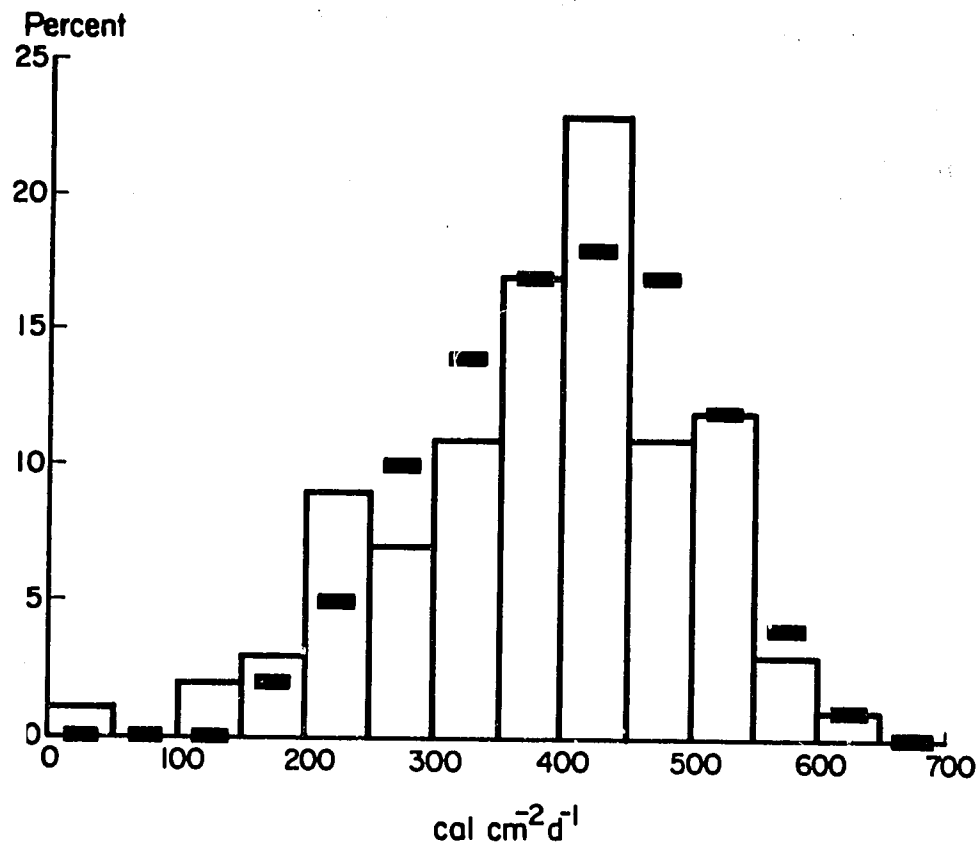

Fig. 3 - Solar Radiation Distribution
Histogram - Observed
Bars - Estimated

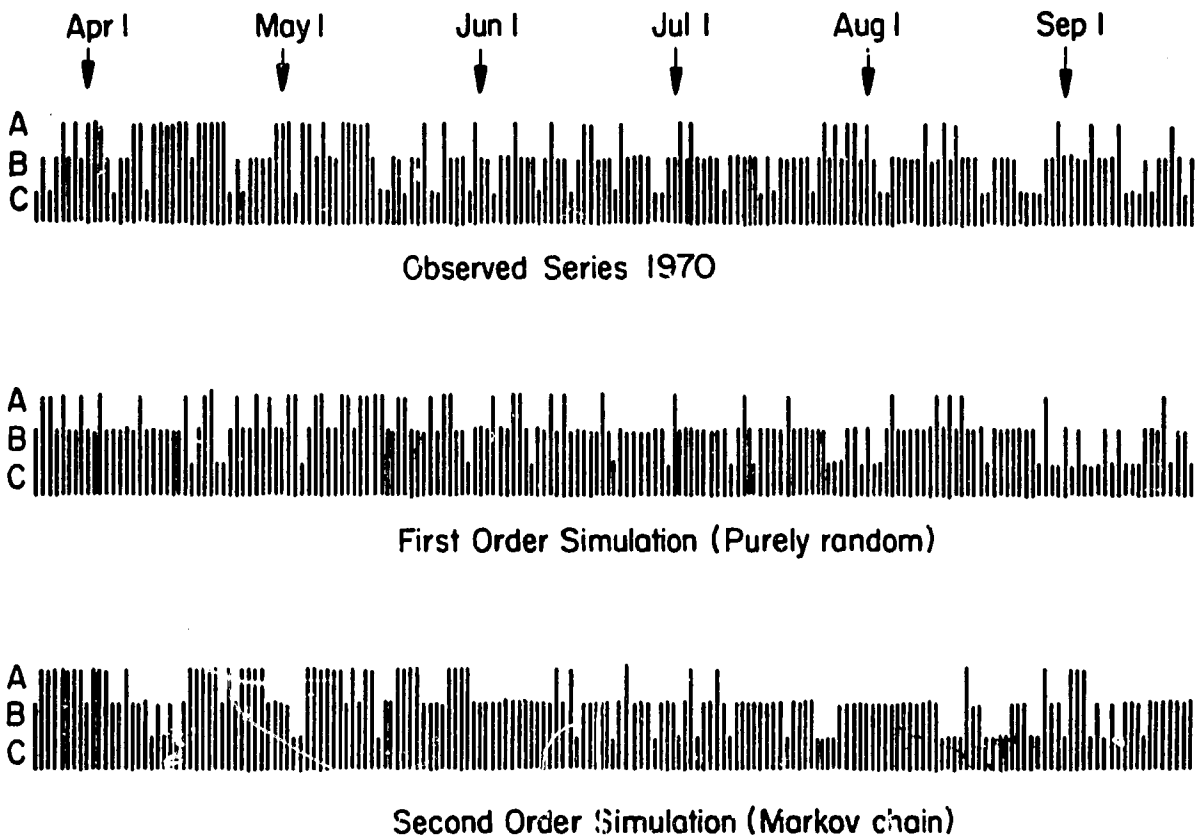

Fig. 4 – Time Series of Solar Radiation Levels of Bangkok

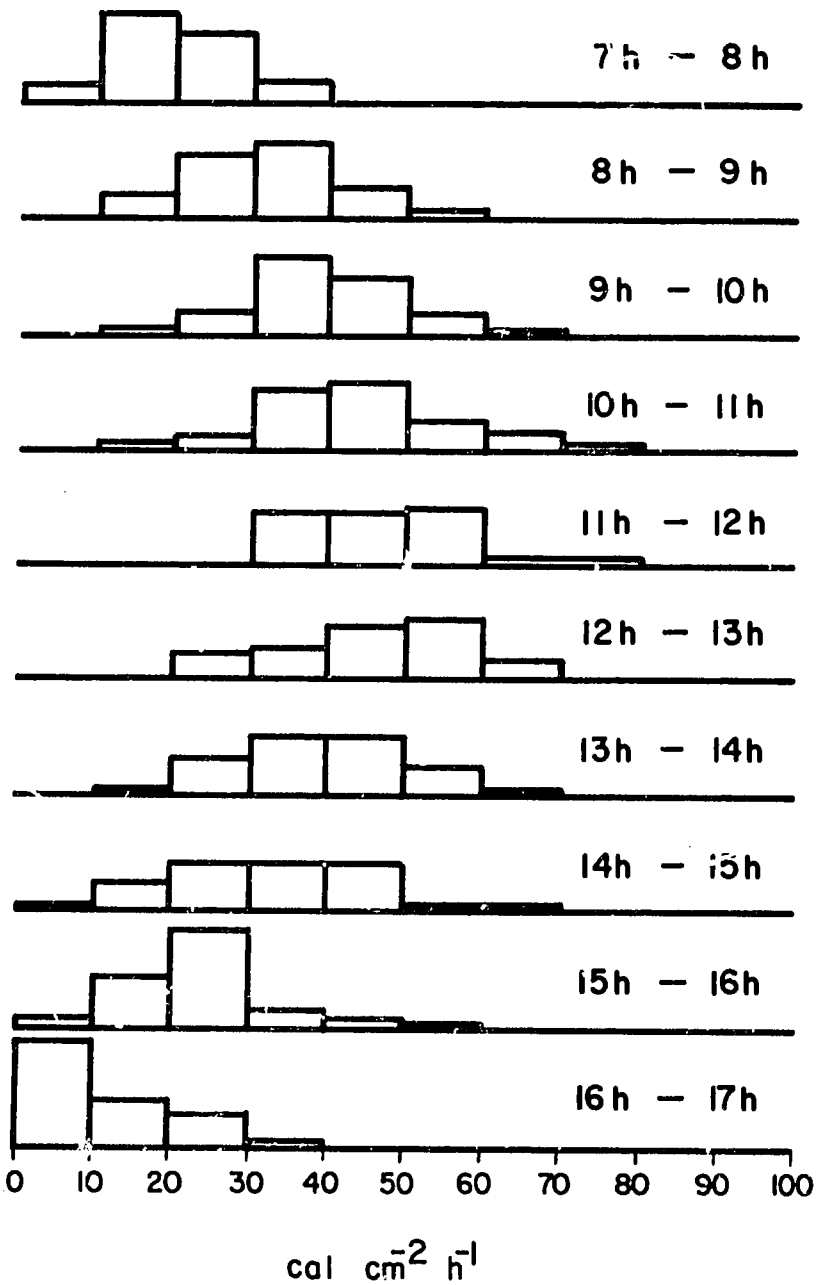

Fig. 5 – Relative frequency histograms of hourly total solar radiation at Chiang Mai for days with daily total solar radiation from 300 to 400 cm^{-2}d^{-1} in the period 29 May to 15 July

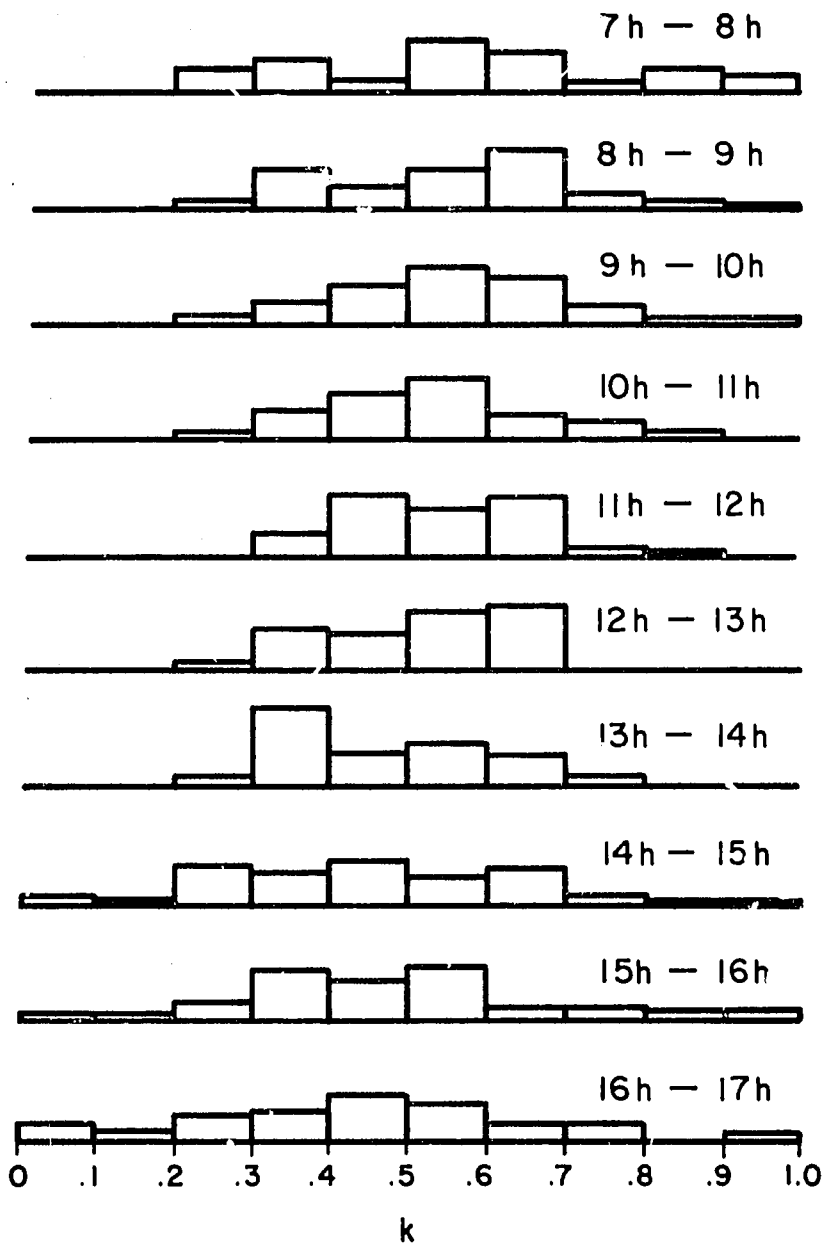

Fig. 6 – Relative frequency histograms of values of k at Chiang Mai for days with daily total solar radiation from 300 to 400 cal $cm^{-2}d^{-1}$ in the period 29 May to 15 July

A Mathematical Model for Solar Radiation in Thailand

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Abstract

A compact first order random model for simulating daily totals of solar radiation and hourly solar radiation fluxes by computer is described. It is based on detailed studies of solar radiation data for Thailand and is expected to be applicable over the entire South-East Asian peninsula. Empirical formulae (binomial distributions) have been found to give satisfactory approximations to the probability distributions needed. Consequently the model can be operated with only a modest amount of input information related to the statistics of the daily totals of solar radiation throughout the year. Provision is made for estimating the separation of the solar radiation fluxes into their direct and diffuse components.

Introduction

These notes define a mathematical model of solar radiation received at ground level in Thailand. The model provides a method for calculating daily totals of global solar radiation and hourly values of the direct and diffuse solar radiation fluxes under specified degrees of cloudiness. It also enables one to simulate these quantities as a first order random process. A computer program of the model has been written in APL. Full details are given in AIT Research Report No. M5.

Variables

ND: Day of the year, n_d. The year is assumed to have exactly 365 days. On 1 January $n_d = 1$, on 2 January $n_d = 2$, etc. On 31 December $n_d = 365$.

NP: Seasonal period, n_p. The year is divided into eight periods, defined by standard values of the solar declination, as follows:

From 14 Jan. to 26 Feb. $n_p = 1$.
From 27 Feb. to 12 Apr. $n_p = 2$.
From 13 Apr. to 28 May $n_p = 3$.
From 29 May to 15 Jul. $n_p = 4$.
From 16 Jul. to 31 Aug. $n_p = 5$.
From 1 Sep. to 15 Oct. $n_p = 6$.
From 16 Oct. to 29 Nov. $n_p = 7$.
From 30 Nov. to 13 Jan. $n_p = 8$.

PHI: Latitude, ϕ (degrees).

DELTA: Solar declination, δ (degrees).

OMEGA: Solar hour angle, ω (degrees).

ALPHA: Solar altitude, α (degrees).

ZETA: Solar azimuth, ζ (degrees), measured from south west-wards.

ALPHAPRIME: Altitude of the normal to a surface, α' (degrees).

ZETAPRIME: Azimuth of the normal to a surface, ζ' (degrees).

THETA: Angle of incidence of direct solar radiation on a surface, Θ (degrees).

GC: Global solar radiation from a clear sky, G_c (kW/m^2).

IC: Direct solar radiation from a clear sky on a surface perpendicular to the solar beam, I_c (kW/m^2).

DC: Diffuse solar radiation from a clear sky, D_c (kW/m^2).

HC: Daily total global solar radiation from a clear sky, H_c (MJ/m^2).

HD: Daily total global solar radiation, H_d (MJ/m^2).

KD: Daily clearness, k_d, defined by the equation $k_d = H_d/H_c$.

MEANKD: Mean daily clearness vector, $\bar{k}_d$. This is an 8-vector in which the i-th element is the mean value of k_d for the period $n_p = i$.

PKD: Daily clearness probability matrix, $P(k_d)$ (%). This is an 8 x 10 matrix. The i-th row $P(k_d)_i$ consists of the percentage probabilities of the values of k_d for the period $n_p = i$. The j-th element $P(k_d)_{ij}$ of the row is the percentage probability for $k_d = j/10$. The value $k_d = 0$ is not admitted.

RD: Diurnal ratio matrix for solar radiation, R_d (%). This is an 8 x 2 matrix. The i-th row $(R_d)_i$ contains the mean morning and afternoon totals of global solar radiation for the i-th period as percentages of the mean daily total. The first element $(R_d)_{i1}$ is for the morning, and the second element $(R_d)_{i2}$ is for the afternoon.

GH: Hourly global solar radiation vector, G_h (kW/m^2). This is a 13-vector in which the i-th element $(G_h)_i$ is the global solar radiation for the hour of the day i + 5.

IH: Hourly direct soalr radiation vector, I_h (kW/m^2). This is a 13-vector in which the i-th element $(I_h)_i$ is the direct solar radiation for the hour of the day i + 5.

DH: Hourly diffuse solar radiation vector, D_h (kW/m^2). This is a 13-vector in which the i-th element $(D_h)_i$ is the diffuse solar radiation for the hour of the day i + 5.

KH: Hourly clearness vector, k_h. This is a 13-vector whose elements are defined by the equation $(k_h)_i = (G_h)_i/(G_c)_i$, where (G_c) is the global solar radiation that would be obtained from a clear sky at the hour of the day i + 5.

PKH: Hourly clearness probability matrix, $P(k_h)$ (%). This is a 3 x 11 matrix. The first row $P(k_h)_1$ consists of the percentage probabilities of the values of $(k_h)_i$ for $1 \leq i \leq 6$. The second row $P(k_h)_2$ consists of the percentage probabilities of the values of $(k_h)_i$ for $i = 7$. The third row $P(k_h)_3$ consists of the percentage probabilities of the values of $(k_h)_i$ for $8 \leq i \leq 13$. The j-th element of a row is the percentage probability for $(k_h)_i = (j - 1)/10$.

Data

The daily clearness probability matrices at named stations are given below.

PKDCHIANGMAI

0	0	1	2	4	7	18	43	23	2
0	0	2	2	4	15	32	36	8	1
0	0	2	5	10	19	30	26	7	1
0	1	5	16	21	23	21	10	3	0
0	1	11	22	21	20	15	7	3	0
0	0	4	9	15	19	23	19	10	1
0	1	2	3	8	8	13	28	28	9
0	0	2	4	4	6	14	31	35	4

PKDKHONKAEN

0	1	2	3	5	12	28	34	14	1
0	1	3	4	8	22	35	23	4	0
0	0	1	6	14	23	29	21	5	1
0	1	4	12	21	26	22	12	2	0
0	1	8	18	20	21	19	10	3	0
0	2	7	11	16	19	20	16	8	1
0	1	2	2	5	9	21	30	23	7
0	0	1	2	4	8	18	32	27	8

PKDBANGKOK

1	1	1	6	7	16	29	25	11	3
1	1	2	4	6	14	29	30	11	2
0	2	4	11	15	20	21	21	5	1
1	2	7	11	20	28	18	10	3	0
0	3	7	18	28	23	13	6	2	0
2	3	9	16	20	19	17	9	4	1
1	1	3	8	12	15	18	23	16	3
0	1	2	3	5	10	18	30	27	4

PKDSONGKHLA

0	0	1	4	10	22	31	23	8	1
0	0	2	4	10	20	32	24	7	1
0	1	2	6	14	25	30	17	5	0
0	0	4	11	19	26	25	13	2	0
0	1	4	10	19	25	25	13	3	0
0	2	7	14	22	23	19	9	3	1
1	4	11	15	16	17	18	13	5	0
0	2	6	13	16	21	21	15	5	1

The diurnal ratio matrices for solar radiation at named stations are given below.

RDCHIANGMAI

51	49
51	49
53	47
52	48
53	47
51	49
50	50
50	50

RDBANGKOK

50	50
50	50
51	49
53	47
54	46
54	46
52	48
51	49

Functions

JAN, FEB, MAR, APR, MAY, JUN, JUL AUG, SEP, OCT, NOV, DEC: Each of these functions takes the day of the month as its explicit right argument and yields the day of the year as an explicit result.

DATE: This function takes no explicit argument, but yields a six-character result for the day and the month in accordance with the value of n_d.

All the functions below assign values to named variables in accordance with the values of other named variables. They take no explicit arguments and yield no explicit results.

FINDDELTA:

$$\delta = a_0 + a_1\cos t + a_2\cos 2t + a_3\cos 3t + b_1\sin t + b_2\sin 2t + b_3\sin 3t,$$

where $t = 360(n_d - 80)/365,$

$a_0 = 0.386470,$ $a_1 = -0.792624,$

$a_2 = 0.377853,$ $a_3 = 0.030124,$

$b_1 = 23{,}259526,$ $b_2 = 0.131544,$

$b_3 = -0.167013.$

FINDSOLARPOSITION:

$$\sin\alpha = \cos\phi.\cos\delta.\cos\omega + \sin\phi.\sin\delta$$

If $\alpha = \pm 90^\circ$, then $\zeta = 0^\circ$. Otherwise ζ is the solution of the simultaneous equations

$$\sin\zeta = \cos\delta.\sin\omega/\cos\alpha,$$

$$\cos\zeta = (\sin\phi.\cos\delta.\cos\omega - \cos\phi.\sin\delta)/\cos\alpha.$$

FINDTHETA:

$$\cos\Theta = \sin\alpha.\sin\alpha' + \cos\alpha.\cos\alpha'.\cos(\zeta - \zeta').$$

FINDCLEARSKYRADIATION:

If $\alpha \leq 0^\circ$, then $G_c = I_c = D_c = 0$.

Otherwise the following equations are used.

$$G_c = F\,\Sigma_{s=0}^{6}\, c_s z^s,$$

where $F = 1 - 0.0335\sin 360(n_d - 94)/365,$

$z = (1 - \alpha/90)^2,$

and $c_0 = 1.1049,$ $c_1 = -1.4354,$ $c_2 = -1.0720,$

$c_3 = 6.6849,$ $c_4 = 13.8990,$ $C_5 = 13.0798,$

$c_6 = -4.4631$

$$I_c = F \sum_{s=0}^{6} c_s z^s,$$

where $c_0 = 0.9864$, $c_1 =$ [illegible], $c_2 =$ [illegible]

$c_3 = 3.1705$, $c_4 =$ [illegible], $c_5 =$ [illegible]

$c_6 = -0.9217$,

$$D_c = G_c - I_c \sin a$$

FINDPKD:

The daily clearness probability matrix is [illegible] the help of the following equation.

$$P(k_d)_i = 100\, C_s^9\, F^s\, (1 - F)^{9-s}$$

where $F = (10(\bar{k}_d)_i - 1)/9$,

$C_s^9 = 9!/s!(9 - s)!$,

$s = 0, 1, \ldots, 8, 9$

This function is for use when $\bar{k}_d$ is [illegible]

FINDKD:

The daily clearness k_d is assigned a value at random in accordance with the percentage probabilities in the [illegible] and n_p is found from n_d.

FINDDAILYRADIATION:

Values are assigned to H_c and H_d in accordance with the following equations.

$$H_c = c_1 + c_2 \cos t + c_3 \cos 2t + c_4 \cos 3t$$
$$+ c_5 \sin t + c_6 \sin 2t + c_7 \sin 3t$$

where $t = 360(n_d - 80)/365,$

$$c_i = A_{i1} + A_{i2}x + A_{i3}x^2 + A_{i4}x^3,$$

$$x = (\phi - 12.5)/7.5,$$

and the 7 x 4 coefficient matrix A is as follows:

26.789453	-0.760391	-0.265078	-0.007734
0.092481	-0.050012	0.004731	-0.006719
1.209688	-0.025625	-0.008438	-0.005625
0.018456	-0.025926	-0.013168	0.015157
3.172571	2.431533	0.008367	-0.012203
0.112969	0.075469	0.007031	-0.037969
-0.064616	0.071846	0.005554	-0.037515

$$H_d = k_d H_c$$

FINDKH:

Each element of k_h is assigned a value at random in accordance with the percentage probabilities in $P(k_h)$. The elements of $P(k_h)$ are calculated from the following equations.

$$P(k_h)_i = 100\, C_s^{10}\, (k_i)^s\, (1 - k_i)^{10-s},$$

where $C_s^{10} = 10!/s!(10 - s)!,$

$$s = 0, 1, \ldots, 9, 10,$$

and the k_i are determined as follows:

$$k_1 = 1 - (1 - k_d)^q,$$

where $q = ((R_d)_{r1}/50)^{1.5}, \quad r = n_p;$

$$k_2 = k_d;$$

and $\quad k_3 = 1 - (1 - k_d)^q,$

where $\quad q = ((R_d)_{r2}/50)^{1.5}.$

The value of n_p is found from n_d.

Before k_h is accepted a weighted mean m of its elements defined by

$$m = \Sigma_{t=1}^{13} (k_h)_t \cos 15(t - 7)/\Sigma_{t=1}^{13} \cos 15(t - 7)$$

is compared with k_d. If $|m - k_d| < .05$, then the vector k_h is accepted. If $|m - k_d| \geq .05$, then the procedure is repeated until an acceptable vector is obtained.

FINDHOURLYRADIATION:

Values are assigned to the elements of G_h, I_h and D_h in accordance with the elements of k_h by the following method.

Let ω be a 13-vector of solar hour angles -90, -75, ..., 75, 90.

Let α be a 13-vector of solar altitudes for the hour angles in ω. If now any element of α is negative, it is replaced by a zero element.

Let G_c be a 13-vector of the global solar radiation values from a clear sky calculated for the solar altitudes in α. Then the elements of G_h satisfy

$$(G_h)_j = (k_h)_j (G_c)_j.$$

Let I_c be a 13-vector of the direct solar radiation values from a clear sky for the solar altitudes in α, and let r be a 13-vector whose elements satisfy the following conditions.

$$\text{If } \alpha_j = 0, \text{ then } r_j = 1.$$
$$\alpha_j > 0, \text{ then } r_j = ((G_c)_j - (I_c)_j \sin \alpha_j)/(G_c)_j.$$

Then the elements of D_h satisfy

$$(D_h)_j = \{1 - (.623\ (k_h)_j^{\ 2} + .227\ (k_h)_j^{\ 4})(1 - r_j)/.85\}(G_h)_j.$$

Finally, the elements of I_h satisfy the following conditions:

If $\alpha_j < 2.5$, then $(I_h)_j = 0$.

If $\alpha_j \geq 2.5$, then $(I_h)_j = ((G_h)_j - (D_h)_j)/\sin \alpha_j$.

TABLE 1

Global variables

Symbol	APL name	Symbol	APL name	Symbol	APL name
n_d	ND	Θ	THETA	$P(k_d)$	PKD
ϕ	PHI	G_c	GC	R_d	RD
δ	DELTA	I_c	IC	G_h	GH
ω	OMEGA	D_c	DC	I_h	IH
α	ALPHA	H_c	HC	D_h	DH
ζ	ZETA	H_d	HD	K_h	KH
α'	ALPHAPRIME	k_d	KD		
ζ'	ZETAPRIME	$\bar{k}_d$	MEANKD		

TABLE 2

The functions JAN to DEC

```
[1]  ∇ D←JAN N
     D←N
     ∇

[1]  ∇ D←FEB N
     D←N+31
     ∇

[1]  ∇ D←MAR N
     D←N+59
     ∇

[1]  ∇ D←APR N
     D←N+90
     ∇

[1]  ∇ D←MAY N
     D←N+120
     ∇

[1]  ∇ D←JUN N
     D←N+151
     ∇

[1]  ∇ D←JUL N
     D←N+181
     ∇

[1]  ∇ D←AUG N
     D←N+212
     ∇

[1]  ∇ D←SEP N
     D←N+243
     ∇

[1]  ∇ D←OCT N
     D←N+273
     ∇

[1]  ∇ D←NOV N
     D←N+304
     ∇

[1]  ∇ D←DEC N
     D←N+334
     ∇
```

TABLE 3

The function DATE

```
    ∇ D←DATE;M;N;I
[1] M← 12 4 p' JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT NOV
    DEC'
[2] N← 31 59 90 120 151 181 212 243 273 304 334 365
[3] I←(ND≤N)⍳1
[4] N←0,N
[5] D←(2 0  ND-N[I]),M[I;]
    ∇
```

TABLE 4

The function FINDDELTA

Preassigned variable: ND

Specified variable: DELTA

```
    ∇ FINDDELTA: T
[1] T←(ND-80)×360÷365
[2] DELTA←0.38647 + (¯0.792624×COS T) + (0.377853×COS 2×T) +
    (0.030124×COS 3×T)+(23.259526×SIN T)+(0.131544×SIN 2×T) +
    (¯0.167013×SIN 3×T)
    ∇
```

TABLE 5

The function FINDSOLARPOSITION

Preassigned variables: PHI, DELTA, OMEGA

Specified variables: ALPHA, ZETA

```
    ∇ FINDSOLARPOSITION; C; S
[1] ALPHA←((COS PHI)×(COS DELTA)×(COS OMEGA))+((SIN PHI) ×
    (SIN DLETA)
[2] ALPHA←ARCSIN ALPHA
[3] C←((SIN PHI)×(COS DELTA)×(COS OMEGA))-((COS PHI)×(SIN
    DELTA))
[4] C←C÷((89.995<|ALPHA)× C)+((89.995≥|ALPHA)×COS ALPHA)
[5] S←(COS DELTA)×(SIN OMEGA)×(COS ALPHA)
[6] ZETA←((S≥0) (S<0)) ARCCOS C
    ∇
```

TABLE 6

The function FINDTHETA

Preassigned variables: ALPHA, ZETA, ALPHAPRIME, ZETAPRIME

Specified variable: THETA

```
    ∇ FINDTHETA
[1] THETA←((SIN ALPHA)×(SIN ALPHAPRIME))+(COS ALPHA)×(COS
    ALPHAPRIME)×(COS(ZETA-ZETAPRIME))
[2] THETA←ARCCOS THETA
    ∇
```

TABLE 7

The function FINDCLEARSKYRADIATION

Preassigned variables: ND, ALPHA

Specified variables: GC, IC, Dc

```
    ∇ FINDCLEARSKYRADIATION;Z;F
[1] Z←(1-ALPHA÷90)*2
[2] F←(1-0.0335×SIN(ND-94)×360÷365)×(0<ALPHA)
[3] GC←F×(1.1049+Z×¯1.4354+Z×¯1.072+Z×6.6849+Z×¯13.899+Z×
    13.0798+Z×¯4.4631)
[4] IC←F×(0.9864+Z×¯0.2001+Z×¯1.1883+Z×3.3705+Z×¯5.7674+Z×
    3.7206+Z×¯0.9217)
[5] DC←GC-IC×SIN ALPHA
    ∇
```

TABLE 8

The function FINDPKD

Preassigned variable: MEANKD (8-element vector)

Specified variable: PKD (∘ x 10 matrix)

```
    ∇ FINDPKD;P;S
[1] P←(MEANKD-0.1)÷ 0.9
[2] S←(⍳10)-1
[3] PKD←((8⍴100)∘.×(S!9))×(P∘.*S)×((1-P)∘.*(9-S))
    ∇
```

TABLE 9

The function FINDKD

Preassigned variable: ND (scalar), PKD (8 x 10 matrix)

Specified variable: KD (scalar)

```
    ∇ FINDKD;NP
[1] NP←+/ND≥(14 58 103 149 197 244 289 334)
[2] NP←NP+8×(NP=0)
[3] KD←0.1×1 RANDOM PKD[NP;]
    ∇
```

TABLE 10

The function FINDDAILYRADIATION

Preassigned variables: PHI (scalar), ND (scalar), KD (scalar)

Specified variables: HC (scalar), HD (scalar)

```
    ∇ FINDDAILYRADIATION;X;T
[1] X←((PHI-12.5)÷7.5)* 0 1 2 3
[2] T←(ND-80)×360÷365
[3] T←1,(COS 1 2 3 ×T),(SIN 1 2 3 ×T)
[4] HD←KD HC←+/(COEFFICIENTS+.×X)×T
    ∇
```

TABLE 11

The function FINDKH

Preassigned variables: ND (scalar), KD (scalar), RD (8 x 2 matrix)

Specified variable: KH (13-element vector)

```
∇ FINDKH;NP;S;K;PKH;M
[1] NP←+/ND≥(14 58 103 149 197 244 289 334)
[2] NP←NP+8×(NP=0)
[3] S←(⍳11)-1
[4] K←1-(1-KD)*(RD [NP;]÷50)*1.5
[5] K←K[1],KD,K[2]
[6] PKH←((3⍴100)∘.×(S!10);×(K∘.*S)×((1-K)∘.*(10-S)))
[7] KH←13⍴0
[8] KH[⍳6]←0.1×(6 RANDOM PKH[1;])-1
[9] KH[7]←0.1×(1 RANDOM PKH[2;])-1
[10] KH[7+⍳6]←0.1×(6 RANDOM PKH[3;])-1
[11] M←+/KH×(0 0.034 0.066 0.093 0.114 0.127 0.132 0.127 0.114
     0.093 0.066 0.034 0)
[12] →(0.05≤|M-KD)/8
     ∇
```

TABLE 12

The function FINDHOURLYRADIATION

Preassigned variables: PHI (scalar), ND (scalar), DELTA (scalar), KH (13-element vector)

Specified variables: OMEGA (13-element vector), ALPHA (13-element vector), ZETA (13-element vector), GC (13-element vector), IC (13-element vector), DC (13-element vector), GH (13-element vector), IH (13-element vector), DH (13-element vector)

```
∇ FINDHOURLYRADIATION;R
[1] OMEGA←15×(⍳13)-7
[2] FINDSOLARPOSITION
[3] FINDCLEARSKYRADIATION
[4] GH←GC×KH
[5] R←(DC+(ALPHA≤0))÷(GC+(ALPHA≤0))
[6] DH←(1-(KH×KH×0.733+KH×KH×0.267)×(1-R))×GH
[7] IH←(GH-DH)÷((SIN ALPHA)+ ALPHA< 2.5)×1 25)
∇
```

TABLE 13

Trigonometric and inverse trigonometric functions

```
∇ Z←COS A
Z←200A÷180
∇

∇ Z←SIN A
Z←100A÷180
∇
```

```
∇ Z←ARCCOS Y
Z←(¯20Y)×180÷○1
∇

∇ Z←ARCSIN Y
Z←(¯10Y)×180÷○1
∇
```

TABLE 14

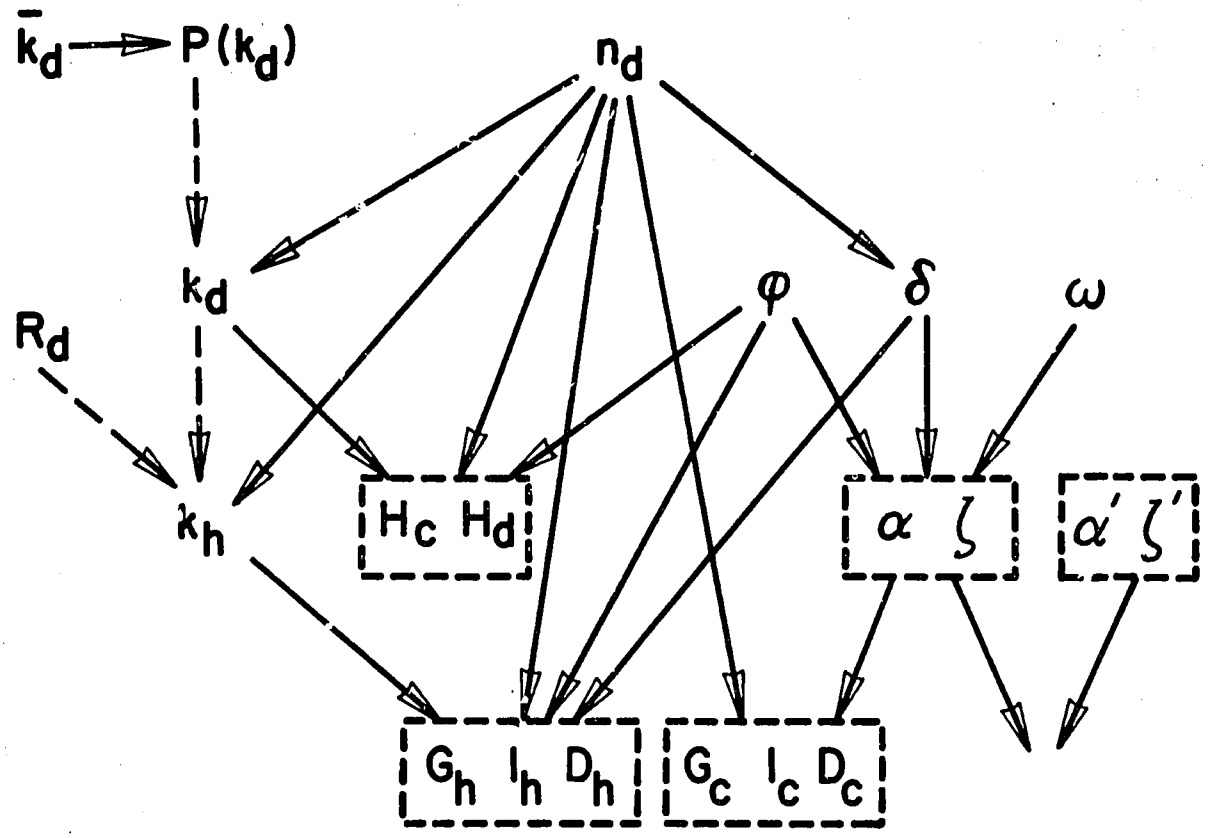
The function RANDOM

```
      ∇  I←N RANDOM P;C
[1]   I←N⍴0
[2]   C←0
[3]   C←C+1
[4]   I[C]←((?100)<⌊0.5+⍎/ )⍳1
[5]   →(C<N)/3
      ∇
```

TABLE 15

Example of a simulation Function

```
      ∇ SIM
[1]   ND←0
[2]   ND←ND
[3]   FINDDELTA
[4]   FINDKD
[5]   FINDKH
[6]   FINDHOURLYRADIATION
[7]   N←0
[8]   N←N+1
[9]   DATE,(4 1  KD),(4 1  KH[N]),(6 2  DH[N]),(6 2  GH[N]),
      ((⌈35×DH|N|)⍴' '),'D',((⌊35×GH|N|-DH|N|)⍴' '),'G'
[10]  →(N<13)/8
[11]  →((ND+15)<365)/2
      ∇
```



Relations of Dependence between Main Variables.

