APPROPRIATE TECHNOLOGY AND THE RURAL ENERGY SECTOR IN SOUTH EAST ASIAN DEVELOPING COUNTRIES.

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ABSTRACT

Given increasing problems in the availability, affordability and deliverability of commercial primary and secondary energy resources, coupled with growing macroeconomic uncertainties, the use of renewable, non-commercial energy resources has been actively promoted in rural areas of developing countries. This, in addition to the fact that conventional, 'state-of-the-art' energy facilities present technical problems, are inequitable and pose potential environmental hazards, has led to proposals for instituting alternative, intermediate or 'appropriate' technologies in rural settlements. This thesis identifies technical, economic, social, cultural and institutional barriers to the introduction of intermediate or 'appropriate' technologies in rural areas. The cases of solar and biogas technologies in Korea, Malaysia, Papua New Guinea the Philippines and Thailand are considered.

Policy and planning process recommendations are made on the roles of government, voluntary aid-agencies and the rural user, to overcome the obstacles to implementing these technologies. These recommendations cover the micro (village) and macro (regional and national) levels over two time horizons, and stress the need for a comprehensive approach to discerning rural needs, followed by integrated technology diffusion through effective program and project implementation. In addition, this thesis identifies the need for a continuous collection of information on rural socio-economic conditions and potential for rural interfuel substitution and finally, recommends research into improving technical efficiencies of alternative energy technologies such as solar and biogas.

Alternative or intermediate energy technologies such as solar and biogas can play an important role in augmenting rural energy supply. Unless steps are taken to remove the identified barriers to implementation in future technology diffusion efforts, this potential will not be realized. Policy and planning process recommendations made in this thesis present means through which these barriers could be removed.

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CHAPTER I: INTRODUCTION

A. Hypothesis, Objectives and Scope

My hypothesis is that, given present conditions in developing countries, certain potentially 'appropriate' energy technologies have had little success in ameliorating the less than ideal energy condition of rural areas in developing countries. This apparent inappropriateness is due to economic, technical, social, cultural and institutional factors.

My study is based on the following assumptions:

a. Both primary and secondary commercial, non-renewable energy resources are unaffordable, unavailable and not deliverable to rural dwellers in developing countries.

b. Developing countries in general are faced with increasing uncertainties in their macro-economic environments which affect their reliance on imported fuels.

c. Conventional energy technologies often have irreversible negative impacts on the biophysical environment.

These assumptions have led to the active promotion of 'appropriate' technologies in developing countries, particularly to aid in the rural development process.

The purpose of this thesis is to identify the social, cultural and institutional factors that have to be considered in future efforts to implement solar and biogas technologies in developing countries. The thesis draws upon experiences of selected countries: Korea, Malaysia, Papua New Guinea, Thailand and the Philippines. Information from India is also referred to in a few instances.

Specific objectives in this study are three-fold:

a. To develop the above assumptions further and validate them based on an analysis of the current energy situation.

b. To examine the economic, technical, social, cultural and institutional barriers to both diffusion and utilization of appropriate technologies and, finally

c. To propose policy and process options to remedy the rural energy situation through a coexistence of both 'hard' and 'soft' technologies and through an integrated policy and process approach to technology diffusion taking into account the actors, roles and relationships involved.

B. Rationale

Solar and biogas technologies have often been referred to, in the literature, as "appropriate energy technologies". Academic disciplines have differing views on appropriate technology per-se. Some dismiss the infatuation with them by claiming, quite justifiably, that they are just reinvented wheels [Toffler 1980, Naisbitt 1986]. Others reject the concept by arguing the case for modernity based on continuous societal evolution. Some allude to these technologies as being monetarily infeasible whims. Ardent environmentalists and deep ecologists however, remain convinced that spaceship earth is headed towards an irreversible catastrophe, given our romance with all things big and use the environmental carrying capacity argument to support their hypothesis. They tend to align with the Schumacher influenced 'Small is beautiful' philosophy [Schumacher 1973]. Others such as Vandenburg [1986, 1-4] stress the need for such technologies based on an analysis of the structure of technology and its relation to society and argue that reinvented wheels are part of progress. Disciples of the Schumacher philosophy furthermore, tend to refute the 'whim' label put forth by some economists by arguing that there are employment opportunities in the field of appropriate technologies both in terms of direct production and human participation.

In addition to contributing to the inter-disciplinary debate on 'appropriate' technology, I see three major related factors supporting further study of this subject:

a. the oil-shocks of 1973 and 1979 and the potential for their recurrence in the near future with detrimental economic and social effects in developing countries.

b. the potential role that appropriate energy technologies could play in meeting the basic needs of rural dwellers in developing countries, interlinked with

c. the deficiencies that, in my opinion, have plagued modern energy technologies right from the time of their adoption by developing countries.

Each of these are considered below.

a. Over the past decade, a vast amount of literature has been compiled on the promise of alternative energy technologies for meeting rural energy requirements in developing countries. The oil shocks of 1973 and 1979 were in part responsible for renewed research efforts into the technical and economic viabilities of these alternative technologies, particularly solar and biogas. However, institutional, social and cultural impediments to implementing these technologies, if considered at all, were relegated to a second place. In fact, implementation objectives of past programs and projects aimed at disseminating solar and biogas technologies in the countries selected, were often solely derived from analyses of technical and economic viabilities. Insufficient emphasis was placed on social and cultural variables in articulating strategies to implement these technologies, leading to a less than ideal situation in their emplacement, acceptance and subsequent utilization.

b. Appropriate technologies are not something new. Technology that satisfies the need of an individual could indeed be termed appropriate. The dilemma is that as needs become more and more complex so does technology. A way out of the dilemma is to view technology as a marriage between form and function. Thus appropriate technologies, such as solar and biogas, have a basic form to serve a basic function and in doing so, satisfies a basic need [Singer 1977]. The importance of satisfying a basic need through the use of a technological form understandable by its end-users is a major factor in the choice of appropriate technology in the energy sector as proposed in this thesis. Furthermore, by instituting small-scale solar and biogas technologies which use renewable inputs, basic needs are satisfiable in a more sustainable or regenerative manner. The adoption of such technologies thus appears rational in the context of developing countries.

c. Present policy dealing with the use of conventional 'mega' energy technologies ignores the fact that these technologies often:

1. utilize resource inputs which are non-renewable;
2. rely on deficient secondary energy distribution systems;
3. are inefficient, in terms of the resource input to energy output ratio; and
4. have irreversible impacts on the biophysical environment.

Although solar and biogas technologies were introduced into South-East Asia in the post World War II era, their dispersion was mainly sporadic. It was in the early 1960's that their potential first came to prominence as a direct result of the oil-shocks. Planned efforts by governments to diffuse these technologies were also initiated around the same time. Present investment into alternative energy technology programs is about US$100 million in the region and is partly financed by multilateral lending institutions. In addition, these efforts are sometimes operated by voluntary aid agencies independent of government programs and projects. Unless comprehensive studies are undertaken to articulate barriers to effective implementation and utilization of these technologies, both human and financial resources in this effort will be inadequately utilized.

Finally, an extensive literature review indicates that there is no comprehensive treatise that attempts to put together the different forces at play that can act as barriers to the diffusion of solar and biogas technologies in less developed countries [LDC's]. This thesis is a step in that direction. Information generated, therefore, should be useful to policy makers in the Asia-Pacific region, the private sector, voluntary aid-agencies and the rural development practitioner interested in facilitating the process of change.

C. Organization

The thesis is organized into six parts:

1. Chapter II examines the Asian economic and social setting and the reasons for the institution of alternative energy technologies: the deteriorating macro-economic climate and

the deficiencies of modern energy generation technologies in the selected countries. The chapter discusses the types of energy both available to and affordable by rural dwellers using energy expenditure profiles of rural dwellers. In addition, certain conceptual advantages of alternative or small-scale energy technologies are discussed, together with the social and institutional factors effecting the adoption of these technologies.

2. Chapter III reviews two technological forms solar and biogas, their modifications and advantages, and the different forms of solar and biogas technologies that presently exist in the Asia-Pacific region.

3. Chapter IV discusses the economics of both solar and biogas technologies drawing on the Korean and Filipino experience as well as experience outside the selected countries, in India. The chapter also points out some drawbacks in benefit-cost analyses carried out to date.

4. Chapter V elaborates on end-user problems with solar and biogas technologies from three perspectives -. the economic/technical, social and institutional - by testing certain prestated conditions derived from the literature.

5. Chapter VI examines the adequacy of existing government policies and programs to facilitate the the diffusion of solar and biogas technologies to rural dwellers in the countries selected.

6. Chapter VII generates a set of recommendations for future efforts to disseminate these technologies in the Asia-Pacific region from both the macro and micro village levels taking into account the socio-economic and institutional problems discussed in chapters IV and V.

D. Method

a. **Data Collection** was done through an extensive literature review using the facilities of the UBC library system. In addition a computer search was carried out on ENERGYLINE in the DIALOG on-line network. Numerical data were gathered from annual reports of the United Nations Economic and Social Council for Asia and the Pacific [UNESCAP], the Asian Development Bank [ADB], the International Bank for Reconstruction and Development [IBRD], the International Labor organization [ILO] and reports from the Resource Systems Institute of the East-West Center, University of Hawaii.

In addition, a limited number of questionnaires pertaining to the Indian National Biogas program, were sent to key informants in India and the United States. Results from the questionnaire are described in the appendix and referred to in the main body of the text.

b. **Analysis** of numerical data was done using Pascal programs on the UBC mainframe Michigan Terminal system [MTS]. In addition, LOTUS 123 and D-BASE III packages were used in sorting data and representing it in graphical form.

CHAPTER II: THE SETTING: MACRO ENERGY PROBLEMS

This chapter discusses some of the reasons for the institution of alternative and small-scale energy technologies in rural areas of the countries selected and developing countries in general.

In essence, the advantage of instituting appropriate energy technology at the rural level appears to lie in the fact that developing countries, including those in the Asia-Pacific, have problems in the availability, affordability and deliverability of conventional energy resources, they have problems associated with their macroeconomic environment and finally, problems caused by operational deficiencies of modern, large-scale energy generation technologies and facilities. These three, either independently or together, constitute an energy problem from a 'macro' perspective.

Appropriate technology, as defined in this thesis, is an 'appropriate' mixture of hardware and software. Hardware is the physical form, optimal for satisfying the desired function, whereas software is the information and other support service requirements for these technologies. Software, as can be seen, cannot function independent of the hardware whereas, at present, hardware appears to function without software.

Arguments for the institution of small-scale and more 'human' technologies have been put forth and some perspectives of this argument are examined in this thesis.

2.1 Availability, Affordability and Deliverability of Commercial energy

In three words, energy problems facing any developing country lie in the availability, affordability and deliverability of both primary and secondary commercial energy resources such as petroleum and other crude oil derivatives. The question of availability, when dealing with primary, commercial and non-renewable energy resources asks:

1. How much of the conventional energy resource is available locally?

2. How much is derived exogenously or imported?

In the selected countries of the Asia-Pacific, a larger proportion of conventional energy resources necessary for consumption is imported(1).

The affordability of secondary, commercial and non-renewable energy resources, has to do with the issue of how affordable these resources are, given present market conditions and projections of future supply, demand and price patterns. This issue is particularly crucial to the low income rural dweller in rural Asia. Regulatory intervention in the energy marketplace in the form of subsidies(2), and taxes(3) are what maintain the price regimes of energy resources to both urban rural dwellers. Taxation on commercial secondary non-renewable resources have, in addition, acted to curb consumption particularly by rural dwellers in the Asia-Pacific, with the result that there is a widening difference between per-capita consumption and requirements of commercial, non-renewable and secondary energy in rural Asia [Harrison 1983, IBRD 1981].

Given a shortfall in the availability of primary and secondary commercial and non-renewable energy resources such as petroleum and other derivatives of crude oil, it is not unrealistic to expect an increase in the level of taxation that governments can be expected to impose which could manifest itself in price increases at the point of final consumption(4). The urban dweller may cope with this increase, less so the rural dweller whose income often does not increase as rapidly as general inflation.

The issue of deliverability concerns itself with the adequacy of energy supply infrastructure for meeting energy demand such as oil and gas pipelines and other forms of energy transportation. A brief review of the World Bank's literature shows that almost all the countries selected have inadequate infrastructure both in terms of quality as well as quantity [IBRD 1979 1981 1983].

In connection with the issue of affordability, the World Bank notes that for more than 60% of less developed countries even if the supply of conventional energy resources did match demand, the relative price of the resource would place it beyond the reach of more than 40% of rural dwellers. Inadequacy in energy supply infrastructure, therefore, tends to reflect not only the deliverability of the resource but also its affordability.

Aggregate primary and secondary commercial energy requirements are contrasted with aggregate energy availability in figures 1a-1e. Figure 2 presents total oil imports by the countries in the thesis and gives an indication of the proportion of energy imports to indigenous availability. Oil imports are used as an indicator, as in all the countries selected oil accounts for more than 50% of commercial energy consumed [ADB 1982]. It is evident in all countries, with the exception of Malaysia, that there is a major difference between energy resources available and energy resources required.

2.2 Macro-economic uncertainties

Developing countries in general are faced with tremendous uncertainty in their macro-economic climates. These uncertainties are further exacerbated by three major factors:

1. *The debt crisis.*
2. *Trade deficits and shortages in foreign exchange.*
3. *Increasing rural unemployment and underemployment.*

As will be seen, all three are interrelated.

2.2.1 The debt crisis

The debt crisis constitutes a serious problem in developing countries in general, especially those in the Asia-Pacific region. Fig. 3 gives an idea of the net external debt of the selected countries in the Asia-Pacific region. What should be noted is steep increases in the period 1974-83. It can be hypothesized that a major reason for this increase in

Fig. 1   Energy availability vs. requirements: Korea, Malaysia, Papua New Guinea, Philippines