Table 4.16 – Example of a Simulation Program

```
      PHI←13 .73
      PKD← PKDBANGKOK
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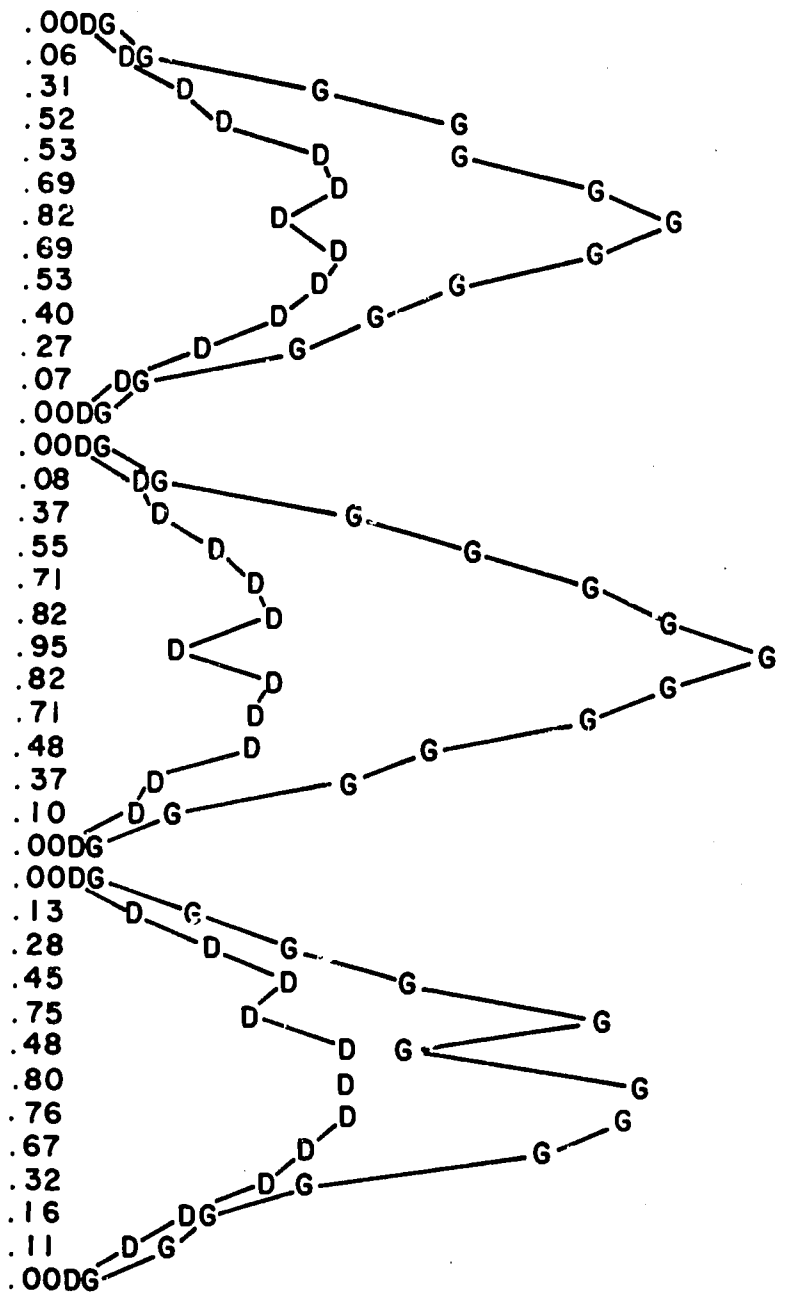

Windmill Technologies Development In Thailand

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Thailand Institute of Scientific
And
Technological Research, Bangkok, Thailand

Introduction

Wind is a form of renewable energy which is always in a non-steady state due to the wide temporal and spatial variations of wind velocity. As a result, it is extremely difficult to develop a windmill with optimal performances although considerable R & D efforts in this direction have been made.

In Thailand, various designs of windmills for water pumping have been developed and some designs are presently manufactured commercially. At present, there are reportedly several thousand windmills for water pumping in operation throughout the country. However, windmills are not yet used for electricity generation.

This paper presents an overview of windmill applications for water pumping in Thailand. The estimated wind energy potential is reviewed and various existing designs are discussed. It is hoped that the paper will clearly portray the present status of windmill technology in Thailand.

Wind energy potential in Thailand

Based on a number of assumptions, simplifying, PINICH and others (1981) estimated the total wind energy potential in Thailand to be 4.4×10^{10} kw-hr. Figure 1 shows a map of Thailand with isolines of average wind potential energy plotted from the average wind power per unit land area for 53 stations in the country as shown in Table 1. The figures for each station were obtained from the analysis of wind velocity data recorded at 3 hour intervals. The data covered a 13 year period from 1965 to 1978.

The velocity data were transformed to the velocity at 10 m height from the ground using the Forst equation. The available wind power per unit area was then calculated assuming uniform distribution of the wind velocity all over the unit area.

In the application of these results, there are some factors which should be considered. First, the actual output power measured from a windmill is lower than that of the theoretical value. The difference depends on the design and efficiency of a windmill. Second, installations of windmills at over 10 m height will get more power than those at 10 m height. Third, the average power value shown in Table 1 and Figure 1 were obtained from the analysis of data of wind velocities which varied from 0 m/s to the maximum measured value. The values of starting and stopping operation were not considered in the calculation.

Consequently, the magnitudes of wind energy potentials at the meteorological stations should be applied with some reservations. However, they would be valuable for preliminary site selection.

Development of Windmill in Thailand

Several governmental and private organizations are presently involved in development of windmills primarily for water pumping. The reason that more attention is paid to windmills for water pumping is the simplicity of water pumping systems when compared to power generation systems. Another reason is a great demand in rural areas for mechanical lifting of water for irrigation. Compared with other alternative renewable energy sources such as solar and biomass, wind energy seems to be more economical and simple.

Several types of windmills are used for water pumping including the Sail Wing type, Wooden Turbine Blade type, Multi-Blade type, Savonius type, and Augmented Turbine type windmill (see Fig. 2,3). Details of all the above-mentioned windmills are given in Table 2. These windmills are designed to have a low revolution speed and use a crankshaft to a reciprocating

for power transmission to a pump. Typically, a water lifting system using a windmill consists of 4 major parts which can be briefly described as follows:

1. Turbine Blade. Turbine blades are made of various kinds of materials such as wood, bamboo mat, sail cloth, metal, etc. Each turbine blade is shaped in such a way that aerodynamic force acting upon it creates as much torque as possible. The number of blades and the blade diameter vary directly with the designed load i.e. total dynamic head, and pumping capacity. Data for one commercial type windmill are presented in Table 3.

2. Turbine Shaft. The turbine shaft is the most important part of the system. It must be strong enough to withstand the torque and the centrifugal force created by the rotation of turbine blades. Therefore, it should be made of a special grade of steel.

3. Turbine Tail. This part of the system serves as turbine controller. It turns the turbine automatically to face the wind. In addition, when coupled with a cam it automatically stops the blade rotation if wind speed is too great.

4. Pump. Normally, a piston pump is coupled with the windmill because of its low rpm requirement. It has been proved to have good performance and durability. The cylinder should be made of stainless steel lined with brass alloy hard enough to withstand friction between itself and the piston. The piston size varies directly with the diameter and number of turbine blade to balance the power output with the designed load as shown in Table 3.

Performance of Sail Wing Type Windmills

The National Energy Administration (NEA) has evaluated the performance of sail wing type windmills like the one shown in Figure 4 for water pumping. The system consists of 8 sail wings attached to 5.40 m long wooden spars. Each sail wing is coated with plastic and its area varies from 2

to 4 m^2. The V-shape tail is made of bamboo mat and the turbine shaft is made of steel supported with Teper ball bearings. The piston pump is made of thick P.V.C. with an inner diameter of 76 mm. (3 in.) and the piston ring is made from camel leather. The piston moving distance is 125 mm.

Results of the performance tests are summarized in Figures 5, 6, and 7. The power output of the windmill at an average wind velocity of 9 km/hr as determined from Figures 5 and 6 is approximately 12.7 watts. The system is capable of pumping water by the rate of 13 litre/min (600 m^3/month) at a total discharge head of approximately 6 m. The system starts to operate at an approximate wind velocity of 5-6 km/hr and stops operating at that of 3 km/hr.

This particular type of windmill is easier to manufacture than the metal multi-blade type windmill. For the same capacity and head, the sail wing type windmill is likely to be less expensive than the metal multi-blade type windmill. However, whether it will be more economical would depend on its working life. Unfortunately, there are no relevant data available. Therefore, a concrete conclusion cannot be drawn on the economic aspect of the sail wing windmill.

Conclusions

The following major conclusions may be drawn:

1. The total wind potential at 10 m height was estimated to be 4.4×10^{10} kw-hr. The estimation was based on the analysis of wind velocity data collected at 53 meteorological stations scattered all over the country. The estimated figures for each individual station should be applied with some reservations. In general, the data are useful for preliminary selection of windmill sites.

2. At present, several types of windmills are used in Thailand for water pumping. Their designs, materials, efficiencies, and prices were found to vary significantly as would be expected. However, their cost-

effectiveness could not be compared due to the lack of standard performance data.

3. A few designs of sail wing type windmill were tested and the power output was found to be 12.7 watts at the 9 km/hr wind velocity. The system has a pumping capacity of 13 litre/hr (600 m^3/month) at a total discharge of approximately 6 m.

REFERENCES

1. Pinich, Banterng, Boonchai, and Kwan., Estimated Wind Energy Potential in Thailand, July 1981.

2. B. Sowantragul., Theory and Design of Wind Turbine, Dec. 1978.

3. S. Nantasri., Present Uses of Wind Turbine in Thailand, Dec. 1978.

4. Summary report, Seminar on Solar and Wind Energy, National Research Council, Bangkok, 1981.

5. National Energy Administration, Paper No. WE 002-P2, The Performance Test of 8 Sail Wings Type Windmill Model WE 002, 1981.

TABLE 1

Average Wind Power Potential

Place	Wind Power Potential (kw/km^2)	Place	Wind Power Potential (kw/km^2)
Bangkok	6.184	Kanchanaburi	8.509
Koh Samui	29.592	Koh Sichang	19.038
Khon Kaen	5.448	Phumipol Dam	6.576
Khlong Yai	8.379	Chanthaburi	3.977
Chon Buri	14.216	Chum Phon	24.125
Chaiyaphum	9.515	Chiang Rai	3.800
Chiang Mai	5.507	Sap Muang	6.561
Don Muang	40.970(25.43)	Trang	20.728
Tak	10.577	Nakhon Phanom	5.324
Korat	4.391	Prachuap Khiri Khan	17.996
Nakorn Si Thammarat	8.722	Narathiwat	11.943
Nan	2.122	Pattani	12.021
Prachin Buri	5.411	Phetchabun	6.184
Phitsanulok	2.010	Phuket	6.121
Phrae	5.349	Mukdahan	11.020
Phuket Airport	28.968	Mae Sariang	2.440
Mae Sot	11.227	Roi Et	6.775
Mae Hong son	1.525	Lop Buri	7.537
Ranong	8.163	Lam Pang	3.081
Loei	5.239	Songkhla	32.799
Sakhon Nakhon	9.885	Surin	4.279
Suphan Buri	9.091	Sattahip	36.292
Surat Thani	4.732	Hat Yai	16.972
Nong Kai	4.099	Aranyaprathet	4.360
Hua Hin	13.120	Udon Thani	2.483
Uttaradit	1.364	Ubon Ratchathani	17.372

SOURCE: Pinich, Banterng, Boonchai, Kwan., Estimated Wind Energy Potential in Thailand. July 1981.

TABLE 2

Types of Windmill for Water Pumping

Nomenclature	No. Of Use	Manufacturer	Price (Baht)	Technical Data
A. Popular Used Windmills				
1. Bamboo Mat Sail Type	3000	Villager, Local factory	9,500	Blade Dia.: 6-8m Pumping Cap.: 46m^3/hr Total Lift Head: 0.6m Wind Velocity: 13km/hr
2. 2-4 Wooden Blades Type (Cha Chueng Sao)	2000	Villager, Local factory	1,200	Blade Dia.: 6-8m Pumping Cap.: 90m^3/hr Total Lift Head: 0.9m Wind Velocity: 21km/hr
3. Multi-Blade Type (U.SA.)	1500	Thai U.SA.	See Table 3	See Table 3
4. Multi-Blade Type	300	Chonburi	Unknown	Unknown
B. New Developed Windmills				
1. Sail Wing Type (NEA)	10	National Energy	12,000	See section 4
2. Sail Wing Type (K.U.)	3	Kasetsart University	12,000	Blade Dia.: 4m Pumping Cap.: 1.7m^3/hr Total Lift Head: 4.5m Wind Velocity: 10-12km/hr
3. Cycle Wheel Type	2	Songkhla University	12,000	Blade Dia.: 3.2m Shaft Power: 125w. Wind Velocity: 3m/s
4. Multi-Blade Type	8	King Mongkut Institute of Technology	33,000	Blade Dia.: 3-4m Piston Dia.: 4 in. No data test
5. Sail Wing Type	20	American Volunteer	Unknown	Designed by Sahores
6. Savonious Type	10	Several Organizations	Unknown	Low efficiency
7. Augmented Turbine	2	Kamthorn Plysummit	Unknown	Sail Wing Dia.: 3.8m Turbine Dia.: 1.2m Height of Turbine: 1.2m Pumping Cap.: 0.46m^3/min Total Lift Head: 0.5m Wind Velocity: 10km/hr

SOURCE: Summary Report, Seminar on Solar and Wind Energy, National Research Council, Bangkok, 1981.

TABLE 3

Technical Data of Multi-Blade Type Windmill

Dim. of Turbine Blade (ft.)	Height of Structure (m.)	No. of Blades	Dia. of Piston (in.)	Rate of Water Pumping (litre/hr)	Wind Velocity km/hr	Price (Baht)
20	15	45	18	24,000	10	120,000
18	15	45	16	20,000	10	100,000
16	15	45	12	16,000	10	93,000
14	15	30	10	12,000	10	71,500
14	15	30	6	6,000	10	64,000
12	15	30	4½	2,500	10	51,000
10	15	30	3	2,000	10	35,000
8	15	20	2½	1,200	10	28,000

SOURCE: Thai U.S.A. Industrial Factory

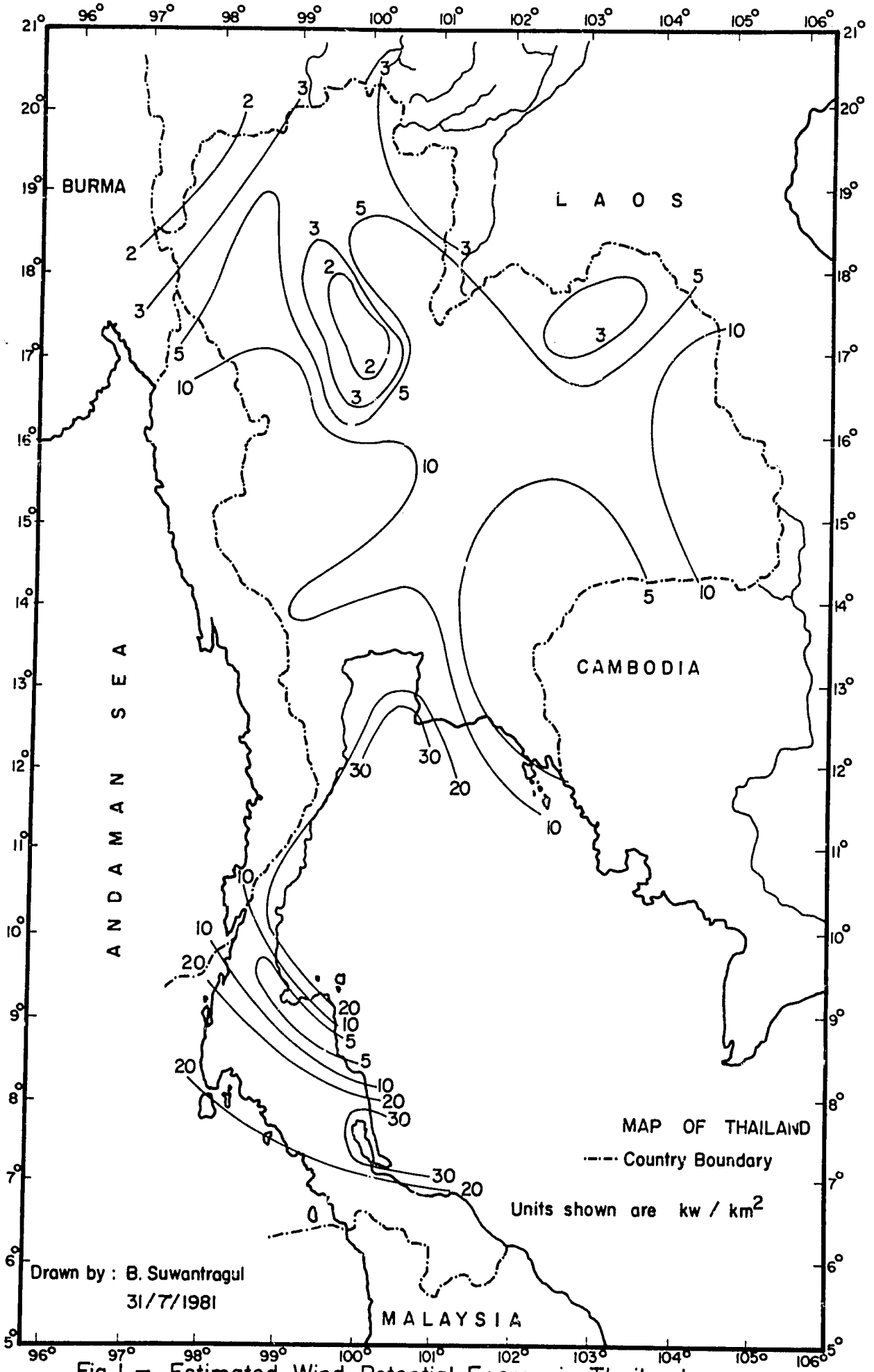
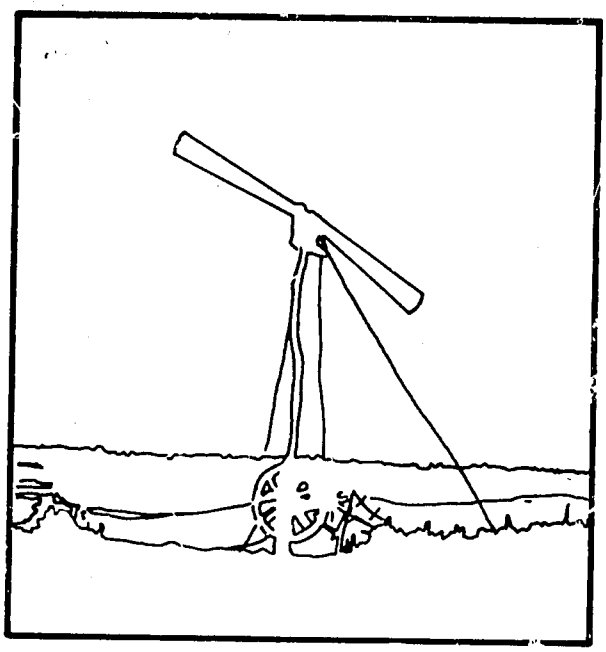
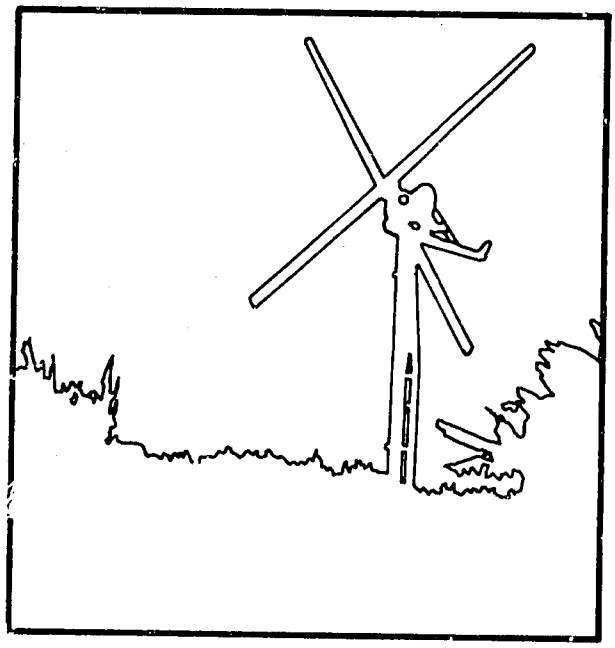


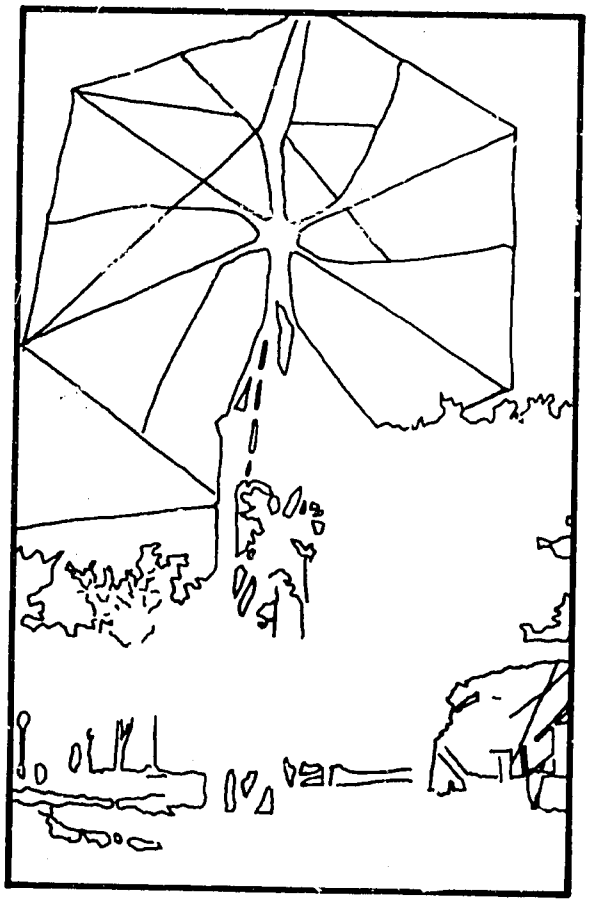
Fig. 1 – Estimated Wind Potential Energy in Thailand



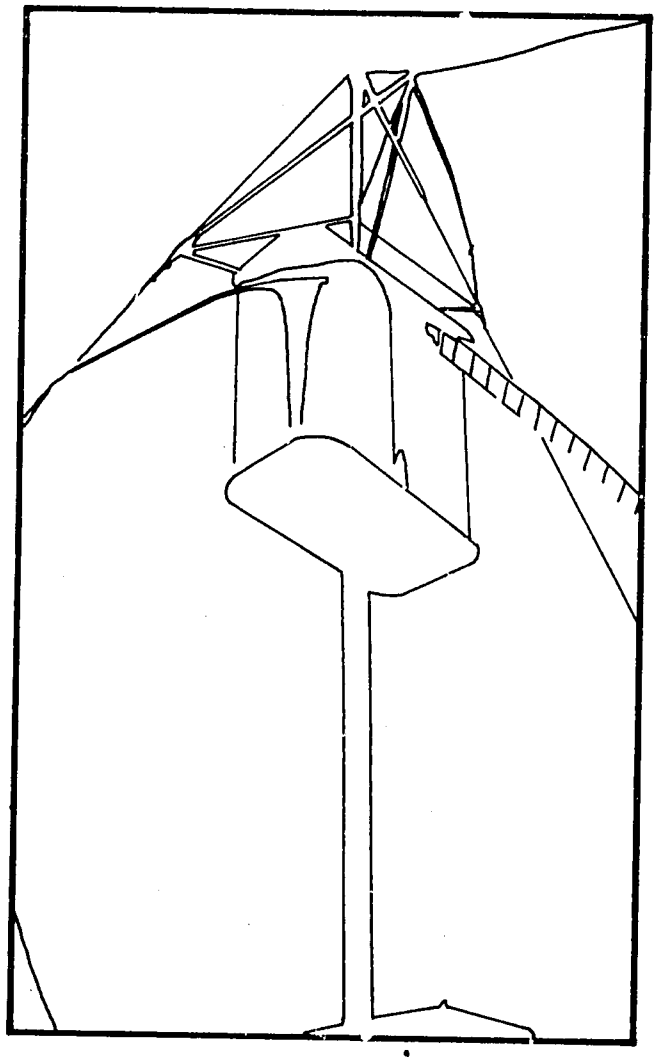
2 Wooden Blades Type



4 Wooden Blades Type

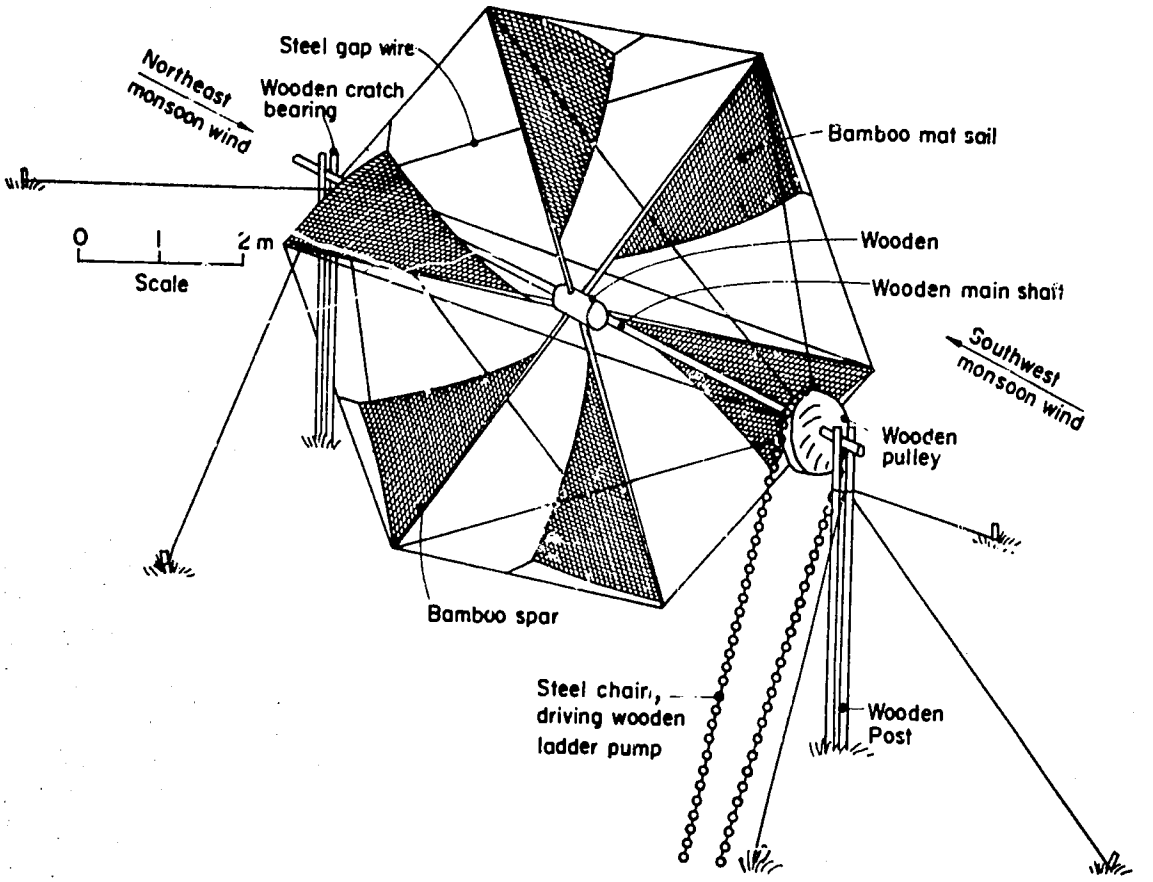


Sail Wing Type

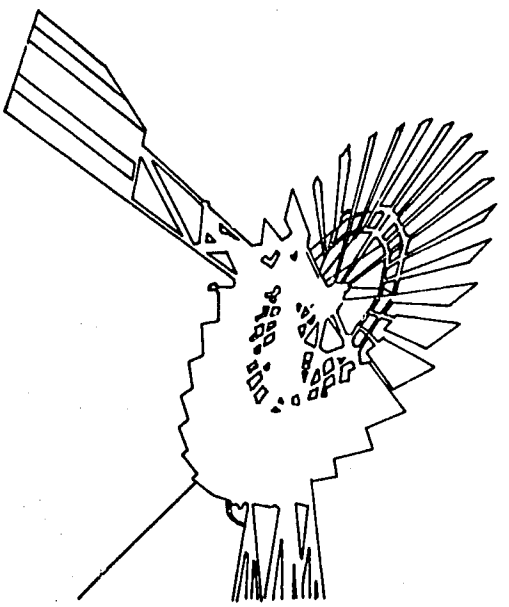


Savonious & Darious Type

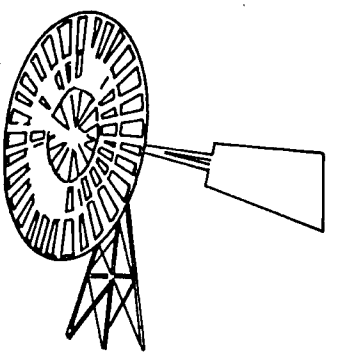
Fig. 2



Bamboo Mat Sail Type



Metal Multi-Blade Type



Cycle Wheel Type

Fig. 3

8 Sail Wings Type Windmill
manufactured
by
National Energy Administration (N E A)

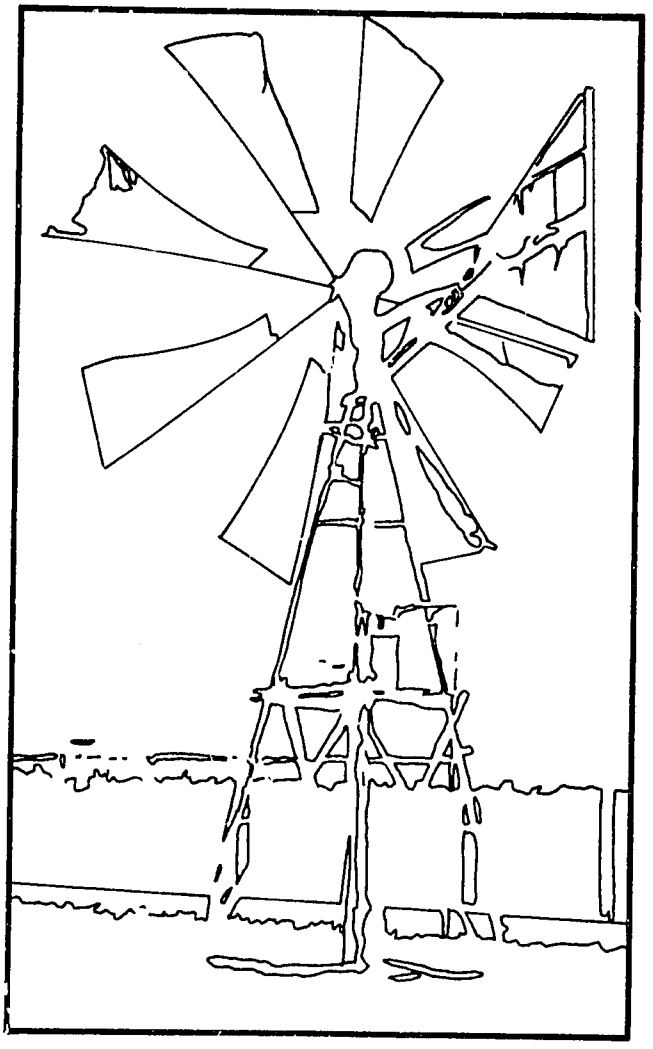


Fig. 4

Blade diameter: 6 m, turnable to face the wind for all direction

Piston diameter: 76 mm.

Operating wind velocity: 5-20 km/hr

Pumping capacity: 7,000 m^3/hr

Total discharge head: 6 m

Applications: pumping water for consumption and cultivation

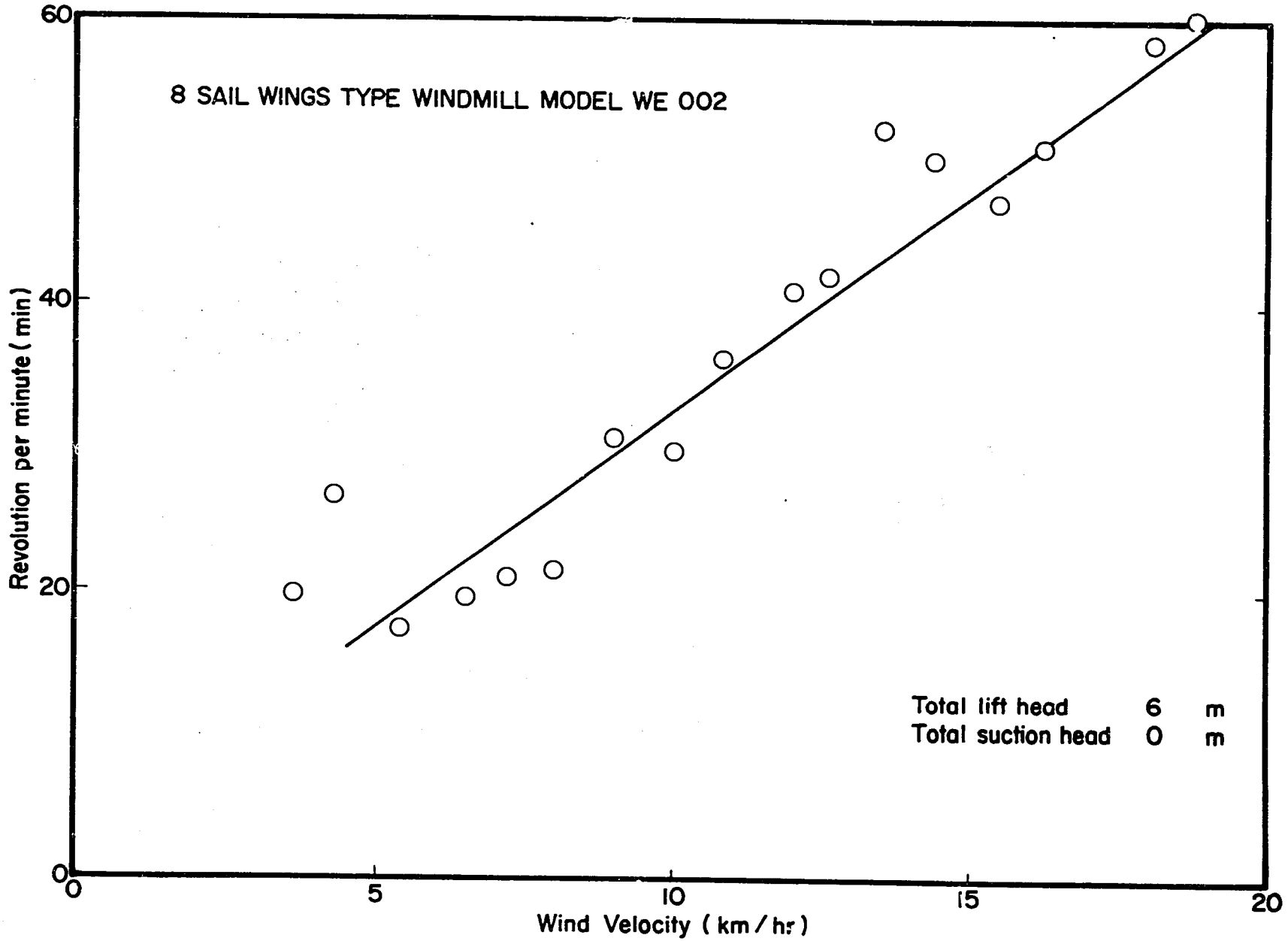


Fig. 5 – Revolution vs Wind Velocity (Piston reciprocating pump single acting Ø 7.6 mm Type wp2)

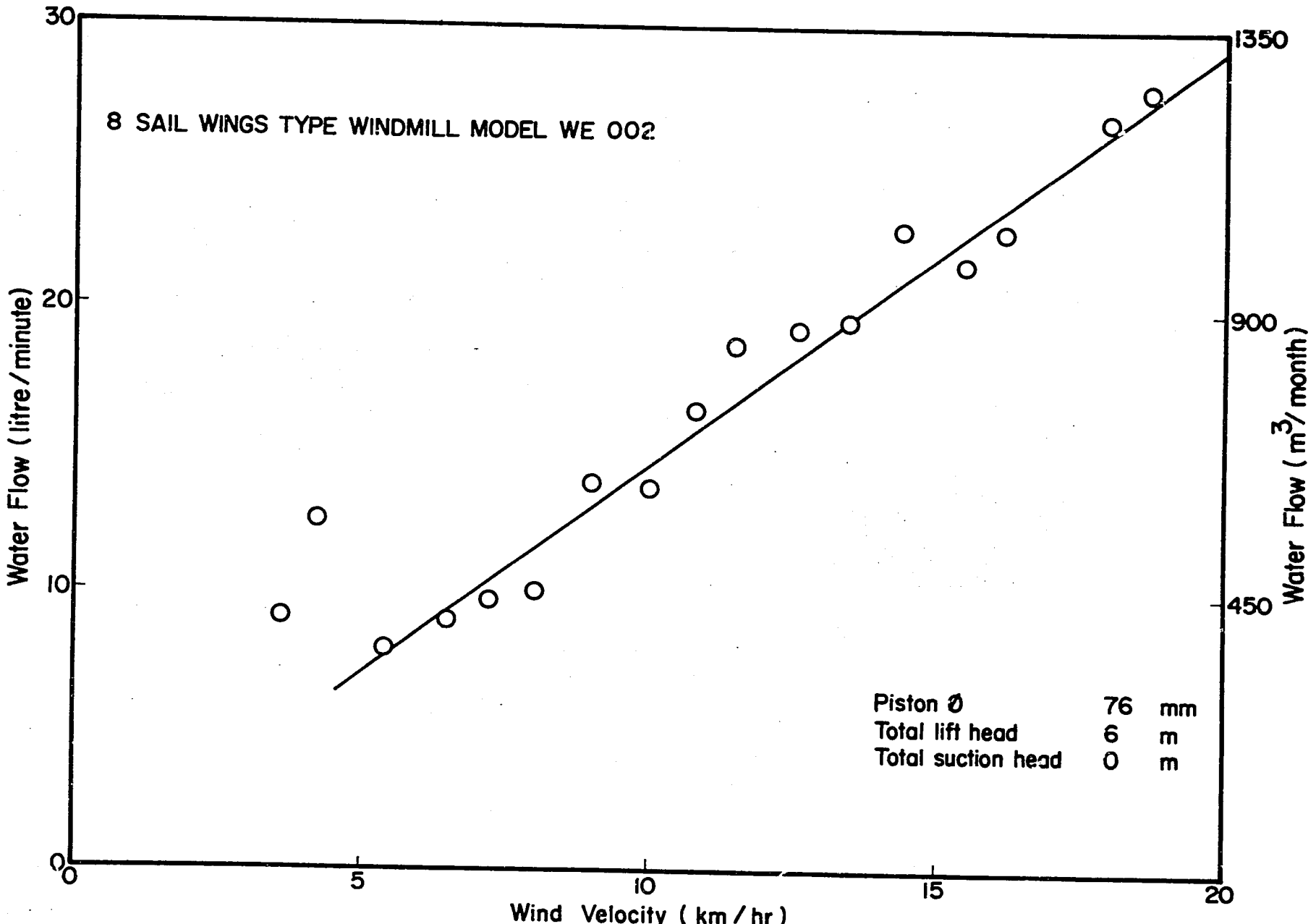


Fig. 6 - Flowrate vs Wind Velocity (Piston reciprocating pump-single acting Type wp 2)

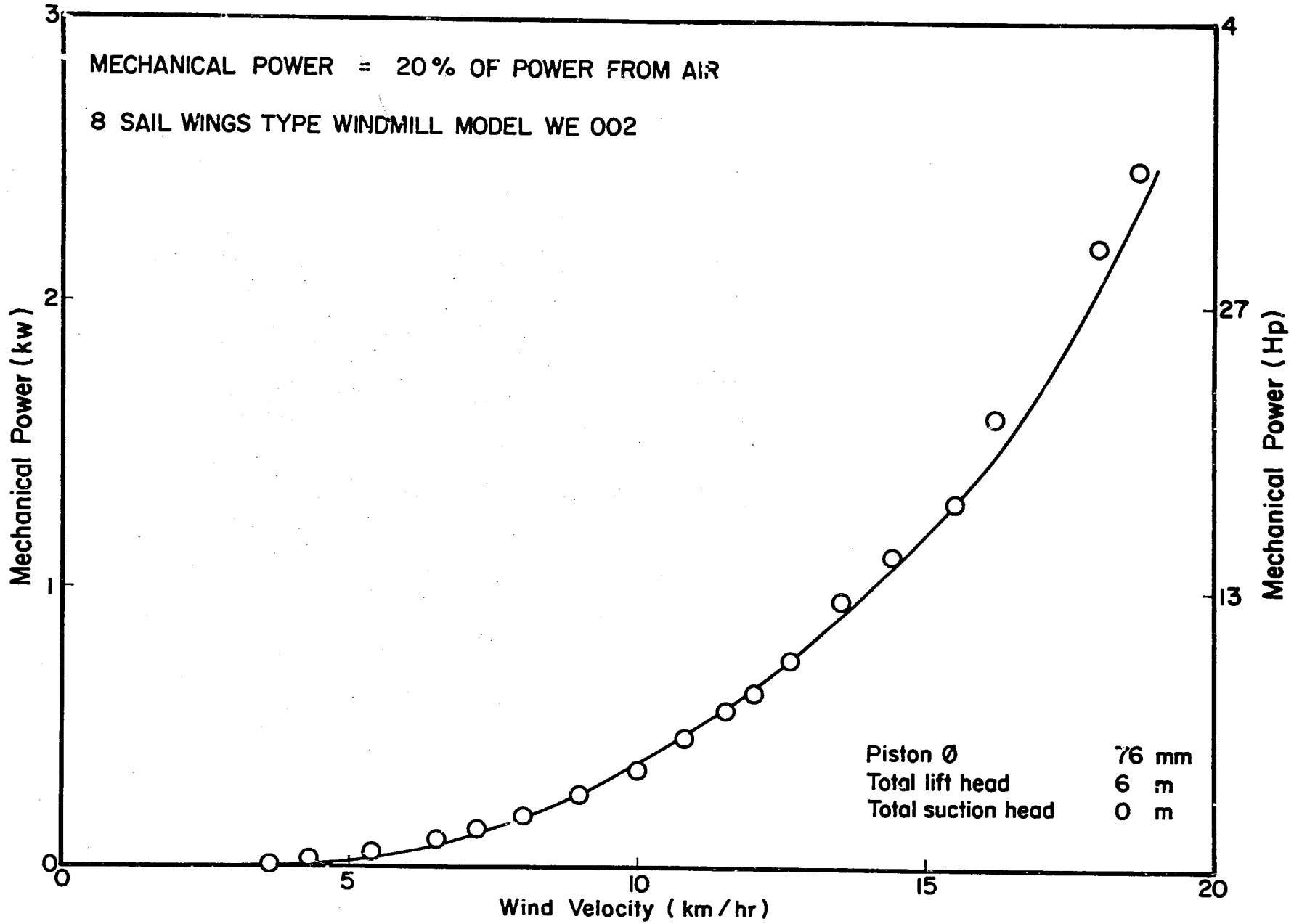


Fig. 7 – Power vs Wind Velocity (Piston reciprocating pump-single acting Type wp 2)

Solar Energy: Teaching and Research Programmes At Department of Physics Universiti Kebangsaan Malaysia

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Bangi, Selangor

Abstract

This paper presents the teaching and research programmes on solar energy at Universiti Kebangsaan Malaysia. The importance of energy curriculum in the teaching of physics in the form of both lectures and laboratory exercise for the undergraduates are discussed.

The current and future research programmes on solar energy are also given. These includes the expansion of research facilities for measurement of basic data, and development of material characterisation laboratory.

Introduction

The role of institutions of higher learning such as UKM, and other universities in the ASEAN region, in pioneering research programmes on energy is an important one. At a time when the world is seeking new sources of energy to replace petrol, the role entrusted to us, university teachers, is even more demanding. Only through research and development programmes, and the development of awareness among the younger generation can the substitution of conventional energy be speeded up.

It is also the role of UKM to educate the undergraduates on the science of energy. This can be done through both lectures and experimental work.

In this paper, we shall present to you the courses offered to undergraduates at our physics department. These courses are a modification of

the normal trend of physics teaching in universities, and include topics on energy and problems that are more relevant to the national interest. The laboratory exercises are also geared to introducing more experiments that have direct relevance to the courses.

We shall also present to you the research programmes that have been done in the department. The research is very basic and has contributed little to the national programme. However, in the next stage of our research we plan to do more, given the correct funding and assistance.

Undergraduate courses

The physics curriculum at undergraduate level is normally based on the following topics:

a. mechanics
b. thermodynamics
c. sound and waves
d. optics
e. electricity and magnetism
f. electromagnetic theory

The above courses are well known as classical physics, developed before the nineteenth century. During the later stages of training, i.e. in the third and fourth years such courses as quantum mechanics, relativity, solid state, nuclear physics and electronics are taught as compulsory or elective courses.

Such a physics curriculum has been reviewed by:
Jafri (in Phys. Educ. 14, 120, 1979.)

the courses are remarkably rigid and stero-typed and are heavily biased towards the tranmission of a large volume of information. Physics is presented as a closed dogmatic system of immutable laws which can only be studied in the language of mathematics. This dampens the enthuasiasm of many students and alienates them from the subject.

The subject of energy is traditionally given in topics like thermodynamics and mechanics. This then spreads further into conservation laws and the different types of energy. A block diagram of typical topics found in most textbooks is shown in Figure 1. This approach is, however, disadvantageous to those students with poor backgrounds.

Figure 2 gives the physics courses offered at our university. The shaded blocks indicate that these courses need to be modified to include topics that are of relevance to energy problems. For the third year undergraduates, we have an elective course on energy physics. Topics in this course include, survey of energy resources, solar radiation, and solar energy utilization.

Figure 3 illustrates the relationship between pure physics and solar technology. This figure does not give the whole spectrum of physics. A reformulation of optics, thermodynamic and heat transfer should be seriously considered, bearing in mind the background of the national problems.

For laboratory teaching, we introduce teaching units that will give the students direct experience on energy conversion practices in addition to the standard mechanical heat and optic experiments. These experiments include a heat pump, refrigeration, two phase heat exchanger, and photocell units along with various techniques of temperature measurement.

In the final year, students undertake project topics under supervision of the teaching staff. Topics that have been dealt with thus far include, refrigeration, solar cooking, mechanical heat pump, photovoltaic cells, solar radiation, and measurement of the effects of atmospheric pollution on solar collectors.

Finally, the student is required to submit and present a seminar report to the members of the department.

The Postgraduate Courses

For postgraduates we offer the following course work cum research:

a. Physics of materials

b. Solar Energy

c. Biophysics

d. Physics Education

Currently, we only have one postgraduate student and he is taking solar energy for his course work, and solar energy refrigeration for his research. It is too early to assess the success of this programme, but given funds and assistance we will work hard to achieve success.

Research

Most of the experimental research on solar energy has been carried out as students' projects. The students, all of whom are in their final year, are each given a topic to work on, supervised by one lecturer. The project normally takes two semesters to complete, at the end of which a report has to be submitted.

Some of the areas that have been researched include, mechanical heat pumps, refrigeration systems, solar cooking, solar collectors and photovoltaic cells. Two staff research projects are currently being carried out. The first one is on SnO_2 thin film selective surfaces. This research project is funded by a university research grant. Since this work is at a preliminary stage, we do not have any result as yet. The second project is on a solar steam cooker. This project is an extension of some earlier projects carried out by final year students.

Instrumentation

We do not have the appropriate instrumentation to pursue research on solar energy. As a result we have used simple and basic laboratory equipment. The department must expand the instrumentation facilities if we want to do more research on this field.

The shopping list now includes a pyrheliometer (Kipp & Zonnen CM 12),

prynometer, radiation balance and reflectometer. For sample preparation and characterisation, we shall have a SEM with EDS, chemical vapour deposition equipment, argon arc furnace, radio frequency furnace, electric furnace and a spark erosion machine. Also included are data collection and processing equipment, a 96 K RAM microprocessor with 500K storage and digital thermometer.

We hope that most of the above equipment will be with us before the end of this year.

Conclusion

1. In the past few years, since introducing the new physics curriculum, we have found the students' interests in energy research encouraging. Some of our graduates are currently involved in energy research with other institutions in Malaysia and abroad.

2. Material is undoubtedly the number one problem that has to be resolved. To find a local, cheap and easily available material suitable for solar energy research is not easy. It is for this reason that we are setting up a material research group.

3. We look forward to a more positive contribution to solar energy research now that we are ready to move to a new site with a new and much bigger building. We have also been given a five acre test site for a solar house yet to be developed and funded.

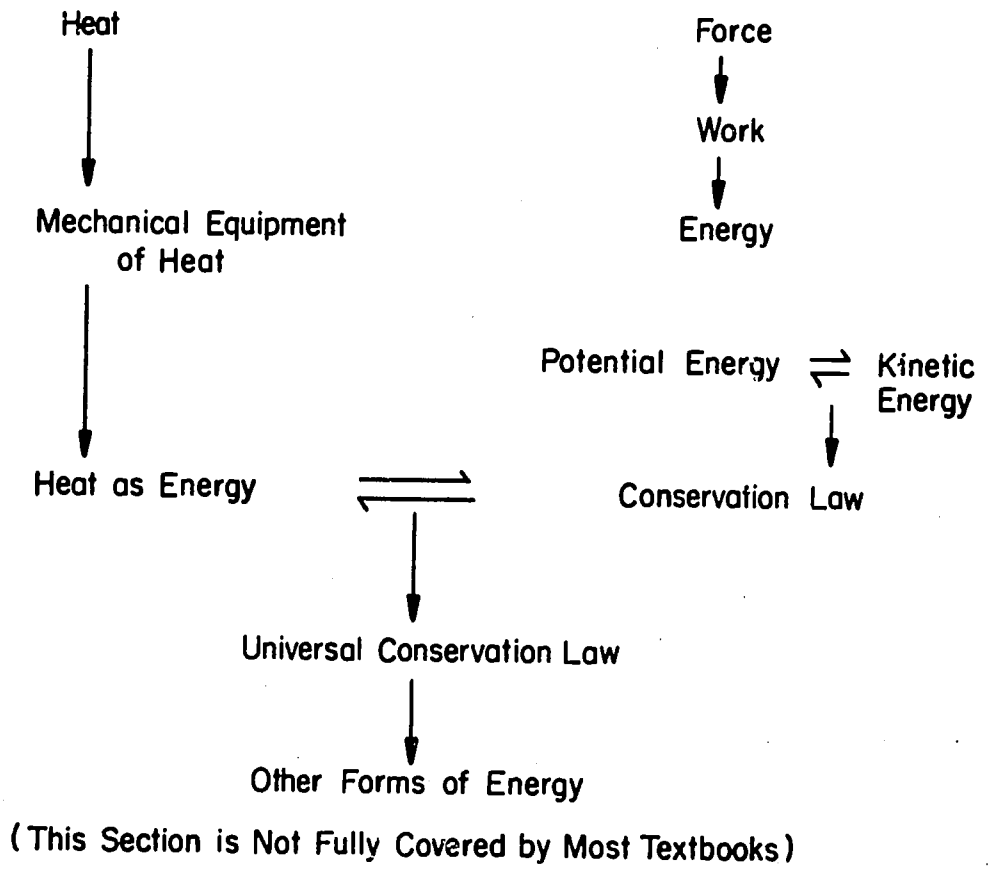
Heat
Mechanical Equipment of Heat
Heat as Energy
Force
Work
Energy
Potential Energy
Kinetic Energy
Conservation Law
Universal Conservation Law
Other Forms of Energy
(This Section is Not Fully Covered by Most Textbooks)

Fig. 1

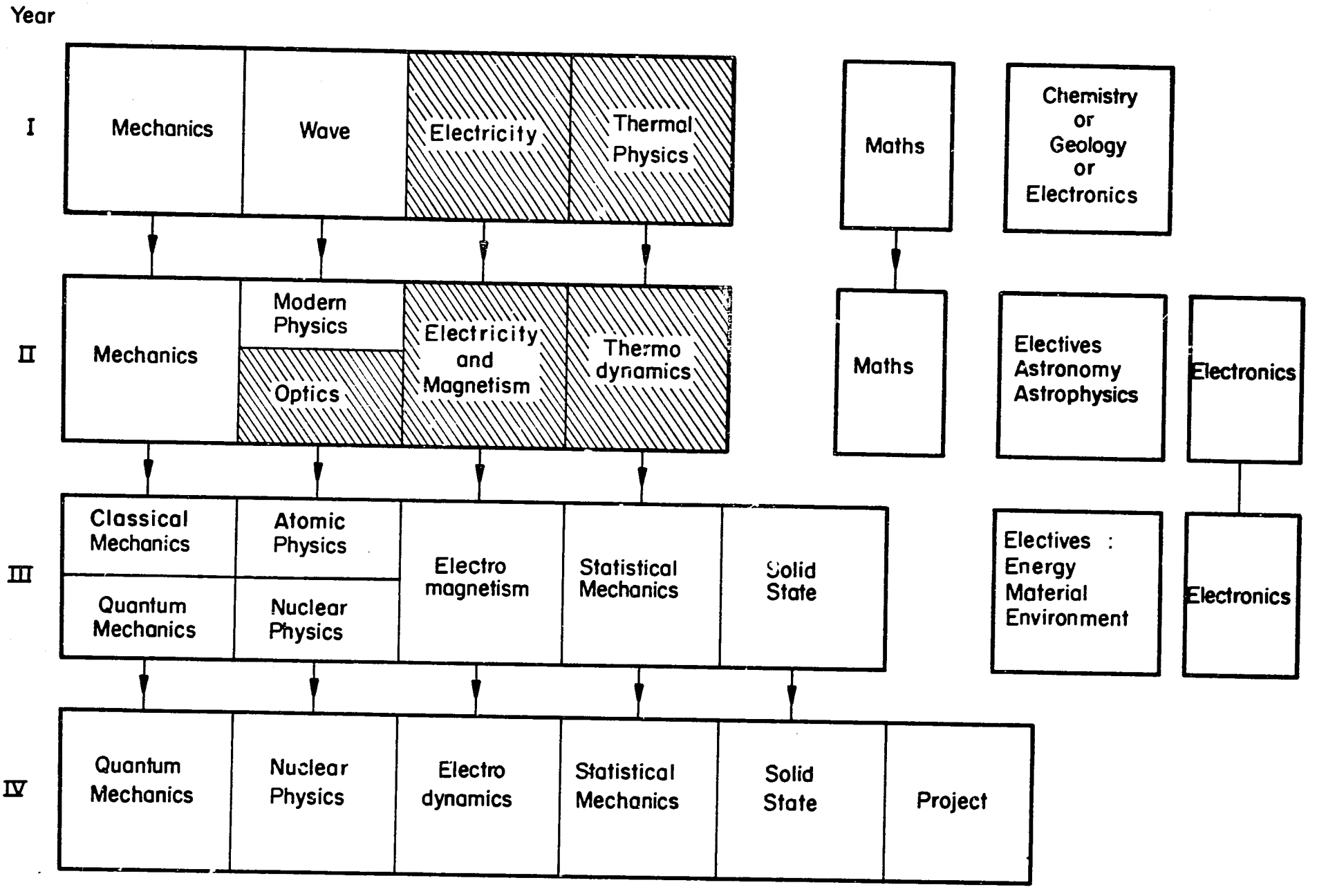
Year
I
Mechanics
Wave
Electricity
Thermal Physics
Maths
Chemistry or Geology or Electronics
II
Mechanics
Modern Physics
Optics
Electricity and Magnetism
Thermo dynamics
Maths
Electives Astronomy Astrophysics
Electronics
III
Classical Mechanics
Quantum Mechanics
Atomic Physics
Nuclear Physics
Electro magnetism
Statistical Mechanics
Solid State
Electives : Energy Material Environment
Electronics
IV
Quantum Mechanics
Nuclear Physics
Electro dynamics
Statistical Mechanics
Solid State
Project

Fig. 2

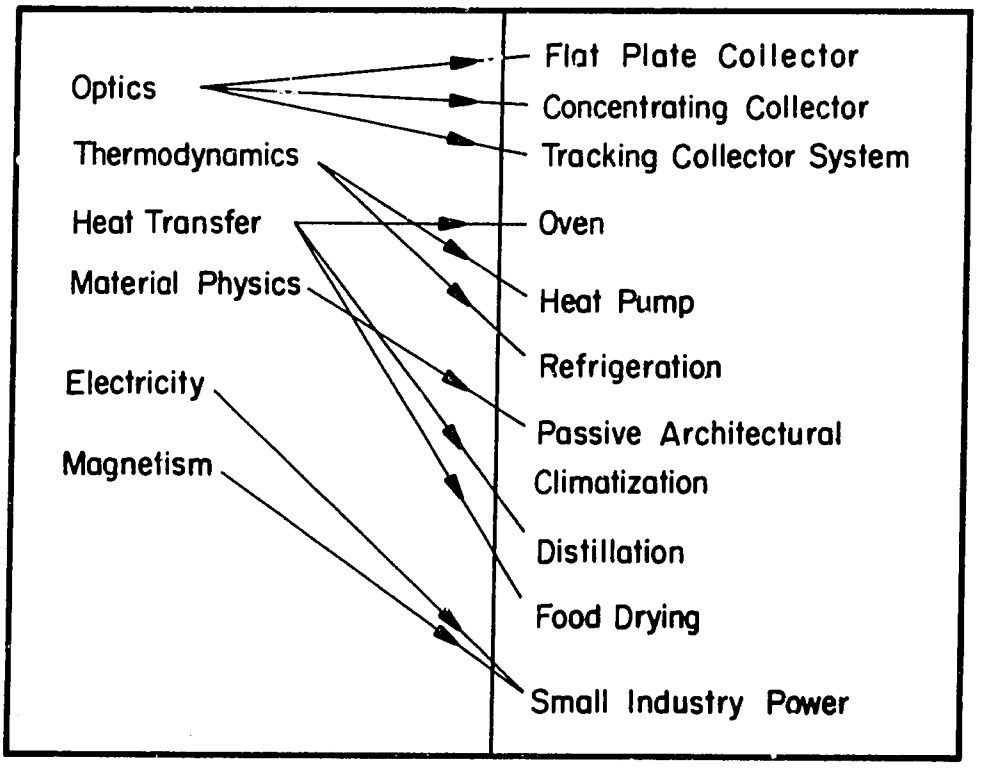
Optics
Thermodynamics
Heat Transfer
Material Physics
Electricity
Magnetism
Flat Plate Collector
Concentrating Collector
Tracking Collector System
Oven
Heat Pump
Refrigeration
Passive Architectural Climatization
Distillation
Food Drying
Small Industry Power

Fig. 3

Energy Planning in Developing Countries

Joy Dunkerley

In thinking about energy planning, there are two important guiding principles to be borne in mind. The first is the need for realism. Planning strategies should be based on realistic assumptions and take into account the acute resource constraints present in all developing countries. Second, energy planning should be seen as a continuous process flexible enough to deal with the many uncertainties which beset the energy sector.

Energy planning consists basically of three types of activities - the establishment of goals, the development and evaluation of strategies, and the resulting implementation of policies.

Establishing Goals

Goals for the future are of course rooted in the problems of the day, in particular the problems stemming from the increases in oil prices which took place in 1973/74 and 1979/80. For the oil importing developing countries this meant a sharp rise in oil import bills and frequently a rise in prices of non-oil imports, reflecting the inflationary effects of higher oil prices on exports from oil-importing industrial countries. External deficits rose steeply from about $11 billion in 1973 to $80 billion currently. The external debt incurred to finance these deficits is now at $300 billion compared with $85 billion in 1973. Annual economic growth rates for the developing countries as a whole fell from 6 percent before 1973 to 5 percent between 1973 and 1980. Forecasts for the next ten years made by the World Bank indicate a continuation of these low growth rates.

Many developing countries also face major problems stemming from shortages in supplies of traditional fuels which still provide an average 40 percent of total energy supplies, scarely less than oil. The effects of traditional fuels shortages cannot be easily quantified but qualitatively

there can be no doubt about their importance. Buying wood fuels in some cities of the wood-short Sahel has been estimated to require one-fourth to one-third of the average laborers' income. In parts of upland Nepal 200 to 300 person days of work per year are required to gather a family's fuelwood. In addition, deforestation and loss of ground cover stemming from over-use of fuel has serious environmental consequences which in turn affect living standards. Tree removal can eliminate top soil in upland areas, silt over fertile valleys, destroy reservoirs by siltation and reduce food production.

The oil importing countries in short are in the grips of two energy crises rather than one, and because of the possibilities of substituting one fuel for another, the position of traditional fuels has been aggravated by the rise in oil prices. The crises of traditional fuels is of long standing. Before 1973 cheap oil products held out hope for the solution of the fuelwood crisis. Indeed, several countries including Indonesia subsidized kerosene with the explicit aim of slowing deforestation. Now that this is no longer possible the traditional fuel problem takes on a new urgency.

In the most general terms the goal of energy planning in all countries, rich and poor, oil importers and exporters, is to secure adequate and reliable sources of energy at least cost. However, in developing (and other) countries, energy planning has traditionally encompassed several other objectives, notably access of the poor to energy, regional development and environmental control. Since the rise in oil prices additional objectives have come to the fore. For the oil exporting countries, control over the depletion rate of their reserves has developed as a major goal. For the oil importing countries, the control of oil import bills has become a critical objective. For rather different reasons both oil importing and exporting countries plan to reduce the shares of oil in their domestic energy consumption.

The development of energy strategies

There are, broadly speaking, three elements in a strategy for dealing with rising prices of oil imports - increasing domestic production of oil and other forms of energy to displace imports, reducing oil imports, and increasing foreign exchange earnings to pay for the higher import bills.

1. Increasing domestic production[2]

What is the energy resources endowment of the oil importing countries? There are grounds for both pessimism and optimism in finding new oil and gas reserves in developing countries. On the optimistic side, it is evident that many countries have not been adequately investigated for oil and gas. On the negative side, many experts believe that only relatively small amounts of oil and gas remain to be discovered from entirely new areas, such as the non-oil developing countries. This judgment, however, applies particularly to large reservoirs. Even though most of the world's oil may be found in such reservoirs, substantial reserves may still exist in small and medium-sized fields, adequate to provide part if not all of the commercial energy consumption of many of these countries. Among the oil importing developing countries, oil has been discovered in five countries (Benin, Chad, Niger, Ivory Coast, Sudan) that are not producers at present, and others (for example, Brazil, Chile, Pakistan) are actively trying to increase exploration efforts.

The recent rises in oil prices have also renewed interest in coal - at one time the mainstay of the world's energy economy. Coal has three particular advantages - it is a familiar fuel, usually cheaper than oil, and is relatively abundant - which compensate to some extent for the environmental problems connected with its use. Developing countries are estimated to have about 10 percent of world economically recoverable reserves, though only 2 percent of geological resources. This discrepancy may be due to lack of recent exploration for coal. Significant deposits are beleived to exist in many African countries (Nigeria, Zimbabwe, Swaziland and Bostswana). Resources may be much higher than current estimates in Colombia and Brazil, and new sources of coal in Asia may include Bangladesh, Taiwan,

Korea, Philippines, and Indonesia. Even if countries do not have domestic coal, imported coal could be an interesting alternative to imported oil.

Many of the oil importing developing countries are well endowed with renewable energy reserves. The amount of hydroelectricity available in some developing countries is very large compared with foreseeable future needs. Thus in Africa only 1.5 percent of the hydro potential is now developed, and for Asia the total is 8 percent and Latin America 6 percent. And these may be underestimates, not fully taking into account recent higher costs of thermal generation, nor the potential for small scale projects.

The solar resource tends to be relatively high in quality in much of the developing world, though local climatic and seasonal effects must be taken into account in assessing resources realistically.