1. a KOREA: Availability vs. Requirements

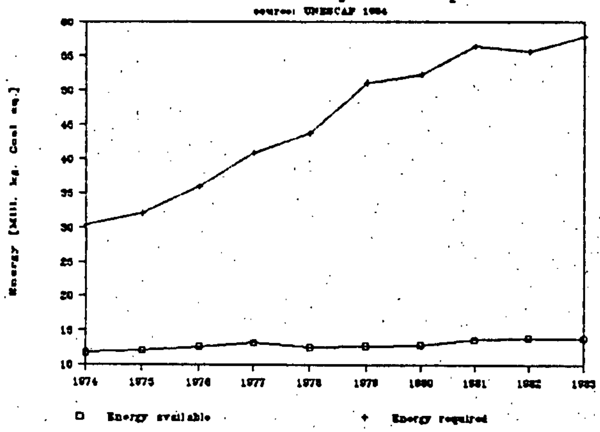


Fig. 1. c Philippines

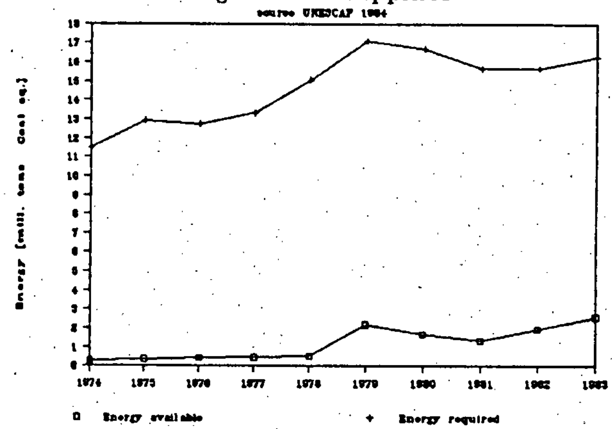


Fig. 1. b MALAYSIA

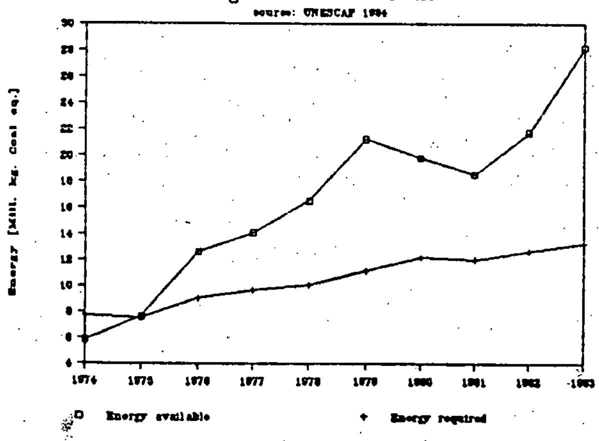


Fig. 1. d Papua New Guinea

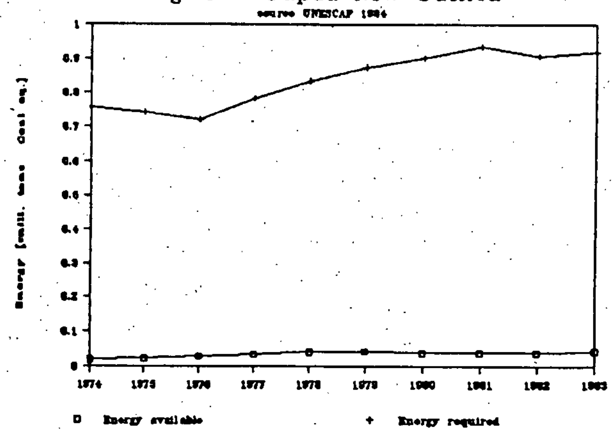


Fig. 1 Energy availability vs. requirements: Thailand

FIGURE 1e:**Thailand: Availability vs. Requirements**

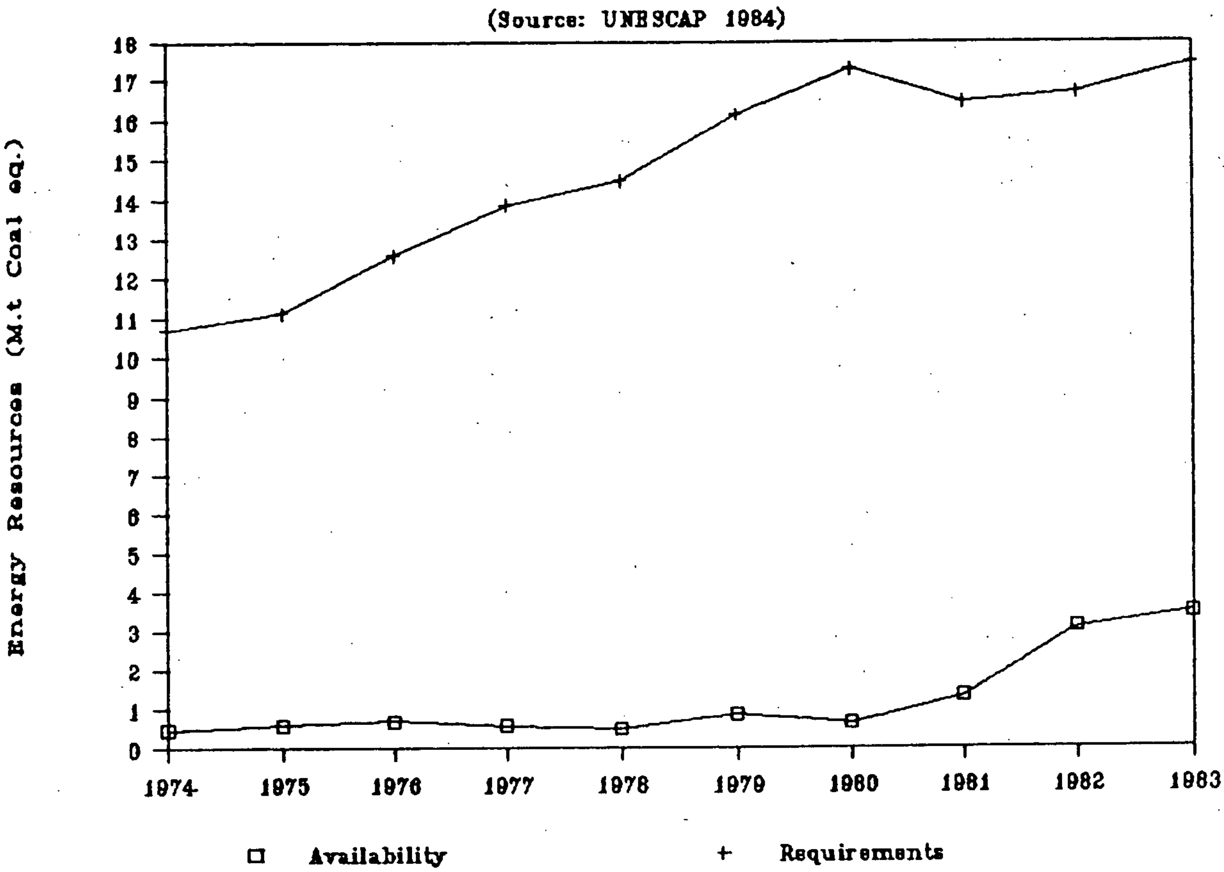
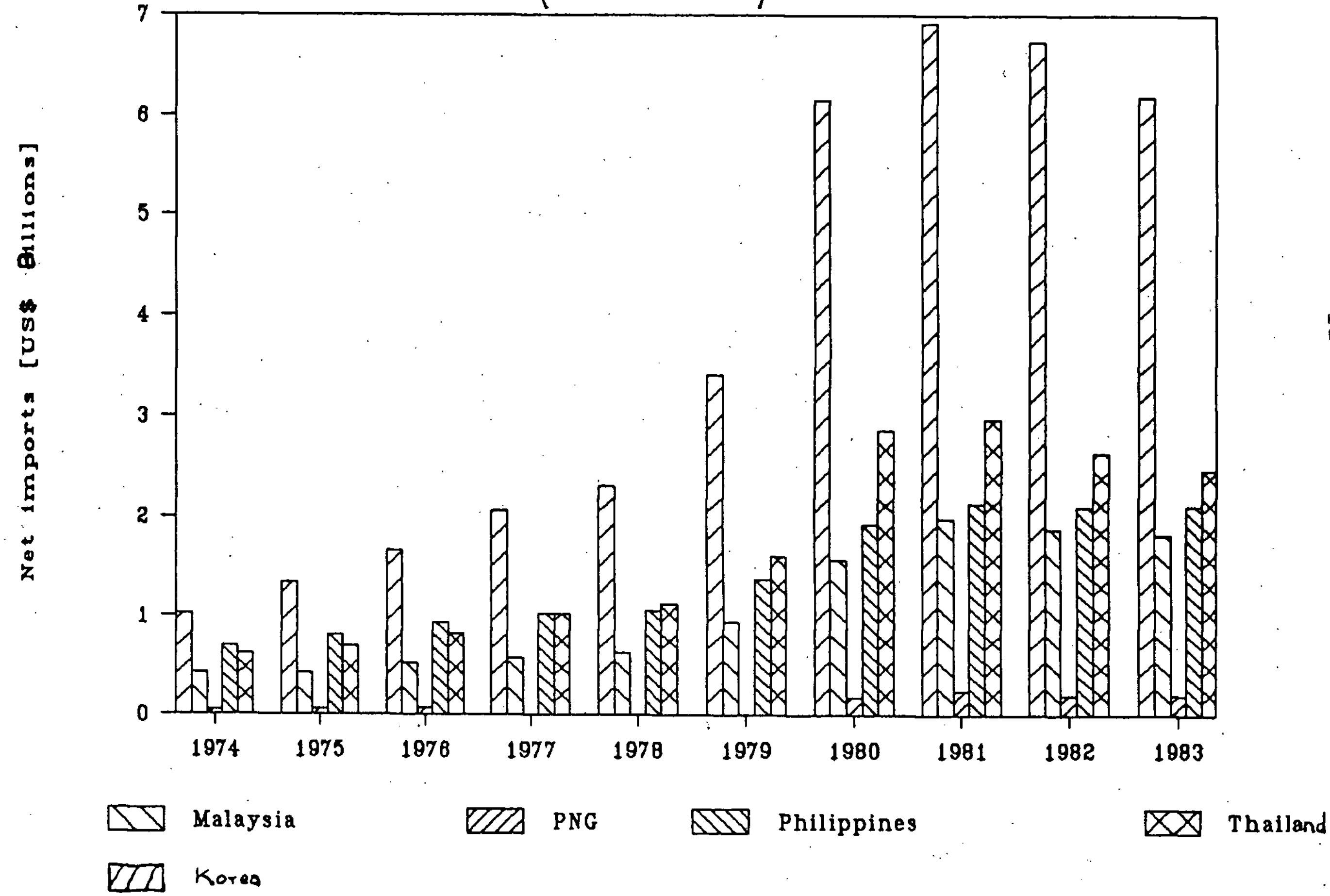


FIGURE2 : Petroleum/Pet.prods. Imports

(source ADB 1985)



debt is corresponding increases in world oil-prices in the decade 1970-80. It is interesting to note that even an oil-rich country such as Indonesia has accumulated serious long-term debt because of an obligation to development plans that were to have been financed with oil-generated revenues. Other plausible reasons for this increase in debt include an increase in general imports and resource mismanagement with pressures for consumption from increasing population [Edelman 1978, Beers 1982, Viksnins 1979](5).

2.2.2 Trade deficits and shortages in foreign exchange

From the perspective of less developed countries massive energy and technology imports, in the pursuit of conventional economic development and growth, occurred in the pre 1973 'era of cheap energy' [Harrison 1983, Edelman 1978]. In part responsible for fuelling these imports were the dictates of national and regional economic development models or 'big-bang' theories [Friedman 1966, Hirschman 1978,1979] which stated that one way of stimulating economic growth and industrial activity was through the setting up of energy dependent industries and production complexes. With these complexes in hand and with the price of energy increasing during the decade 1970-80, the only way for less developed countries to continue import-dependent production in these complexes, was to borrow heavily from both private and multilateral financial institutions [Edelman 1978, Griffith-Jones 1985]. These institutions financed injections of capital into developing countries in part, by recycling Arab 'petrodollars' which aided in the financing of these continually increasing imports [Viksnins 1979]. A major proportion of external debt was accumulated in the Asia-Pacific region in this decade.

The incorporation of energy intensive agriculture in part acted to increase the cost of producing agricultural commodities for sale on world markets [Smil 1985]. Such cultivation techniques required continually increasing commercial energy inputs, available only through increased importation. Increase in energy imports by far exceeded increases in agricultural exports, leading to a worsened balance of payments situation. This worsened balance of payments together with the accumulated external debt of most nations in the Asia-Pacific region has acted to lower the value of local currencies making imported agricultural and industrial inputs even more expensive for indigenous consumers [Levi 1983, Todaro 1985, Viksnins 1979]. The lowered value of local currencies completed the vicious circle implying that the LDC's had to export more primary commodities in order to earn the same quantity of foreign exchange to be able to afford increasing energy imports and energy intensive agricultural products. An increase in protectionist trends in industrialized economies has made this process more difficult [IBRD 1987].

One manifestation of this dilemma in the oil-importing developing countries of the Asia-Pacific region is the inability to finance further imports of energy without the allocation of an inordinately large proportion of export earnings, leaving fewer resources for further growth and development.

Figure 4 indicates the increase in trade deficits in the selected countries during the period 1970-84. Fig. 5 indicates the net change in foreign exchange reserves. It can be seen that trade balances and foreign exchange reserves are in deficit for most of the selected countries.

2.2.3 Unemployment and Underemployment

Development in the oil importing developing countries of the Asia-Pacific region is characterized by increasing mechanization and the substitution of labor by technology. In association with high population growth rates [on the average about 2% per annum in most of the developing countries in the Asia-Pacific region](6), it can be seen that there is an increase in the size of the labor-force without a commensurate increase in the size of the employment market. Increasing and uncontrollable rural-urban migration serves to further worsen this problem of employment and infrastructure provision for urban areas [Singer 1977].

FIGURE 3 NET EXTERNAL DEBT: ASIA-PACIFIC

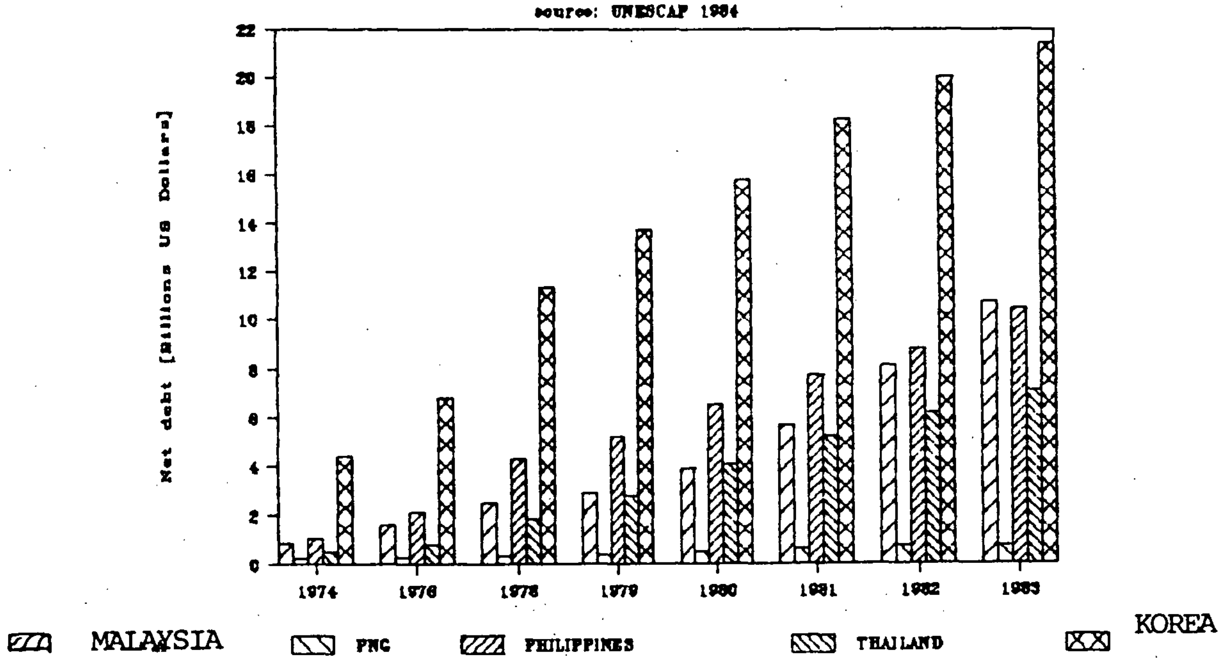


FIGURE 4 TRADE DEFICITS: ASIA-PACIFIC

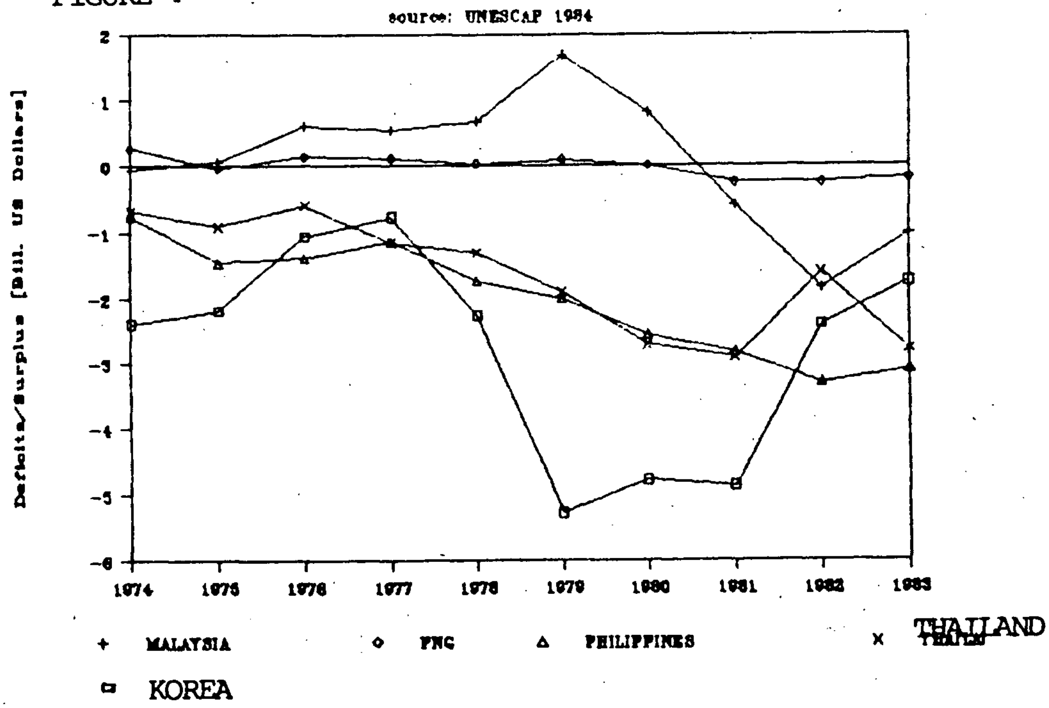
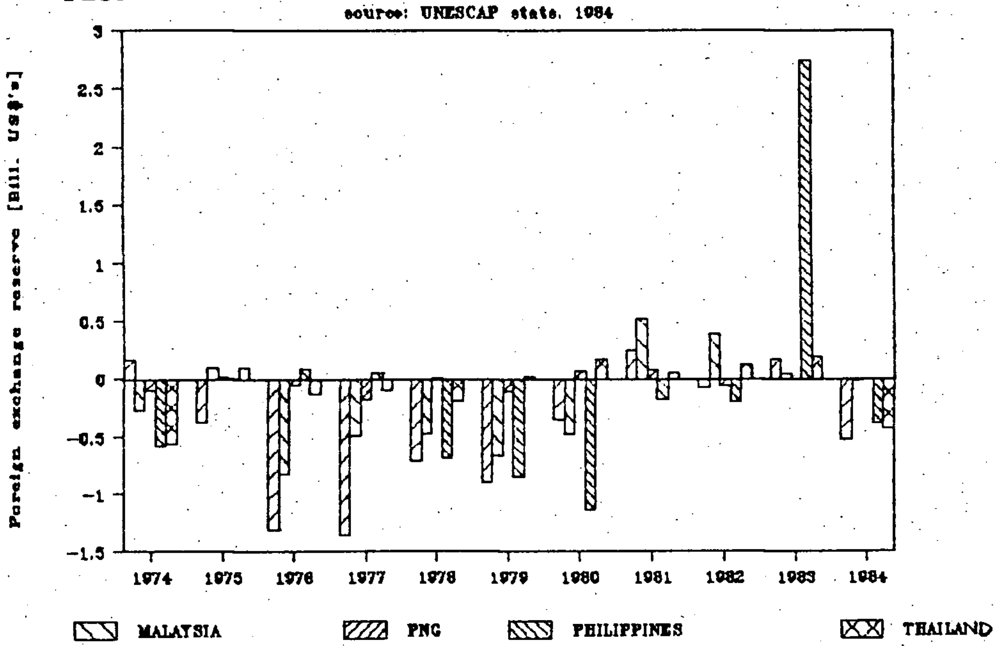


FIGURE 5 CHANGE IN FOREIGN RESERVES

source: UNESCAP stats. 1984



Increases in trade deficits, changing patterns in world trade and levels of external debt have a bearing on the level of employment in the less developed economies of the Asia-Pacific region. Most of these economies rely on trade to generate economic growth and trade implies production, with production implying employment. Many less developed countries have to rely on imports of raw materials to augment local resource inputs and sustain the production process and its employment capacity. With a drop in the magnitude of foreign exchange reserves necessary to finance these imports, the repercussions on the level of production activity, and in long run, employment, are obvious [ILO 1983 1984 1985].