Biomass resources include forests, crop and animal residues, and more recently the production of special field crops for energy purposes. In general, in most non-arid countries, biomass is a potentially very abundant resource - for many, perhaps the only significant energy resource for practical near-term use. The emphasis here must be on "potential." As we have seen, tropical forest lands are already under pressure. To turn this situation around and fulfill their potentials, the forests of the developing world must be more efficiently managed to produce a sustained yield of wood for energy and other uses. This means that the strongest effort must be made to produce forest products both in plantation and village woodlots on a sustained yield basis, and to improve yields through better harvesting practices, fertilization, and genetic research.

Crop and animal residues are also potentially available for energy use, but in a rather different way than forest products as they are often already fully utilized for fertilizer, animal feed, or in many countries, as a replacement for firewood. In either case, wastes are quite likely already being put to some economic use and their diversion to energy uses may create additional problems.

This summary of energy resources in the oil importing developing countries as a group gives grounds for modest optimism. But it is important to note that these resources are not equally distributed among this large group of countries. Some are more richly endowed than others. In particular there is a disturbing number of countries, largely poor countries in Asia and Africa, which are short of all resources, and which also have currently a high rate of energy import dependence.

2. Reducing oil imports

This can be achieved in a number of ways. The amount of energy (particularly oil) used in producing the national output can be reduced. This may involve some re-assessment of development policies, many of which were designed at a time of low and falling energy prices. These now need to be looked at in the light of new conditions. While it is important to avoid a disproportionate or obsessive concentration on the energy sector to the detriment of general economic development, there are a number of cases where higher energy costs suggest basic changes in development policy.

One example would be the type of industrial development to encourage. Some industries (iron and steel, cement, chemicals, plastics) are highly energy intensive. When oil supplies were cheap, it was possible for countries without major domestic energy reserves to develop such industries. Now this option is less attractive. Planning for industrial development must of course consider all factors of production, but there are a range of important industries in which high cost energy is a major constraint.

Oil imports can also be reduced by improving the efficiency with which oil and indeed all energy is used. It is often thought that there is little room for conservation in poor countries where energy consumption is already low. But there is developing evidence in all sectors that important opportunities exist to save energy even at low consumption levels. In the transport sector, which typically uses forty percent of total oil

supplies in developing countries, major variations in passenger car ownership suggest that savings of gasoline could be achieved without adverse effects on economic growth or welfare. In Brazil, for example, there are 40 passenger cars per million 1975 US dollars of GDP compared with only 4 in Korea. Improvements are also possible in the energy efficiencies of both passenger cars and trucks, and greater attention could be paid to the many forms of public and private transport other than the private automobile - jitneys, taxis, motorized bicycles, and scooters. Reduction in urban congestion through traffic engineering, road paving and improved bus services could lead to important conservation of liquid fuels.

In industry, wide variations in the amounts of energy used in similar industrial processes suggest that here too energy could be saved either through "housekeeping" changes or through some more substantial changes in procedures. The rapid rate of industrial production in developing countries will permit a faster turnover of the industrial capital in an energy-conserving direction.

It is possible to achieve substantial savings in both rural and urban households through introduction of more efficient appliances. Most rural households, for example, depend for their cooking needs on traditional fuels which are used very inefficiently. Technically simple improvements in wood-burning cooking stoves could double efficiencies and save an estimated 100 mtoe or more of biomass annually as well as reduce the environmental costs of fuel use - potentially a much more cost-effective scheme than introducing highly subsidized kerosene.

Finally, oil imports can be reduced by using other fuels wherever possible. At the moment transportation is virtually 100 percent reliant on liquid fuels, but to a greater or lesser extent, the other sectors can reduce dependence on oil. The electricity-generating sector is the most promising. Here existing oil-burning plants can be converted to gas, or, at greater expense to burning coal. Of greater importance over the long

run, new capacity need not rely on oil. In the industrial sector some retrofitting is possible, but again the greatest opportunities will be in future expansion. In the household sector, which depends largely on two problem fuels - oil and fuelwood - the substitution of other fuels is of particular importance. Candidate fuels for substitution are liquified petroleum gas for kerosene, briquettes made from solid fuels, and solar energy for hot water heating.

C. Increasing export earnings

The first two options concern the energy sector, but the energy sector cannot be divorced from the economy as a whole. This leads to a third option, earning foreign exchange to pay for higher oil import bills. For some countries, especially those with substantial manufacturing export sectors, the most efficient policy may be reliance on export promotion to earn the foreign exchange for higher priced oil. This certainly seems for many countries to have had the most successful approach in the years after 1973. An analysis[3] of the post-1973 experiences of 24 developing countries indicates that those countries which concentrated on increasing exports, by establishing realistic exchange rates and providing adequate incentives for savings and investment, made a more successful domestic adjustment. Among the newly industrialized countries, for example, growth rates in the export-oriented countries decreased from 7.4 percent in 1973 to 5.9 percent in 1973-76, but rose again to 9.7 percent in 1976-79. In NICs following more inward-oriented policies, on the other hand, rates of growth fell from 6.9 percent pre-1973 to 5.0 percent in 1973-76, and did not recover in subsequent years. An interesting point is that those countries which were more successful at expanding exports also were more successful in compressing non-oil imports, as their domestic industry was in a good position to substitute for imported goods.

There are several lessons to be drawn here. The first is the importance of establishing correct policies in response to external shocks

such as increases in oil prices. The second is that the "outward" - looking policy is a feasible option for a good many countries. It is not restricted to the NICs but has wider application to several other countries. It does not, however, seem a realistic option for the poorer countries of Africa and Asia, where overall development problems predominate and lack of resilience or economic infrastructure hampers adjustment to shocks such as higher oil prices. For these countries, other solutions must be found. Finally, the efficacy of the export-oriented strategy will depend on the industrial countries keeping open their domestic markets to exports from the developing countries. This may be the most effective single way of helping developing country oil imports cope with higher import bills.

Although these options have been described separately, in most cases the overall strategy will contain elements of each. Given the rise in prices, all countries will look to improving the efficiency with which energy is used. It is important to realize, however, that for developing countries energy conservation merely reduces the rate of increase in energy consumption. Increasing quantities of high-priced oil will still be needed so that attention to domestic energy production, fuel substitution and higher export earnings will all be necessary. The combination will be different according to the individual country and in particular its energy resource endowment. These principles can be illustrated by the energy planning strategies outlined in the energy plans of several countries.

Mexico is an example of a major oil and gas exporter, though still quite a poor country with current GDP of about $2,000 a year. In addition to oil and gas, Mexico possesses significant resources of other forms of energy - metallurgical and steam coal, hydroelectricity, geothermal and uranium. Given higher oil prices it might have been expected that Mexico would concentrate on oil development, and indeed a strong growth in the oil and gas sector is anticipated. But the development of the energy sector has been subordinate to fast but stable and equitable internal development, including provision of jobs and regional development.[4] The

goal, in other words, is healthy development of the economy rather than the most rapid development of oil and gas. A related aim is the development of local skills in all aspects of energy development, even though this implies slowing the rate of energy development. Consequently, oil and gas exports are planned to rise to a level of 1.5mbd and 300mcf by 1982 and then stay constant to 1990 on the assumption that such a level will provide adequate foreign exchange to finance internal development.

At the same time, envisaging the eventual depletion of oil, the Mexican government plans to develop other forms of energy. By the year 2000, oil products will count for a rather smaller share of total consumption than at present - though still high, at 65 percent. Furthermore, in the recent energy program, considerable attention is paid to conservation, again with the long-term future in mind. Under this program energy consumption is planned to grow by 6.0 percent annually from here to the end of the century. This is a high rate of increase but much lower than that previously planned (8.4 percent). Of course, these are still "paper" plans, and the fact remains that Mexican energy prices are still far below international prices. But the important point is that conservation has been accepted in principle.

The case of Nigeria, another major oil exporter, is rather different.[5] Nigeria is still a poor country (with an annual income of $1,000, one-half Mexico's) and at the very beginning of the industrialization process. The emphasis in past energy "planning" was to increase oil revenues with which to undertake necessary infrastructure and development projects, including the growth of refinery capacity. Nigeria, the world's ninth largest producer, still imports over 40 percent of its petroleum products. More recently, emphasis is changing or broadening. As with Mexico, greater interest is being shown in acquiring knowledge of and control over petroleum technology. The vexing question of distribution of energy products closely linked with regional imbalances is being examined and efforts are being made to improve it. Conservation takes second place to improved distribution. Perhaps a harbinger of concern over depletion, other forms

of energy are being developed - hydroelectricity and an attempted revival of the coal industry.

Among the oil-importing countries, present levels of import dependence and future possibilities of reducing it vary considerably. India[6] lies somewhere in the middle, depending on imports for only one-half of total oil consumed. Unlike the other countries, coal is the major commercial fuel, accounting for 62 percent of total commercial supplies. Traditional fuels also play a significant role, accounting for 50 percent of total energy. India has a long tradition of energy planning integrated into the macroeconomic planning of the Five-Year Plans. Two features of this planning history are a long-standing and explicit concern with traditional fuels, and the policy drive to maintain coal as the major fuel, even before the increase in oil prices. This has proved quite a difficult task. Given the declining competitiveness of coal before 1973, it is remarkable that such a large share of commercial energy use (63%) has been retained by coal.

Plans for the future given in the latest government report, the Working Group for Energy Policy, indicate a continued rise in domestic production of all types of energy: coal, oil and gas, and primary electricity (both hydro and nuclear). The rise in coal and primary electricity will, however, be more rapid than average, compensating for the decline in traditional sources. The share of oil is planned to remain constant at about 15 percent of total energy consumption - exceptionally low for a country with a large industrial sector. Even so, imports of crude will double, implying the need to increase export earnings.

Until quite recently, energy planning in India was mainly supply-oriented, based on a supposition - widely shared at the time - that the amount of energy consumed is fixed by the level of output. The planning problem was, therefore, to investigate how this supply could be met. In the recent WGEP report, however, there is recognition of the flexibility of energy consumption and attention to conservation possibilities. In the next 20 years, for example, energy consumption is planned to increase

by only 4 percent, compared with 5 percent from 1973 to 1979, even though economic growth rates are assumed to be higher.

Two Caribbean countries - Guatemala[7] and Jamaica[8] offer interesting contrasts. Both are heavily dependent on oil imports. Guatemala relies on imports for 97 percent of total commercial energy supplies, though traditional fuels account for one-half of total energy consumption. Jamaica is in a worse position: oil imports provide 99 percent of total supplies of commercial energy - the other 1 percent is electricity - and 90 percent of all energy, including traditional fuels (bagasse).

Guatemala's future prospects are, however, quite promising as the country has considerable unexploited domestic resources of hydro-electricity and petroleum. The main thrust of policy is therefore to develop these two sources of energy. It is estimated that only 2 percent of total hydrothermal resources have so far been developed. Following successful petroleum exploration, Guatemala is expected to be able to meet demestic energy demand from local production. So far there has been little interest in conservation. Part of the difficulty is that an exceptionally high (65 percent) part of the total petroleum consumption is in transportation, largely, it is assumed, public transportation, so that the opportunities to save oil may be quite limited.

Jamaica, on the other hand, has very limited resources. The current five-year plan includes the development of a range of indigenous activities - oil and gas exploration, hydropower, and peat. Solar air conditioning, methane generation from biomass, wind for irrigation and charcoal are also being investigated. But in recognition of the relative paucity of indigenous resources, emphasis is laid on the other two strategies - increasing export earnings and promoting conservation. An analysis of end uses for energy will be carried out in order to provide a basis for conservation and fuel substitution measures. Given the importance of existing energy-intensive industry in Jamaica - about one-half of petroleum products is consumed by the bauxite industry - future economic growth is to be much less energy intensive.

Brazil[9] and the Republic of Korea[10] - both newly industrializing countries with large industrial sectors - also offer interesting contrasts. Both are highly dependent - 80 and 100 percent, respectively - on imported oil for 40 percent and 60 percent of total energy consumption.

In Brazil oil imports account currently for about 40 percent of total export earnings and service on the massive debt for most of the rest. There are plans, therefore, to keep oil imports down to current levels by the end of the century. The initial thrust of policy was major increases in domestic energy production. Domestic production of oil and gas is to be increased by inviting foreign firms to help in exploration and development, a sharp break with past experience, and by engaging in joint production abroad. Coal production is to be increased and incentives given for certain industries, particularly the cement industry, to use it. The immense hydroelectric potential is to be tapped. Anydrous ethanol made from sugar cane already substitutes for 20 percent of gasoline use, and is being extended for use in specially designed car engines.

At first little attention was paid to conservation, in fact, lack of conservation incentives led to an increase in oil imports in the 70's. Now, prices of petroleum products have been increased and attention is being paid to possibilities for conservation in the transport sector, which accounts for 55 percent of all oil consumption.

In addition, the Brazilian government has seen the need to increase foreign exchange earnings. An aggressive export policy for agricultural products, minerals and armaments is being pursued, especially in oil-producing countries.

The Republic of Korea, on the other hand, has limited domestic resources - some coal and a small amount of hydroelectricity. Coal industry output, despite considerable subsidies, has stagnated in recent years, but there are current plans to double production within 5 or 6

years. Lacking other domestic resources, there are plans to accelerate the nuclear program - with as many as 30 generating facilities projected for the turn of the century.

At first, conservation was given little attention, but more recently there has been a move to modify development policy. Before the oil price rises, there were plans to develop heavy, energy-intensive industries. Now these plans are being revised. Starting dates for some major petrochemical and steel projects have been postponed, and there are plans to reduce government support in the shape of low-interest loans, etc., for energy-intensive industries. Despite these efforts, Korea will still need to import, and, like Brazil, is very aggressive in promoting exports and sales of services abroad, particularly to the oil-producing countries.

In brief, the energy planning of these countries includes all three elements of energy strategy - increased production, conservation and higher export earnings. In each case, differences in resource endowment are reflected in the emphasis given to the different strategies. Concern for conservation, however, seems to have developed later than interest in expanding domestic production, although by now conservation features even in the plans of some oil exporters. For those countries where the oil sector is a major part of all economic activity, there is a lively realization of the connection between energy and the macro-economy. But even in others there is growing realization of the need to increase export earnings to finance higher oil bills.

The assumptions and constraints

Most planning exercises are based on estimates of future consumption and production derived from models of the energy sector. Recent assessments of energy demand modelling in India, Brazil, Indonesia, Korea, Mexico, Egypt and Turkey[11] indicate considerable variation in the quality and complexity of current models. All typically take into account the expected level of economic activity, and make an effort to model aggregate consumption rather than individual sectors such as coal or electricity, as was frequently done in the past. Several introduce energy prices and

government policies, and some have incorporated a scenario approach, which has the advantage of illustrating the effects of different policy paths and focuses attention on the possibility of options.

On the other hand, these models have certain weaknesses. The data base is generally poor in quality and coverage. Sometimes, as in the case of traditional fuels, that is because data are not available. But sometimes it is because data are not accessible or have not been assembled in an easily usable form. A second weakness of the current crop of projections is that they do not explicitly model the effect of energy prices on energy consumption. Official projections in India, Brazil, Mexico, and Korea all indicate a sharp fall in future energy/GDP coefficients, which could be taken to indicate price effects reinforced by government action. But there is no indication of the income and price elasticities involved or the relative weight of price and nonprice incentives.

A third weakness may be that these models do not take into account sufficiently the technical possibilities and difficulties of interfuel substitution. Energy is not perfectly substitutable in all of its forms, and failure to take into account technological reality can lead to inaccurate projections.

Finally, many of the current projections do not take into account the problem of supply availability. Thus, there may be delays in the construction of electricity-generating facilities, in the extension of rural electrification and in keeping coal production up to planned output levels. The importance of discontinuities and uncertainties in the energy supply sector is more pronounced in developing rather than industrial countries, and among developing countries it is probably of greater importance to the poorest, such as India and Indonesia. There is ample evidence that this has been a major factor in the past. In India, for example, an analysis of coal industry plans from 1960 to 1980 showed actual production to be consistently and significantly below planned production, often by a very wide margin. In the twenty years from 1955 to 1976, the same was true of electricity. Nor are these problems confined to India. The electricity

sector in Brazil and other countries have experienced similar shortfalls in planned capacity expansion.

This suggests that planning also involves a realistic assessment of constraints. These can take many forms - political and social as well as economic.[12] Perhaps the major constraint lies in the availability of resources either to pay for imports or to invest in domestic energy production. For most countries, oil imports will have to rise in the future to meet the needs of economic development. Oil imports into the oil-importing developing countries already amount to $50 billion, or about 25 percent of their total import bills. For some countries it is even bigger - 40 percent in both Brazil and India. The World Bank estimates that with a 3 percent increase in oil prices a year in real terms the real cost of oil imports will more than double over the next 10 years. If oil imports are not to take a larger share of total imports than at present, export earnings must also double over that period - not an easy achievement in an era of growing protectionist sentiment. It is quite easy to see that foreign exchange availabilities could continue to constrain supplies of imported oil, and even intensify the problem.

Similarly, the investment implications of higher domestic production are of major importance. It is, of course, difficult to estimate the total costs of domestic energy programs in the presence of so many unknowns. But one estimate from the World Bank assumes that investment requirements in commercial energy, at present standing at about $25 billion for the oil-importing developing countries, should rise 50 percent to an annual average of $35 billion (in 1980 $) from 1981 to 1985 and to $53 billion (in 1980 $) from 1986 to 1990.[13] This represents 3.2 percent of GDP by 1990, compared with about 2.3 now. A large part of this investment will continue to be for electric power. Indeed, one of the reasons for the sharp increase in capital requirements stems from the changing composition of the power generation sector towards capital-intensive nuclear generation as opposed to oil generation. In the past, foreign capital flows, largely official lending, provided an average of about 80 percent. In the future, however,

this share will fall to one-half with a greater contribution from private sources, suppliers and eurocurrency markets.

One-half of the investment needed for the power sector will still be in the form of local resources. The financial bases of utilities in many countries are, however, very poor. Thus, one observer points out that "the financing problems have been due more to inadequate domestic funding rather than any lack of foreign loans."[14] (sic) In the absence of adequate resources generated by the utility sector, funds must be diverted from other productive sectors.

Besides calling upon scarce financial resources, an expanded domestic energy program will also use other factor inputs - land, labor - which may be equally scarce or, in a given area, not available at all. This again means that in some circumstances project evaluation will have to take into account other development activities that might compete for resource use. In practice, a major defect in markets for the supply of new and unfamiliar energy technologies may be lack of information and expertise.

An important constraint in developing some sorts of energy projects is lack of infrastructure. Transport costs are critical for some biomass projects, so that the presence or absence of a road network can be a decisive element in determining economic feasibilities. In oil and gas, too, infrastructure is of major importance. Gas is frequently flared, even at present high energy costs, because of the lack of a pipeline system to take it to major markets. Similarly, lack of infrastructure has been advanced as reason why the international oil companies have been reluctant to engage more actively in oil exploration in developing countries. Oil has been found in Chad, for example, but the total lack of infrastructure and the distance from ports deters exploitation. Similarly, the development of the coal trade may be held up by lack of coal-handling facilities. By and large, this suggests that the more developed the infrastructure, as in many of the richer developing countries, the more options will be open. The same argument applies within a country. Regions which are well served by infrastructure are likely to fare better than those without.

Preferences and values can also constrain various types of energy development. In the United States, for example, a high value has been set on environmental amenity which has on some occasions slowed energy development. Comparable examples from the developing country context are distaste for generation of biogas on the basis of human and animal wastes and reluctance to cook outside during the day, which has held back development of simple solar cookers. Such constraints are not limited to rural areas. The introduction of alcohol fuels depends on motorists' willingness to accept lower performance.

Views on equity or "fairness" can seriously constrain some energy options. Strong opposition to increases in prices of transport fuels is a case in point. The question of equity may be crucial in village technologies. In many areas the village is largely self-sufficient in energy, which is in turn distributed in some accepted manner. Any change to introduce a more efficient technology, like biomass, will mean that some win and others lose, and therefore may be difficult to introduce. This question of equity can also arise on a regional basis. Some preferred development may leave a region significantly worse off and therefore be unacceptable.

Implementation

Planning consists of more than development of strategies and recognition of constraints - indeed the development of strategies may be the easiest part of the process. Frequently the more difficult is implementation. In formulating implementation policies governments are not writing on an empty slate. There has traditionally been considerable government presence in the energy sector.

Before 1973, however, the government role in the energy sector was limited. Though it is difficult to generalize over a large number of countries, it seems in retrospect that in the 1950's and to a greater extent in the 1960's the strategy of the governments of oil importing

countries, both industrial and developing, was to rely on imported oil to accomodate their rapidly increasing energy needs. In those days oil, the most flexible of all sources of energy with current technology, was declining in price. Sharp increases in imports could, therefore, take place without imposing major burdens on the balance of payments. In the traditional energy sector, too, there was little direct government intervention. Fuel from crop and animal wastes and much fuelwood are typically produced and consumed outside commercial markets and, as such, escapes direct government intervention. Of the traditional fuels that have been commercialized, charcoal-making is regulated in some countries, but the bulk of firewood was free from regulation. The two major energy subsectors, therefore, experienced little direct government intervention.

But governments did not practice a policy of complete laissez-faire. They took advantage of the rising share of oil to impose taxes on such products as gasoline (to increase revenues, it should be noted, rather than to promote conservation) and to subsidize such items as kerosene (which was widely used by the poor) and sometimes fuel oil and diesel to promote industrial development. Some countries (India, Korea) made efforts to control deforestation. Those countries (again India, Korea) which had major coal industries threatened by increasing oil imports took steps to minimize the damage by subsidizing the industry or by imposing taxes on the competing fuels. India eventually assumed public ownership of the coal mines. In all cases, countries' governments played a major role in the electric utilities. The nature of this role varied from country to country: in some the electricity sector is government-owned and theoretically, at least, subject to strong government direction, though in practice many led a relatively independent existence. Even in those countries where the utility industry was privately owned, it was typically regulated by the government. In brief, the major development in the energy sectors of the oil-importing developing countries in this period was, therefore, not the subject of formal ex ante governmental planning but rather a spontaneous ad hoc response to developments in energy subsectors. Action was taken in areas where and when problems arose; government policy was reactive

rather than initiating. In this sense, comprehensive energy planning represents a break with the past. On the other hand, energy has always been an area of recognized government intervention which may facilitate acceptance of a wider role.

The question of the nature of the government role in the energy sector hinges on the role of energy prices in encouraging production and conservation. There is widespread perception that energy is not sensitive to price increases, especially in developing countries, where severe market distortions may exist and where, in any event, much energy is produced and consumed outside the commercial economy.

On the demand side, the perception that energy is not sensitive to price increases is at first sight confirmed by the fact that consumption of commercial energy in LDC's fell very little after 1974 despite the sharp rise in oil prices. There are a number of reasons for this development. First, energy prices to consumers, though rising in most cases, did not rise as much as might have been expected from the dramatic increase in oil prices. Second, sufficient time may not have elapsed to permit the installation of new, more energy-efficient equipment appropriate to higher energy prices, since in many operations energy costs are a small part of total costs. Third, rates of economic growth continued to be high after 1973, and under any reasonable assumptions of income and price elasticities of demand for energy in the developing countries, the influences of income growth will outweigh the effects of higher energy prices. This does not mean that the effects of prices are not important. Rather, it means that given the rates of economic growth anticipated in developing countries, and indeed necessary if living standards of high populations are to be improved, the rates of growth in energy consumption will continue to be high. The effects of higher energy prices will be to moderate the rates of increase.

A more careful look at the data suggests, however, that energy prices have had an impact on consumption. The energy/GDP elasticities coefficients of the oil-exporting developing countries, where domestic energy

prices, as in Mexico, probably declined in real terms, rose from just over 1 to 1.46. On the other hand, the energy coefficients of the oil importers, where prices rose, fell from 1.3 in the 1960s to 0.94 in the 1970s.[15] There is additional evidence on a more disaggregated level of the responsiveness of energy consumption to energy prices. This responsiveness is, however, assumed to be quite moderate (in the -0.3 to -0.4 range).[16]

The main purpose of energy pricing should be to promote economic efficiency. This means pricing energy products to reflect the long-run opportunity costs of using energy. One of the main elements at present in establishing such a price is the foreign exchange cost of energy imports (or energy exports in the case of exporting countries) reckoned not necessarily at actual exchange rates but at "shadow" rates, including the effects of the balance of payments on the economies of the developing countries. This means that it would be appropriate to tax several petroleum products in order to take into account their economic as well as financial costs to the economy.

A second aim of pricing policy which frequently conflicts with the first is the promotion of social equity through subsidizing energy products used particularly by disadvantaged groups - notably kerosene, in some cases diesel, lpg, electricity in rural and poor urban areas, and coal products for domestic use. Some of the subsidies to household fuels also had a second purpose - to reduce overuse of wood and thus improve the forest resource. In this case the subsidy would capture major economic benefits.

The difficulty with subsidies now is that with the rise in oil prices they have become extremely expensive, and it may be appropriate to look for other means of achieving the same end - in the case of deforestation to promote extensive replanting schemes, or in the case of assistance to the poor to develop other forms of fuel.

There are several drawbacks to subsidies. First, artificially low prices encourage consumption and discourage conservation - just the opposite of what is needed at times of rapidly rising oil prices. Second, it is difficult sometimes to confine the benefits to the targetted group. Thus, subsidized kerosene is used not only by the poor, indeed, in many areas the poor cannot afford even subsidized kerosene, but also by the relatively affluent. Third, the subsidy/tax structure of petroleum products can lead to severe distortions in the use of these products with subsidized kerosene being substituted for heavily taxed gasoline. And finally, the subsidies may be benefitting foreigners rather than nationals. In Egypt, for example, one-half of total aluminum production - based on low-cost electricity - is now exported, which means that Egypt is in effect subsidizing its trading partners.[17]

In addition to such pricing policies, governments have frequently introduced other measures to achieve energy objectives. These include rationing, quota allocations (much used in India) and regulations concerning who should use different types of energy - such as forbidding utilities to use oil. In addition, governments make efforts to alter the stock of energy using equipment by, for example, taxing or forbidding the use of large cars and indeed altering the whole nature of energy demand by deciding the sorts of industries to be established and the type of transportation network to be developed.

On the supply side, it might be thought that a five-fold increase in real prices of petroleum over 10 years would in and of itself be sufficient to encourage increased production. In fact, the results have been somewhat disappointing, though given the large lead times for energy projects we may not yet have seen the full effect on the increase in prices on production. The government typically plays a dominant role in energy supply, either through ownership of energy resources or through its role in investment decisions, so that government policies are usually critical to the speed and conditions of energy development. In the electricity sector the rapid expansion in facilities owes much to government direction and assistance with obtaining investment funds, often from international

donors. In oil and gas, governments determine the types of arrangements conducted with foreign oil companies. Thus, high energy prices may be a necessary rather than sufficient condition for increased supply. The amount of exploration which has taken place in the oil-importing developing countries since 1974 has been rather low.[18] This disappointing performance can be due either to the reluctance on the part of the international companies to go abroad at the present juncture or to the stringency of the conditions imposed by the host countries. There are recent indications that some countries are prepared to relax some of the conditions attached to development.

The implementation of sector-wide energy policy implies the need for sector-wide means of communication and decisionmaking. This is all the more important and difficult in the energy sector due to the existence of very powerful subsectoral institutions with a large degree of autonomy. Experience among countries varies, and it is not possible to detect a pattern. Even in the most "planned" economy (India), it has proved so far impossible to establish a central energy unit. One observer attributes the shortcomings in energy policy implementation to "deficiencies in the decision-making process and the inadequacies of the administrative structures available for implementation of energy policy. Matters related to energy policy have been dealt with in different ministries in a somewhat uncoordinated manner, and efforts to set up a coordinating group at the level of ministers to review periodically the demand and supply situation of energy have not succeeded". In Mexico, although a Commision de Energeticos (composed of the Directors of the Secretaria de Patrimonio y Fomento de Industria, the Ministries of Commerce, Agriculture and Hydraulic Resources, Pemex, Federal Electricity Commission, the National Nuclear Energy Institute and the National Council of Science and Technology) has been set up, their mandate is to co-ordinate rather than initiate energy policies. In other countries, too, there appears to be difficulty in establishing appropriate forms of communication and administration encompassing the entire energy sector and linking it closely with macro-economic management.

Conclusion

Most developing countries have only recently begun to think about sector-wide energy policy. So far, the emphasis has been on the development of projections and strategies rather than on implementation. Problems of implementation may prove quite difficult, as they will involve review of pricing and other policies developed during a time of low energy prices and the growth of new institutions with sector-wide responsibilities in place of the existing institutions based on energy sub-sectors.

While it is too early to make more than a temporary assessment of the effects so far, it appears that relatively little attention has been paid to the traditional sector, important though that is, particularly after the oil price increase. In addition, it is not clear how the planning process will deal with the inevitable uncertainty which afflicts the energy sector, and how feedback will be incorporated into the planning process. These are problems which confront all countries these days, and are not unique to the developing countries. But the presence of so much uncertainty does argue for a relatively flexible planning approach which can react quickly to change.

FOOTNOTES

1. The author wishes to express her appreciation for Sandra Glatt's help in the preparation of the paper.

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3. B. Balassa, Weltwirtschaftliches Arch./Rev. World Econ. 117,62 (1981); "The policy experience of twelve less developed countries 1973-78" (staff working paper 449, World Bank, Washington, D.C., 1981); "Adjustment to external shocks in developing economies" (staff working paper 472, World Bank, Washington, D.C., 1981).

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by Hiwhoa Moon, paper presented at the second symposium for the World's Fair, Knoxville, Tennessee, August 1981.

11. Joy Dunkerley, "Assessments of Energy Demand Projections for Selected Developing Countries" and "Future Energy Consumption in India, Brazil, Republic of Korea and Mexico".

12. This section largely based on Joy Dunkerley et al, Energy Strategies for Developing Countries.

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14. "Financing Energy in Developing Countries" by Efrain Friedmann in Energy Policy, Vol. 4, No. 1, March 1976, and Energy in the Developing Countries, World Bank 1980.

15. Joy Dunkerley and Shelley Matsuba, "Energy Consumption in the Developing Countries" in U.S. Energy Outlook: A Demand for the Eighties, a report prepared by the Congressional Research Service for the use of the Committee on Energy and Commerce of the U.S. House of Representatives, 97th Congress, 1st Session, Committee Print 97-Q.

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17. Joy Dunkerley, "Assessments of Energy Demand Projections for Developing Countries", op. cit.

18. Harry G. Broadman, "The Pattern of Petroleum Investment in Non-OPEC Developing Countries: Company and Country Roles," paper prepared for the United Nations Ad Hoc Meeting of Energy and Petroleum Experts: "Energy in the Eighties," (New York, December 14-18, 1981).

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Planning and Programming of R&D Projects On Alternative Energy Development

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Introduction

The energy system is a part of each sector of the economy. Energy can be considered as the blood of economy. Lack of proper planning for energy supply may cause illness in the economy. Energy development plans must conform to national development plans; otherwise national objectives may not be achieved.

A typical energy system consists of energy supply and conversion activities, e.g. oil exploration, oil extraction, oil refining, power plants, electric transmission and distribution networks, oil refining, solar heating etc. It is a general practice to divide the economy into sectors with each sector performing its own planning. Plans for each sector will later be integrated to form a national development plan.

Concept of economic planning

Due to the complexity of the economy, it is impossible to plan all economic activities simultaneously. Economic planning is typically divided into 4 steps:

Step 1: Macro economic analysis, taking into consideration the past behaviour of the economy and the trends of world economic situation.

Step 2: Sectoral demand analysis.

Step 3: Sectoral planning; determining optimum investment and pro-

duction and/or imports, optimum pattern of prices. Emphasis on assuring that prices are set so as to clear all markets, i.e., planned supply match demand.

Step 4: Integration of all sectoral plans. Contribution of each sector to trade deficit, investment requirement, employment level, national debt, etc. will be accounted and cross-checked with the macro results of step 1. If there is some discrepancy, some action will be taken to reduce this discrepancy to an acceptable level.

Close cooperation between sectoral planning units and the central planning team, especially in steps 2 and 4, is necessary to the formulation of a good national development plan. For most developing countries, the major obstacle in national development planning tends to be an organizational one, namely, the lack of cooperation among related organizations.

Sectoral Demand Analysis

Information obtained from macro-economic analysis will be used as input for sectoral demand analysis. This information, including consumer price index, world oil price index, GDP forecast, value added in each sector, etc., will be further analyzed to forecast sectoral demands. The most widely used techniques in such analyses are econometric and input output analyses. Each country usually has its own input output (I/O) tables. Unfortunately, I/O tables generally include very little detail for the energy sector. I/O tables can be useful if used in combination with econometric equations for energy demand which are developed from past trends.

Formulation of Energy Plan

The information needed to formulate a national energy development plan is considerable. The first set of needed information is energy demand. The second set is energy resource availability (eg. How great

is the oil reserve? What is the achievable potential for solar energy?) The third set is information on existing energy system. And the fourth set is technical and cost information for energy processes or activities being considered.

Energy planning can be considered as composed of three basic tasks, as follow:

- energy resource assessment
- energy supply planning
- formulation of pricing policy

Energy Resource Assessment

For conventional energies, including oil, coal and natural gas, size of the reserves has to be determined from exploration and drilling. High technology is required for resource assessment of these commercial energies. There is usually an organization, separated from the energy planning body. taking responsibility for this task and supplying information to energy planners. Non-conventional energy resource assessment is similarly complicated because nonconventional energy resources are widely and evenly scattered throughout the country.

Most non-conventional energy development projects emphasize rural development not oil substitution. For example, solar rice dryer is merely an improvement over conventional low-efficiency solar drying. Biogas projects and fast-growing tree plantations are firewood substitues to prevent deforestation. Most non-conventional energy will be locally used. It is very expensive to collect the non-conventional energy and transmit it to replace oil based energy in industrial or urban areas, becuase such a project will take up large amounts of land and investment capital.

Competition between conventional energy and non-conventional energy has to be carefully investigated. Their social costs and benefits have to be compared at rural sites. Transportation and distribution costs of

conventional energy to rural sites will be a large portion of the price and will differ from site to site. However, it is impossible to investigate every rural site in the country. A sampling of rural sites is done instead of full-scale investigation. The size of non-conventional energy resources within the country can be estimated from sampled sites.

Energy Supply Planning

A lot of energy development projects are formulated by both government and private sector each year. Justification of these projects depends on their cost and benefit to the economy. "When should each project start or should it be rejected?" is the question that energy planners have to answer. One way to answer it is to use project selection and/or dynamic programming techniques. However, if the number of candidate projects is large and relation among these projects is complicated, these techniques will be impractical. Such techniques are more suitable for smaller systems, e.g. electric subsector. For large scale systems like the national energy system, it is more practical to ignore individual projects and view the energy system as a network of energy supply and demand activities, and model the system with mathematical equations for relations among activities in it. The I.C. network of an energy model for Thailand is shown in Appendix A. With the assistance of this model, an energy development plan can be formulated. Criteria for selecting systems are least cost, least import, maximum income redistribution or some combination of the three. A technique commonly used in this step is linear programming. The formulated energy plan will be used as guideline by various energy subsectors for their own planning.

The plan formulated by LP technique can be fully achieved if government is able to control or guide the decision concerning each activity. Fortunately, in most countries energy development is closely controlled or run by government through enforcement or special promotion if it proves to be beneficial to the economy as a whole.

Formulation of Pricing Policy

The energy sector usually consists of various activities (e.g. coal mining electricity generation, oil and gas refining, oil and gas extraction) with each activity owned or run by a different organization. Each organization will try its best to make more profit. If energy prices do not satisfy all involved organizations, investment and production will not occur as planned. Taxes and subsidies will be major government measures in controlling energy prices. If high energy prices are desired, taxes will be applied. If low prices are called for, the energy sector has to be subsidized by government. Without subsidies, low prices may lead to energy shortages as demand runs ahead of supply.

Appendix A

Energy System Network for Thailand

Country : Thailand Year :
Subsystem : Lign-Coal Scenario :

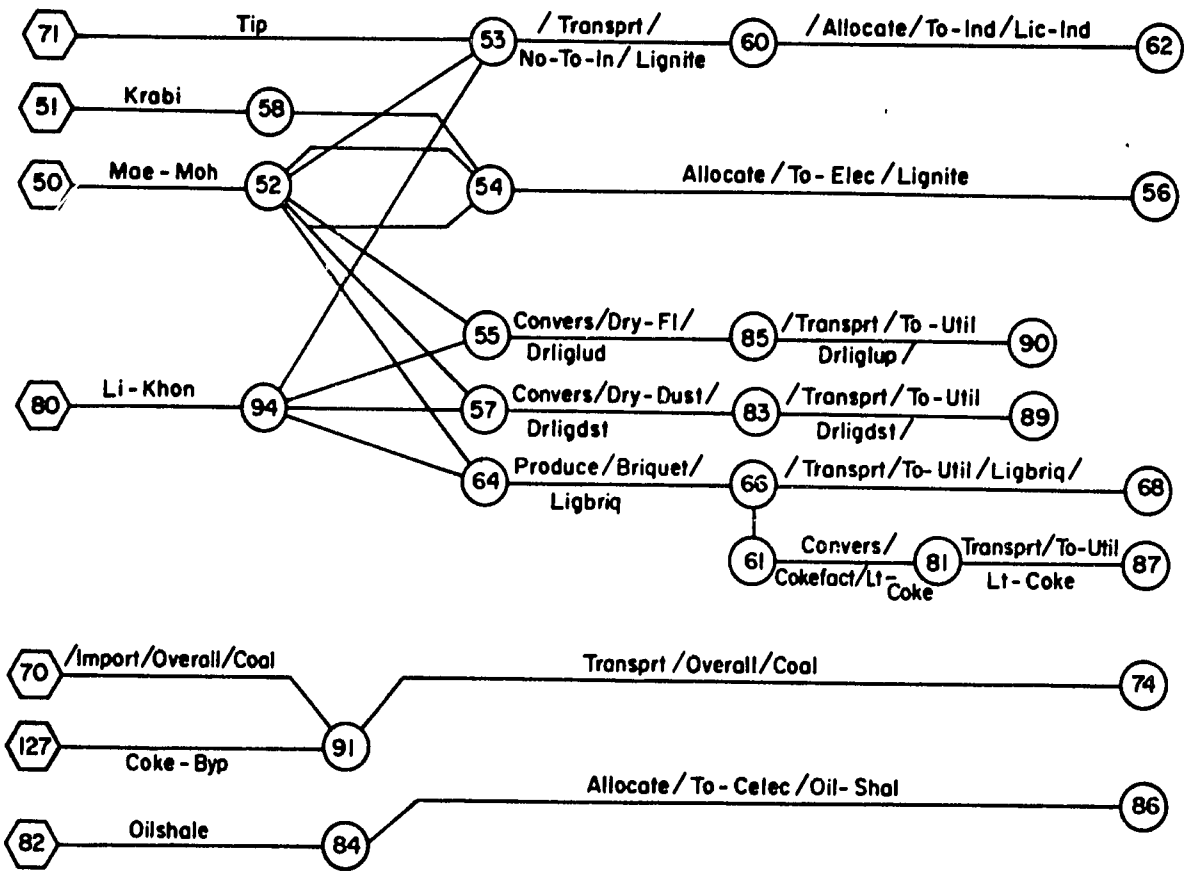

Exhibit I

Country : Thailand Year :
Subsystem : Gas Scenario :

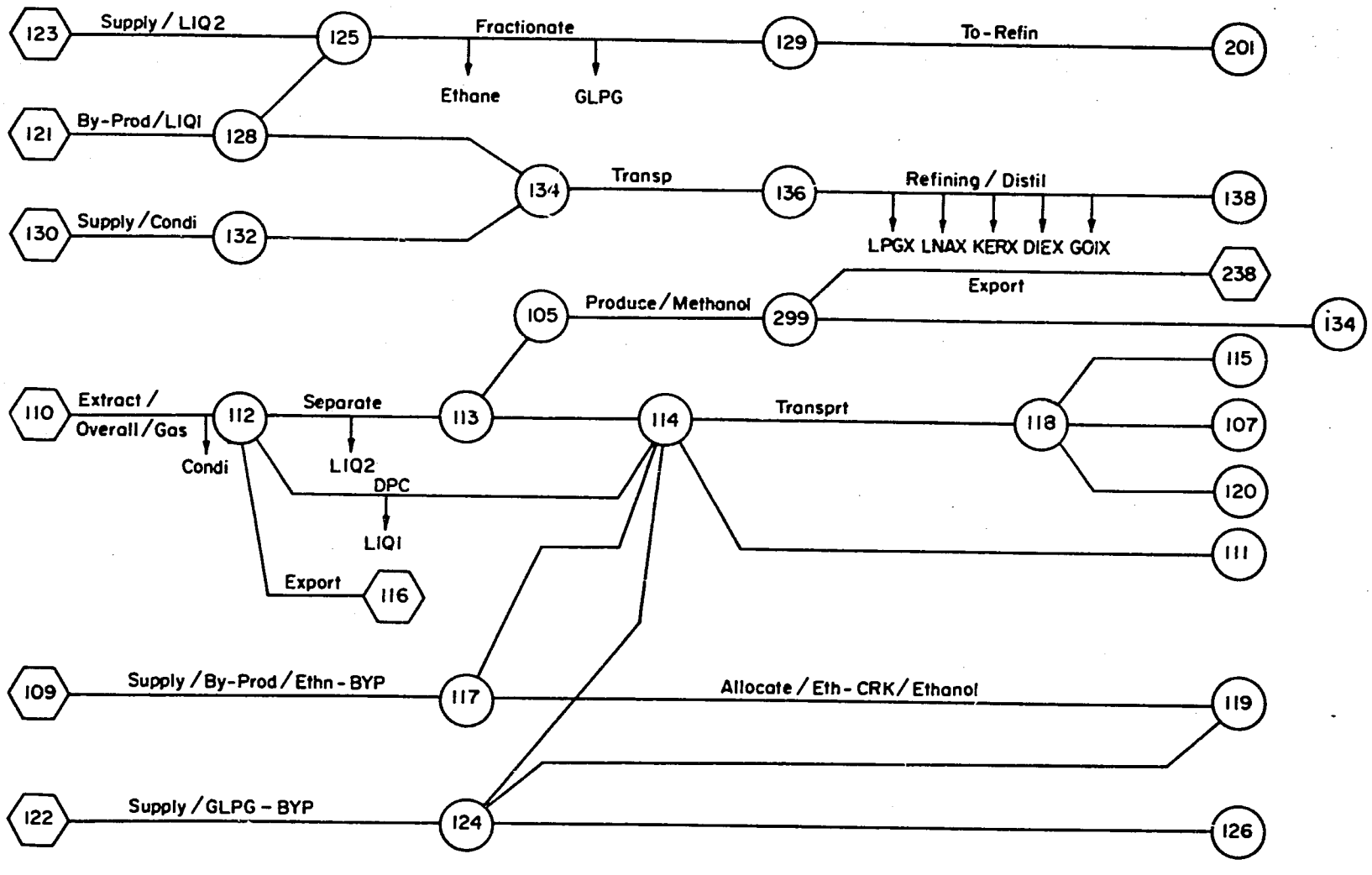

Exhibit 2

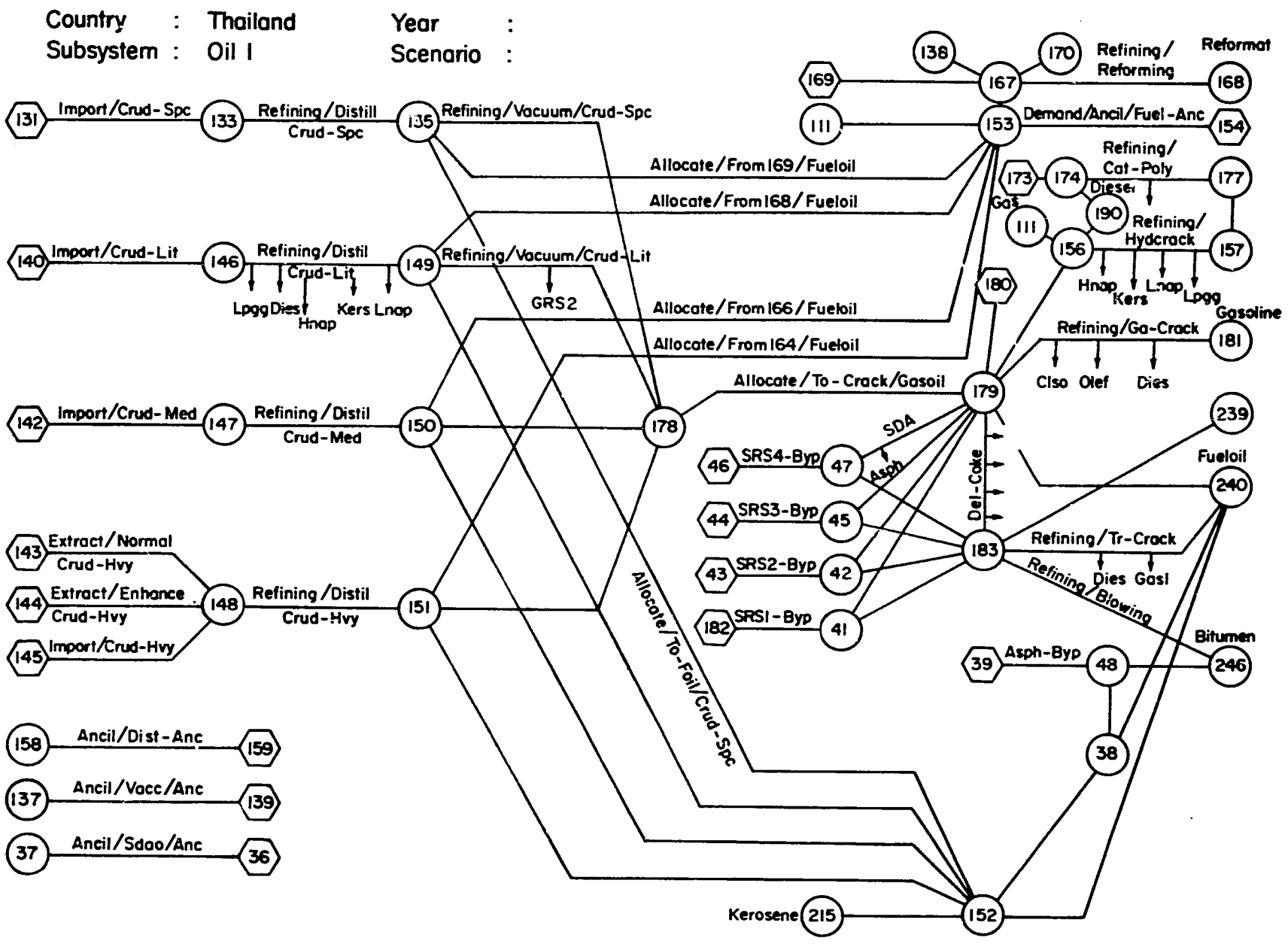
Country : Thailand
Subsystem : Oil I
Year :
Scenario :
131 Import/Crud-Spc
133 Refining/Distill Crud-Spc
135 Refining/Vacuum/Crud-Spc
140 Import/Crud-Lit
146 Refining/Distil Crud-Lit
Lpgg Dies Hnap Kers Lnap
149 Refining/Vacuum/Crud-Lit
GRS2
142 Import/Crud-Med
147 Refining/Distil Crud-Med
150
143 Extract/Normal Crud-Hvy
144 Extract/Enhance Crud-Hvy
145 Import/Crud-Hvy
148 Refining/Distil Crud-Hvy
151
158 Ancil/Dist-Anc 159
137 Ancil/Vacc/Anc 139
37 Ancil/Sdao/Anc 36
Allocate/From169/Fueloil
Allocate/From168/Fueloil
Allocate/From166/Fueloil
Allocate/From164/Fueloil
Allocate/To-Crack/Gasoil
178
Allocate/To-Foil/Crud-Spc
169
111
138
167
170
Refining/ Reforming
Reformat
168
153
Demand/Ancil/Fuel-Anc
154
173
174
Refining/ Cat-Poly
Diesel
177
Gas
190
Refining/ Hydcrack
111
156
157
Hnap Kers Lnap Lpgg
180
Gasoline
Refining/Ga-Crack
181
Clso Olef Dies
179
239
Fueloil
240
46 SRS4-Byp 47
SDA
Asph
44 SRS3-Byp 45
43 SRS2-Byp 42
182 SRS1-Byp 41
Del-Coke
183
Refining/Tr-Crack
Dies Gasl
Refining/Blowing
Bitumen
39 Asph-Byp 48
246
38
Kerosene 215
152

Exhibit 3a

Country : Thailand
Subsystem : Oil II (1)
Year :
Scenario :

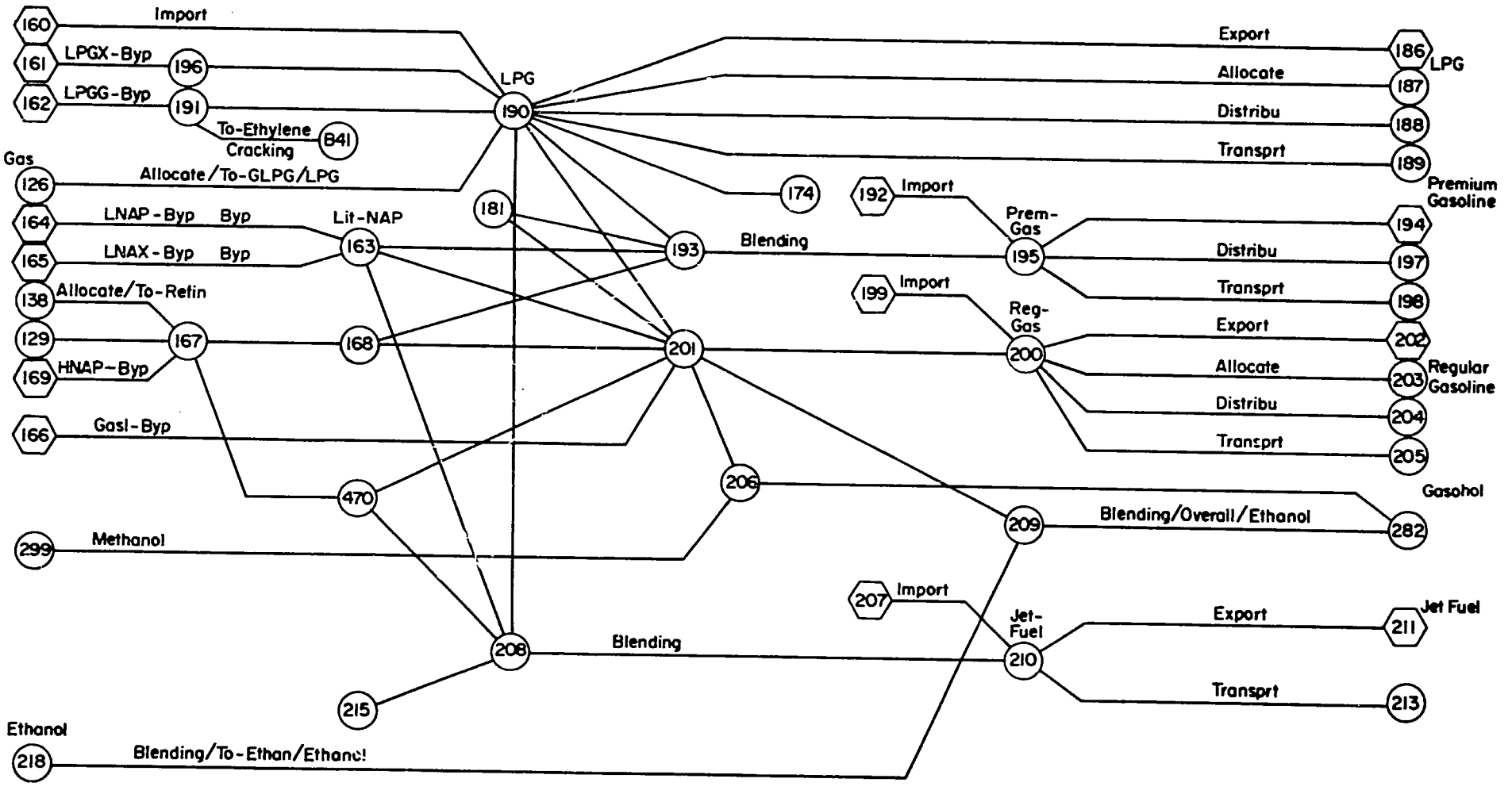

Exhibit 3b

Country : Thailand Year :
Subsystem : Oil II (2) Scenario :

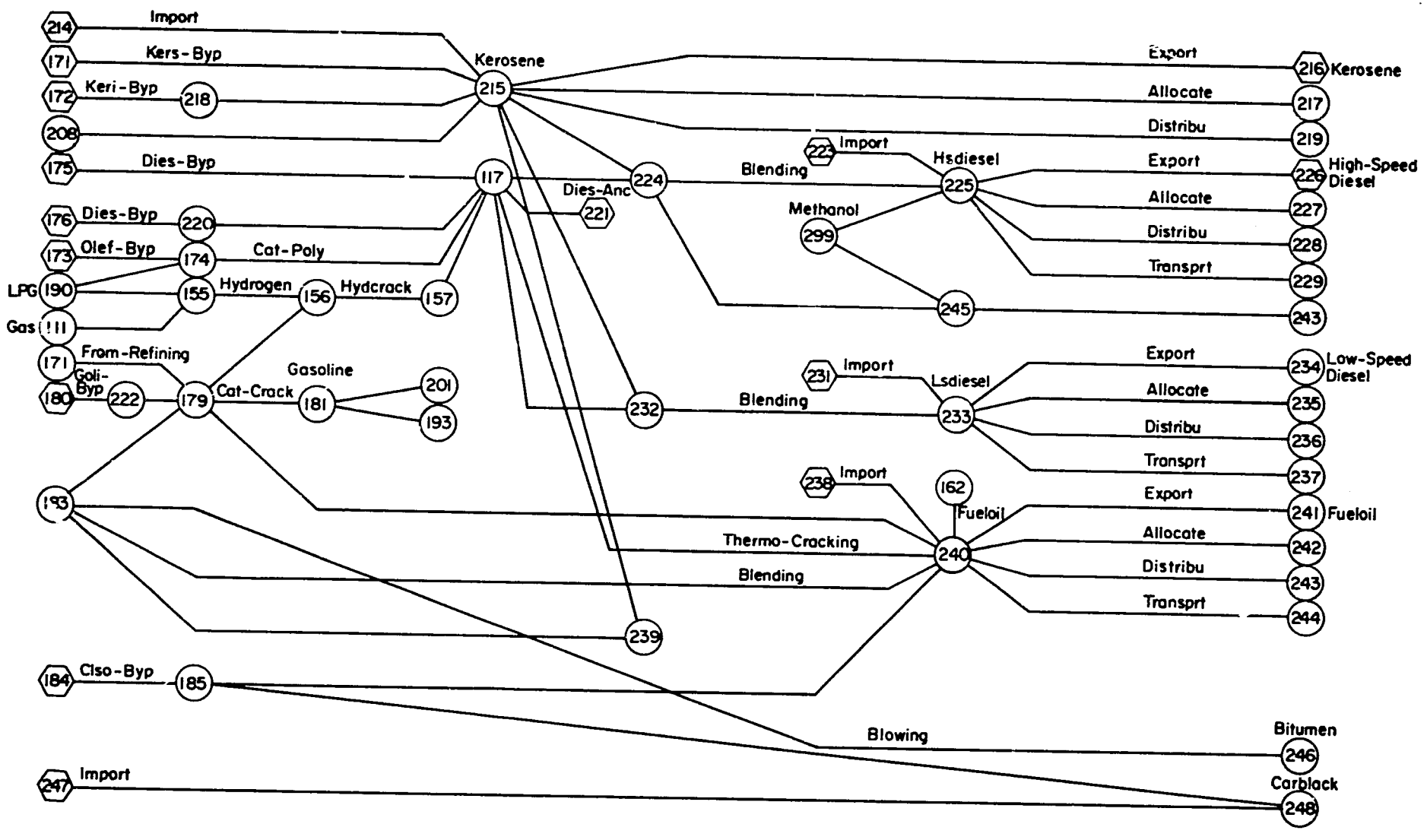

Exhibit 3c

Country : Thailand Year :
Subsystem : Othersup Scenario :

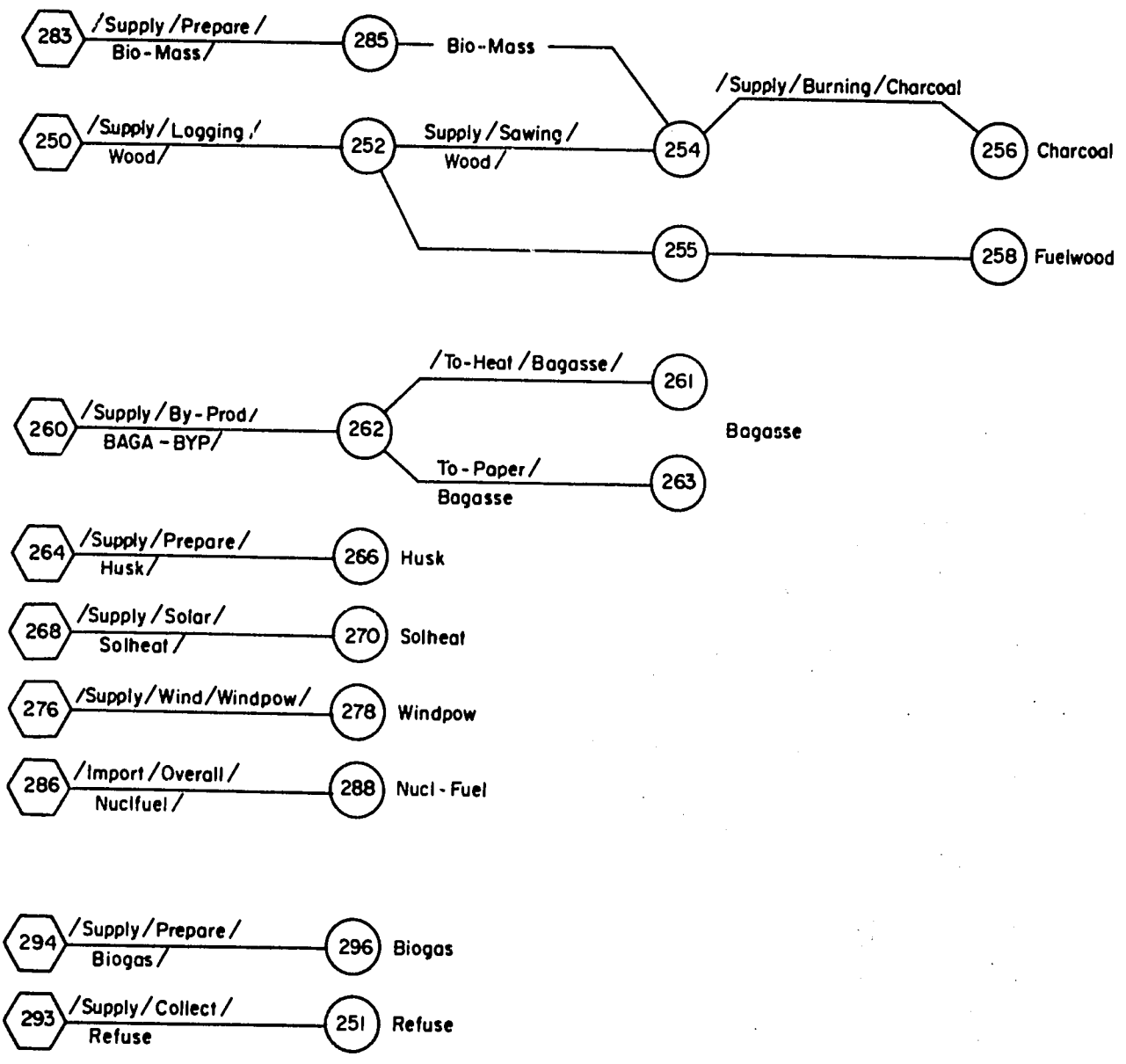

Exhibit 4

Country : Thailand Year :
Subsystem : Renelec Scenario :

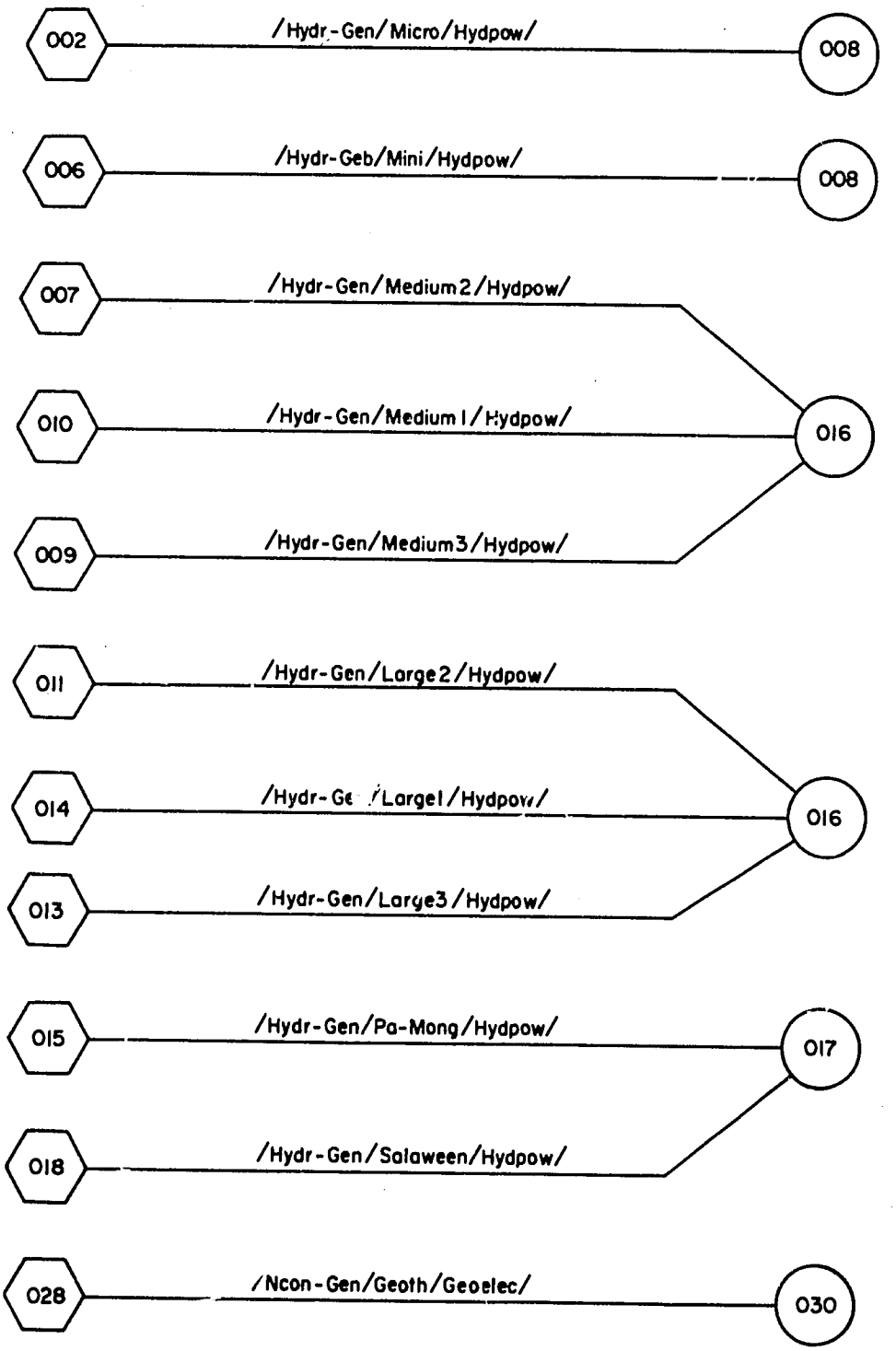

Exhibit 5

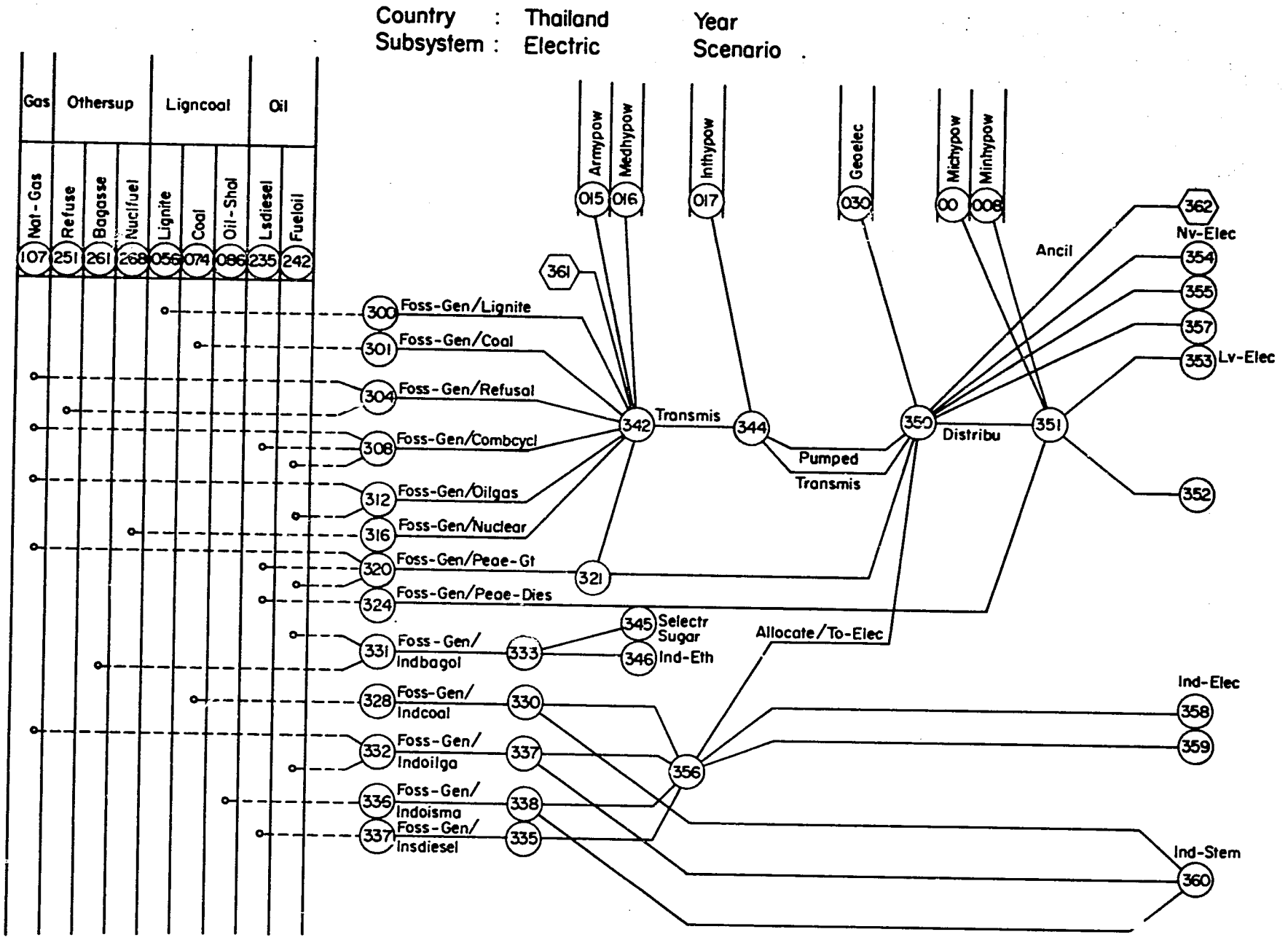
Country : Thailand
Subsystem : Electric
Year
Scenario .
Gas
Othersup
Lignicoal
Oil
Nat-Gas
Refuse
Bagasse
Nuclfuel
Lignite
Coal
Oil-Shal
Lsdiesel
Fueloil
107
251
261
268
056
074
086
235
242
Armypow
Medhypow
Inthypow
Geoelec
Michypow
Minhypow
015
016
017
030
00
008
361
362
Nv-Elec
Ancil
354
355
357
353
Lv-Elec
352
300
Foss-Gen/Lignite
301
Foss-Gen/Coal
304
Foss-Gen/Refusal
308
Foss-Gen/Combcycl
312
Foss-Gen/Oilgas
316
Foss-Gen/Nuclear
320
Foss-Gen/Peae-Gt
324
Foss-Gen/Peae-Dies
331
Foss-Gen/
Indbagol
328
Foss-Gen/
Indcoal
332
Foss-Gen/
Indoilga
336
Foss-Gen/
Indoisma
337
Foss-Gen/
Insdiesel
342
Transmis
344
Pumped
Transmis
350
Distribu
351
321
333
345
Selectr
Sugar
346
Ind-Eth
330
337
338
335
356
Allocate/To-Elec
Ind-Elec
358
359
Ind-Stem
360

Exhibit 6

Systems Approach to Problems of Non-Conventional Energy Development

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Introduction

The development of such non-conventional energy resources as solar, biomass, biogas, wind, waves, geothermal, tidal and so forth, has to be looked upon as part and parcel of a necessary and continuous process of replacing the depleting conventional energy resources such as oil, coal, gas and other fossilised fuels. The options of nuclear and hydro are two possible solutions, but the underlying problems of land allocation, environmental devastation, political setbacks in uranium fuel supply and utilization have restricted the use of these sources.

These problems are no doubt soluble. In the context of national and regional objectives for energy development, it is important to determine the malleability of national and regional objectives to suit the ever-changing international energy environment.

Objectives of non-conventional energy development

The planned use of energy is a powerful tool for economic and social change. Energy policy must be sponsored by the executive branch of Government with other national priorities. In the Asean context, the national priorities are also consistent with broad regional priorities.

Two broad objectives of a national policy should be:

1. economic production of all locally available renewable and non-renewable energy forms in line with the national development strategy.

2. improved management for maximum productive use of all energy forms, locally produced or imported.

The non-conventional energy resources should be anticipated to bring significant impact to economic and social change beyond the year 2000. This time horizon is necessary because by that period the world may face shortages of fossil fuels. The take off should begin as early as possible to give enough time for energy assessment. The time limits of energy transition may change in response to depletion of conventional resources earlier or later than currently anticipated.

In this respect, a series of preferred energy policies will form the objectives, depending on the "energy status" of the country. Oil-surplus countries, those with oil resources in excess of their domestic consumption, would have major energy development objectives to extend the exploitation period of the resources, and to invest export revenues for future resource exploration. In energy-balanced countries, where energy production more or less balances domestic demand, major objectives will be to increase national energy supply in step with the country's economic growth to prevent future energy import dependence and to develop such indigeneous energy sources as solar and hydro. Energy deficient countries would have objectives similar to those of energy-balanced countries. These objectives may be supplemented by the need to minimize energy imports, pursue energy conservation and develop exports with which to pay for energy imports.

The understanding of these objectives is an important prerequisite towards defining the real problems related to non-conventional energy. They are "real" problems because they are placed in the proper perspective of national development. For instance, if our objective is to extend the depletion time of resources can non-conventional energy technology such as, say, photovoltaic cells, make significant impact in reducing the consumption of conventional energy resources? When will it be expected to make a breakthrough in terms of technology transfer and the availability of local expertise? These are necessary questions which have to be answered with time and magnitude functions in order to chart its possible inputs. The input points could help in problem definition.