Fig. 6 compares national and rural unemployment in four countries selected in this study. From the graphs it is evident that:

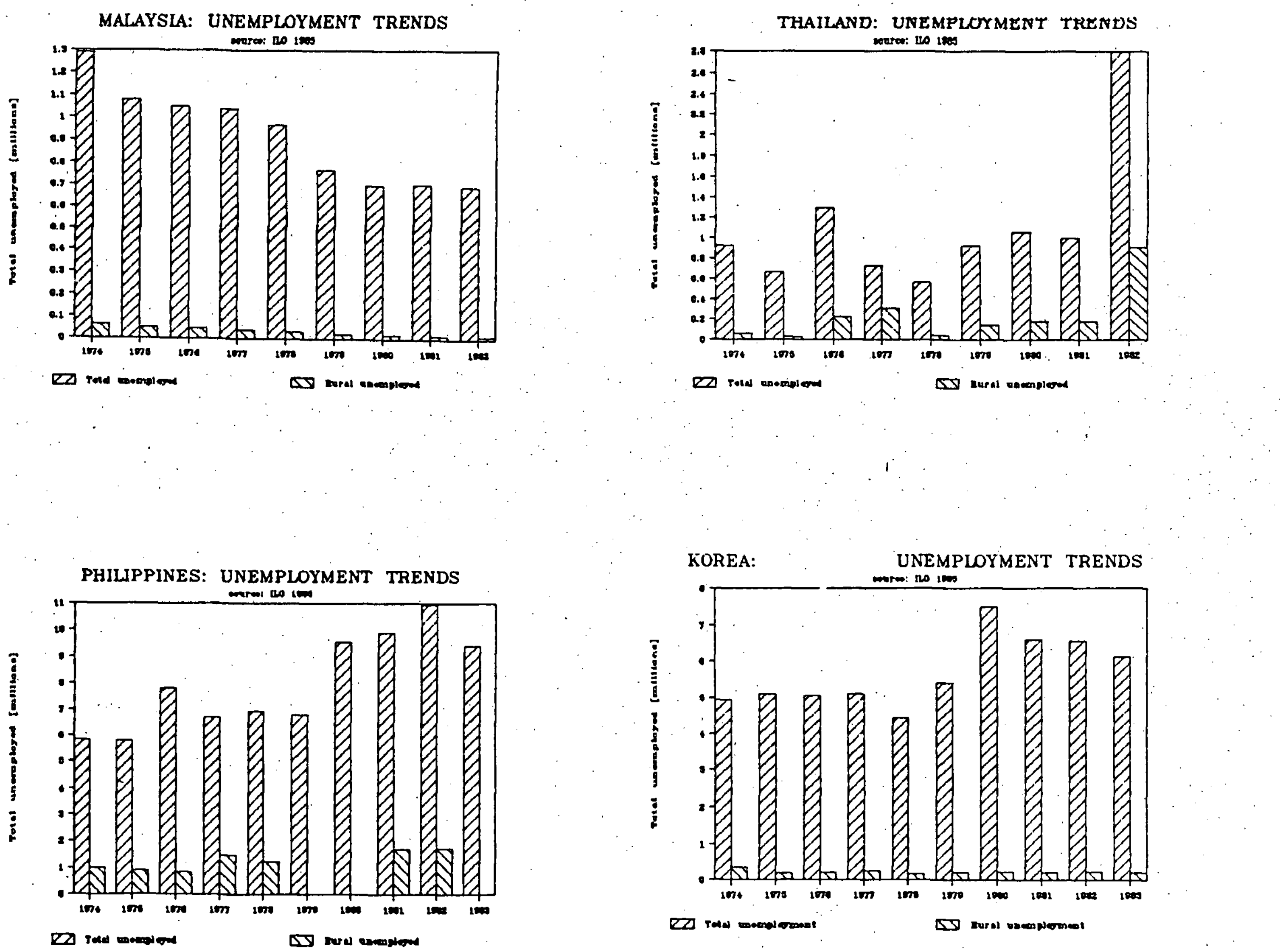
1. Although rural unemployment comprises a smaller percentage of total unemployment in both the Philippines and Korea the magnitude of rural unemployment in both these countries has been increasing at a faster pace than total unemployment.
2. In the case of Malaysia and Thailand, rural unemployment forms a significant proportion of total unemployment. Trends appear to indicate that in Malaysia, rural unemployment is on a decline whereas in Thailand rural unemployment is on the increase since 1978.

The percentage of 'disguised' employment in the form of underemployment is, firstly difficult to measure and secondly has often been referred to as more urban in nature, such as underemployment in the urban informal sector [Das 1986]. An informed source, however, estimates the level of rural underemployment at 2 out every 3 workers in the case of Thailand and the Philippines [ILO 1986].

2.3 Deficiencies of modern energy technologies

Deficiencies of modern energy generation technologies, particularly in the context of the Asia-Pacific region, can be broadly classified into three categories:

Fig. 6 National and Rural unemployment in the Asia-Pacific: Malaysia, Thailand, Philippines, Korea



a. *Questionable Technological efficiency.*

b. *Inadequate Distributional equity.*

c. *Potential for negative impacts on the Biophysical Environment.*

2.3.1 Questionable technological efficiency

In this thesis, technological efficiency is defined as the ratio of energy output to resource input. The precise efficiencies of energy generation technologies are difficult to measure in the context of developing countries. What can be measured, however, is technological inadequacy given a scenario of rampant population growth and rural to urban migration. Population in most of the countries selected is increasing at the rate of about 2% per annum. The corresponding energy requirements of the population can be calculated using statistics on per capita energy consumption rates. One problem in this approach is the fact that rates of energy consumption are not static with respect to both the type and quantity of energy consumed [Harrison 1983]. In addition, the incomes of the population in most developing countries, the Asia-Pacific region being no exception, usually increase at a slower rate than the demand for secondary energy [ADB 1982]. Given the hypothesis that increased energy consumption is in part caused by population increase and that the income of the population does not increase correspondingly, can a solution which focusses solely on improving and expanding conventional technology or incorporating "technical fixes", work? In this sense, conventional energy technology in the Asia-Pacific region is inefficient, because of its inability to cope with rapidly increasing demand.

This picture is not altogether unrealistic. Rural dwellers are often the beneficiaries of rural electrification programs which are funded through development aid. What is ignored is the fact that many rural dwellers cannot afford the energy output from these facilities(7). Secondly, 'state of the art' technology generally requires an advanced level of operation and maintenance, often unavailable in developing countries, leading to frequent breakdowns and technical malfunctions [ILO 1986]. These malfunctions increase energy prices. Demand, given rampant population growth and urbanization, is always on the increase in most developing countries. Assuming the technological fix solution and given the uncertain macro-economic environment, improving and expanding conventional energy facilities such as oil refineries, adds to the high level of accumulated net external debt. On the one hand, the World Bank [1983] notes that "most of the oil refineries in developing countries are over 15 years old and were designed to minimize capital costs at the expense of higher energy consumption. The increased cost of energy over the past decade [1973-83] makes it worth considering several changes to increase energy efficiency". They conclude that as refineries get older and "because attention to maintenance, especially preventive maintenance, has generally been inadequate, substantial repairs and replacement of equipment are necessary". They recommend a refurbishment of these refineries based on their size and the size of the market that they serve(8). On the other hand, the same institution, in association with other commercial ones, point out the dangers of increasing debt in developing countries. The problem therefore becomes one of balancing an increasing level of external debt with increased external funding for the installation or refurbishment of primary resource conversion facilities, such as petroleum refineries.

Another factor that influences the efficiency of technology is the level to which it has been 'tropicalized'. Often, designs for the technology are conceptualized in areas distant and with different climatic conditions from the area for which they are destined [Harrison 1983].

Given this fact, improvements in conventional technologies will not necessarily help to ameliorate the efficiency issue. Alternative or appropriate technologies could augment commercial energy supply to the rural dweller without the need for periodic rationalizations common with conventional energy technologies. In addition, these alternative technologies assume a greater importance if they can be instituted in areas that are not economically viable to service by conventional energy supply. The ideal situation of coexistence of hard and soft paths, as envisioned by Lovins [1979], is therefore achievable. Required is the necessary commitment on the parts of both the end-users and governments in the Asia-Pacific region.

2.3.2 Inadequate distributional equity

Modern energy generation technologies have failed to provide distributional equity. Two major reasons have been offered for this drawback:

a. An inadequacy in infrastructure.

b. A polarization of benefits.

a. As alluded to in section 1.2, most developing countries suffer from a lack of adequate energy supply infrastructure in terms of both quality and quantity. Even if infrastructure does exist, given the macro-economic setting and the non-affordability and unavailability of spare parts, they are often in an irrecoverable state of disrepair. Secondly, sophisticated distributional infrastructure tends to be concentrated in relatively urbanized areas as part of larger locational decisions, and is, in part, responsible for increasing rural to urban migration [IBRD 1979 1981 1983, McGee 1985].

b. By virtue of the fact that infrastructure is concentrated in urban areas, it is asserted that there is a polarization of benefits accruing from these energy projects. Urban dwellers have preference over rural ones when it comes to locational decisions for siting production and distribution facilities [Dunkerley 1980, Taylor 1981]. Furthermore, assuming that locational decisions are favorable to rural dwellers, secondary energy such as fertilizer supplied to rural areas is likely to benefit the already wealthy or that group that has access to and legitimation within the existent political system [Harrison 1987, Roy 1983]. Appropriate or intermediate technology could play a part in changing this imbalance, firstly by its rural application and secondly by capitalizing on pre-existing traditional distribution networks often related to rural settlement-specific social hierarchies.

2.3.3 Potential for impacts on the biophysical environment

Environmental degradation in developing countries is increasing at an alarming pace as a result of unregulated production of energy and its by-products [Chatterji et.al. 1981; Matthews et al 1981]. One perspective is that the situation exists because of lax environmental protection legislation. The institution of alternative energy technologies at the rural level, especially those technologies that recycle waste viz. the biogas digester, removes the need for both creating and monitoring environmental legislation. Even if the two forms of technology co-exist, it is still a vast improvement compared to the situation where there is widespread environmental degradation, inadequate legislation and monitoring and no alternatives [Deudney & Flavin 1983].

Table I is a qualitative representation of the intensity of the impact of conventional energy technology on the biophysical environment in the selected countries. It can be seen that issues of major and immediate concern are increasing air pollution from an increased use of coal and radioactive waste disposal in Korea. An issue of medium concern is increasing deforestation caused by increased rural energy demand in Malaysia and Papua New Guinea. In addition, it is speculated that further offshore oil and gas development in the Philippines will have negative impacts on sensitive coastal zones.

2.4 The rural energy scene

Central to a comprehensive understanding of the rural energy problem, is an elaboration of the types of energy consumed by rural dwellers and the relation between rural energy consumption and rural income.

2.4.1 Types of energy

Table II summarizes the different forms of energy that are available, affordable and deliverable to the rural dweller. The sources of energy, as is seen from the table, are

Table I. Conventional Energy technologies and their impacts on the biophysical environment (source: Fesharaki, Brown et.al. 1982 p.231)

	Air Pollution from increased use of Coal	Disposal of Radioactive wastes from Nuclear Plants	Offshore Oil & Gas development on Coastal Zones	Hydropower and Land-use	Deforestation from increased rural energy demand
KOREA	***	***			*
MALAYSIA			*	*	**
PAPUA NEW GUINEA				*	**
PHILIPPINES	*	*	**	*	*
THAILAND			*	*	*

KEY: *** Major Concern
** Medium concern
* Some concern

Table II Summary of Energy sources and rural end-uses in the Asia-Pacific region (source: Barnes D. quoted in Pearce D., & Webb M., 1987)

Rural End Uses	Electricity	Batteries	Kerosene	Other pet. prods.	Coal	Biogas	Water power	Human power	Animal power	Biomass sources	Animal waste	Wind	Solar
DOMESTIC													
Cooking	*		*		*	*				*	*		*
Lighting	*	*	*			*							
Heating	*		*		*	*				*	*		*
Cooling	*												
Refrigerator	*		*			*							*
Radio/TV	*	*			*								
Ironing	*				*					*			
Potable Water	*			*			*	*	*			*	
AGRICULTURE													
Pumping	*			*					*				
Irrigation				*	*				*			*	
Ploughing				*				*	*				
Sowing				*				*	*				
Harvesting				*				*	*				
Threshing	*			*			*	*	*				*
Drying	*		*	*	*					*		*	*
Grinding	*			*	*		*	*	*	*			
Transport				*				*	*				
Storage								*	*				
COMMERCIAL													
Lighting	*	*				*							
Refrigerator	*	*											
Heating	*	*			*	*				*			*
Cooking	*												*
Transport				*				*	*				
INDUSTRY													
Motive power	*												
Lighting	*					*							
Heating	*				*	*				*			*
Transport	*							*	*				

primarily non-conventional and have been classified as non-commercial [IBRD 1980]. Figure 7 is a comparison of gross annual expenditures on non-commercial [including firewood, paddy husk, charcoal, coconut branches, and paddy straw] and commercial energy sources by different income categories in Thailand. Figure 8 is a similar representation for the Philippines: It represents the total energy consumed from commercial and non-commercial sources by different income groups(9).

Table III is a generalization of the Korean case. It indicates the type of fuel available to the rural dweller, the amount needed per day, the cost per unit and the total daily expenditure on energy for cooking and other domestic purposes. The aggregated quantities indicate projected values of annual gross expenditure on different energy sources by a five-person household assuming a constant rate of consumption.