Defining the problems of non-conventional energy

There are many ways to look at a problem. The normal problems of energy plantations are the large acreage requirements necessary to allow 8 to 10 years cycle. This acreage could instead be utilized for food crops which can thrive on marginal lands such as the sago plant in swampy lands and the palm oil plants on hill slopes. In the case of peninsular Malaysia, with a land mass of 32.5 million acres and only 3.1 million acres of virgin forests, 5.0 million acres are logged-over forests and 4.7 million acres are unproductive forest lands. Will the cultivation of energy crops instead of food crops on 10 million acres of unproductive and logged-over land provide a viable contribution towards photosynthetic energy storage? The priorities of each problem are understood, but the relationship of these problems with energy demand, modes of utilization such as conversion into alcohol, and competition with energy-related food production are equally important towards redefining the problem of energy plantations.

Problem definition is itself a jig-saw puzzle. All the bits and pieces of these "mosaic" problems can be put together to produce the problem in totality. The problem is viewed on a wider basis of social, economic and cultural aspects. Biomass fuels of the non-commercial sector make up a substantial portion of total energy consumption in the range of 40-75 percent for many developing countries. Is fuel wood the predominant biomass energy source for household cooking in rural areas? What is the position in Malaysia with regard to the type of fuel used for rural household cooking and how much does this make up in our total energy consumption?

The definition of the problem is a heavy task. It must be based on reliable data. However, the initial definition of the problem can start without adequate data. The "real" problem can be determined as the national objectives are outlined and this should be considered as soon as possible before further iterative processes take place. At the least, it would lead to the next step and a very necessary one, creation of a data base

The problem can also be looked at from the legal side. Will solar energy technological advancement be enough when the legal system is not prepared to protect the rights of a person against obstruction of continuous sunlight due to a massive solar collector plate installed in the neighbourhood? Or, how do land strata laws apply for anything above the land such as the wind and solar energy?

Another aspect of the problem is the relation to national economic policy such as revision of tax laws to encourage the development and usage of non-conventional energy. Other problems involve political decisions of the government to amend certain laws extending the scope of legislative provision to such sectors as building laws, utility regulation, and the like.

Data base: energy accounting

In order to prepare a planned approach towards solving an already defined problem, an energy data base is required and the data base should include the following modules:

1. Energy Flows Account in the form of highly disaggregated energy balances broken down to regions, subsectors, and energy forms.

2. Energy Technology Account with relevant information on existing and potential future technologies.

3. Energy Price Account broken down to all energy forms, supplies and demands.

4. Energy Resource Account which should include theoretical and technical potentials of all indigeneous energy resources both conventional and non-conventional, commercial and non-commercial and identification of their accessibility in economic and strategic terms.

This data base is in a constant dynamic process of adjustment. It has to be updated regularly and its capacity is expandable. The data input has to undergo a constant reviewing process to prevent the problem of "garbage in: garbage out". For instance, if a wind measuring anamometer has been producing data for the past few years but it is wrongly placed on a cliff top subject to eddies and turbulence, then it must be repositioned on a slope for direct wind flows and the data inputs updated.

Analysis: energy planning

The analysis of given data is a systematic method. It is planned approach towards data extraction, processing and computation into set formats. It should address non-conventional energy issues on three different levels. The first level assures the consistency of national energy strategies with other national priorities. The second level aims at the optimal energy use and energy diversification between the different energy subsectors while the third level deals with master plans for individual subsectors such as electricity transport, etc.

In the case of Malaysia, biomass energy is immense. The country, in 1979 produced 4.2 million tonnes of crop residues with energy value of up to 4,600 GHWe per year (in 1979, NEB's electrical energy generated is about 7,400 GWHe). Under the Fourth Malaysia Plan the acreage for agricultural development would double. By the end of 1990, the linear increase of crop residues produced would double the energy potential to about 9,000 GWHe per year. The national energy strategies in Malaysia may be based on several possible national energy scenarios, which are carried out for three stages i.e. 1980. 1990 and the year 2000. In the scenario which represents a situation where minimal efforts are made on the gas and hydro sectors to expand further, the contribution to energy equivalent from crop residues in terms of bdoe (barrels per day of oil equivalent) will be about 15% total oil requirement. Under the scenarios where the economic hydro potential is fully utilized (including Pelagus, in Sarawak), the contribution of crop residues would increase to 20% of total oil requirement. Based on the

Gross Domestic Product (GDP) projections at a growth rate of 8.1% annually, as forecasted in the Outline Prospective Plan of the Third Malaysia Plan, the energy contribution from crop residues against a background of total energy consumption will be about 12%. This shows even at this very preliminary stage that crop residues can provide for significant energy diversification between the different energy subsectors. The economical location for utilization of crop residues will be at the point of production because of the diffuse nature of the resource which makes collection, transport and storage costly.

In relation to master plans for the electricity subsector, transport subsector etc., crop residues will have to be properly characterised. Each type of crop residue differs from each other. For instance, the coconut husk is more practical for alcohol production while the rice-husk, a low carbohydrate substrate, is more useful for heat and electricity production.

Energy planning for these non-conventional avenues would also involve resource and energy management studies, the appropriate technology inputs and investment requirements. This plan should lead to the actual groundwork for implementation of prototype solutions to omit or commit several analytical conclusions made.

(Fuel Oil: 1 GWHe = 1,819 boe (31% efficiency)

Feedback: Energy development

The existence of functional prototype units using non-conventional resources are the only reliable sources of operating information. This is an essential feature in energy development. The feedback stage should be retraced backwards to the point where the problem is defined. It interfaces with all strata of energy accounting and analysis right to the point of implementation. Consider, for instance, the utilization of rice-husk for power generation. At the initial stage the problem was just environmental.

The piling of rice-husks threatened the fertility of rich padi lands and even the continuous operation of the rice drying and milling complexes.

The intermediate method was to incinerate these rice-husks for drying of padi. Information feedbacks at this stage showed that the heat generated was excessive for drying. The next method was to use these rice-husks for power generation. Preliminary information shows that this will be inefficient, however. Further information feedbacks on energy technologies showed that several efficient processes are possible. As technical and economic analyses were carried out there were also other possibilities of rice-husk utilization such as extraction of industrial carbon, anti-acid cement making, boards and road making. The process of feedback information continues from the commercial, industrial and academic circles. Even at the decision-making stage there is also information on investment and resource issues. The analysis shows that power generation will be an economic way to solve the rice-husk disposal problem, but definitely this is far from final analysis. Two functional systems will be built, commissioned and reanalysed. Any problems derived from these functional units will comprise feedback information at the development stage. The overall results should indicate whether the unit would fulfill the objectives as set earlier. This stage may cover a period of 2 to 3 years, giving ample time for proper assessment on all aspects of the unit. If the objectives are not met, the problems have to be redefined. Is it the rice-husk disposal problem or could it be the drying and milling process itself which needs more heat energy for all other forms of predrying and storage drying? Through analysis of the data base processes it may be that a possible solution is to increase the output of steam by more rice-husk inputs from surrounding areas.

This induction process will continue until the objective of an efficient rice production process is met loading us to the reproduction of these systems for wider application.

Corporate vehicle: Investment into energy development

The creation of a corporate vehicle should stimulate the development of economically usable local energy sources and related technologies in association with the private sector on a firm commercial basis. This vehicle will act as both an investor and an enterpreneurial force for the Government in the development of renewable energy resources.

It will implement projects purely on an economic basis taking into consideration initial capital deployment and total costs in relation to returns from real term revenues and government incentives (like tax relief etc.). Apart from the cost factors there are also such other factors as growth of local technological capabilities for manufacture and maintenance of new equipment.

The feedback information would continue to be obtained at this stage. The corporate organization which may have heavy government investments, may turn out to be merely a finance company rather than an independent entity. These corporate objectives have to be reviewed should "derailment" occur by turning back to the actual problems in question.

For instance, the solar photovoltaic industry to be set up by a foreign investor may have a complete detachment from the usage of local silicon sources, expertise and know-how which have been built through the various stages of energy development before corporate vehicle is created. The original problem will have to be redefined. Will the, say, 5% contribution from solar photovoltaic cells to energy consumption in the year 2000 be a worthwhile investment venture for locally backed-up manufacturing industry or preferably an amalgamation of the already established multinational semiconductor industries to locally manufacture these cells? The problem could be amplified to a scale completely unrelated to investment, like the possible effects of toxic disposals of certain semiconductor elements which may make the government to review local manufacture or impose some other controls.

Policy Implementation and Review

The successful implementation of energy policies will depend on the levels of responsibilities carried out by various government departments, statutory authorities and commercial institutions. The outline of responsibilities is as follows:

a) responsibility for overall energy policy and planning including electricity tariff analysis, fuel pricing, fuel taxes/duties.

b) development and maintenance of up-to-date external energy data base (such as Industry, Government, Household, Commerce, Transport, Rural, Agricultural).

c) development of national energy accounting system and energy modelling.

d) development of energy auditing capability.

e) development of national energy conservation programme.

f) forecast of energy production, demand and prices.

g) development and maintenance of up-to-date energy resources inventory.

h) economic analysis of energy programmes and projects.

i) development of public energy awareness programmes.

j) review and advice on energy-related codes, laws and regulations (including building standards).

The final stage of the systems approach will be returned to the stage of reviewing the national objectives. It could be possible that more oil reserves are discovered in the Asean region which may give the region more resource depletion time. The time function objective may shift further. Or, drastically, a breakthrough made in cheap hydrogen production from sea water may change the entire non-conventional strategy with more emphasis on the production of hydrogen fuels.

Information retrieval problems

Information is the basic element in all the stages of a systems approach. Information is transmitted through communication media. The media of communications such as radios, T.V.'s, books and verbal means are areas which are frequently subjected to information distortions. Distortions, although not deliberate, are commonly due to built-in obstructions. A project which has been carried out with 5 years feasibility study would not be an easy source of feedback information on the "dark" side of the story because of the preconception that the detailed and thorough feasibility study would have looked in all the possible problems.

These obstructions to real information can be effectively removed by more interaction between all influential and relevant agencies and departments to assist with information retrievals.

Conclusion

The lead time for non-conventional energy development will extend beyond the year 2000. This long lead time is an advantage for early starters in this field. A systems approach is a time consuming and painful process of trial and error. It is important, however, to provide the basic necessities for the well-being of the future generation.

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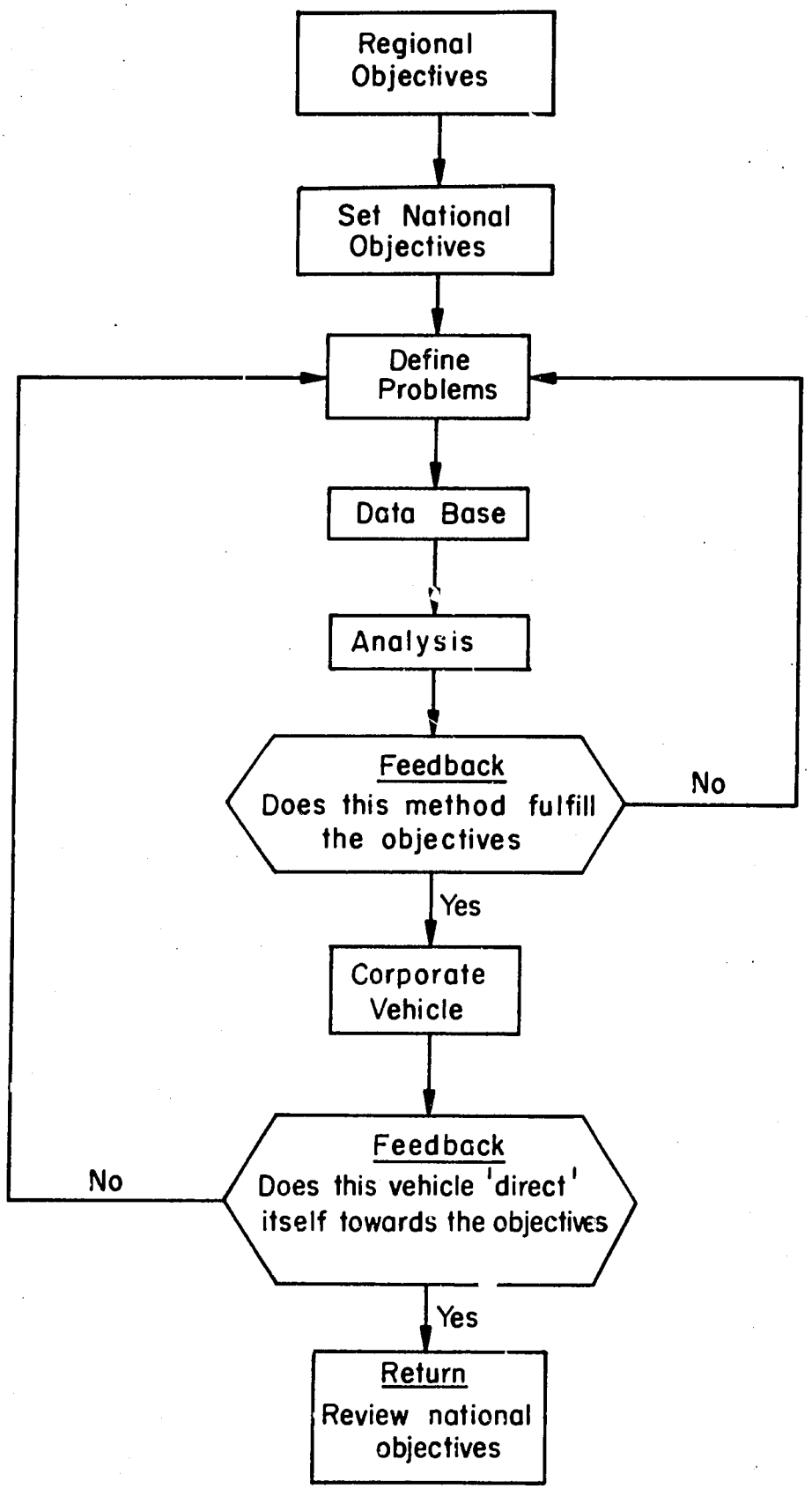
Appendix A :

Overall Systems Approach



Developmental Studies for Selected Local Inventions Pertaining to Non-conventional Sources of Energy

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Background

Our culture has been enjoying the benefits of a cheap, easily available energy source, fossil fuels, for generations. Today, practically all of our luxuries and necessities are dependent on coal, natural gas and oil. The reserve limitations of these fossil fuels has become a platform for politicians, a bargaining point for diplomats, a lucrative commodity for the rich and a glaring reality for everyone.

Because we have built our culture and standard of living on easy energy, conventional wisdom pushes us harder and harder to find alternative energy sources capable of feeding our excessive needs. The most obvious alternative has been the search for less accessible deposits of fossil fuel - further offshore and deeper in the ground. But very soon the cost of retrieving new reserves will exceed the benefits provided by them. The search for more oil can only be a short term solution with long term implementations for the environment.

Further down the line, many see the development of nuclear power as the answer to our energy problems. In fact, the country plans to erect nuclear power plants to partially supply our energy needs and one is under construction in Bataan. The development of nuclear power may present a more complex problem. In the first place, uranium itself is a limited resource and for a country like ours all the fuel for the proposed plant will be imported draining further the dollar reserves of the country. There are also the inevitable nuclear wastes generated and left behind by nuclear power plants that threaten the very existence of life. Lately, a controversy has arisen on the safety of nuclear power plants resulting in a worldwide slowdown in their construction.

We are, therefore, left with one alternative energy source that could supply much of our needs - solar power and all of its manifestations in the wind, water and plants.

There are many ideas for harnessing the power from the said energy sources, and the Philippine Inventors Commission is rich with such undeveloped ideas. To date, there are some 160 inventions pertaining to non-conventional energy sources requesting assistance from the Commission for development and perfection. These inventions may be the answer to strengthen our economy which is being eroded by the oil crisis. Imported oil, whence 95% of our commercial energy requirement comes, is becoming too costly for our pockets. Since the crisis in 1973, the Philippines has been spending about ₱7.2 billion on the commodity every year.

National policy on energy had thus been redefined along lines that would assure sustained development despite the oil shortage. Energy self-reliance, a goal the country has set for itself, spells on one hand, weening away from oil as an energy source; and on the other hand, exploring alternative local sources of energy.

This project is being proposed to explore the talents of local inventors who have answered the call of the time. Although not all the patented inventions are meritorious for commercial production, it is very logical that some of them could be the missing links to solve our energy problems. Moreover, all those inventions were made in the local climate and thus, are very adaptable to our local condition.

It is on this premise that this proposal should find merit for financing, for it will not only offer some solutions to our energy needs but also would develop local technology that would boost the image of science and technology in the country.

Introduction

The Philippine Inventors Commission (PIC) now Philippine Invention Development Institute (PIDI) under R.A. 3850 and as amended by P.D. No. 1433, is empowered to grant financial aid to local inventors, utility model makers or industrial designers, to enable them to develop, perfect and produce their inventions, utility models or industrial designs duly patented or those which are patent pending, up to the pilot scale to demonstrate their operatability and industrial applications. It is also authorized to recommend to government lending institutions, inventions that are beneficial to our country to enable inventors to manufacture their inventions.

As of May 1980, there are around 160 inventions pertaining to non-conventional sources of energy filed with the Commission for assistance. Although the Commission has extended financial assistance to some of the inventions, assistance was limited to patenting and construction of prototype models without thorough study on their commercial viability due to limited funds and staff, absence of proper monitoring system and lack of an effective commercialization strategy.

Moreover, the increasing number of inventors seeking the said assistance and the continuous escalation of cost for developmental studies in contrast with the Commission's meager budget with insignificant increases, if any, every year limits the PIC financial assistance program to only a few inventions.

Objectives of the Project

1. To systematically identify, evaluate and select meritorious locally patented inventions pertaining to non-conventional sources of energy.

2. To establish criteria for the evaluation and selection of the said inventions.

3. To test identified inventions by the construction of commercial model/ Pilot Plants to determine their economic potentials through actual test runs and field operations.

4. To establish a system for monitoring indigenous technology power generation research to hasten its development.

5. To coordinate and act as a liaison to other government agencies and private institutions/busimessmen for the commercialization of viable inventions/innovations.

6. To develop marketing strategies for commercially viable inventions to facilitate introduction to the market.

Methodology

To effectively accomplish the overall objectives of the project, it is divided into three phases.

Phase I: Search and Identification:

1. Data Base Creations: Abstracts will be prepared for all patented and patent pending inventions pertaining to non-conventional sources of energy which include their operation, principle behind the design, working drawing, and other data and information, that may facilitate screening.

2. Series of Initial Screening: All the inventions in the data base will be screened by a panel which will subject them into three levels of evaluation namely:

a. Technical Level - to assess the "manufacturing ability" and availability of technical know-how/raw materials for their manufacture.

b. Professional Level - to assess the technical/engineering feasibility.

c. Businessman's Level - to assess the commercial viability and market potential.

A statistically based model will be designed to facilitate analysis and evaluation of results.

Phase II: Testing, Development and Commercialization Strategy Formation

1. Technological Test: Construction of commercial model/pilot plant to test the effectiveness of the invention, measure their efficiency and generate sufficient data needed in assessing the inventions' commercial viability. Moreover, a field study will be undertaken to compare performance with existing or similar products now in the market.

2. Market Test: The developed invention/innovation will be subjected to series of demonstrations to determine its acceptability to prospective customers and to identify target markets.

3. Pre-Investment Feasibility Study: The information from the above two tests will be collated, studied and evaluated through the preparation of a pre-investment feasibility study.

4. Commercialization Syndicate: The above study will be published or disseminated to concerned government agencies and private business organization and feedback information will be used for Phase III of the project. The organization of the syndicates of potential investors on the project will be catalyzed by PIC in consultation with the inventors concerned.

5. Other Studies: Other studies that may be needed to ascertain the technical, commercial, and market feasibility, particularly for unique inventions, will also be undertaken. Feedback information will be further studied to ensure commercial viability.

Phase III: Commercialization Activities:

Activities in this phase will be applied only to inventions passing

the first two phases. The endeavour can be undertaken either by a joint effort of the Commission and the EDB or by the Commission alone. The activities involved in this phase are the following:

1. Project Study Preparation: A thorough project study will be prepared by reputable persons or management organizations.

2. Business Formation: Presentation of the project study through workshops/seminars or dialogue with interested parties of financiers.

3. Financing Arrangements: A very lenient financing scheme will be formulated through the cooperation of EDB, DBP, PNB and other financing institution to facilitate their commercialization and introduction to the market.

4. Further Studies: Studies for other problems that might crop-up during the execution of this phase.

Summary of Report

This report covers only Phase I of the whole project. Phase I involves search and evaluation of patented inventions/innovations which lead to identifying projects that will be pushed for developments. This phase includes data base creation on inventions and innovations pertaining to non-conventional source of energy, screening, evaluation, and engineering cost estimation for the construction and/or fabrication of selected projects.

Data have been set-up by categorizing and classifying inventions and innovations into six different areas, namely, solar, wind, water or wave, bio-chemical, geothermal and solid and molded fuel sources.

Evaluation and selection for the development is based on three levels of criteria: Professional Level, Technicians Level and Businessmen Level. These are all based on tecnnological and economic viability and adaptability - extent of utility, replicability, availability

technology know-how and manpower, availability of materials and machines and equipment, simplicity of construction, market competitiveness and the consideration of technological and social impact. Please refer to Annex I for evaluation criteria.

Out of the patented inventions and innovations screened, only six were initially selected for development. Four inventions are from solar energy area, one is from molded/solid fuel and energy source, and one is from water energy area. These are then considered and recommended for development and commercialization. Annex II shows the inventions/innovations that were recommended for development.

As of this date, only Phase I of the project has been completed. A complete technical report was submitted for evaluation and Phase II of the project will soon be started. From the six inventions/innovations selected for development, two or three maybe recommended for Phase III, the commercialization activities of the selected invention/innovation.

"ANNEX I"

Proposed Evaluation Criteria

I. Technicians' Level (Skilled)

A. Feasibility of Fabricating/Mass Producing the Invention

a) Local availability of technical know-how

b) Local availability of machines for fabrication

c) Local availability of raw materials, parts and instruments

d) Availability of fabricator/machine shop to construct the invention

B. Workability of the Invention

a) Based on the evaluators' experience, attest invention's operation as claimed

b) Suggestion on the design to make the invention more efficient/effective

c) Related existing machine/process

C. Approximate total cost to fabricate one invention

a) Labor Cost

b) Material Cost

c) Number of months/days to complete fabrication

D. Recommendations to facilitate/simplify the fabrication of the invention

II. Professionals' Level (Theoretical)

A. Technical Aspect

a) Determine if design principle conforms with accepted laws and theories of science

b) Efficiency/output of the invention

"Annex II"

c) Indigenous material utilization

d) Attest invention's operation as claimed

e) Suggestions on the design to make the invention more efficient/ effective

B. Social Desirability

a) Cost/Benefit ratio

b) Social and environmental effects

c) Recommendations to facilitate/simplify the fabrication of the invention

III. Businessmen's Level (Practical)

A. Profitability - Cash investment on development vs. expected cash dividend if commercialized

B. Feasibility - The viability, desirability and practicability of the invention

C. Competitive position of the invention in relation to existing similar products, i.e. price quality and efficiency

D. Local and foreign market potential

E. Economic benefits that will accrue from the invention.

Inventions/Innovations Recommended for Development

1. Title : Drier Utilizing Solar Energy
   Patent No. : I-9798
   Date Patented : March 17, 1976
   Patentee : Felix Caoile

This invention relates generally to driers and more particularly to

"Annex II"

a drier which utilizes solar energy to extract moisture from various materials and products such as grains, cereals, seeds, crop, meat, fish, coconut, lumber, fruits and others.

It is a known fact that various drying apparati are presently used, such as the direct or indirect heat driers, steam driers and open air driers. Present direct or indirect heat driers whether heated by the burning of waste materials, bunker oil, liquified petroleum gas or other fuels have been found unable to produce uniform quality drying due to the difficulty in the maintenance of constant temperature and uniform exposure of the materials to be dried. There is also the danger of overheating.

Steam driers, on the other hand, although producing good results, are very expensive and require high capital outlay and high operating and maintenance costs.

Open air drying is economical but very inconvenient and risky, being subject to unpredictable weather conditions and contamination.

The subject invention will provide a drier which will minimize contamination and maximize effective use of solar energy by trapping it; a drier which is safe in that the temperature ranges in it are within limits; a drier which is very simple and therefore could be easily and cheaply manufactured and maintained.

2. Title : Combined High Efficiency Solar Radiation Collector and Heat Storage

Patent No. : I-10665

Date Patented : August 2, 1977

Patentee : Felix Caoile

This invention relates in general to devices which converts solar energy to heat energy and more specifically to a high efficiency solar radiation collector and heat storage for use in drying agricultural,

marine, and forest products such as grains, fish, timber and others.

The combined solar radiation collector and heat storage comprises a closed hollow structure having insulated walls and several spaced apart staggered baffles. The sections within the closed hollow structure are filled with river stones; and a solar radiation collecting means disposed on the inclined side of the closed hollow structure. The solar radiation collecting means comprises a main heat absorbing panel, several staggered baffle plates disposed normally on said main heat absorbing panel, an inner glass panel disposed from said innerglass panel in which the spaces between them are preferably evacuated. The said solar radiation collector means is being internally connected to the closed hollow structures; whereby the heat generated in the solar radiation collector means is conveyed to the closed hollow structure.

3. Title : Solar Heater
   Patent No. : UM-3829
   Date Patented : January 16, 1980
   Patentee : Americus Ramos

This innovation generally relates to improvements in solar heaters for heating fluids such as water by solar energy. In particular, the utility model relates to a solar heat collector or heat accumulator of the molded type having double glazing effect.

Presently, the production of hot water for use in most commercial and residential establishments entails high costs and substantial amounts of electrical and gas energy. However, the use of solar heat collectors which make use of sunlight or solar rays will save household and/or industrial expenses.

This invention provides a utility model of a solar heater having a double glazing effect and a selective surface heat absorbing sheet. The innovation is simple in structure, with low construction cost, is highly

efficient, has a long life, and is adapted to absorb and/or collect solar heat suited to create high fluid temperatures.

4. Title : Solar Energy Collector Device
   Patent No. : UM-35422
   Date Patented : June 20, 1979
   Patentee : Carlos Acosta

The utility model relates to solar energy collector device and more particularly to an improved solar energy collector device utilizing helium gas and copper tubings as its absorbers.

Flat plate type solar energy collectors in the market today are limited to heating water for domestic use. More complicated types of solar collector devices are being utilized for higher temperature requirements which employ tracking mechanisms to concentrate sun's rays in heating the absorbers. However, said devices are very expensive and require additional maintenance.

The utility model of a solar collector device eliminates the tracking mechanism and utilizes helium gas as the heat transfer medium. The utility model provides an alternate heater in absorption type refrigeration and can also be used as a preheater on boiler feed water. It also provides an economical means of heating ovens and water for domestic use.

5. Title : An improved Waterwheel for a Mini Hydro Electric Plant
   Patent No. : UM-4663
   Date Patented : August 21, 1981
   Patentee : Pedro Dalagan & Marcelino Concepcion

The utility model relates generally to a power generating apparatus and more particularly to an improved waterwheel for a mini-hydro electric plant in which the force of water flowing from canyons, gorges or even brooks is converted into mechanical power to drive an alternator to generate electric current.

"Annex II"

Several countries that are normally dependent on imported fuel have undertaken hydroelectric development to meet their electric power demands. The most commonly installed hydroelectric plants include a high-head and low-head installation types. In the former, the water is brought from the supply reservoir through an open canal at a low gradient to a small chamber or forebay on the hillside above the powerhouse where a short, steep pipeline conveys said water to the turbines. The low-head installation type utilizes a dam with a powerhouse constructed on one flank thereof and provided with a headrace or tailrace, whichever is more convenient. The above types of hydroelectric plants are beset by pronounced drawbacks and disadvantages inherent in their construction and operation. Hydroelectric plants of these types are constructed utilizing delicate parts which require close and constant attention during operation.

These problems are overcome by the subject utility model providing for an improved waterwheel for a mini-hydro electric plant featuring simplicity in construction and economy in manufacture, which can be easily maintained and repaired and which can be built with suitable indegenious materials.

The construction of the mini-hydro electric plant is deemed necessary to demonstrate its operability and application for the generation of electricity of small industry plant or lighting provision for rural houses. This kind of project will greatly benefit the economy of our fast developing country, as it is responsive to calls for attaining self-reliance in energy, particularly in non-conventional energy sources and for lessened dependence on imported fuels and oils and machineries for generation of electricity. The development and use of this energy generation is deemed practical and economical in providing the energy needs of rural areas and small communities or areas where cost of fuel delivery is extremely high or where electric supply is poor.

"Annex II"

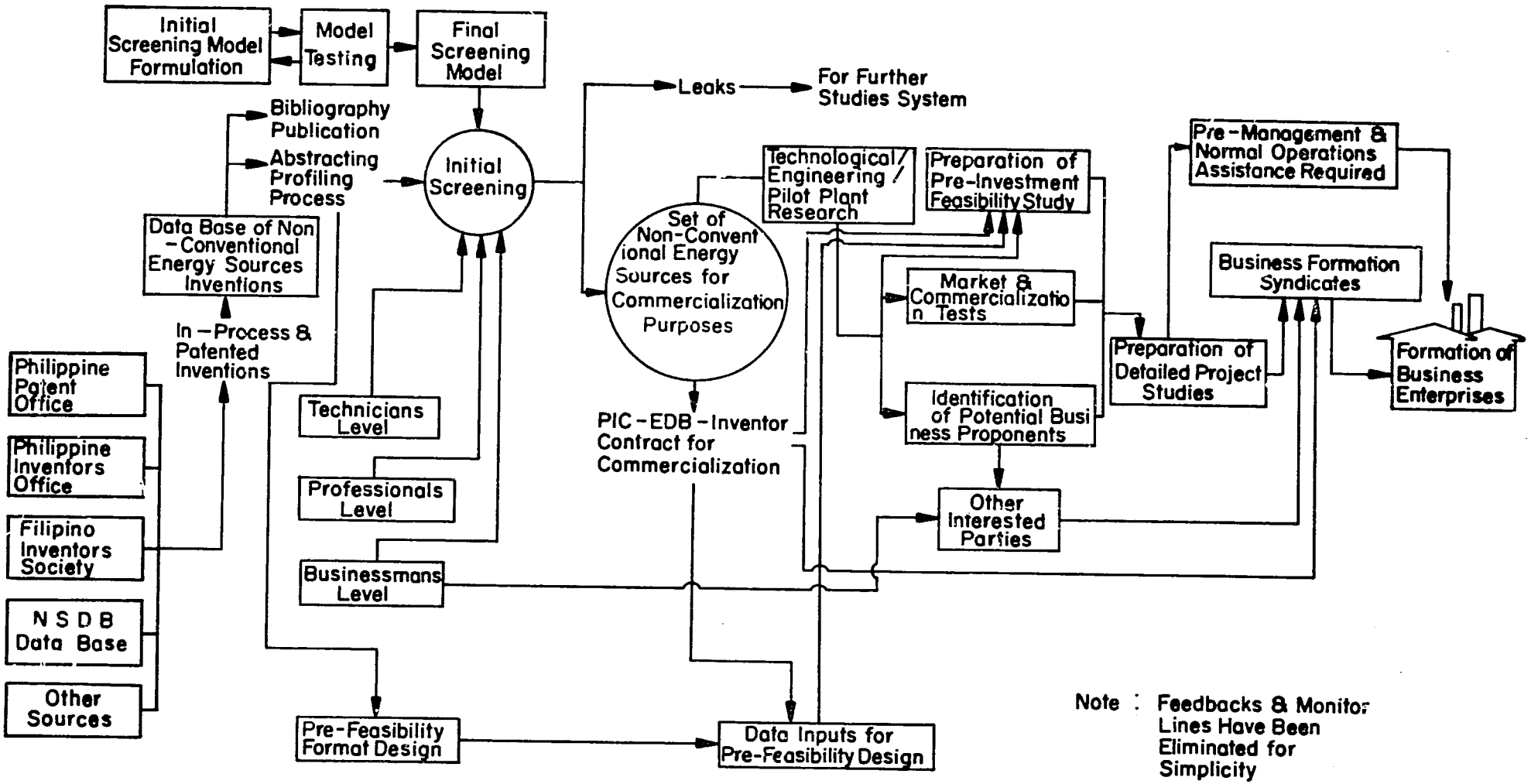
6. Title : Integrated Charcoal Kiln and Indirect Copra Dryer
   Patent No. : I-11664
   Date Patented : May 12, 1978
   Patentee : Teofilo A. Masulit

This invention relates to a dryer and a kiln in general but more particularly to an indirect dryer and a kiln adapted for the production of charcoal from copra.

Existing copra dryers and charcoal kilns are constructed in separate units requiring a large area with attendant disadvantages.

The development and use of this invention is deemed practical and economical in view of the advantages it offers in reduced space and time requirements, unified cost of fabrication and simultaneous production of high grade copra and charcoal. This invention provides for a kiln and dryer needed in the development of the coconut industry, particularly in providing improved quality charcoal and dried copra.

SCHEMATIC DIAGRAM FOR PROJECT IMPLEMENTATION



Overview: Energy Resources

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Abstract

Energy consumption of the Philippines in 1980 amounted to 88.3 million barrels of oil equivalent (MMBOE) or roughly 1.8 barrels per capita, lower than the 1978 consumption levels of developed countries and such other Asian countries as Korea and Singapore. Our projections show that in 1985, total energy consumption may reach 133.7 MMBOE or about 2.5 barrels per capita, pointing to the increasing demand for energy supply in the future.

It is the policy of the state to achieve self-reliance in energy supply. In line with this policy, the government has accelerated the development of the country's energy resources. The government expects to obtain at least 50 percent of energy demand from indigenous sources by 1988. Increased production and utilization of other energy sources will effect gradual shifts in oil-use such that by 1988 non-oil contribution shall have reached 30 percent.

Of the non-oil sources, hydroelectric energy will contribute the largest share 22.3 MMB representing 12 percent of total energy supply. Coal will account for about 19.8 MMB or 10 percent of the energy mix. Geothermal and non-conventional energy sources will provide the balance.

Introduction

The Philippines is an archipelago consisting of 7,100 islands and is divided into three main groups: Luzon, Visayas and Mindanao. Its total area measures 300,000 square kilometers.

Its population is estimated at 47.9 million, 36 percent of which are in the urban areas while the rest are in the rural areas. Population growth has decelerated from an average of 3.0 percent in the 60's to 2.7 percent in the 70's due to family planning consciousness. Literacy rate is 89 percent.

In 1980 Gross National Product (GNP) stood at 264.3 billion pesos or US$ 34.1 billion at current prices while per capita income amounted to US$ 714.

The country's major exports in terms of value are sugar, coconut, mineral (copper concentrates) and forest products; its major imports consist mostly of capital goods and crude oil.

The Philippines energy consumption in 1980 amounted to 88.3 million barrels of oil equivalent (MMBOE) (Table 1) or roughly 1.8 barrels per capita, lower than the 1978 consumption levels of such Asian countries as Korea and Singapore (Table 2). Forward projections show that by 1985, total energy consumption should increase to 133.7 MMBOE or about 2.5 barrels per capita (Table 3).

Institutional Framework

In order to integrate and coordinate the functions of the various agencies pertaining to the exploration and development of energy sources, the Ministry of Energy (MOE) was created by Presidential Decree issued in October 1977. It has, among others, the power and function to formulate and complement the government's policies, plans and programs on energy resource development. Prior to the establishment of the MOE, the primary government agency involved in research, development, promotion, and delivery of new and regenerative sources of energy was the National Science and Technology Authority (NSTA) formerly the National Science Development Board. Both agencies maintain close working relationship. The NSTA and its agencies is primarily concerned with R & D up to the pilot phase. Once fully developed such technologies are forwarded to

concerned agencies. The MOE also undertakes R & D to accelerate development of the different conventional sources of energy.

The NSTA's complementing arms for R & D projects on non-con energy sources are the National Institute of Science and Technology (NIST), Philippine Forest Products and Industries Development Institute (PFPRDI), Philippine Institute of Volcanology (PIV), and the Philippine Invention Development Institute (PIDI). In addition, the NSDB's attached agencies like the Philippine Council for Agriculture and Resources Research Development (PCARRD), the National Research Council of the Philippines (NRCP) also contribute in the development of non-conventional sources of energy.

Aside from the above-mentioned agencies, numerous other institutions are involved in energy. The University of the Philippines System (UPS) undertakes R & D on new and renewable sources of energy. The National Electrification Administration (NEA) implements the mini-hydro and dendrothermal power projects. The Ministry of Agriculture (MA) through the Bureau of Animal Industry (BAI), undertakes the widespread application and utilization of biogas. The Ministry of Human Settlements (MHS) through the Farm System Development Corporation (FSDC) is in charge of the widespread application of wind power for water pumping and irrigation and gasifier technology for transportation and irrigation. The National Food Authority (NFA) also conducts researches on the utilization of Agricultural wastes, including rice hulls, for alternative sources of energy.

Energy Resources

It is a declared policy of the state to achieve self-reliance in the country's energy requirements. Pursuant to this policy the MOE and NSTA developed an energy R & D and delivery program covering three areas:

I. Conventional Sources of Energy - Exploration, Development and Management (including effluent processing and treatment)

1. The oil exploration program targets 203 exploratory wells within the next decade. Of the total, 133 (66 percent) are offshore and

70 (34 percent) are onshore. To meet the target, about 20 wells are to be drilled annually, equating to an annual depth of 155,400 feet or a ten-year total of over 1.5 million feet. Oil discovered in off-shore Palawan resulted in the first commercial production of crude oil.

2. A ten-year coal development program aims to put our recoverable resources into the mainstream of energy activities. Initially, the targeted coal markets will consist of present coal users and NPC coal fired power plants with an aggregate capacity of 1,325 MW by 1988. The annual aggregate consumption from these two sectors is expected to increase from the present 265 thousand metric tons to about five million metric tons by 1988.

   Philippine coal ranges from lignite to anthracite but the over-whelming majority of coals lie near the borderline between sub-bituminous ranks. Their heating values are typically from 8000 to 1100 BTU's per pound. In general, Philippine coal is best suited for steam production and the firing of cement plants.

   With the issuance of P.D. 972, the Government has taken a step to accelerate exploration, production and utilization of local coal resources providing incentives miners and users of coal.

3. Geothermal energy is a surface thermal manifestation in high heat flow regions where volcanic activity is very intensive.

   The Philippine Institute of Volcanology (PIV), an agency of the National Science and Technology Authority (NSTA) pioneered in the initial R & D as early as the 1960's with 1 hp. pilot model at Tiwi, Albay proving that geothermal energy could be a potential source of electric power.

   The geothermal sector targets the development of a total of eight fields by the year 1988 adding five more to the currently developed fields at Tiwi, Albay; Makiling-Banahaw, Laguna, Palimpinon, Southern

Negros and Tongonan, Leyte. The prospective four fields are Manito in Albay, Mambucal in Negros Occidental, Manat in Davao and Kalinga in the Mountain Province.

Through the issuance of Presidential Decree 1442 or the Geothermal Act of 1978, geothermal development could be pursued by both private and government-service contractors.

4. Appraisal of the country's hydro potential indicates some 8,000 MW of this power source. This is equivalent to 50 MMBOE/year based on a 50% factor load. At present, slightly more than 10% of this is tapped with more than half of this potential programmed to be developed (4,373 MW) in the 1980's.

   Presently, there are eight mini-hydro plants operating in various areas of the country. In the next ten years mini-hydro projects will be receiving increased attention by the National Power Corporation and the electric cooperatives.

5. Uranium - There are known uranium areas in the Philippines and presently, airborne survey finished 3,264 line-kilometers and exploratory drilling reached 11,748 meters. The on-going sensitive ecological issues hinder early utilization of this energy source. The nuclear plant construction that was suspended has been resumed. The plant has a capacity of 620 MW and is expected to be on stream on or before 1985. It is projected to supply 6-9% of the total energy source mix by 1985.

II. Non-Conventional Sources of Energy Utilization, Development and Management (including effluent processing and treatment).

1. There are today over 15,000 square feet of collectors installed and operational in homes, hotels and private industries. To date ten local companies are engaged in design, fabrication, installation, and marketing of solar water heating system.

2. Wind - its potential is site-specific. The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) is conducting a research on a "Wind Turbine System" for PAGASA Radar Station at Basco, Batanes.

   In Bansud, Oriental Mindoro, a local design for a water wheel generating 30 KW of electricity was installed to irrigate the nearby fields.

   The Energy R & D Center, formerly the Center for Non-Conventional Energy Development (CNED) of the Philippine National Oil Company (PNOC-ERDC) has designed and tested various types of windmills using inexpensive materials suitable for low-lift irrigation and operate at low wind velocities.

3. Waves - Ocean waves for power generation also await intensive exploration. A double acting turbine has been designed to top ocean waves to produce power for navigational buoys and light houses.

4. Biomass - Another source of indirect solar energy collecting sunlight by plants and other matters to produce organic compounds. Sources include, among others, trees, algae, animal and agricultural waste and decaying plants. These are converted to fuels by which producing solid, liquid or gaseous fuels through various processes. Biomass can be broken down into:

   4.1 Alcohol Fuel - Alcohol is a derived product of fermentation. It can be produced from various starchy and cellulosic materials.

   The government has subsidized the production of alcohol from sugarcane on commercial scale with a capacity of 9 million liters annually which will contribute 1,534.6 thousand barrels-of-oil equivalent in 1983 and 5.817 MMBOE in 1989. The product is now in the market and is known as alcogas with 20% alcohol and 80% gasoline mixture.

4.2 Biogas, produced by the anaerobic fermentation of organic wastes consists of 50-70% methane with the rest being non-combustible gases. Biogas can be utilized to provide lighting, cooking, power generation for individual houses, industrial farms and small communities.

The biogas system has been found viable in the Philippines. There are about 500 biogas system. Maya Farms, a food processing plant has its livestock farm energy requirements fully supplied by biogas. Sixty percent (60%) of the energy used in meat processing and canning plant comes from biogas.

4.3 Producer Gas - This biomass source can be generated from such agricultural by products as woodwastes, rice hulls, coconut husk and shells, etc. It can be used to substitute or augment fuel for diesel engines for small-scale power generation and rural irrigation.

Portable producer gas engines to be used in constant power demand application such as pumping, small-scale electric power generation have been established. Recently established to produce commercially gasifier motor vehicles is the Gasifier Manufacturing Corporation.

A barrio is electrified using agricultural waste materials as fuel. Gas generated from coconut husks is used to power a generator that provide 30-KW of electricity. This plant serves 100 families in a remote rural area at Bo. San Antonio, Kalayaan, Laguna and has shown diesel fuel savings of 65 to 75%.

4.4 Dendrothermal - A typical dendrothermal plant consists of a wood-fired boiler-generator for power generation for rural areas not serviceable by power grid. Giant ipil-ipil (Leucaena Leucocephala) a fast growing tree species is considered a choice wood fuel.

A 500 KW unit will be constructed inside the Bureau of Forest

Development reforestation area in Occidential Mindoro. This project covers 3,260 hectares of which over 1,000 hectares have already been planted with ipil-ipil tre s.

The National Electrification Administration is conducting a nationwide dendrothermal energy survey. Fifty one (51) sites have been identified for energy plantations with an area of 1,000 hectares per site to provide fuel for 3 MW power plants. Each 1,000 hectares tree plantation is divided into 10 modules of 100 hectares each.

4.5 Natural Gas - In the form of low-pressure natural gas seepages, or marsh gas, natural gas can substitute for LPG for domestic cooking and lighting.

Field studies on gas seepages were spearheaded by the Philippine Institute of Volcanology (formerly the Commission on Volcanology) an agency of the National Science and Technology Authority. Surveys confirmed reported gas seepages in various places of the country. Twenty (20) pilot models were established covering seventeen (17) provinces.

III. Energy Conservation System/Devices Development and Utilization stressing the need to evaluate and develop energy conservation systems and devices with at least 10% savings on fuel-burned waste for re-utilization or conversion into usable products.

1. An alcotipid device was developed. It makes possible for a low grade alcohol (95% purity) to be fed into a 4-stroke internal combustion engine with partial displacement of gasoline by 20 to 50%. It can be installed on jeeps, cars and trucks without alternative of engines.

2. Another device developed is the alco-diesel device. It is an energy saving device used in diesel engine capable of displacing about 40% of an engine's diesel fuel with a mixture of 70% alcohol and 30% water.

Increased production and utilization of other energy sources will effect gradual shifts in oil-use such that by 1988 non-oil contribution shall have reached 30 percent. Of the non-oil sources, hydroelectric energy will contribute the largest share, 22.3 MMB representing 12 percent of total energy supply. Coal will account for about 19.8 MMB or 10 percent of the energy mix. Geothermal and non-conventional energy sources will provide the balance. Overall, more than 50% of total energy demand should be met by domestic supply by 1985.

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Table I

Energy Consumption, By Sector (In MMBOE)

	1975	1976	1977	1978	1979	1980
Transportation	27.8	28.6	30.2	31.3	31.9	32.1
Industry	30.6	31.9	34.6	36.5	38.2	36.0
Commercial	5.7	6.1	6.8	7.0	7.5	7.8
Residential & Others	10.2	10.7	11.6	11.2	11.7	12.3
Total	74.3	77.3	83.2	87.0	89.3	88.2

SOURCE: Ministry of Energy

Table II

1978 Comparative Per Capita Energy Consumption of Selected Countries (In Million Barrels of Oil Equivalent)[1]

Country	Per Capita Energy Consumption (MMBOE)
United States	51.2
Canada	44.7
Germany, Federal Republic of	27.1
United Kingdom	23.5
France	19.7
Japan	17.2
Union of Soviet Socialist Republics	24.8
China	3.6
Singapore	11.1
Malaysia	3.2
Korea, Republic of	6.1
Indonesia	1.3
Thailand	1.5
Philippines[2]	1.8

1/ Using the standard 4.5 barrels of oil = 1 metric ton of standard hard coal of 12,000 BTU/lb.

2/ 1980 data.

SOURCE: World Bank. World Development Report 1980

Table 3

National Energy Sources Mix
(In Million barrels-of-oil equivalent, MMBOE)

	1980		1981		1985	
	Volume	Percent	Volume	Percent	Volume	Percent
Power						
Hydro	6.27	7.11	7.26	7.42	17.08	12.78
Geothermal	3.42	3.88	5.34	5.46	16.34	12.22
Coal	0.26	0.29	1.15	1.18	8.38	6.27
Oil/diesel	21.46	24.34	19.50	19.93	7.02	5.25
Nuclear	-	-	-	-	2.81	2.10
Nonconventional	-	-	-	-	1.37	1.02
Sub-Total	31.41	35.62	33.34	34.08	53.00	39.64
Non Power						
Oil	56.03	63.55	63.16	64.55	66.44	49.70
Coal	0.71	0.81	1.17	1.20	9.55	7.14
Nonconventional	0.02	0.02	0.17	0.17	4.71	3.52
Sub-Total	56.76	64.38	64.50	65.92	80.70	60.36
Total commercial energy	88.17	100.00	97.84	100.00	133.70	100.00
Oil Share	77.49	87.89	82.66	84.50	73.46	54.94
Total indigenous	14.45	16.39	22.48	22.97	65.37	48.89
Per capita		1.83		2.00		2.47
Nonenergy consumption*	3.10		3.40		3.70	
Memo Total**	91.27		101.24		137.40	

* Nonenergy consumption refers to petroleum only.

** Memo total is the sum of total commercial energy and nonenergy consumption.

SOURCE: 5-year Compressed Energy Program 1981-85.

Energy Forecasting for Pelita IV

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INTRODUCTION

Energy constitutes one of the determining factors for the achievement of Indonesia development targets. During the decade of the nineteen seventies, energy was not a problem for Indonesia because energy requirements could be easily met from domestic resources. However, facing rapid population growth and an increasing pace of industrialization in the years ahead, management of energy resources should be implemented as early as possible in a rational and effective manner.

The historical data starting from 1963 show that during the period 1963-1969 the increase in total commercial energy consumption in Indonesia averaged 5.2 percent per year, whereas for the period of the last decade of 1970's the average increase was 12.0 percent.

Indonesia's commercial energy resources are available in great amounts. Oil resources total about 50 billion barrels (recoverable deposit); natural gas, 32 trillion cubic feet; coal, about 18 billion tonnes; hydropower, 31.000 Megawatts; Geothermal, 8000-10000 Megawatts. However, the pattern of energy resources is unbalanced since oil is the largest commercial energy source. In 1980, 80 percent of total commercial energy consumed was petroleum products. This situation should be changed as oil has an important role as a source of state income and is a depletable natural resource. It is necessary to take immediate steps to ensure that the Indonesian economy does not rely too heavily on oil and use as much of the other energy resources as possible.

With the above as background information, this paper describes the forecasting of Indonesian energy for Pelita IV (1984/85 - 1988/89).

Current Energy Use

In the last decade, the consumption of fossil fuels and hydro grew at an average annual rate of about 12 percent. The latter part of the decade starting from 1977 has experienced an extraordinary rate of increase surpassing 20% annually. This rate can be expected to continue in the near future as the country develops an infrastructure in electric generation, cement, fertilizes production and urbanization with increased access to motorized public transport and private vehicles.

Total commercial energy demand in 1980 amounted to 182 million barrels of oil equivalent (Mboe) of which 80% or 149 Mboe is based on oil. Natural gas comprises 15 percent of commercial energy and hydropower 3 percent.

Industry is the largest energy consuming sector using 29 percent of total commercial energy. Principally this sector uses oil, natural gas, and coal. The role of natural gas and coal in Indonesia's current domestic use is limited but may well change in the future as coal is increasingly used in electric generation and also in industry.

Oil products account for 88 percent of commercial energy use. About 30 percent of them are used in each of the three major consuming sectors industry, households and transportation. About 8 percent is used by the public utility sector.

Energy purchased by the industrial sector in 1980 amounted to 66 Mboe most of which is petroleum products. The largest consumer of petroleum products in this sector is cement and the largest consumer of natural gas is the fertilizer industry where gas is used as a feedstock. Nearly one half of the petroleum products purchased by the sector is used to generate electricity.

Petroleum used in the transportation sector amounted to 49 Mboe in 1980. In addition, small amounts of coal and firewood are used by railroads. More than 80 percent of the total petroleum products in this

sector is used by road transport, the remainder is used by ships, air and railroads.

The household sector consumed 37 percent of all commercial energy used in the country in 1980. Kerosene comprises the greatest proportion of household energy followed by electricity and LPG. Household uses are principally cooking and lighting. About 2 million of Indonesia's 29 million households use electricity for lighting and the remainding households use kerosene lamps.