2.4.2 Energy and rural income

Two factors affect the magnitude of rural energy consumption. The income of the rural dweller, determines affordability of commercial fuels such as kerosene and associated petroleum products and hence, levels of consumption. It is seen that in the case of the Philippines that non-commercial fuels are generally accessible and therefore preferred by people whose incomes range from 2500-5000 pesos per annum. There are exceptions especially in Luzon and Mindanao where similar energy sources appear preferable to the highest income group: greater than 5000 pesos per annum. As the graphs indicate, all income groups in Thailand appear to consume a greater proportion of non-commercial energy sources compared to commercial sources. High income North-Easterners appear to prefer non-commercial energy including firewood, biomass and animal waste, but in general the lowest income category, less than 25000 Baht per annum, appears to be the largest consumer of non-commercial renewable energy resources. Similar generalizations can be drawn for the cases of Malaysia, Korea and Papua New Guinea. The pervasive impact of low rural income on energy consumption patterns is ubiquitious in all of the countries

FIGURE 7

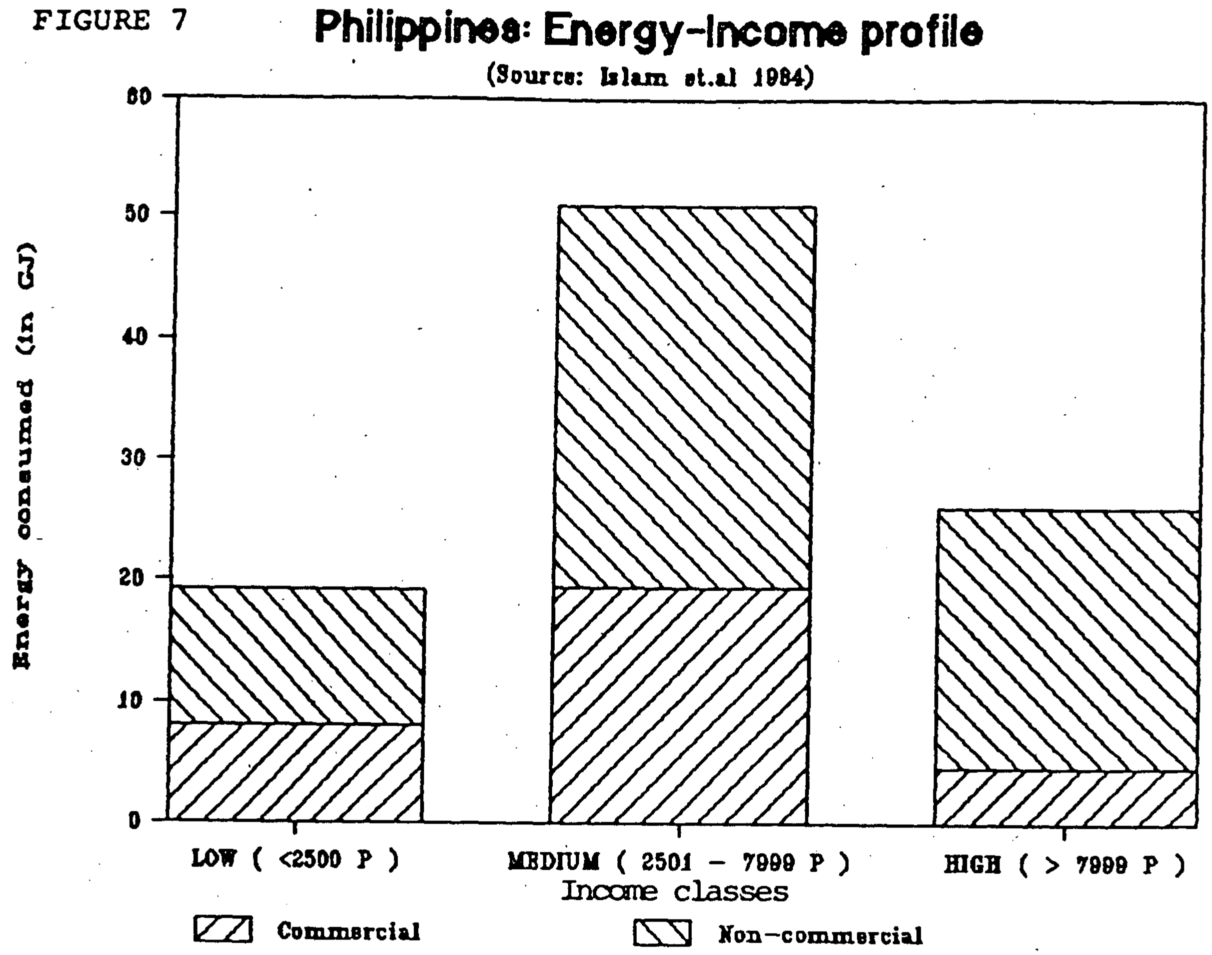


FIGURE 8

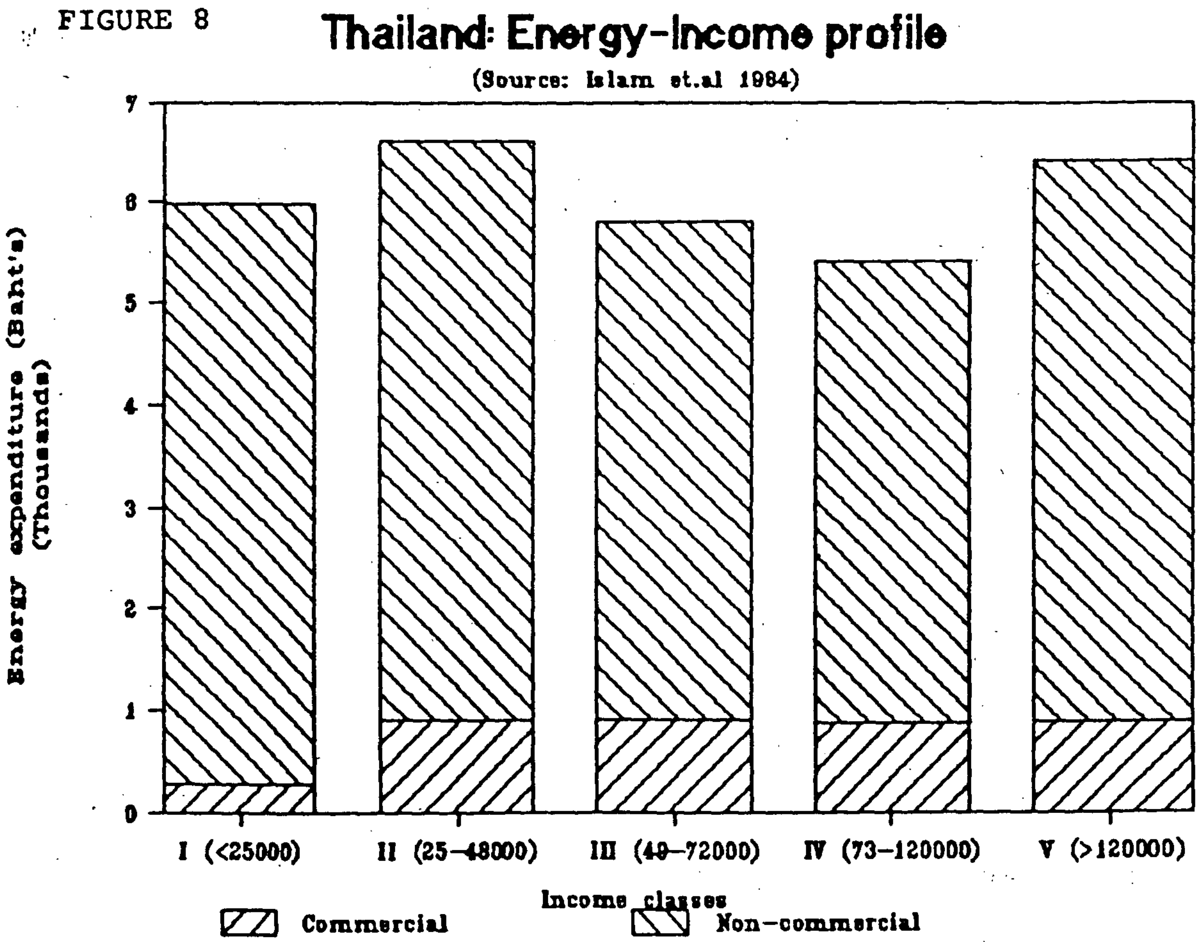


Table III Korea: Cooking fuel type and cost
Five person household

(Source: Chun 1984)

Fuel Type	Amount needed per day	Unit cost (Won/Unit)	Daily cost (Won)	Annual cost (Won)
Biogas	1 Cubic Meter	112.7/cu.m.	112.7	33,600
Propane	0.5 Kg	627/Kg	313.5	94,200
Kerosene	0.9 Litres	179/Litre	161.1	48,000
Coal Bricks	2 pieces	95/piece	190.0	57,000
Electricity	6KWh	61.18/KWh	367.08	110,100

selected.

The other important factor is the availability of the fuel itself. Variables such as graft and corruption cannot be represented quantitatively as the *prima causie* but it is possible that they play a major role in determining the availability of commercial fuels to the low income rural dweller(10).

2.5 Appropriate Technology at a conceptual level

The concept of appropriate technology has different connotations to different people. Daly [1977] views appropriate technology as a manifestation of a steady state and integrated relationship between human and natural environments "so that we do not overpower the self-healing capacities of natural systems to maintain themselves and support life". Bender [1978], on the other hand, adopts a more pragmatic approach to defining appropriate technology as, he argues, its adoption would entail developing social, economic and environmental diversity so that communities and regions can provide for their own needs without "putting all their eggs into a single shrinking basket of imported and depleting resources". Both Van der Ryn [1975] and Schumacher [1978] are of the opinion that the adoption of appropriate technology would mean creating and managing systems that require "less capital, less machine-watching and paper shuffling; but more 'personal' involvement and 'direct' production" [Schumacher 1978, p. 113].

The adoption of soft energy paths, argues Lovins [1979], is necessary for energy self-sufficiency and security of energy supply. Traversing a soft-energy path implies an extraction of renewable resources from a 'commons' [Hardin 1968]. In other words, because a soft-energy path implies a sustainable use of renewable energy resources, the tragedy of overconsumption without replenishment, resulting in a potential depletion of resources from the commons can be averted. By using renewable resources in this way the resource base can be utilized in a more sustainable manner beneficial to present as well as future users of the commons.

Appropriate technology has long been alluded to as having implications for enhanced community involvement and participation in the production process. People of the stature of Gandhi, Schumacher, Sri Aurobindo and Mother Teresa who stressed the measures of equity and participation advocate the use of these technologies to both enhance social relationships as well as to broaden the context of traditional economic approaches to community development. Jones [1983], in addition, stresses the sense of achievement ensuing from the use of these technologies, which is lost in the mass production, 'assembly-line' approach to production.

Notwithstanding these conceptual advantages, it must be borne in mind that there are operational and tangible benefits associated with the use of alternative technologies, especially from the perspective of developing countries. These include the fact that their use creates jobs where they are needed most, in the rural areas, in addition to their potential role in the satisfaction of basic needs at the rural level. Lastly, they could play an important part in arresting the present rate of environmental degradation not only by virtue of resource conservation but also by minimizing the flow of effluents into the biophysical environment [Singer 1977; Islam et.al. 1984; UNESCO 1984].

2.6 "Appropriate software"

Software in an appropriate system, as mentioned at the outset, comprises information and other support services necessary for the efficient installation and operation of the technology [Hughes et.al 1985]. It incorporates the notion that there needs to be adequate training, research and development for both innovation in hardware as well as in functions such as education and improving end-user participation. To date, as will be seen in chapter V of this thesis, most of the countries in the Asia-Pacific region have established research and development centers to provide software support to the rural end-user. Some examples are the Office for Rural Development in Korea, Kasetsart University in Thailand, SPATF [South Pacific Appropriate Technology Foundation] and The Ministry for Rural Development in Papua New Guinea [Power 1980, Arthornthurasook 1984, Chun 1984].

Summary

1. Developing countries in the Asia-Pacific region are characterized by problems in the availability, affordability and deliverability of primary as well as secondary commercial and non-renewable energy resources.

2. These difficulties are exacerbated by prevalent macro-economic conditions exemplified by the debt crisis, trade deficits, shortages in foreign exchange and high levels of both national and rural unemployment.

3. Conventional energy technologies have failed to meet the secondary, commercial energy requirements of rural dwellers by virtue of the fact that their technological efficiencies are questionable, their distribution is inequitable and they have detrimental impacts on the biophysical environment.

4. From an analysis of rural income-energy consumption patterns, the poor in the Asia-Pacific region appear to be almost wholly dependent on non-commercial energy resources.

5. Appropriate energy technology appears, at a conceptual level, to be a viable part of an energy supply system which incorporates coexistence of hard and soft paths.

6. It is argued at a conceptual level that the institution of 'appropriate' technologies in developing countries leads to less 'paper-shuffling' and 'more direct production'.

This is the setting in the Asia-Pacific region today. This setting must be borne in mind for the balance of this thesis in order to have a more focussed understanding of the problems of appropriate energy technologies and possible policy responses to solve the rural energy problem.

CHAPTER III: THE TECHNOLOGIES

This chapter presents a review of different forms of appropriate or intermediate technologies, solar and biogas. Their distribution the Asia-Pacific region is also articulated.

3.1 Solar technologies

Solar energy systems range from simple to complex. There are three basic components in a solar energy generation system: a collector, a concentrator and a conversion unit. The process of energy generation is simple. Radiation from the sun reaches a collector which concentrates the energy and then transmits it to some form of conversion system. The amount of solar energy reaching the collector is regulated naturally as opposed to, say, a natural gas delivery system. The lesser the number of obstacles to the path of solar radiation the greater the magnitude of the energy generated.

Six factors affect both the quality and quantity of solar energy produced from a collector-concentrator-converter complex [Myers 1984]:

i. Site characteristics and the geographical location of a site determine the amount of incident solar radiation. Altitude and type of climate, whether cloudy or clear, are other important site-specific variables.

ii. The location of the solar collector on site.

iii. The orientation of the collector.

iv. The time of day.

v. The time of year, and

vi. Atmospheric clearness in terms of the collector's proximity to tall buildings and other urban features as well as the level of pollution, natural or anthropogenic.

Solar energy systems are of two types: Active and passive.

a. Passive: These include both passive cooling and passive heating types. They are generally less technology intensive and rely on practices such as better insulation in residential buildings and the system could therefore depend on choices of building materials. An example of a community sized passive heating system is a solar pond [Lura 1979, Bronfman 1983]. It works on the principle of creating a temperature differential for using a thermocouple to generate electricity. Passive systems tend to place an emphasis on the collector and concentrator. In the case of residential areas, a better choice of building materials and insulating mechanisms implies a better collector and concentrator set-up. Proponents of passive solar systems argue, and quite justifiably so, that savings in heating and utility costs are what result from passive systems [Myers 1979, UNESCO 1983]. Passive systems, however, are used more in an augmentative capacity and are not generally for the sole purpose of generating energy through a conversion process such as in active systems. Table IV indicates the types of passive solar technology that have been adopted in the Asia-Pacific region.

b. Active: Active systems, on the other hand, are technology intensive and rely on the state-of-the-art to facilitate collection, concentration and conversion. This is evidenced by the various forms of active technologies available on the U.S. market [see table V]. Based on collector specifications, active systems can be subdivided into systems that have tracking collectors and those which do not. In this context, an independent category would be photo-voltaic active systems. Within tracking collectors further subdivision is possible into those that track the sun along one axis and those that are two-axis tracking. Shown in Table V are some active systems still in the demonstration stage. Among the non-tracking systems, the most important are simple flat plate collector systems and their various commercial modifications: Thomasson, Calmac, PPG, Sunworks, Honeywell, Lennox and Solaron systems. The solaron design is further modified into a concentrator type collector so that both collection and concentration occur at the same point with no 'transmission' losses. Table VI is an illustration of the different types of active solar technologies present in some countries of the Asia-Pacific. A more detailed discussion is pursued in chapter V.

Table IV Passive solar technologies in the Asia-Pacific

(Sources: Eggers Lura 1979, Power 1980, KIER 1980, Chirrarattananon 1984, Malaysia Natnl. papers 1979)

Country	Examples	Date initiated	Current status
Korea	. Solar Homes	1977	In existence
	. Solar cookers	1982	In existence
Malaysia	Not clear	Not clear	Not clear
Papua New Guinea	. Solar lumber dryers	1979-80	Not clear
Philippines	. Solar cookers	1978	In existence
	. Solar ponds	1980	In existence
Thailand	. Solar Homes	1979	In existence

Table V Active Solar technologies on the U.S. market
(source: US Office of Technology Assessment)

Non-Tracking	One-Axis Tracking	Two-Axis Tracking
. Simple Flat Plate Collector	. Albu/West	. Ganged Collector
. Flat Plate onstage	. Sandia	. Lower Parabolic
. Thomasson	. Acurex	. Carousel
. Calmac	. Solartek	. Francia
. Modified Calmac	. Beam	. Fresnel state
. PPG	. General Atomic	. 'Demomode'
. Sunworks	. Scientific Atlanta	
. Honeywell	. AAI/Suntech	
. Lennox		
. Solaron		

Table VI Active Solar technologies in the Asia-Pacific
(source: Eggers Lura 1979, Malaysia Natl. paper 1980, Chirrarattananon 1984, Phil. Min. of Energy 1977

Country	Examples	Date initiated	Current status
Korea	.Experimental plants	1979	unclear
Malaysia	.Cogeneration units	1978	unclear
Papua New Guinea	unclear	unclear	unclear
Philippines	.Experimental plants	1980	in existence
	.solar cookers	1978	in existence
Thailand	.private photo-voltaic installations	1982	in existence

Solar energy has many uses. Flat plate collectors can be used for both water and space heating. Derivatives of the simple flat plate collector include the Thermosiphon water heater, forced circulation water heaters and swimming pool water heaters. A range of other uses of the simple flat plate collector include space heating; combinations with heat-pumps; desalination purposes; distillation; salt production through drying; solar cooking and drying; refrigeration and air-conditioining and finally, facilitating the transformation of solar energy into mechanical energy [Lura 1979].