The public utility generation system in Indonesia currently consists of over 300 isolated systems that are scattered throughout the islands. Of a total 2710 Mw installed by March 1980 (including some hydroelectric sites operated by institutions other than the state-owned public utility, PLN) over 70 percent or 1976 Mw is on the island of Java. Sales by PLN (including its purchases of hydropower generated by other institutions) have grown at an average yearly rate of 17.5 percent between fiscal year 1975 and 1979. Residential, commercial and industrial consumers purchase 45, 35, and 19 percent, respectively.

Energy Demand Projections

The projections of energy demand are based on the assumption that all energy sources except oil are supplied according to their maximum capacities while oil is a balancing factor to equate supply and demand. The total energy sector demand is derived from the total sum of energy sector consumptions i.e household, industry transportation, and electric power generation.

Projection of household energy consumption is based on growth in household substitution of fuels, rural-urban migration, and the population growth rate of 2.3 percent per year.

The projection of energy consumption in the industrial sector is based on industrial plant capacity expansions and subsector prognoses. The plant

capacity expansions depend in turn on the supply of energy. The subsector prognosis is steady growth rates following historical trends.

The projection of energy consumption in the transportation sector is based on the growth rate of GNP and histrical trends. Both GNP and historical trends influence the number of vehicles and the petroleum products consumed.

The projection of electricity generation is based on PIN; a generation expansion plan with some modification to include hydropower plants not owned by PLN. In this projection the energy for electricity generation is supplied from all sources but petroleum products again balance the demand and supply.

Energy demand projected

In the first year of Pelita IV commercial energy consumption is projected to be 297 Mboe growing to 423 Mboe in the last year of Pelita IV. These projections represent an average annual growth rate of 9.3 percent between 1984/85 and 1988; lower than the 12% annual rate of the 1970's.

The mix of fuels meeting energy demand for Pelita IV changes gradually with the share of petroleum products decreasing. On the other hand, hydropower and coal increase rapidly in line with the diversification programs of the GOI. All hydropower is used to generate electricity and coal is used for both the industrial sector and electricity generation. The amount of natural gas consumed increases at a lower rate than energy as a whole.

The rate of increase in the consumption of geothermal is the highest of all energy forms during Pelita IV. The 0.418 Mboe figure projected for the first year of Pelita IV grows to 6.7 Mboe in the fifth year. This rapid growth comes from the construction of geothermal power plants in several locations due to be completed before the end of Pelita IV. Those locations are in Kamojang and Gunung Salak, both West Java; Bali and the other locations in East Java and Sumatra.

Coal shows the second highest rate of increase. Increasing at an average rate of 58 percent, the 7.6 Mboe of coal consumed in the first year becomes 47.5 Mboe by the end of Pelita IV. Contributing to this high rate of increase is the construction of a coal-fired power plant of 1400 MW in Surabaya to be completed during Pelita IV. The cement industries which consume coal as a replacement for petroleum products also contribute to this growth. The share of coal rises from 2.6 percent of total commercial energy to 11.3 percent in the end of Pelita IV.

The role of hydropower in meeting the energy demand also grows rapidly expanding by 15.5 percent annually. The expansion of the Asahan power plant of 600 Mw and the completion of several hydropower projects in Java, with total capacity of 1200 Mw, contribute to increasing the share of hydropower from 6.5 percent of total demand to 8.1 percent in the end of Pelita IV.

Natural gas consumed during Pelita IV will increase at a rate of 3.2 percent annually but its share will decrease from 27.1 percent in the beginning of Pelita IV to 21.5 percent in the end of Pelita IV. Most of this energy is used in the industrial sector. The greatest consumers are fertilizer and cement factories.

The rate of increase of petroleum products will be only 5.5 percent during Pelita IV. The demand is expected to increase from 189 Mboe to 243 Mboe. But its share will decrease from 63.7 percent in the beginning of Pelita IV to 57.5 percent in the end of Pelita IV. This is due to the replacement of oil by other sources of energy, primarily coal.

Projected Energy Demands by Sector

Table I presents a picture of the distribution of projected energy demand for commercial energy by sector. The share of total commercial energy for the electric power sector increases steadily during Pelita IV from 13.0 percent to 22.2 percent. The share of commercial energy consumed by the household sector declines from 20.7 percent in the beginning to 18.1

percent in the end of Pelita IV. The industrial and transportation sectors also account for a smaller share of total commercial energy consumption in the end of Pelita IV. However, the energy consumption for all economic activities increases steadily in absolute terms. Household sector consumption increases during Pelita IV at an average rate of 5.4 percent annually, from 61.5 Mboe in the beginning to 76.5 Mboe in the end of Pelita IV. The industrial sector also grows at a rate of 5.4 percent annually during Pelita IV or from 130.4 Mboe to 160.8 Mboe. The rate of increase of energy consumption in the transportation sector of 8.5 percent is a little higher than other sectors. The energy consumed in this sector increases from 66.4 Mboe to 92.1 Mboe. The electric sector consumption rate increases 25 percent annually, the highest of all sectors. Consumption of primary energy for electricity rises from 38.5 Mboe in the beginning to 94.1 Mboe in the end of Pelita IV.

Conclusions

Background information has been given on the energy situation and current energy uses. The energy demand projection underlying the forecasting of energy during Pelita IV have been given as well.

Based on the above description, it can be concluded that during Pelita IV:

1. The share of non-oil resources, especially coal and geothermal energy, will increase. Both energy sources are utilized mainly for electricity generation.

2. The share of oil is expected to decline as more non-oil sources are used, mainly in the industrial sector and for electricity generation. In this forecast, oil will be used to balance supply and demand.

3. Among all sectors of activity, the electricity generation sector is expected to show the highest rate of growth. This will be due to the completion of large coal-fired (in Surabaya), hydropower, and geothermal units during Pelita IV.

Table I

Primary Energy Consumptions

Kboe

Sectors	1984/85	%	1985/86	%	1986/87	%	1987/88	%	1988/89	%
Household	61,556	20.7	65,162	20.0	68,519	19.3	72,263	18.7	76,490	18.1
Industry	130,450	43.9	139,860	43.0	148,400	41.7	154,350	39.9	160,810	38.0
Transportation	66,498	22.4	72,1[illegible]0	22.2	78,283	22.0	84,937	22.0	92,175	21.8
Elect. Generation	38,575	13.0	48,217	14.8	60,271	17.0	75,341	19.5	94,175	22.2
Total	297,079	100	325,389	100	355,473	100	386,841	100	423,632	100

Table II

Energy Demand for Pelita IV

Kboe

Sources	1984/85	%	1985/86	%	1986/87	%	1987/88	%	1988/89	%
Coal	7,651	2.6	19,190	5.9	27,446	7.7	34,064	8.3	47,456	11.3
Natural Gas	80,560	27.1	84,496	27.5	90,629	25.5	90,930	23.5	91,283	21.5
Hydropower	19,271	6.5	24,951	7.7	25,913	7.3	29,152	7.5	34,426	8.1
Geothermal	418	0.1	680	0.2	3,103	0.9	4,635	1.2	6,744	1.6
Petroleum Products	189,179	63.7	191,072	58.7	208,382	58.6	228,062	59.0	243,723	57.5
Total	297,079	100	325,389	100	355,473	100	386,841	100	423,632	100

Conventional and Non-Conventional Energy Utilization in Singapore

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Introduction

Singapore is a small island state occupying an area of approximately 600 square kilometres. It has an urban population of about 2.4 million people 80% of whom live in high-rise public housing estates. The economy of Singapore is based mainly on her industrial, manufacturing and commercial activities, entrepot trade and banking and other financial activities. Singapore, as most of us here are well aware, has no natural resources. Except for pig, poultry and fish farms and a handful of vegetable farms, every item of food is imported. The same situation exists in its energy needs, every joule of energy, from the fuel for its power stations to gas for cooking, is imported.

Owing to the differences in both geography and economy between Singapore and other countries of the region, the problems and priorities associated with conventional as well as unconventional energy needs and usages are of a different nature. This short country report on Singapore provides an overall view of Singapore's conventional energy usage and its priorities; to outline some unconventional energy applications and the research and development activities in this area; and lastly, to consider areas of contributions which Singapore can make toward activities within region.

Current Energy Production and Use

Singapore's energy needs are met entirely by import of petroleum products, the main items of which are crude oil and fuel oil. Several million

tonnes of petroleum products are imported annually. The amount imported is in excess of Singapore's own energy needs so that a proportion is processed and exported. This is possible because of the large scale refinery facilities provided by the major oil companies. A breakdown of the various petroleum products imported shows that crude oil constitutes 91% of the total energy imports with fuel oil and naptha for the production of town gas constituting smaller fractions, 8% and 1%, respectively.

The amount of petroleum products utilised locally is in the order of a few million tonnes. Usage of this imported energy can be classified under four categories. The transport sector, which includes ground, sea and air transport, utilises the largest percentage of the energy imported for local use. In the year 1981, this sector consumed approximately 72% of the fuel imported for local use. The industrial sector's consumption constitutes 7%, the government sector of which the electricity generation board is the main user, constitutes 18%, the remaining fraction of the fuel imported for local use goes to local oil traders and dealers.

A further breakdown of the energy consumptions for the transport and government sectors shows that in the former case, sea transport utilises almost 90%. By comparison, service stations, which provide fuel for almost all transport vehicles, (excluding the semi-government Singapore Bus Services) account for 10% of the energy consumption in the transport sector.

The Public Utilities Board, Singapore's electricity, water and gas body, accounts for almost all of the energy sold to the government sector. Within the PUB, except for a minor fraction utilised in the production of town gas, much of the fuel oil goes to the generation of electricity at its three major power stations. The present total generation capacity of the PUB's power stations, is about 2000 Megawatts, (power generation is via steam turbines, although gas turbines have been included in the PUB's expansion programs). This capacity is sufficient to meet Singapore peak demand of about 1000 Megawatts. The daily demand trend of Singapore's electricity consumption has a profile similar to that of any densely populated industrial city with peaks at 1400 and 1600 hours.

Total annual electricity consumption for 1981 was about 6000 million kilowatt hours. The private sector, which covers all manufacturing, industrial and commerical activities, accounted for about 74% of the total electricity consumption. The public sector, which includes all public lighting, port and airport facilities and government and semi-government bodies, accounted for about 9%. Household electricity consumption accounts for most of the remaining 17%.

Priority Area of Conventional Energy Use

In recognition of the ever increasing cost of energy, the government has introduced programs comprising both incentives and penalities to inculcate energy consciousness in the individual and in the industries. The need to avoid waste or inefficient use of energy in Singapore is a national objective since electricity is still relatively inexpensive at about 20 cents per kilowatt hour. High household energy consumption is discouraged via a surcharge of 10% of the total utility bill when the utility bill exceeds $80 per month (normally, the monthly utility bill for households without airconditioning is well below $80 per month). This surcharge is waived for industries, if efficient energy use is found to exist. In the case of public buildings such as hotels and office blocks, where airconditioning accounts for the major portion of the utility cost, poor insulation (OTTV exceeding $45W/m^2$) is penalised via a surcharge of 20%. Incentive schemes to be introduced by the government include financial assistance to the industries for replacement of machineries with high energy consumption by energy efficient ones, and to the purchase of energy saving devices.

At the national level and on a long term basis, programs to instill energy conscionsness have been initiated. An island wide "Energy is Precious" compaign is underway. Talks and seminars on energy saving are being organised for the general public and the industries.

Unconventional Energy Applications

Unconventional energy applications have been initiated only in recent

years and are motivated by the desire to save fossil energy via augmentation from unconventional sources. Examples of such applications are still few in number and are centred mainly on flat-plate solar collectors for hot water needs. Photovoltaic systems for beacons and radio-telephones for off-shore islands and a garbage incinerator are other applications.

The initial use of solar collectors in Singapore is concentrated on club houses and hotels. Hot water from the collectors is used mainly for shower or kitchen facilities in the club houses and hotels. These are small scale applications. Hospitals, mainly private ones, have recently embarked upon plans to install solar collectors to augment their hot water needs. Some examples of flat-plate solar collector applications are the Tanglin Club, Changi Golf Club, Shangrila Hotel and the St. Marks' Hospital. A large scale solar collector system was initially proposed for the new Changi Airport but did not materialise due possibly to technical grounds or cost. A large scale application proposed and already contracted for is a 900 panel system for hot water supply to the Changi Prison. Each panel measures 2 ft. x 4 ft. Hot water from the collectors will be used by the prison laundry unit which traditionally provides the laundry service to the government hospitals. Application of solar collectors at the household level is rare and this is primarily due to both the limited land and roof area and the initial cost involved.

In addition to the use of photovoltaic cells for buoys and beacons, solar cell panels have been installed in two off-shore islands, Kusu Island and Pulau Seking, to power public radio-telephones. In each case panels from Tideland Signal corporation are used. It has been found that the single-crystal solar cell modules from Tideland Signal, although expensive, are more reliable due to better encapsulation. The use of solar cells for powering air-pollution and other environmental monitoring equipment has been considered but could not be implemented due to the high cost of solar cells.

Disposal of both domestic and industrial refuse poses problems in a situation of limited land area. It is for this reason that the Ulu Pandan

garbage incinerator was constructed a few years ago. At present, the Ulu Pandan incinerator disposes of close to 350,000 tons of garbage annually. This constitutes about one-third of Singapore's refuse volume. The electrical energy generated for 1981 was approximately 50 million kilowatt hours and was sold to the Public Utilities Board for the most part.

Unconventional Energy Research and Application Studies

Research and development studies on unconventional energy applications are centred mainly in the Department of Mechanical and Electrical Engineering at the National University of Singapore.

Unconventional energy research and application studies in the Mechanical Engineering Department are broadbased while the efforts of Electrical Engineering Department is concentrated on basic studies in the semiconductor physics of solar cells, experimentation on the fabrication of cadmium-sulphide cell via a dry process, numerical modeling and efficiency improvement studies on single-crystal silicon cells.

In the Department of Mechanical Engineering, on going research and application studies include solar collector performance and testing. Various types of collectors such as evacuated type, inverse-flat-plate as well as the conventional flat plates are being studied. The performance of air-conditioning systems using solar energy is being carried out on a commercially available absorption unit, the Yazaki system. A research project initiated recently in the area of solar cooling investigates the use of a low pressure Freon jet.

In the area of solar energy storage, active research is being carried out on the performance of salt ponds.

Performance and application studies on photovoltaic cells were initiated about three years ago. These pilot projects were carried out on small scale systems (25-50 peak watts). With the experience gained, a research project on a larger scale (1.135 kw) system is now underway. This study

is devoted mainly to the performance of the solar cell system for water pumping application and constitutes part of a solar energy research project sponsored by the German government through the German Technical Assistance Scheme (GTZ). The major effort of the Department in this GTZ project is on solar collector performance and testing.

Conclusion

Being a small city-state with no natural resources and with an economy wholly dependent on her industries, entrepot trade and commercial facilities, Singapore's problems and priorities not only in energy but in many other areas such as housing, transportation, labour, social behaviour and medical care, are different from those of the other countries in the region. The existence of these differences, however, does not imply that cooperation and joint efforts especially in the area of energy studies, are not possible.

In the area of conventional energy use, Singapore's priority is in educating its people to be energy conscious in the factory, office and in the home. The schemes of incentives for efficient use of energy and penalties for inefficient use are being monitored and much can be learnt from their long term outcomes.

Although Singapore cannot offer practical experience on the use of such unconventional energy sources as solar energy for agricultural applications, it can, with time, provide information on the technical and economic aspects of solar energy for large scale hot water heating. It is anticipated that with the emphasis placed on energy saving, large scale users of hot water such as the food and drinks processing industry, hotels and hospitals, will see the need for the installation of solar collectors.

The diversity of on-going research and development projects on unconventional energy in the Faculty of Engineering of the National University of Singapore indicates the active interest of the faculty in this field. We hope for constant and close interaction especially with the

engineering and technical institutions within the region. A bulletin on unconventional energy studies and projects would be invaluable. Through such a publication, we would be aware of the specialised fields of interest to the region, be able to avoid duplication of efforts, and anticipate the contributions we can make towards unconventional energy applications in the region.

Framework For Alternative Energy Research and Development Programme In Thailand (1982-1986)

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Abstract

Status review of alternative energy technology in Thailand is presented. The demand projection of alternative energy during the 5th National Economic and Social Development Plan (1982-1986) is outlined. Target areas/activities and the required budget for research, development, demonstration and promotion of 9 selected areas, namely, solar thermal processes, photovoltaics, biogas, biomass production, biomass conversion, alcohol, wind energy, geothermal energy, and seed oils and resins are described.

Introduction

The Energy Policy and Energy Development Plan of the National Economic and Social Development Plan of Thailand calls for the accelerated development and increased utilization of domestic energy resources. For subsequent discussions, it is useful to categorize these resources into two groups, namely.

1. Commercial alternative energy sources. The principal domestic energy sources are lignite, hydro-electric and natural gas. The targets of the increases in production and utilization are natural gas from 250 x 10^6 ft.^{3}/day in 1982 to 525 x 10^6 ft.^{3}/day in 1986, hydroelectric generating capacity from 1,269 MW in 1980 to 2,013 MW in 1986 and lignite utilization in electricity generation from 210 MW in 1980 to 885 MW in 1986.

2. Other alternative energy sources. The sources include biomass and derivatives (wood, alcohol, city refuse, biogas), microhydro, oil shale, geothermal, solar and wind. By 1986, energy from these alternative sources

will constitute approximately one percent (the oil equivalent figure being 220-290 x 10^6 litres) of the total annual energy demand.

However, such contribution cannot be downplayed in terms of the people benefitted and the social consequences when one considers that these energy resources will be made available in rural areas. Some inferences could be drawn from the large disparity in energy consumption between people in Bangkok Metropolis (10% of total population) and the rest of the country; the oil consumption ratio is 6:1 and the electricity consumption ratio 10:1.

The paper incorporates a brief status review in the areas of solar energy (thermal and photovoltaic processes), wind energy and bioenergy systems. The contributions of other alternative energy sources, excluding lignite, hydroelectric and natural gas, to the Fifth Plan will be discussed. Programmes on research, development and demonstration are presented.

Status Review on Alternative Energy Technology

1. Solar Energy

1.1 Solar Thermal Processes

Solar Drying

Cabinet-type and box-type solar dryers using free convection have been locally developed for the drying of fruits, vegetables, meat and fish. Working drawings of the dryers (a few thousand of them) have been distributed to various parts of the country. During the next few years, economic and social assessments of these dryers will be conducted in rural areas of at least 5 regions of the country through a Thai-US renewable energy project.

Free convection-type dryers with transparent plastic covers have been developed and demonstrated for paddy drying. They are being used by limited numbers of farmers in the central plain for off-season paddy. Forced convection-type dryers with a flat plate air heater and a cylindrical air

convection-type dryers with a flat plate air heater and a cylindrical air being developed for grain drying.

Solar Distillation

Portable solar stills with aluminum or stainless steel bodies have already been developed and used in the country. Stationary solar stills having brick-and-mortar bodies are also being demonstrated. A few thousand drawings have been distributed to people in rural areas on request. Light-weight stills using fibre-reinforced plastic bodies are being developed. Research and development on more efficient solar still such as regenerative type, vertical absorber type, etc., will be carried out during the next few years. Economic and social assessments of portable and stationary solar stills will also be conducted through Thai-US renewable energy project.

Solar Hot Water Heating Systems

A detailed report on solar hot water heating systems is presented elsewhere at this Seminar.

Solar Thermal Electric Power Systems

During the next fifteen years, the Thai government plans to bring electricity to about 50,000 rural villages. Many villages are, however, so remote that electrification from the national grid system would be too costly for their small power requirements. Solar thermal electric power systems may provide more suitable decentralised systems. The technical and economic feasibility of two solar thermal electric power systems, namely the central tower system and distributed collector system are being studied in Thailand. The project is sponsored by the Electricity Generating Authority of Thailand. A pilot system having 100 kWth capacity might be constructed by the end of this decade; demonstration and testing of local technology will be emphasised in the project.

1.2 Solar Photovoltaic Processes

Photovoltaic (PV) panels have been installed at some rural health stations since 1976 by the Ministry of Public Health and the Medical Volunteers Foundation to supply electricity for communication equipment. Each station is equipped with a PV panel of 15W or 30W. Nearly 300 panels are being used at these stations. No significant deterioration of panel performance has been reported. It is projected that at least one kilowatt of PV panels will be installed annually for this purpose alone for the next few years. A 150-W array, the largest installed unit in Thailand, is being employed by the Electricity Generating Authority of Thailand (EGAT) to supply electricity for lighting and electronic appliances at a geothermal drilling site in northern Thailand. In addition, EGAT has been conducting field tests of PV panels from over 10 manufacturers since 1980 at a test station on the eastern coast. Discolouring of cells and encapsulants and electrode swelling were observed in some panels.

Another potential user of PV cells in rural Thailand will be the Telephone Organization of Thailand, with more than 500 signal repeating stations throughout the country. A typical power requirement of each station is 5-10 kW and is met by employing 2 diesel generators and a battery bank having 2-hour storage capacity. Some existing electrical generators are being replaced this year. Serious consideration will be given to new generating systems employing only PV arrays or combinations of PV arrays and diesel generators if the requisite system reliability can be adequately guaranteed. Over 100 repeating stations have been identified as possible PV installation sites.

2. Wind Energy

EGAT is now sponsoring development of 1 kWe wind electric power systems (WEPS) by Prince of Songkla University (horizontal axis type) and by KMIT Thonburi (gyro-rotor type). Aluminum turbine blades are being extruded by one local factory. Small generators (DC and AC) having up to 5 kW generating capacities have been specially designed

and fabricated for wind machines. In addition, EGAT has imported some horizontal-axis wind turbines with electrical generators and plans to test them by the end of 1982. These imported units have rated power outputs comparable to those of locally developed ones though the latter only develop their power at much higher rated windspeeds.

3. Bio-Energy Systems

One advantage of using biomass energy is local availability. In Thailand, most of the energy needs of the rural populations are met by fuelwood and charcoal from both forests and farming areas. However, greater use of these materials has decreased the availability of forest resources since 1977. It is estimated that demand for firewood will increase to 34 million m^3 while production will be around 14 million m^3 in 1985. There is an urgent need to supply more local energy for agricultural and household use. Biogas is one of our candidates since the technology is appropriate to rural conditions as comparatively sophisticated devices and highly qualified expertise are not involved.

3.1 Biogas

Biogas technology was introduced into Thailand over a decade ago by the Division of Sanitation, Department of Health, Ministry of Public Health. The prime objective was hygienic disposal of wastes from manure which accumulated under houses or within compounds. Biogas promotion remained a low priority until 1973. Since then, the number of installations has increased. Because of the energy crisis, this technology has been integrated as waste treatment and energy yielding process. The current total number of plant now exceeds 400 units most of which are located in the central and the northern parts of the country. During 1973-1976, the Division of Sanitation, Department of Health was the most active government agency in biogas development and promotion. The popularity of biogas among rural people declined in 1978. Reports on biogas units in each region indicated that active installations were only 40% of the total units build at the end of March, 1978. The major reason for the disuse of the units was corrosion of the steel or galvanized iron

gas holder. This problem is difficult to remedy in remote rural areas due to the lack of welding or soldering equipment and skills. Another handicap in biogas applications is the relatively high capital cost, often beyond the means of rural people. Because of government subsidies for the purchase of gas holders, the continued promotion of biogas technology is debatable.

Biogas plants installed in Thailand

There are two main types of biogas plant that had been developed in this country, the Indian digester with floating gas holder and the Chinese digester (fixed-dome digester). To reduce the capital cost, the jar digester with separate gas holder was designed and introduced by the National Energy Administration (NEA). Though this type is cheaper than the Indian digester, it tends to leak and fails easily owing to cracking. As a result, the NEA design is no longer recommended.

With regard to the bag digester, the system is not as widely used as the type mentioned above. Recently, most new installations were Chinese design instead of the Indian digester. The substitution resulted from the corrosion of the gas holder after 2 years' operation. However, it is hard to quantify the advantages of the Chinese type over the Indian. Thai users need more experience in digester performance before evaluations can be made.

Alternative Energy Demand Projections

Emphasis on alternative energy development and use during the Fifth Plan and their impacts are illustrated by the projections of demand from various alternative energy sources. The demand projections have been carried out for 3 different scenarios, namely:

a. No accelerated development of alternative energy.

b. Accelerated development of alternative energy without energy conservation measures.

c. Accelerated development of alternative energy with energy conservation measures.

Table 1 shows the demand projection of the 3 aforementioned scenarios. It can be seen that:

1. In the absence of accelerated development of alternative energy only "traditional" biomasses (i.e. rice husks, bagasse, firewood and charcoal) are included.

2. Accelerated development of alternative energy will bring into the national energy picture such new energy resources as biogas, alcohol, tree plantations, city refuse, microhydro, oil shale, solar, wind and geothermal.

By conservative estimates, the 1986 contributions of (the last year of the Fifth Plan) these newly developed alternative energy forms are approximately

a. 11% of "traditional" alternative energy (mostly biomass).

b. 5% of indigenous alternative energy (natural gas, hydro, lignite, and biomasses).

c. 1.2% of total annual energy demand.

Target Areas/Activities for Research, Development, Demonstration and Promotion for the Fifth Plan

Operation plans describing selected areas/activities for research, development, demonstration and promotion and the required budgets have been prepared by the National Research Council of Thailand. The plans have been formulated within the context of the demand projections of the Fifth Plan stated in Section 3 and incorporate activities deemed necessary in strengthening technological development capabilities in energy technology in the long term. The areas that have been addressed

by the operating plans are:

1. Solar thermal processes
2. Photovoltaics
3. Biogas
4. Biomass plantation
5. Biomass conversion (pyrolysis, gasification and combustion)
6. Alcohol
7. Wind energy
8. Geothermal energy
9. Energy from seed oils and resins

Target areas/activities for the 9 areas are as follows:

1. Solar thermal processes

- Production of process heat, up to 150°C, for commercial and industrial applications.
- Solar assisted dryers with collector areas larger than 20 m^2.
- Solar distillation systems with basin areas larger than 20 m^2.
- Solar airconditioning systems with at least 2 tons of cooling capacity.
- Solar refrigeration systems for food and medicine preservation at 0°C.
- Solar thermal electric power systems larger than 10 kWe for rural electrification and pumping.

2. Photovoltaics

- Crystalline silicon solar cells fabrication technology (from imported Si wafers to cell encapsulation)
- Balance-of-system technology (e.g. storage, power conditioners, tracking units)

- Engineering design of PV systems

- Accelerated tests and monitoring of already installed PV systems (more than 200 of 15-W or 30-W arrays)

3. Biogas

- Surveys of industrial-scale food and agricultural wastes

- Feasibility study and engineering system design of biogas plants and farms

- Development of family-type biogas technology

- Biogas production from medium scale industry wastes

- Downstream utilization of sludges as fertilizers, animal feeds and nutrients.

- Demonstration and promotion

4. Biomass Plantations

- Collection of information and appropriate technology in:

a. Species selection and improvement technology
b. Seed, nursery and planting technology
c. Management and maintenance of biomass plantation
d. Growth monitoring and productivity evaluation projection
e. Harvesting, collection and transportation technology
f. Economic models for returns on calculating investment
g. Socio-ecological development strategies

- Demonstration of appropriate existing technologies with promotion programmes for:

a. Village woodlots to produce biomass input for gasifier-driven electrical generators (10-30 kWe)

b. Fast-growing tree plantations at every subdistrict level

c. Agro-forestry demonstrations

5. Biomass pyrolysis, gasification and combustion

- Production of producer gas from agricultural wastes, woods and charcoal
- Improvement of charcoal production at both family-level and industrial-level
- Destructive distillation (pyrolysis) of agricultural wastes
- Fluidized bed gasification/combustion (for electricity generation)

6. Alcohol

- Alcohol as fuel for diesel engines
- Studies on sugar-cane, cassava and microorganisms in alcohol production
- Village-level alcohol production
- Demonstration plant (industrial scale) for alcohol production from agricultural products.

7. Wind energy

- Development of wind energy systems for water pumping and electricity generation
- Industrial standards for wind turbines
- Technical and economic evaluation of wind energy systems
- Demonstration of wind energy systems for irrigation pumping and water supply pumping

8. Geothermal energy

- Geothermal heat for drying (e.g. tobacco curing) and refrigeration

- 50 kW and 20 MW electricity generating plants

9. Energy from seed oils and resins

Table 2 shows the proposed budget for:

a. Research and development activities, and

b. Demonstration and promotion activities

It should be noted that the total required budget of 1316.3 million baht (approximately US$ 57 million) for all activities will bring about an additional energy supply of 607 million litres of oil equivalent. The price of this addition energy, if it is derived from imported crude oils (approximately US$ 138 million), exceeds the budget required, notwithstanding the impacts of the activities in strengthening technological capabilities and other social benefits.

With regards to the commercial alternative energy resources (i.e. natural gas, hydro and lignite) and nuclear energy, no operation plans and investment plans have been made public yet. The development plans of these energy resources, together with the investment projection, are under the responsibility of the following agencies:

a. Petroleum Authority of Thailand
b. Electricity Generating Authority of Thailand
c. Metropolitan Electricity Authority
d. Provincial Electricity Authority
e. National Energy Administration
f. Office of Atomic Energy for Peace, and
g. Military Energy Department

Conclusions

The 5th National Economic and Social Development Plan calls for accelerated development and utilization of alternative energy. The newly developed alternative energy (excluding natural gas, lignite and hydro) will contribute approximately 1.2% of the total annual energy demand in 1986. Operation plans and the required budgets for 9 selected alternative energy resources have been prepared. Specific target-areas/activities are delineated. Approximately US$ 57 million is required during the 5th Plan for the activities.

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* NESDB = National Economic and Social Development Board.

TABLE 1

Demand Projection For Other Alternative Energy
(in x 10^6 litres of oil equivalent)

		1982	1983	1984	1985	1986
Bio-Energy						
- rice husks	(a), (b), (c)	55.0	55.3	55.7	56.1	56.5
- bagasses	(a), (b), (c)	1,207.4	1,235.3	1,271.4	1,295.1	1,323.5
- firewoods	(a)	461.0	468.1	475.0	481.7	487.3
	(b), (c)	495.5	464.7	469.4	446.5	446.5
- charcoal	(a)	1,470.7	1,520.6	1,583.1	1,629.6	1,658.1
	(b), (c)	1,470.7	1,520.6	1,583.1	1,590.7	1,622.6
- city refuses	(a)	-	-	-	-	-
	(b), (c)	-	-	-	-	70.8
- biogas	(a)	-	-	-	-	-
	(b), (c)	1.1	3.4	5.6	7.9	10.1
- alcohol	(a)	-	-	-	-	-
	(b), (c)	35.2	70.4	105.6	105.6	105.6
- wood from plantation	(a)	-	-	-	-	-
	(b), (c)	-	-	-	66.2	66.2
Microhydro	(a)	-	-	-	-	-
	(b), (c)	4.0	6.0	11.6	17.3	28.6
Oil Shale	(a)	-	-	-	-	-
	(b), (c)	-	-	11.5	11.5	11.5
Solar Energy	(a)	-	-	-	-	-
	(b), (c)	0.5	0.9	1.5	2.4	3.4
Wind energy	(a)	-	-	-	-	-
	(b), (c)	0.1	0.1	0.2	0.2	0.4
Geothermal	(a)	-	-	-	-	-
	(b), (c)	-	-	-	7.2	7.2
Total	(a)	3,194.1	3,279.3	3,385.2	3,462.5	3,525.4
	(b), (c)	3,235.0	3,360.1	3,521.2	3,680.8	3,831.5

TABLE 2

The Proposed Budget In Millions Of Baht For The 9 Areas

		1982	1983	1984	1985	1986	Total
Solar thermal processes	(a)	3.0	6.5	11.0	12.0	13.5	46.0
	(b)	3.5	4.5	11.0	17.0	18.0	54.0
Photovoltaics	(a)	4.7	8.8	7.0	4.5	3.5	28.5
	(b)	0.8	5.8	6.3	4.3	4.3	21.5
Biogas	(a)	8.0	5.6	4.8	3.0	3.0	24.5
	(b)	9.8	13.1	16.6	20.5	24.2	84.3
Biomass plantation	(a)	0.2	0.2	0.2	0.2	0.4	1.2
	(b)	40.0	40.0	40.0	40.0	40.0	200.0
Biomass conversion	(a)	5.5	8.2	7.8	0.9	1.0	23.4
	(b)	4.6	4.9	22.5	29.8	40.8	102.6
Alcohol	(a)	6.4	5.1	2.5	1.4	1.4	16.7
	(b)	-	80.4	50.4	30.0	-	106.8
Wind energy	(a)	-	1.8	1.5	2.2	2.2	7.7
	(b)	-	17.7	17.9	18.6	18.0	72.2
Geothermal energy	(a)	1.8	13.6	23.0	220.3	203.2	462.0
Seed Oils and resins	(a)	-	2.0	7.3	0.8	0.8	11.0
TOTAL		88.4	218.2	229.7	405.6	374.5	1316.3

Energy Planning in the Asean Countries

Report of the Energy Planning Group

Energy in Asean Countries

The energy sectors of the five Asean countries display both differences and similarities (see Table 1). The major differences concern oil resources and production. Two of the countries, Indonesia and Malaysia, are net exporter of oil. Another two, the Philippines and Thailand, by contrast, are heavily dependent on imported oil which accounts for 85% and 75%, respectively, of total energy supplies. Paying for these oil imports imposes a heavy burden on the economies of these two countries. The case of Singapore is rather different. This country is dependent on imports for its total energy consumption which includes the feedstock needs of a major regional refinery complex. Much of this imported oil is, however, re-exported either as refined products or embodied in other goods The effects of high import dependence on the economy are more limited for Singapore than for the other two oil importers. All three, however, share the problem of vulnerability to supply interruptions.

Despite distinctions between oil importers and oil exporters, the Asean members share several energy problems. All countries, though differing in energy resources, are concerned with increasing supplies of other forms of energy, including non-conventional ones, in order to diversify their energy economies. For the oil importers, this will lead to reductions in imports through higher domestic production or through a greater diversification of energy imports. For the oil exporters, increased domestic production of other forms of energy will delay the depletion of oil resources or release more oil for export. Both Indonesia and Malaysia, despite their current substantial levels of oil exports, could become net oil importers within a relatively short time, about 10 to 20 years. In all ASEAN countries, energy consumption and oil consumption in particular has been rising rapidly, frequently in

response to subsidized or low energy prices. And even in those countries where energy prices are already at international levels additional efforts to encourage the more efficient use of energy are being considered in recognition of the major burden imposed on the economy by higher oil prices. The transport sector, which typically uses about one-half of total oil, is a favourite candidate in many countries for more intensive conservation activities.

The position of traditional fuels, including the whole question of improved supplies of energy to the rural sector, is also a common problem faced by all Asean countries, with the single exception of Singapore. In all these countries, traditional fuels are in short supply in some areas. Even when there is no supply shortage, however, there is a need to upgrade the quality of energy available to rural populations in order to add to their productivity and standard of living.

Present State of Energy Planning

The urgency and complexity of these problems have led most Asean countries to consider some measure of overall energy sector planning, in contrast to the episodic sub-sectoral planning which has taken place so far. Such policy analysis and planning involves a continuous identification of issues, policy formulation, delineation of options, analysis of options, implementation, and feedback. These processes are described in papers presented at the workshop by Joy Dunkerley, Wesley Foell, and Ahmad Faizul bin Shamsudin. While each country approaches this process in its own way conditioned by its own institutions, there has, in general, been clear identification of issues and options based on the characteristics of their energy sectors described in section 1 and Table 1. All wish to reduce the share of oil in total consumption and to promote the efficiency with which energy is used. There is greater variation in progress with the analytical framework. A basic building block of the energy planning process is adequate data on energy production and consumption and on the major variables which affect energy. Though it is difficult to generalise

over five countries, it appears that a good deal of energy data are already available on a regular basis. These include limited time series data on both aggregate and disaggregate consumption, including forms (coal, oil, gas, electricity); main consuming sectors (industry, transportation, residential/commercial, non energy). This "balance sheet" approach is desirable as it permits analysis of interfuel substitution within consuming sectors. On the supply side, energy resource data are available for several countries. Teresita Valdez's paper, for example, gives detailed data for the Philippines. In some cases, however, resource surveys have not been updated to take into account higher energy prices, and may thus be underestimated. Another weakness is the lack of data on energy cost and prices, and the almost complete lack of knowledge about production and consumption of traditional fuels which provide a substantial part of total energy supplies in the Asean countries save Singapore.

In order to provide a useful planning tool, these energy data must be related to socio-economic variables. National accounts and population data are now widely available. Most countries have a recent input-output table which can be used in energy planning. Some measures of output for the main consuming sectors are also available. Again there are gaps: data on output variables such as disaggregated industrial production, transport activities (passenger and freight ton mile in urban and inter-urban transport), urban and rural family budgets and commercial office space are all inadequate.

Data on energy supply and consumption are used to project energy supply and consumption over the planning period. The length of the planning period differs among countries. The Philippines, Thailand and Indonesia have five years plans. While there are useful exercises carried out within the framework of current five year economic planning, there is a need for a longer terms prespective to take into account the long lead times and time horizons of energy projects, and transition from depletable fossil fuels to an energy supply based on sustainable sources of energy.

The complexity of existing models for projecting energy supply and and consumption varies considerably between countries and is often constrained by data. In several countries, aggregate energy consumption is related to estimates of economic activity (GDP) and to energy price changes, and sectoral energy consumption is related to a few basic indicators of sectoral output. The papers given by E. Daryanto and T. M. Soelaiman for Indonesia and Teresita Valdez for the Philippines illustrate these procedures. Supply estimates for such relatively short periods of time are necessarily determined by projects under way or near completion. A much more elaborate energy modelling procedure was introduced in a paper on modelling in Thailand by Pongsa Pornchaiwiseskul. This model involves the following sub tasks: scenario selection, macro economic analysis, sectoral demand forecasting, energy resource assessment energy conversion technology assessment, energy demand processes assessment, energy plan optimization, energy pricing. Though seemingly ambitious, the group was assured first that the data needs can be met without excessive effort and second that the model was easy to run. In these circumstances other Asean countries may wish to extend their modelling efforts. Whatever the degree of complexity, it is worth bearing in mind the rule of Wesley Foell that a good model must be "useful, usable, and used". This points to the importance of integrating the modelling process with other links in the planning chain, especially with those who are responsible for implementing and formulating energy policy.

Though the systems approach to planning described here applies to the energy sector as a whole, it is equally relevant to planning of non-conventional forms of energy. This approach ensures that the effects and implications of non-conventional projects on other parts of the energy economy are explicitly taken into account on both the supply and demand side. An example given by Ahmad Faizul bin Shamsudin is the effect of co-generation projects using agricultural wastes on electricity load factors - a problem which can be overlooked in process analysis.

Many of the modelling techniques currently used have been developed in the industrial countries which raises the question of how far they can

can be appropriately used in the different conditions of the developing countries. A particular weakness is, for example, the limitation of many modelling exercises to commercial fuels despite the fact that traditional fuels are a major source of energy in all Asean countries (except Singapore). The systems approach seems equally relevant to the modelling of traditional fuels. More effort should be to include these fuels in energy forecasting and to make explicit the linkages between the traditional and commercial sector. Similarly, energy modelling ought to be sensitive to issues such as employment and environmental costs.

Implementation

Implementation is perhaps the most difficult part of the planning process. The major objectives of most of the Asean member countries increase domestic production of energy resources, to encourage conservation, and to shift consumption away from oil, whether imported or domestically produced. The five-fold increase in crude oil prices over the last nine years provides incentives in all three areas. For a number of reasons, however, these incentives may not be strong enough to achieve desired results in the relatively short time frame of policy. This is particularly true for the oil importing countries whose high import bills are currently a heavy burden on the economy. These countries have typically introduced additional measures to encourage energy production and curb demand. In the Philippines, for example, gasoline stations are closed at week ends and imports of large cars are to be prohibited. In both the Philippines and Thailand, taxes on gasoline have been increased and future oil fired electricity generation will be controlled.

In the oil importing countries, on the other hand, prices of many energy items are subsidised. The practice of discouraging energy production and encouraging consumption could reduce oil export surpluses in the future, and, of special relevance to the subject of this workshop, can make the commercialisation of non-conventional sources of energy very difficult. Typically, many new sources of energy must be subsidised in

the early stages to overcome consumer conservatism and to permit the size of the market to expand to capture economics of scale. There will, therefore, need to be a double subsidy element in the commercialisation of non-conventional energy in circumstances where it must complete with already subsidised energy.

On the side of increasing energy supplies, the activities reported in this workshop testify to a high level of R and D support for a wide range of non-conventional energy sources. A second aspect of implementation is institutional procedures. Before the oil price increases, these functions tended to be situated at the sub-sectoral level - such as the electricity, coal or oil agency - and not closely related to overall economic planning. The essence of energy sector planning is, however, the coordination of energy activities over the whole energy sector and their compatibility with nation wide economic planning. In all Asean countries there has been a movement to consolidate the main branches of the energy sector (oil, gas, coal, electricity) in one agency - typically a Ministry of Energy. Responsibility for non-conventional energy is, however, often shared among several agencies such as Science and Technology owing to its high R and D requirements.

In all countries energy planning, usually done by the Energy Ministry, is now closely integrated with overall economic planning.

Recommendations

Although we ranged widely in our discussions, we were unable to cover all the important aspects of planning, especially as related to non-conventional forms of energy. Zinnia Teruel's paper on the Philippines Invention Commission indicates the new sorts of institutions which will be needed in the development of non-conventional fuels. New forms of financing, for which we did not have special information, will also be needed. Nor were we able to investigate in detail the problems and techniques of individual project evaluation. The Sharief, et al, paper on economic assessment of

microhydro power generation in rural areas provides an interesting approach to project evaluation.

On the basis of our discussions, however, three general points did emerge - the need for better data, improved modelling and net pricing regimes more in consonence with stated energy policies. More specifically our recommendations within an ASEAN context are:

A. Analysis

1. Increase use of Landsat information by improving interpretation capability in Asean countries and promoting exchanges between Asean and US

Energy related data on energy and minerals deposits, characteristics and extent of vegetation and forests, and land utilization can be derived from Landsat output. The last two groups of data are extremely important in the planning of biomass utilization as the question of land for food vs. energy production must be adequately addressed.

2. Establish data base for rural energy

This data base should, in general, include data on types, tasks and amount of traditional fuels, as well as, conversion technologies and converters. The related socio-economic data to be included are typically those data needed for labour and time allocation studies.

3. Adapt energy modelling techniques to the special conditions of Asean countries

Energy planning models, many of which were developed specially for the conditions of industrial countries should be adapted to take into account the special concerns of Asean countries. There is a need to integrate traditional and commercial sources of energy and to evaluate the effects of different strategies on employment and the environment.

B. Implementation

4. Investigate ways to conserve electricity use

It is estimated that air conditioning accounts for 50% of peak electricity demand in capital cities of ASEAN countries. Efforts to promote conservation of electricity through, for example, load management in air-conditioned office buildings could improve load factors significantly.

5. Establish common Asean standards for performance and specifications of non-conventional energy devices

At present, for example, suppliers of PV modules do not provide common standards of performance and specification. It is suggested, therefore, that ASEAN countries look into the possibilities of establishing such standards.

C. Institutions

6. Disseminate information among Asean institutions on non-conventional energy activities

This dissemination of information will help prevent unnecessary duplication of R & D efforts. Furthermore, it will permit the sharing of experiences in implementation activities.

7. Increase assistance programmes for manpower training in non-conventional energy

At present, there is a need among ASEAN countries for programmes to enhance the capability of local institutions to conduct both R & D and energy planning, including energy modelling and data base management.

These recommendations are made in the spirit of ASEAN cooperation and in the hope that they will contribute to the further strengthening of of this cooperation.

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TABLE 1

The Energy Economics of Asean Member Countries

	CHARACTERISTICS	PROBLEMS	SOLUTIONS
Indonesia	Oil exporter, reasonably endowed with other sources of commercial energy, Traditional fuel shortages.	Anticipated decline in oil exports due to high domestic consumption. Rural energy situation.	Increase supplies of non-oil domestic production, diversify fuel supplies, conservation.
Malaysia	Oil exporter, well endowed with other forms of energy including traditional energy.	Rapid depletion of oil resources, possible net importer of oil within 10 years.	Development of alternative energy resources.
Philippines	Oil importer 85% of total consumption provided by oil imports. Some domestic energy resources.	High import bills and vulnerability to supply stoppage.	Development of conventional and non-conventional domestic energy resources, stockpiles, conservation, diversification of sources of supply.
Singapore	Imports all energy including feed-stock for major refinery sector. Virtually no domestic resources.	Vulnerability to supply stoppage.	Conservation, development of solar energy.
Thailand	Oil importer. Imports cover 40% of export earnings. Some domestic energy resources.	High import bills and vulnerability to supply stoppage.	Maximise domestic resource exploitation, diversify energy resources and sources of supply, energy conservation.