The obvious advantage associated with solar technologies is that they are environmentally benign(1); they utilize resource inputs that are both renewable and indigenous; and are available to all end-users with relatively simple technology, unlike the complexity associated with conventional 'state-of-the-art' energy technologies.

3.2 Biogas Technologies

A biogas digester employs the principle of anaerobic fermentation or digesting organic waste material to produce methane. This process is both facilitated and catalyzed by microbes in the waste material. The solid remnant of the digestion process, the sludge, serves as a useful fertilizer(2).

The digestion process occurs in a pit with an inlet and two outlets. The wastes are 'dumped' in through an inlet and the gas generated, being lighter than the surrounding sludge, floats to the top and is released through the top outlet. The sludge is 'washed' out from the bottom outlet. In some Chinese designs, a valve has been used at the top to control the velocity of the gas flow [Buren 1978]. There are various suggestions on appropriate materials for constructing these digesters and this is an area of current technological research(3).

Three major factors influence the amount of biogas that can be generated from a given quantity of organic wastes [Meynell 1976]:

a. The microclimate of the area. Fermentation is facilitated by a temperature range of 20-30 degrees centigrade.

b. The materials used in the construction of the digester. Metals are less efficient and prone to corrosion with excessive and repeated usage [Meynell 1976].

c. The composition and purity of the waste material itself; if diluted with inorganic wastes, the performance is lower than for pure organic wastes.

Table VII gives an idea of some different modifications of biogas technologies with a note on how they differ from each other. In the context of less developed countries the 'wet' [batch] and 'dry' [plug-flow] styles appear to be the most popular(4). There are two sizes of digesters that this thesis is concerned with: The family sized and the community-sized digesters. Both of these can be either dry or wet types, but community-sized digesters are rarely 'dry' in nature [Taylor 1981, Lichtman 1983, Gowen 1985, Gupta 1983, Ghate 1979]. Table VIII indicates the distribution of dry style household plants in Korea. It is to be noted that in almost all of the provinces, the number of emplaced digesters have increased almost 50% in the period 1982-83.

In articulating the possible uses of biogas, a Chinese biogas manual notes that one cubic meter of biogas can [Buren 1978]:

i) Light an electric bulb of 60-100W rating for a period of six hours.

ii) Cook three meals for a family of 5-6.

iii) Drive a 3 ton lorry for a distance of 2.8 km.

iv) Generate 1.25 KW of electricity.

v) Run a 1 hp motor for 2 hours.

As noted in section 1.4.1, many areas in rural Asia are already using biogas for some of the functions mentioned above. However, biogas as a fraction of total energy use has yet to be quantitatively determined for many rural areas in the Asia-Pacific.

Table VII Types of biogas digesters
(Source: Meynell 1976, UNESCO 1984, UNEP 1983)

Digester type	Suitable wastes	Gas production	Operating temperatures	Control
Batch ('wet')	Agricultural (Organic)	Irregular	30-35°C	Little
Plug-Flow ('dry')	Agricultural	Continuous	30-35°C	Simple
High-rate	Agricultural Industrial	Continuous	30-35°C	Complex
Anaerobic Contact	Agricultural Industrial	Continuous	30-35°C	Complex
Secondary (inputs from primary)	Agricultural Industrial	None(sent back to primary)	same as primary	Simple

In concluding, some of the benefits that accrue from the entire process are:

a. Micro-control of water pollution and eutrophication, by reducing the quantity of nutrients in the slurry fertilizer, as opposed to the situation when the wastes are allowed to leach directly to the fields and proximal sources of running water. [UNESCO 1984].

b. Anaerobic fermentation results in the removal of certain pathogens in organic waste and can thus be viewed as a process beneficial for the control of water-borne diseases such as schistosomiasis.

c. The process has positive implications for smell and odor control in rural settlements.

Finally, anaerobic fermentation in rural settlements could have positive impacts on sanitation and quality of life. It can help to arrest uncontrolled deforestation and, in doing so, prevent further deterioration and degradation of the rural biophysical environment.

TABLE VIII Distribution of dry style household biogas plants in Korea
(source: Chun 1984)

PROVINCE	1982	1983	TOTAL
Kyunggi	58	59	117
Kangwon	20	44	64
Chungbuk	2	31	33
Chungnam	12	44	56
Chonbuk	4	55	59
Chonnam	20	70	90
Kyungbuk	-	101	101
Kyungnam	2	59	61
Chejudo	36	303	339
Total	154	766	920

CHAPTER IV: SOLAR AND BIOGAS ECONOMICS

This chapter discusses economic aspects of solar and biogas technologies. As Gowen [1985 p.38] notes, "the determination of the financial and economic feasibility of fuel production and/or conversion technology constitutes an important part of energy planning".

4.1 The theory

Prior to a project feasibility study along benefit-cost lines, six questions arise [Santerre 1984; Gittinger 1982; Gowen 1985]:

a. *What is the perspective used in valuing benefits and costs?*

b. *What type of project comparisons are used?*

c. *What is the time horizon used in reporting benefits and costs?*

d. *How are these benefits and costs valued?*

e. *What type of costing concerns the analyst and, finally*

f. *What decision criteria are used to accept or reject a project?*

Table IX is a summary of the different possible answers to the questions posed. The choice of the market perspective differentiates between private individuals and society in general. Disaggregation of techniques which can be used to evaluate the benefits and costs associated with a particular action, include economic, social accounts and environmental impact assessments [Gowen 1985]. Project comparisons have to be done so as to incorporate 'before-after' and 'with-without' scenarios. The time horizons for valuing the costs have to be defined, for example whether first year or annual cash-flows [ACF's]. Valuation measures also need delineation. How do we value the importance of a project? Should market prices, shadow prices, or 'in-kind' values or weights be used [Gittinger 1982, Weisbrod 1983]? The type of costing, whether average or marginal, and finally the

Table IX The answers to six questions in a benefit-cost analysis (Source: Gowen 1985)

Market perspective	Project comparisons	Time horizons	Valuation measures	Costing	Decision criteria
. Economic	. Before/After	. 1st year	. Private funds	. Average	. Break-even
. Social Accounts	. With/Without	. Annual Cash Flows (ACF's)	. Shadow prices	. Marginal	. Net Benefits
. Environmental impacts			. In-Kind values		. Incremental Net Benefits
			. Weights		. Benefit Cost ratio
					. Simple payback
					. Discounted payback
					. Internal rate of return (IRR)
					. Cost effectiveness

criteria on which a decision is taken, all have to be explicitly stated.

Let us examine the six questions in greater detail:

4.1.1 What is the perspective used in valuing benefits and costs?

Assuming a market perspective is used when an impact assessment is done, then financial, economic, social and environmental analyses have to be carried out. A financial analysis is carried out on the assumption that private funds are used in the valuation of both benefits and costs that accrue from a project. Market values represent real (or adjusted for inflation) costs borne by the investor. This analysis further assumes that the market-place can ideally determine the impact of a project. It does not, however, account for both short-term and long-term externalities that accrue from the project. Valuing the externality is in itself a problem especially when the market cannot be the price-setting mechanism. Economic analyses using associated market prices or 'shadow' prices perform that function. Economic analyses account for the short term externalities arising as a result of proceeding with a project and incorporate them into the analysis.

Projects have both short-term and long-term impacts. Economic analyses appear to be useful tools for enhancing and distributing positive project impacts, such as employment or income benefits, as well as tracing negative externalities with a view to mitigating them. What happens, however, when a project over the long-term has an impact on both the investor and society at large, and a cash value cannot be placed on this intangible? Gowen [1985] suggests a form of social accounting for the long-term intangibles that have an impact on society at large. Two ways of conducting social accounting include the use of cost-effectiveness measures and appropriate indices which represent an attempt at putting normative weights on the long-term social impacts of projects [Gittinger 1982, Mishan 1983 quoted in Gowen 1985].

In conclusion, most projects that involve human-environment interaction have an impact on the biophysical environment. No doubt, the significance of an impact is, to a large extent a function of social values. Negative impacts accruing from a project, therefore, need articulation. An environmental impact statement [EIS], arising from an environmental impact assessment [EIA], is a means for articulating these impacts.

4.1.2 What type of project comparisons are used?

Project comparisons are usually done through scenario creation. The impact of a project is estimated through 'before-after' and 'with-without' scenarios. 'Before-after' scenarios picture the impact in terms of what the state of the environment, both biophysical and social, is before the implementation of a project and what it is after the project has been instituted. 'With-without', as the name implies, is the state of the environment(4), with and without the project. Both explicitly assume a time frame. Information generated through these scenarios are useful to both the investor as well as society at large. Scenario creation takes into account all four of the market perspectives alluded to earlier.

4.1.3 What is the time horizon used in reporting benefits and costs?

Three approaches can be identified with respect to how time is considered in a benefit-cost analysis. A first year cost analysis includes only the benefits and costs for one year of project operation. An annual cost analysis, on the other hand, expresses the benefits and costs that accrue annually over the project's lifetime. The third category, Discounted Cash-Flow [DCF] analyses, discounts the values of benefits and costs over the lifetime of the project. In essence, it is an annual cost analysis multiplied by a discount rate. The discount rate varies with factors such as inflation, and risk and uncertainty associated with project implementation. In Table X, as discussed later [p.], it is seen that most analysts have used the Annual (Discounted) Cash Flows [ACF's] as a time horizon for reporting benefits and costs.

4.1.4 How are the benefits and costs valued?

Quantifying benefits and costs in monetary terms involves taking the following steps [Gowen 1985; Santerre 1984; Santerre and Smith 1982; Gittinger 1982; Davis 1986; Anderson 1977]:

a. Identifying the benefits and costs arising from the physical effects of a project.
b. Measuring the monetary values of these benefit and cost streams.
c. Putting these values into similar and constant monetary terms.
d. Comparing the project's benefit and cost streams.

The benefits of using alternative energy technology include the revenue generated from the sale of the energy and savings from displaced fuels. The fixed costs include capital costs such as those incurred in installation and interest on fixed capital. The recurrent costs include those that accrue from .operation and maintenance such as annual fuel bills, repairs, labor, management and administration.

In general, there are four methods of valuing these benefits and costs: private cash values; 'shadow' prices assuming they reflect social opportunity costs; in-kind values representing transactions outside the formal or cash economy, important from the perspective of alternative energy technologies at the rural level; and weighting [Mishan 1983], a highly subjective procedure, that reflects the value which society places on a project, comparable to the practice of pricing intangibles.

4.1.5 What type of costing concerns the analyst?

An average cost analysis represents benefits and costs per unit time. A marginal cost analysis, on the other hand, looks at incremental or net changes in benefits and costs for a defined time period. In other words, an average cost analysis for an enterprise producing widgets is the cost of producing widgets over a year of production, while a marginal cost analysis is the cost incurred by producing an additional widget. In addition, a marginal cost analysis always compares present costs to something eg., past costs, alternative project costs, or marginal benefits vs. marginal costs. From the perspective of appropriate energy technology, average costs appear low as most analyses to date have shown [see table XII]: Marginal costs, which are usually absent from these analyses, fluctuate because of extreme variabilities in the supply of the primary resource for the conversion process. The supply variability is a function of resource availability and technological efficiency, whereas demand, as will be seen later, is a function of technological adequacy and end-user preferences.

4.1.6 What decision criteria are used in accepting or rejecting a project?

There are 9 ways to decide whether or not to go ahead with a project [Gowen 1985; Anderson 1977; Davis 1986]. These include the following.

1. Undertaking a break-even analysis, when net benefits equal net costs.
2. Determining net benefits, when benefits outweigh costs.
3. Determining the Net Present Value [NPV], which is a derivative of the net benefits concept. The difference between the two is that the NPV considers the discounted value of benefits and costs as they accrue over time, whereas the net benefit approach uses direct and non-discounted benefits and costs. The project goes ahead if the NPV is greater than zero.
4. Tabulating incremental net benefits, which are increases in net benefits associated with the project as compared to the case without the project. It could also be used to compare two projects. If the benefits accruing from project A are greater than those accruing from B, the incremental net benefits method can be used to select A.
5. Determining Benefit-Cost ratios used to select projects based on a positive discounted ratio of benefits to costs. Both discounted and undiscounted benefit:cost ratios have been used as decision criteria.

6. Using simple payback techniques the year in which the investment in a project is recovered; it is seldom used as it neglects the time value of money.
7. Using discounted payback techniques, on the other hand, find the year in which capital expenditures are balanced by discounted benefits and are used more often.
8. Determining the internal rate of return (IRR) which is that discount rate which makes the NPV equal to zero. It is sometimes incorrectly used in determining feasibility because some projects have multiple IRR's, arising from a range of attractive discount rates, all of which have different payback possibilities.
9. Using cost effectiveness as a decision criterion when a significant proportion of the benefits or costs associated with a project cannot be monetized. Cost effectiveness measures are generally used to provide non-exclusive and non-rivalrous public goods - those that are beneficial to society at large.

Table X represents a benefit-cost analysis carried out by Liberty Flour Mills for their biogas digester enterprise in the Philippines. It is presented to serve as a typical example representing the complexity and major drawbacks associated with benefit-cost calculations done to date. It is to be noted that most of the costs considered are average costs with benefits derived from a tabulation of opportunity costs such as those arising by substituting biogas for LPG, gasoline, diesel oil and electricity. Again, the absence of a sensitivity analysis should be noted, together with assumptions regarding technical efficiency, evidenced by a lack of different gas production estimates. The attempt to value sludge as fertilizer is another major drawback. Each of these will be discussed in detail in section 4.2 dealing with caveats in benefit-cost analyses.

To point out more significant drawbacks, Table XI shows how the six questions addressed in section 4.1 are answered by recent examples of benefit-cost analyses for biogas systems. It is a summary of different analyses carried out for biogas systems in India. The use of private funds and shadow prices as valuation measures is common to all

Table X An example of a Benefit-Cost analysis
The case of the Maya Farms, Philippines
[source: Maramba 1978]

1. Technical information

Types of digesters:	Continuous fed; four rows.
Total digester capacity:	17,600 cu.ft of digester slurry
Total gasholder capacity :	5000 cu.ft.
Retention time :	25 days.
Manure:Water ratio :	1:1.5 by volume
Manure input :	7500 kg/day
Products output	
Biogas :	15000 cu.ft./day 155000 cu.m/yr
Dry sludge :	750 kg/day; 274 tons/yr.
Liquid sludge [25% loss from leaching and evaporation] :	520 cu.ft./day; 5370 cu.m/yr

2. Cost evaluation (OPPORTUNITY COSTS)

A. Biogas

Biogas produced per annum	:	155000 cu.m.
costs substituted by Biogas		
1. LPG [=1lb @ P 1.0/lb]	:	P 155000
2. Gasoline [=.54l @ P 1.5/l]	:	125550
3. Diesel oil [=.52l @ P 1.2/l]	:	96720
4. Electricity		
suburban [=1.5kwh @ P .35/kwh]	:	81375
rural [=1.5kwh @ P .50/kwh]	:	116250

B. Dry sludge

1. As feed 274t * P600	:	164400
2. As fertilizer 274*P100	:	27400

C. Liquid sludge as fertilizer

5370 cu.m * P 5.14/cu.m	:	27600

3. Financial analysis

A. Capital investment

1. For pollution control or for pollution control and Biogas		
a. Biogas	:	155000
b. Sludge treatment unit	:	55000
		P210000
2. For pollution control, Biogas and fertilizer		
a. Biogas plant	:	155000
b. Sludge conditioner unit	:	65000
		220000
3. For pollution control, Biogas, fertilizer and feeds		
a. Biogas plant	:	155000
b. Sludge conditioner unit	:	65000
c. feed-processing unit	:	35000
		255000

B. Operating expenses

1. For pollution control only or pollution control and Biogas		
Labor	:	9400
interest 17%	:	35700
depreciation 10%	:	21000
repair and maintenance	:	3000
administrative	:	12000
	total	81800
2. For pollution control and fertilizer		
repair and maintenence	:	4000
labor	:	14100
interest 17%	:	37400
depreciation 10%	:	22000
administrative	:	12000
	total	89500
3. Pollution control, Biogas fertilizer and feed		
Labor	:	23500

TABLE X (CONTD.)

interest 17%	:	43350
depreciation 10%	:	25500
repair and maintenance	:	8000
administrative	:	12000
	total	112350

C. Net operating savings and return on investment

1. Biogas works for pollution control and Biogas

	Net operating savings	Investment recovery period
a. LPG substitution	P 73900	2.8 years
b. Gasoline	P 44450	4.7 years
c. Diesel oil	P 15620	13.4 years
d. electricity		
suburban	P 275	na
rural	P 35150	6.0 years

2. Biogas works for pollution control, Biogas and fertilizer.

	Net operating savings	Investment recovery period
a. LPG substitution	P 120500	1.8 years
b. Gasoline	P 91050	2.4 years
c. Diesel oil	P 62220	3.5 years
d. electricity		
suburban	P 46875	4.7 years
rural	P 81750	2.7 years

3. Biogas works for pollution control, Biogas, fertilizer and livestock feed.

	Net operating savings	Investment recovery period
a. LPG substitution	P 234650	1.1 years
b. Gasoline	P 205200	1.2 years
c. Diesel oil	P 176370	1.4 years
d. electricity		
suburban	P 161025	1.6 years
rural	P 195900	1.3 years

Note: All figures in Philippine pesos.

Table XI Some attempts at benefit-cost analyses for biogas systems

AUTHORS	Perspective used in valuing benefits and costs	Type of project comparisons	Time Horizon in reporting benefits and costs	Type of costing	Decision Criteria used
Bhatia 1977	Economic Social	Before/After	1st year Annual Cash flows	Private funds Shadow prices	Net Present Value Benefit cost ratio
Santerre in Islam et al 1984	Economic Social	Before/After	Annual Cash flows	Private funds Shadow prices	Net Present Value
Lichtman 1987 (b)	Economic Social	Before/After	Annual Cash flows	Private funds Shadow prices	Net Present Value
Ghate in Pachauri 1980	Economic Social	Before/After	Annual Cash flows	Private funds Shadow prices	Benefit cost ratio Net Benefits Net Present value
Lichtman 1983	Economic Social	Before/After	Annual Cash flows	Private funds Shadow prices	Net Present Value Discounted payback

of them. However, Lichtman [1987] observes the predominance of in-kind values in rural settings, which have not been incorporated into past analyses. Again, the use of average cost analyses dominates in all, in determining costs that accrue from a project. To conclude, if these analyses are to focus on the social perspective in valuing benefits and costs, they need further elaboration using a comprehensive conceptual framework such as the six questions used in this chapter. Particular importance has to paid to the choice of costing techniques and decision criteria.

4.2 The caveats

By questioning the assumptions of the analysis, caveats in benefit cost analyses for appropriate energy technology projects are examined. These include assumptions regarding the valuation of benefits and the need for accompanying sensitivity analyses. Secondly, by identifying conditions in the socio-cultural environment that cause a departure from the assumptions the need for a more comprehensive benefit-cost calculation is pointed out.

4.2.1 The assumptions of the analysis

At a general level, there are two major assumptions that usually underly all assessments of a project's impact:

a. That the value of a project to society is the sum of the values of the project to individual members of that society, and

b. That the value of a project to an individual is the amount that individual is willing to pay for the project.

What happens when, *ceteris paribus* the above two conditions do not hold: When the sum of individual values are greater than society's values when 'free-riders' exacerbate this problem or where individuals in society do not explicitly state their preferences? Furthermore, the larger problem associated with the second assumption is the determination of consumer willingness to pay [WTP], or willingness to pay to forgo the project. These are areas that need sufficient articulation if an informed and holistic benefit-cost analysis is to be carried out, particularly one using a realistic range of benefits and costs.

At a more specific level, Lichtman [1987, p.349] points out two of the most important drawbacks in most of benefit-cost analyses on biogas experiments in rural areas of developing countries:

a. They tend to overestimate the benefits accruing from the project as a whole by placing a monetary value on the utilization of the slurry effluent, by using associated commercial fertilizer market prices. The underlying assumption, he adds, is that the slurry can be substituted for commercial fertilizer or could be sold for the economic value of its nutrient content. In reality, however, poor farmers cannot purchase fertilizer and there is no economic method to date for trading biogas slurry. He adds that these benefits could actually be an underestimation if either methods to trade biogas slurry are developed or, a fuller reflection of the benefit is incorporated into benefit-cost analyses, for example, the benefit of enhanced crop production.

b. Most analyses carried out so far present the Net Present Value [NPV] or the benefit:cost ratio as a static quantity and very few attempts are made to incorporate sensitivity analyses. If a sensitivity analysis is done, argues Lichtman, the range of benefits accruing from a range of costs could be improved(1). This is particularly important as biogas digesters suffer from a wide range of performance fluctuations depending on the nature of the techology, the climate of the area, the availability of inputs and a host of other factors.

In addition to the specific drawbacks, disagreements over shadow prices, the valuation of benefits accruing from an improvement in health and quality of life and the pricing of benefits accruing from rural energy self-sufficiency are common in almost all attempts at carrying out a biogas plant benefit-cost analysis.

The situation is more or less the same with respect to solar technologies. Although Myers [1984], Lura [1979], UNESCO [1983], UNEP [1984] and other authors have carried out benefit-cost analyses of both passive and active solar technologies proving their viability, the two major underlying assumptions, stated at the beginning of 4.2.1, tend to disprove the viability hypothesis as has been shown by experiments with solar technology projects in Thailand, and Korea (see Chapter V).

4.2.2 The socio-cultural environment.

Technology emplacement has an impact on the socio-cultural environment. Socio-cultural related impacts are generally non-quantifiable in nature, and hence are not generally incorporated into benefit-cost calculations. In a sense, they play a large part in invalidating the two major assumptions underlying most benefit-cost calculations: homogenous social systems with similar utilities for goods and services and, a similarity in willingness to pay.

There are three fundamental forces in rural Asian villages that do not usually manifest themselves in a benefit-cost analysis and hence are construed as caveats in past analyses. [Long & Oleson 1980; Deudney 1983; Brown 1978; Lichtman 1987]. These include:

a. The influence of culture and tradition.

b. The influence of religion.

c. Political influences at the village, local, regional and national levels.

Table XII is a summary of the importance of each of these forces in the selected countries. It is evident that the influence of religion is strong in Malaysia and Thailand and this may have an impact on how benefits and costs of technologies are perceived. In addition, religious practices have a major part to play in determining whether or not the technologies will be accepted. Political influences at the local, regional and national levels

Table XII The importance of social influences in benefit-cost analyses

(Sources: Chun 1984, Long and Oleson 1982, Morse 1984, Brown 1978, Arthornthurasook 1984, Chirrarattananon 1984, Lichtman 1987, Gupta 1983, Deudney 1983)

Factor	Korea	Malaysia	PNG	Philippines	Thailand
Culture and Tradition	*	***	**	**	***
Religion	**	***	*	**	***
Village and local political influences	**	**	**	***	**
Regional and National political influences	**	**	*	***	**

Scale: * ** ***

Weak importance — Strong importance

may have an influence on cost inflation, although no direct quantitative correlation has been done. Culture and tradition have a part to play as an influence in invalidating calculations in benefit-cost analyses. A typical example is the predominance of in-kind values representing transactions outside the cash economy, generally a norm in an Asian rural setting. Benefit-cost valuations have yet to adequately consider such transactions.

To conclude, according to Chun [1984], these forces generally amplify through inter-village communication and can dictate consumer willingness to pay in such social settings. Faith in quasi-religious symbols forms another significant cultural force in Asian villages that can act as an impediment to efforts at introducing new technologies. Finally, the lack of formal education has a major influence on how the economics of technology, appropriate or otherwise, has been and will be perceived in rural settings [Burch 1982, Gupta 1983]. Rural Asia, in this sense, is no exception.

Chapter V discusses these forces in greater detail and makes a case for their consideration by policy-makers prior to the institution of appropriate technologies such as biogas and solar.

Summary

Six questions have to be answered in doing a benefit cost analysis for systems such as solar and biogas. These questions have to take into account the perspective used in doing the analysis, differences in project comparison, time horizons, valuation measures, costing techniques and, finally, decision criteria.

From an examination of an analysis done for a biogas plant in the Philippines and a categorization of different benefit cost analyses done for similar systems in China and India, it is evident that these analyses are incomplete. Reasons for this incompleteness have been attributed to the relation between the assumptions underlying most benefit-cost analysis and the socio-cultural environment, that do not reflect in past analyses, such as religion, tradition and education.

More specifically, the overestimation of benefits from biogas systems, through incorrect attempts to value the slurry effluent and the lack of accompanying sensitivity analyses for benefit cost valuations, have been pointed out as major drawbacks in past analyses.

CHAPTER V: THE PROBLEMS OF SOLAR AND BIOGAS TECHNOLOGIES

> " *Biogas has received a less enthusiastic response from villagers not only because it is 'rural', but also because of cultural symbolism which gives a lower grade to human and animal discharges".* Atal (1984)

For technologies such as solar and biogas, to be termed appropriate, they should be technically, economically and socially appropriate along with an adequate level of institutional support. The purpose of this chapter is to examine the appropriateness of solar energy harnessing and biogas generation technologies in the rural Asia-Pacific setting under two headings:

a. *Technical and Economic.*

b. *Social and Cultural.*

5.1 Technical and Economic appropriateness

From a review of appropriate technology literature, solar and biogas technologies are technically appropriate provided the following conditions are satisfied [Atal 1984, Chun 1984, Arthornthurasook 1984, Lichtman 1987, Moulik 1979, 1983]:

a. A greater part of the labor and materials used in constructing and installing these facilities are available locally.

b. These facilities are designed keeping in mind a range of natural factors such as climate and natural disasters.

c. The technologies do not require highly specialized operation and maintenance.

d. Spare parts are available locally.

A similar literature review indicates that these technologies are economically appropriate provided:

a. Whoever paid to install them also pays the recurrent costs accruing from the operation of these installations. Lichtman [1983, 1987], Bhatia [1977] and Ghate [1979] note that the lack of finance to cover recurrent costs (as explained in chapter III) accruing from the maintenance and operation of biogas facilities in India and China, is a major cause for the state of disrepair and disuse of installed facilities. It is therefore assumed that if an implementing agency subsidized installation costs, further subsidization, in a proportion of recurrent costs, should be provided to make them economically appropriate.

b. Secondary energy from the technologies, solar and biogas, is affordable by the rural dweller without further subsidization by whoever paid to install the technologies. Affordable, in this instance is a function of the income of the rural dweller and the difference between localized marginal costs and global average costs of solar and biogas energy(1).

5.1.1 Biogas digesters

In a paper entitled "Reluctance and selective acceptance: The Korean case", Chun [1984] has discussed the case of biogas technologies in the Republic of Korea. Both Atal [1984] and Chun note that leakage from the digestion apparatus, low operating temperatures in winter and the lack of raw materials for digester inputs are the three most important problems with biogas digesters in Korea. As far as economic appropriateness is concerned, primary research carried out by Atal [1984] and Chun [1984] indicate that government financial support for these digesters was fully withdrawn after their installation. The price of 1 cu.m. of biogas in a typical Korean hamlet has been estimated at 112.7 won [1979; 1US$ = 500won]. This, in comparison to propane 313.5 won, kerosene 161.1 won, coal briquette 190.1 won, and electricity 367.08 won, appears to be affordable by the villager [see table 3, p.27]. The problem is that as technical inadequacies and marginal production costs increase, with constant demand the actual price that a villager has to pay becomes about 240.6 won [Kim 1985]. Biogas is therefore not as affordable in comparison to other energy sources as it may initially appear. Biogas digesters are therefore not as economically appropriate as initially perceived.

A host of technical problems associated with the Thai biogas experience have been identified by both Arthornthurasook [1984] and Atal [1984]. These include problems with leakage from the digestion apparatus, inappropriate materials used in the gas holder, technical assistance being unavailable, spare parts being hard to procure, a lack of raw material inputs and the lack of sufficient water to clean out the digestion pit. With reference to the first condition for economic appropriateness, Thailand has not phased out government support for operation and maintenance of biogas digesters. In this respect it is still economically appropriate. With respect to the second condition, however, problems with affordability in terms of the market price of biogas can be related to technical inadequacies making biogas appear economically inappropriate. Further research needs to be done to determine which condition assumes greater importance, for valid conclusions to be drawn.

Another way of viewing economic appropriateness is in terms of installation costs. The proportion to be paid by the villagers requires a one-time lump sum investment which is perceived as a problem in both Korea and Thailand [Atal 1984]. This high cost has the tendency of making these technologies inappropriate at the outset, even before subsidies to cover recurrent costs are put into place [Arthornthurasook 1984, Mackillop 1980, Power 1980].

The Philippines has experienced similar technical problems with digesters in rural areas. Leakage from the digestion pit, substandard materials used as gas holders, lack of spare parts and the lack of raw materials all constitute technical problems with biogas digesters [Maramba 1978](2), though relatively less, compared to the situation in other countries. The linkage between technical inadequacies, marginal costs, and alternative energy affordability, is well established in the Philippines [Maramba 1978]. In addition, government support for the operation and maintenance of these digesters was sporadic and at present is non-existent. The Maya farm (see Chapter VI), however, continues to subsidize recurrent costs from biogas installations. Detailed information on the nature and extent and extent of subsidization was unavailable to the author at the time of writing this thesis.

Table XIII is a simplified representation of the technical appropriateness of biogas and solar technologies in the selected countries. As is seen, the level of technical appropriateness in terms of the availability of labor and materials, adaptability and suitability to climatic factors, ease of operation, frequency of maintenance and finally, the availability of spare parts appears to be optimal in the Philippines. Both Thailand and Korea come close to achieving the level of technical optimality necessary for efficient operation of biogas digesters but could improve in adapting their technologies to prevalent climatic factors. Malaysia and Papua New Guinea on the other hand, require a lot of research and commitment to achieve the optimal conditions of the other three countries.

Table XIV is a representation of the level of economic appropriateness using the conditions stated in section 5.1 (3). It is evident that Korea and Thailand probably have economically appropriate conditions for biogas technologies. The Philippines, having introduced the private sector to biogas technology diffusion efforts, appears to be diverging from an economically appropriate condition: firstly, because the private sector will operate profitably only if marginal costs approach average costs and secondly, because additional costs are passed on to the rural consumer making the energy unaffordable. Malaysia and Papua New Guinea are lagging behind both in operation and maintenance of these technologies making them technically inappropriate. In addition, strategies to improve conditions of affordability for rural users need improvement if the conditions defined for economic appropriateness are to be achieved.

5.1.2 Solar Technologies

Using the same conditions developed to test the appropriate technical and economic conditions for biogas digesters, it is seen from tables XIII and XIV that solar technologies also have elements of technical and economic inappropriateness. The condition that a greater part of the labor necessary for the installation, operation and maintenance should be available locally is met for all the countries, but the additional condition that construction materials should be available locally, is not. This is particularly the case with Malaysia which has experimented with active solar technologies in conjunction with CNRS of France (see ch.VI). The incorporation of passive solar techniques, on the whole, appear to be a local effort in the cases of Korea and Thailand. Thailand, again, is involved in efforts to diffuse active technologies in close cooperation with both domestic and foreign

Table XIII Technical appropriateness of solar and biogas technologies

(Sources: Lichtman 1983, 1987, Arthornthurasook 1984, UNEP 1983, Chun 1984, Kim 1981, Power 1980, Mackillop 1980, Maramba 1978)

Condition	Korea	Malaysia	PNG	Philippines	Thailand
Local labor and materials	+++	++	++	+++	+++
Natural factors and climate	++	++	++	+++	++
Specialized operation and maintenance	+++	++	++	++++	+++
Local spare parts	++	+	+	+++	+++

Scale: + (Inappropriate) — +++ — +++++ (Appropriate)

Table XIV Economic appropriateness of solar and biogas technologies

(sources: as above in table XIII)

Condition	Korea	Malaysia	PNG	Philippines	Thailand
Operation and maintenance costs borne by agency or firm	++	++	++	+++	+
No subsidy for marginl costs	++	+++	+++	++	++

Scale: As in Table XIII

components of the private sector, requiring an importation of materials, and thus departing from a condition of technical appropriateness.

Solar technologies are well suited to the climatic conditions of all the countries in the sample. Korea, with its emphasis on passive solar technology in both urban and rural areas, satisfies the condition that the technology does not need specialized operation and maintenance. In addition, most spare parts for these passive technologies are available locally. Malaysia and Thailand depart from this condition quite significantly, while PNG and the Philippines adhere to it based on their efforts to incorporate rural passive technologies.

With respect to economic appropriateness (see ch.VI), it is clear that Korea satisfies the condition of operation and maintenance subsidies for passive technologies. It is not clear whether this subsidization results in making this form of energy more affordable, compared to alternative energy resources, for rural dwellers. The situation in Malaysia appears to be ideal although its experimental nature. The government covers the cost of installation, operation and maintenance of the experimental plant that it is setting up to make rural energy affordable, in conjunction with CNRS of France. The cases of PNG, Thailand and the Philippines are not as clear, but information derived from the literature appears to suggest that there is adequate subsidization in Papua New Guinea. Thailand and the Philippines with their reliance on the private sector may satisfy the condition that operation and maintenance costs are taken care of, but whether or not this makes the energy more affordable in the long run, compared to the alternatives, remains to be seen.

In summary, the conditions developed for assessing the appropriateness of solar and biogas technologies appear simple in nature. With respect to economic appropriateness, it is not totally adequate to state that solar and biogas technologies are economically appropriate if recurrent costs are subsidized. The level and type of subsidy has to be defined, recurrent costs have to be estimated and a cost-sharing formula has to be developed if a cost-sharing strategy for recurrent expenditures is accepted. In this thesis, however, simple conditions have been purposefully selected in order to make the conditions more integrated and comprehensive.

5.2 Social and Cultural appropriateness

From a review of relevant literature it is asserted that solar and biogas technologies are socially and culturally appropriate provided:

a. Their use is compatible with prevalent religious practices;

b. Their use does not imply the need to follow culturally repugnant practices;

c. Their use does not imply a change in normal patterns of community life and social relationships;

d. The community decided to receive the technology, i.e. it was not thrust upon them without their participation in the decision making process;

e. Politically vested interests in the community are receptive to the idea of alternative energy technologies.

The compatibility of biogas digesters with rural religious ideology is important. Islam, for example, forbids the handling of animal and human wastes and, as biogas is produced by the anaerobic fermentation of waste material, the acceptance of this technology is not likely to be very high in predominantly Islamic societies such as Malaysia and parts of the Philippines. In addition, some highly stratified societies, even though not by any religious covenant, abhor the handling of animal and human wastes as they find it culturally repugnant such as the case of Korea [Chun 1984, Beers 1982, Lichtman 1987, Dandekar 1979].

Dandekar [1979] emphasizes the importance of the condition that normal community social relationships should not be hampered by the dictates of the technology. This applies in particular to biogas technologies. As noted earlier, the volume of biogas generated depends on climate and the amount of dung available as digester input. This implies that people in the community have to adjust their normal cycle of daily activities to accommodate the flow of gas for cooking and other purposes. The community of Fateh

Singh Ka Purwa in India serves as an excellent example to support this argument (see appendix). Gupta [1983] notes that this community had a gas supply for three hours a day depending on the volume of wastes in the digester. This gas could be available either during the day or at night. People in this community adjusted for a short period of time when the digester was first installed but this waned over the long run, and soon people in the community reverted to costlier biomass and other commercial fuels rather than suffer the inconvenience of climatically induced unavailability.

Who took the decision to put the technology in the village often has a bearing on how well the technology is used. As Lichtman [1987, p.358] notes with reference to the Indian Biogas Program:

> *"The arrival of a jeep full of biogas technicians will not enable the technology to contribute effectively to the improvement of rural life. Such outside technicians are not likely to understand the needs of a particular village, to gain the trust of its residents, and to engage in a dialogue with villagers, so that collectively, projects can be designed to truly respond to village needs. If biogas systems are to play a useful role in rural areas, they must be planned by local [people and] organizations whose focus is overall village development".*

On the other hand, Gupta [1983] notes that the success of the Fateh Singh Ka Purwa experience was due to the participation of government, symbolized by technicians, in a community program and not the community in a government program. It should be noted, however, that there were other factors that played a part in the partial success of this particular example, including the role of a charismatic motivator who was an agent of the government as well as the project's high media profile.

Finally, vested political interests in the community have long played a major part in all aspects of community life: deciding what goes where, who gets what and providing liaison with government officials [Harrison 1983, Beers 1975]. It is often the case that the strongest political interest in a rural Asian village is the largest landowner. If the landowner decides to adopt a new form of technology, the rest of the village has no choice but to follow suit. It could also be that the largest landowners monopolize the output such as biogas sludge from a community based biogas plant or hot water from a community sized photovoltaic panel by virtue of their total control over village life. These possibilities cannot be ruled out as impediments to optimal emplacement and utilization of alternative energy technologies.

Table XV is a summary of the factors that influence social and cultural appropriateness of both solar and biogas technologies, more so biogas, in rural settlements in the Asia-Pacific. As could be expected, Malaysia differs significantly from the other countries, in terms of religious ideology and the use of biogas technologies. Biogas digesters in Malaysia would be socially and culturally inappropriate. Biogas digesters appear to be culturally least repugnant in the Philippines making them socially and culturally appropriate. Rural dwellers in Korea and Thailand had relatively more input in deciding to accept the technology than rural dwellers in the other countries. The presence of this input is a factor in determining appropriateness. Whether its presence alone, independent of other prestated conditions, defines social and cultural technological compatibility remains indeterminate.

Table XV Social and Cultural appropriateness of solar and biogas technologies

(Sources: Power 1980, Mackillop 1980, Chun 1984, Arthornthurasook 1984, Premnani 1979, Maramba 1978, Lichtman 1987, Buren 1976, Long and Oleson 1983, Islam et.al. 1984, Phil. Min. of energy 1981)

Condition	Korea	Malaysia	PNG	Philippines	Thailand
Use compatible with prevalent religion	++++	++	+++	++++	+++
Not culturally repugnant	+++	++	+++	++++	+++
No change in community life	++	nc	nc	++	+++
Community decision	+++	nc	nc	++	+++
Favorable political climate	++	++	++	+++	+++

Scale: + ++ +++++
Inappropriate Appropriate

CHAPTER VI: THE ROLE OF GOVERNMENT

This chapter discusses the role that governments in the Asia-Pacific region have played in facilitating the dissemination of solar and biogas technologies to the rural dweller. There are two fundamental ways in which governments have intervened to facilitate this diffusion process. These have been through institutional support and material support.

Institutional support can be cohesive and integrated as opposed to diffuse and fragmented. A diffuse and fragmented approach has often been the cause of problems in monitoring and evaluating government programs, particularly when a plethora of institutions are involved in providing material support for these programs. Furthermore, diffusedness tends to inflate operating and project implementation costs.

Broadly speaking, there are three ways that the state can offer material support to aid technology dissemination. This assumes that the economics of appropriate technology, from the private sector perspective, renders it unattractive to venture capital [Harrison 1983](1). They are:

1. subsidies.
2. the granting of favorable tax status.
3. direct government involvement in programs and projects.

All three will be discussed in the context of support from governments of the countries selected.

Sankar [1982] has summarized the institutional arrangements for central planning and coordination in the energy sector of the countries selected. Table XVI is a representation of the organizational form of the institutions, and an estimate of their level of integration with National Planning agencies and other energy producing and consuming sectors. The table shows that coordinating committees have a greater role in energy planning, policy and management compared to ministries. Their integration with National Planning agencies appears to be satisfactory but these committees do not appear to integrate fully with other energy producing and consuming sectors.

TABLE XVI Institutional arrangements for central planning and coordination: All energy resources
(Source: ADB 1982)

COUNTRY	Organizational form	Integration with National Planning agencies	Integration with Other energy sectors
Malaysia	Coordinating Committee	Average	Average
Papua New Guinea	Single agency	Average	Average
Philippines	Ministry	Good	Average
Thailand	Ad-Hoc Committee	Below Average	Below Average
Korea	Ministry	Average	Average

Table XVII indicates institutions in the Asia-Pacific region, charged with the responsibility for carrying out research, development and dissemination of solar and biogas technologies.

6.1 The institutions

Prior to a discussion of the role that institutions can play in disseminating alternative energy technologies, the different institutions involved and their respective mandates will be described.

TABLE XVII Government Institutions for solar/biogas technologies

KOREA	. Korean National Cattle Breeding Laboratory
	. Institute of Agricultural Sciences, Office of Rural Development (ORD)
	. Korea Atomic Research Institute
	. Advanced Institute of Science
MALAYSIA	. University of Malaya
	. Malaysian Agricultural Research and Development Institute
	. Mega-Chem Bechad, Klang
PAPUA NEW GUINEA	. Department of Primary Industry
	. Bagi Agricultural Center
	. Office for Village Development
	. South Pacific Appropriate Technology Foundation
	. Papua New Guinea Institute of Technology
PHILIPPINES	. Forest Products Research Institute
	. International Rice Research Institute
	. National Science Development Board
	. De La Salle University of Manila
	. University of the Philippines
	. Ministry of Agriculture
	. National Institute of Science and Technology
	. Bureau of Animal Industry
	. Center for Non-conventional Energy Development
THAILAND	. Kasetsart University
	. National Energy Administration
	. Sanitation Department, Ministry of Health
	. Department of Public Welfare
	. Village Councils (Tambons)
	. Asian Institute of Technology
	. King Mongkut's Institute of Technology

Sources: Phil. Min. of Energy 1977,1981, National paper Malaysia, 1981, Chun 1984, Del Rosario 1981, Power 1980, Kim 1985, Arthornthurasook 1984, UNEP 1983, UNIDO 1978, Kim 1981, Chirrarattananon 1984, Eggers-Lura 1979.

6.1.1 Koreà.

Biogas generation plants in Korea date to 1964. They were first introduced by the Japanese under the umbrella of the Korean National Cattle Breeding Laboratory. In 1967, the responsibility for research, development and facilitating diffusion to the rural dweller became the responsibility of the Institute of Agricultural Sciences, governed by the Office for Rural Development [ORD]. The Institute was primarily responsible for the design of 'wet' and 'dry' style digesters and between 1969 and 1981 was actively involved in the setting up of these plants at the rural level [Chun 1984].

Solar energy, on the other hand, has not had the same level of institutional backing. The two organizations in Korea that have expressed any interest in solar R & D and who test solar cookers at the rural level are the Korean Atomic Energy Research Institute and the Advanced Institute of Science in Seoul [UN 1985].

To summarize, the Ministry of Energy and Resources is the major coordinating agency responsible for planning, providing direction for research and development, and taking decisions regarding investment and pricing. In all these categories, the Ministry has been average indicating the need for improvement [ADB 1982].

6.1.2 Papua New Guinea [PNG]

Agencies set up to facilitate rural development in PNG were, in addition, responsible for installing and maintaining solar and biogas technologies in rural PNG. The forms of technologies ranged from solar heated lumber dryers to family-sized biogas plants.

Rural development in Papua New Guinea places a great emphasis on coordinated activity between local and external agencies. External agencies including arms of UNESCO and FAO have stimulated rural educational infrastructure and agricultural productivity. Some of the local institutions set up to work in tandem with multilateral and bilateral are described below.

. The Department of Primary Industry, focussing on the diffusion of appropriate technology into large-scale plantation type land holdings [Mackillop 1980, Power 1980].

. The Bagi Agricultural Center, a Christian mission responsible for cooperative agriculture, cooperative land management and the use of appropriate technology to achieve both [Power 1980].

. The Office of Village Development, set up in 1976 to stimulate public involvement. One of the strategies for achieving public participation in village development was through an increased use of appropriate technologies for attaining a measure of rural energy self-sufficiency [Power 1980].

. The South Pacific Appropriate Technology Foundation (SPATF), which was instituted to fulfill the software needs of appropriate technologies, in the form of education, on-the-job training and specialized technical training [Power 1980].

Solar energy, on the other hand has only been the focus of research and development efforts over the past 10 years. The main center of R & D activity is in the Papua New Guinea Institute of Technology at Port Moresby [UN 1985](2).

A major coordinating agency is the Department of Minerals and Energy in Port Moresby. Its performance in areas of planning, investment and pricing has been rated average. In addition, the Asian Development Bank notes that direction in research and development, and human resource capability in the energy sector, has been below average. These are areas in need of greater institutional effort.

6.1.3 Thailand

The government of Thailand launched several projects with the objective of disseminating appropriate technologies to the rural dweller. One such example, biogas digesters, were first introduced in the 1940's by Chinese families living in the Northern region. Their advantages were made public by Kasetsart University [Arthornthurasook 1984]. Thai Universities have, to a large extent, remained centers for research and development in alternative energy technologies but transferred responsibility for diffusion to the National Energy Administration [NEA], the Sanitation Department of the Ministry of Health, various agricultural organizations, the Department of Public Welfare and various other provincial and local organizations including the *Tambons* or village councils.

Kasetsart University, the Asian Institute of Technology and King Mongkut's Institute of Technology are three academic institutions involved with solar energy research and development in Bangkok. Government institutions that have played a part in R & D include the Ministry of Agriculture and Cooperatives and the National Energy Administration [Eggers-Lura 1979]. International agencies such as UNESCAP, and the UNESCO regional office for education in Asia have also made a significant contribution in the field of software support for local institutions [UNESCAP 1984].

In the opinion of officials at the Asian Development Bank [1982] committees such as the National Energy Administration in Thailand should place greater emphasis on planning, pricing and providing direction in research and development.

6.1.4 The Philippines

Institutional support for design, research and development efforts in appropriate solar technologies have come mainly from the Forest Products Research Institute, the International Rice Research Institute and the National Science Development Board. Major universities that have been involved in similar efforts include the De La Salle University at Manila and the University of the Phillipines at Quezon City. In addition, the private sector has been actively involved in attempts to diffuse solar technologies to suburban communities, one example is Project Santa Barbara on the outskirts of Cavite city. The American international school at Makati supports facilities for experimental and educative efforts in the field of passive solar technologies [Eggers-Lura 1979, UNIDO 1978].

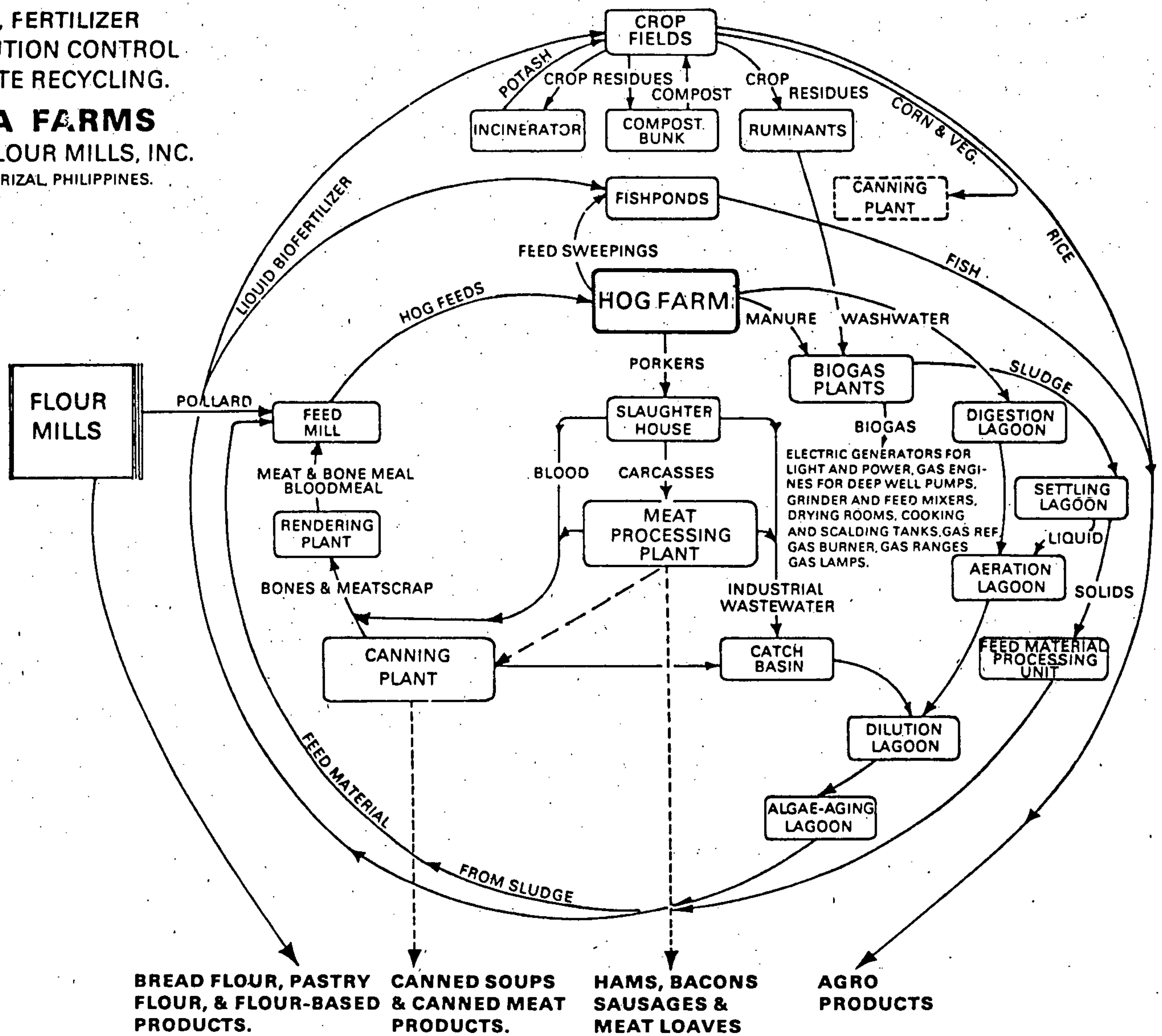
Research, design and development efforts in biogas technologies fall under the jurisdiction of the Forest Products Research Institute and the Ministry of Agriculture [UNIDO 1978]. A private firm in the agro-industrial sector Liberty Flour Mills, set up the Maya experimental farm, whose energy needs are met primarily through the use of biogas technologies. The plant was constructed as an integrated livestock, meat processing and canning operation in the Antipolo Hills of Rizal Province. Pollution control was the reason stated for encouraging investment in the creation of this enterprise and thus formed an integral part of project planning [Maramba 1978]. A schematic diagram of the nature and logistics of the enterprise is shown in figure 9.

In addition, other government institutions that have played a part in encouraging the use of biogas includes the National Institute of Science and Technology [NIST] and the Bureau of Animal Industry. The instruction to set up biogas demonstration projects all over the Philippines came directly from the then President Marcos in 1976. The objective was to set up biogas plants in each of the 12 regions of the country within six months; one in every province within a year and then one in every locality [Del Rosario 1981]. Maramba [1978] notes that the Bureau of Animal Industry has performed well ahead of schedule.

Other International institutions such as the International Rice Research Institute (IRRI) at Manila have played an important part in providing software support.

Other biogas installations, both private and government owned and used for both commercial and non-commercial purposes in the Philippines are listed below [Maramba 1978].

a. The Liberty Foundation Dormitory, a plant that treats sewage from the workers' dormitory at the Maya scheme. The 80-100 residents use the biogas produced for cooking



Logistics of the Maya Farm enterprise

FIGURE 9
(Source Maramba 1978 p.183)

their meals and ironing their clothes. Biogas from another installation is used for providing dormitory lighting. This is a good example of a community sized biogas digester.

b. A backyard piggery in Munyoz, a family sized digester.

c. An orchard in Santa Barbara run by Ms. Manuela Maramba, another example of a family sized digester.

d. A piggery in Calasiao(3).

e. A slaughterhouse in San Juan, a biogas digester intermediate between family sized and community sized.

f. The BAI stock farm in Tarlac, a demonstration plant.

g. The Pampanga Agricultural college, a demonstration and research plant.

Other minor installations include the UP College of Agriculture at Los Banos, Laguna, the Golden farm in Santa Maria, and the poultry and livestock farm at San Pedro.

6.1.5 Malaysia

The University of Malaya at Kuala Lumpur and the Malaysian Agricultural Research and Development Institute at Selangor are two major institutions that have been involved over the past decade in solar technology research and development efforts. A private firm *Mega-Chem Bechad,* in Klang, has expressed an interest in the manufacture of solar lumber dryers and community sized passive solar technologies. To date not much has been done in the form of experimental projects for educational purposes [Eggers-Lura 1979].

Biogas has not stimulated as much interest as solar technologies in Malaysia. To date a few biogas experimental plants have been set up in peninsular Malaysia but no similar efforts have been undertaken in Sabah. The centers of research and development are again the universities, with the University of Malaya at Kuala Lumpur playing a large part [UNIDO 1978].

6.2 Material support

Material support can broadly be subdivided into three categories:

a. Provision of subsidies and technical assistance.

b. Granting a favorable tax status to encourage private sector participation in alternative energy technology emplacement and utilization.

c. Direct government involvement in programs and projects.

Table XVIII is a summary of the material support offered by government agencies for solar and biogas technologies in the Asia-Pacific region.

6.2.1 Korea

In the Korean case, the construction of biogas digesters in rural areas has been greatly facilitated through subsidies. Chun [1984 p.38] notes that "each village in the Chejudo province was to receive the equivalent of US$ 350 [220,000 Won] for the construction of family sized biogas digesters". They were to be paid by the local precinct of the Office for Rural Development [ORD]. The local agricultural cooperatives also played a part in disbursing these subsidies. The subsidies covered the total installation cost of a family sized digester. Another instance of a subsidy was the construction of a village sized biogas plant in Chejudo province where the government covered the total installation cost of about 13,600,000 won [about US$ 27,000], in 1979. This subsidy was also administered through the ORD.

Using the estimates of the subsidy per household plant and the total number of household sized plants in the different provinces of Korea, total government expenditures in the form of subsidies during the period 1979-84 appear to be in the range of US$50,000-100,000. Under this subsidization scheme, operation and maintenance costs were borne by the villagers. As Lee and Kim [1981] note, further subsidization is warranted for the success of these efforts, and they recommend that the rural development program be used as a vehicle for delivery of these further subsidies.

Table XVIII Government institutions, material support and technology dissemination

(Sources: Chun 1984, Arthornthurasook 1984, Kim 1981, Power 1980, Phil. Min. of Energy 1981, Mackillop 1980, LLN 1980, Malaysia Natnl. paper 1981)

Country	Type of support: Solar	Biogas
Korea	. Subsidies . Favorable tax status	. Direct government involvement
Malaysia	. Direct government involvement	. unclear
Papua New Guinea	. Direct government involvement	. Direct government involvement
Philippines	. Favorable tax status . Direct government involvement	. Favorable tax status . Subsidies
Thailand	. Favorable tax status . Subsidies	. Subsidies . Direct government involvement

Government expenditures in the field of solar energy are mainly in research and development. The Korean government supports the development of passive solar technologies by subsidizing the inclusion of passive solar systems in houses. Since 1979, the Ministry of Energy and Resources [MER] has had plans for encouraging the use of passive solar technological designs in the construction of new houses. According to their statistics [quoted in Lee 1981], there were about 45 solar homes in 1979. This number is projected to grow to about 2400 in 1980; 4500 in 1981; 7000 in 1982; 14,000 in 1983 and 250,000 by 1990. At that rate, solar homes should account for over 7% of the Korean total housing inventory in 1990.

To encourage this development, the Ministry of Energy and Resources has set up a special housing fund to provide loans of up to 9.5 million won per solar house. They also have plans to provide tax exemptions for solar home builders. The requirement to purchase housing bonds [2-7% of the purchase/construction price] has been waived on the instigation of MER if the housing unit has built-in passive solar technology. This reduces the initial cost of installing the solar technology by up to 30%. These conditions, however, only apply to new housing starts in both urban and rural Korea.

Government actively supports ongoing research and development in four areas. These include photovoltaic technology appropriate to the Korean environment (1980 budget: 67 million won) solar thermal technology for both heating and cooling (1980 budget: 62 million won), standards development and industrial applications (1980 budget: 50 million won) and finally, house construction and information dissemination programs (1980 budget: 223 million won).

In addition to sponsoring research at institutions of higher technology(4), the Korean government is also interested in stimulating private sector involvement in solar technologies. The Korean Housing Corporation [KHC] sponsored a design competition to select three to five prototype solar homes. Construction of selected designs began in August 1981. Many private sector companies are actively involved in the manufacturing of solar panels for both the domestic market and for export generally to countries in the Middle East. The government encourages this manufacturing through the granting of export subsidies [Korea: Industrial Structure and Export Subsidization Programs, IBRD 1985].

6.2.2 *Thailand*

Biogas has, since its inception in Thailand, been sustained by government expenditures. As Arthornthurasook [1984] notes, as part of the fly breeding place eradication policy of 1965, the sanitation department of the Ministry of Health spent 3000 Baht [about US$ 150] in constructing a basic digester for demonstration purposes. At present, subsidies for the construction of digesters are not as structured as in the Korean case but the government invests about 20% of the average cost, of constructing a family sized biogas digester (about 5553 Baht: US$ 225). In the biogas development plan of 1982-86 the government of Thailand intended to spend about US$ 5,000,000 for the construction of about 106 village sized plants and about 60,000 family sized digesters. The government also plans to include the construction of biogas digesters in their *Rural oriented energy technologies development plan*. The government has earmarked about US$ 18,000,000 for implementing this plan(5).

The Thai delegation to the UNESCAP conference on new and renewable sources of energy held in Bangkok, Thailand 1981, noted the tremendous potential for the use of solar technologies in commercial enterprises such as hotels, factories, hospitals and other allied services. Domestic use was also recommended for northern Thailand. As part of the solar energy development plan, the government funds projects which focus on the development and demonstration of technologies such as solar dryers, solar water pumps, solar water distillation units, small scale solar electricity generation and solar refrigeration and air-conditioning. However, specific monetary figures for implementing this plan have not been quoted. It has been noted that the government intends to fund efforts aimed at educating both rural and urban dwellers about the advantages of solar technologies, as part of the effort to assist the emplacement of these technologies. [NEA, Govt. of Thailand, 1982].

6.2.3 Malaysia

The Ministry of Energy, Telecommunications and Posts notes that "this [biogas] is one form of energy that has hardly been tapped in Malaysia, although the potential to produce such a gas from animal waste is considerable". The livestock census of 1976 shows the presence of of about eighteen million animals capable of producing about 1.23 million tons/annum of animal waste which could potentially generate about 1,617,000 cu.ft. of biogas. There are few government subsidies and expenditures, as the government recognizes that "at the present time, it is not economically viable compared to oil, abundant in Malaysia" [National paper 1981].

Solar technology, on the other hand, has generated more interest both from the Ministry of Energy, Telecommunications and Posts as well as *Lembaga Letrik Negaran* [LLN], the organization responsible "for the promotion of electricity generation with a view to the economic development of peninsular Malaysia and to secure the supply of such energy at reasonable prices" [Nat.pap. Malaysia 1981]. LLN together with CNRS of France are co-sponsoring a research program in electricity generation using photovoltaics. The initial planned capacity is about 100W and proposals are in hand for expanding it to about 1KW. The unit is being constructed and developed in France and will be tested at the Universiti Sains Malaysia at Penang [Nat. pap. pres. at UNCNRSE 1981].

6.2.4 The Philippines

The five-year energy program was initiated by President Marcos in 1981. The establishment of the Center for Non-Conventional Energy Development was part of this program. The Center's mandate was to initiate policies, strategies and projects dealing with both the design and development of direct solar radiation technologies, wind energy, bioconversion to fuels, energy plantations, alchohol for motive power, use of surface gas emanations and the harnessing of energy from hot springs. Within the array of projects defined under the mandate of the Center, the government initiated a biogas program. The Ministry of Agriculture initiated its own program *Biogas ng Barangay* as another means for achieving the same end in 1981. The program's objective was to establish small-scale, family-sized biogas digesters nationwide with an average annual output of 91,500 cubic feet. By the end of 1981 the program experts anticipated the installation of about 625 family-sized digesters, and with succeding increments of 200 annually, the number was anticipated to reach 5425 by 1985. It was estimated by the Center for Non-Conventional Energy that by 1985 total biogas generation would be about 507.8 million cu.ft., or 55.71 thousand barrels oil equivalent.

As the government considers biogas a useful source of energy for rural areas where liquefied petroleum gas and electricity are either costly or unavailable, initial subsidization of plant installation was encouraged. With an increase in private successes (see section 6.1, p.73) biogas technology has become commercialized. The government has therefore instituted a phasing out of subsidies in favor of instituting tax concessions for attracting private sector participation in biogas technologies(6).

Solar technologies, as part of the same program, were expected to contribute about 13.2 thousand barrels of oil equivalent [MBOE] in the period 1981-85 (7). The Center for Non-Conventional Energy has demonstrated through a series of surveys and dispersal/demonstration programs that solar technologies are both economically viable and socially acceptable amongst urban dwellers. Similar demonstration efforts are planned for rural areas [Govt. of Philippines 1981]

Solar energy in the Philippines presents a case of direct government involvement as opposed to the disbursement of subsidies, or the institution of a favorable tax treatment regime. It is anticipated that with increased participation by both users as well as commercial enterprises, a subsidization program could be instituted for further dissemination of solar technologies [Del Rosario 1981].

6.3 Conclusions regarding the role of government

In conclusion one could surmise that there has been an adequate level of institutional and material support by government to facilitate the diffusion and subsequent utilization of solar and biogas technologies and appropriate technologies in general. What is inadequate, however is the level of cohesiveness necessary, to expedite inter-agency consultation, cooperation and finally, coordinated action. It is evident from Table XVI that the plethora of institutions developed, especially in Papua New Guinea, Thailand, and The Philippines, together with their diffuse and often multi-purpose mandates, results in a fragmented approach to policy implementation as opposed to an integrated effort.

This fragmentation could create problems in the monitoring and review phase of policies and programs designed to facilitate the dissemination of alternative energy technologies to rural settlements in the Asia-Pacific. As is seen from the various material support efforts in almost all the countries selected, different forms of material support ranging from subsidies to direct government involvement, are offered by different institutions. This would act to hinder the accounting phase of policy and program monitoring and evaluation.

These two factors are the most important in suggestions for future technology diffusion efforts in developing countries and any recommendations made have to bear these problems in mind.

CHAPTER VII: CONCLUSIONS AND RECOMMENDATIONS

" Given present conditions in developing countries, certain potentially 'appropriate' energy technologies have had little success in ameliorating the less than ideal energy condition of rural areas in developing countries. This apparent inappropriateness is due to economic, technical, social, cultural and institutional factors."

(Defined hypothesis: p.1)

From our preceeding analysis, we can draw the following conclusions.

1. The selected developing countries suffer from debt crises, distributional inequities and deteriorating biophysical environments that affect the availability, affordability and deliverability of commercial primary and secondary energy resources to rural dwellers.

2. One possible solution to rural energy deficiency was thought to have been the adoption of appropriate energy technologies such as solar and biogas.

3. Solar and biogas technologies have elements of technical, economic and social inappropriateness. These factors have received inadequate attention in attempts to diffuse these technologies.

4. From an institutional perspective, governments in the Asia-Pacific region have not responded adequately to the potential energy augmentation function that solar and biogas technologies represent, in rural settlements.

In addition, benefit-cost analyses for these 'appropriate' energy systems have been shown to be inadequate. Biogas and solar energy systems, in the countries selected, are faced with inappropriate technical, economic, social and cultural conditions as discussed in Chapter V. Efforts by government to diffuse these technologies are fragmented thus validating the institutional factor contributing to the lack of success.

Table XIX categorizes these problems from the micro (village) and macro (regional, national) levels. It summarizes the previous analysis and provides a basis for formulating future policy objectives and strategies to achieve these objectives.

The purpose of this chapter is to propose a set of recommendations for future decision-makers in the Asia-Pacific region concerned both with the dissemination of solar and biogas technologies, and with solutions to the rural energy problem.

TABLE XIX Summary of findings

		PROBLEMS	ISSUES
MICRO LEVEL	TECHNOLOGY ORIENTED	. Economic	. inadequate level of affordability, income, subsidies.
		. Technical	. insufficient research, design and development, skills
		. Social/Cultural	. incompatibility with religion, rural lifestyle, political ideologies.
		. Institutional	. lack of cooperation and coordination.
MACRO LEVEL	ENERGY ORIENTED	. Availability affordability deliverability of commercial resources	. imports vs. domestic . debt . trade deficits . shortages in foreign exchange
		. 'mega' energy technologies	. technical efficiency . distributional equity . environmental impact

7.1 Conceptual framework

Issues facing decision-makers have been presented taking two time horizons into account:

a. the short-term - 5-10 years.

b. the medium-term - 10-20 years.

Policy recommendations generated should go beyond proposing means to overcome the obstacles to diffusing solar and biogas technologies and consider the coexistence of hard and soft technologies at two levels:

a. the Micro or village level.

b. the Macro or Regional/National level.

This would balance commercial and non-commercial energy supply to rural areas.

Table XX illustrates policy objectives and strategies for the selected countries. A participatory process, is suggested as an effective approach for facilitating technology diffusion. In addition to representing short-term, micro-level considerations, Table XX also addresses medium-term and macro-level concerns.

7.2 The Short-term

7.2.1 The Micro-level

Policies over the short-term and at the micro-level should minimize social and cultural impediments to solar and biogas technology implementation. One possible means for achieving this minimization is through a participative process where grass-roots input is both solicited and used in decision-making. Rural energy should be treated as a rural basic need and a high priority for financing and implementing institutions. Grass-roots input into both policy making (taking a decision to implement solar and biogas technologies in rural areas) and ensuing policy implementation (emplacing the technologies in rural areas) could play a part in determining the need for policy changes that are congruent with rural

Table XX Summary of proposed Policy objectives

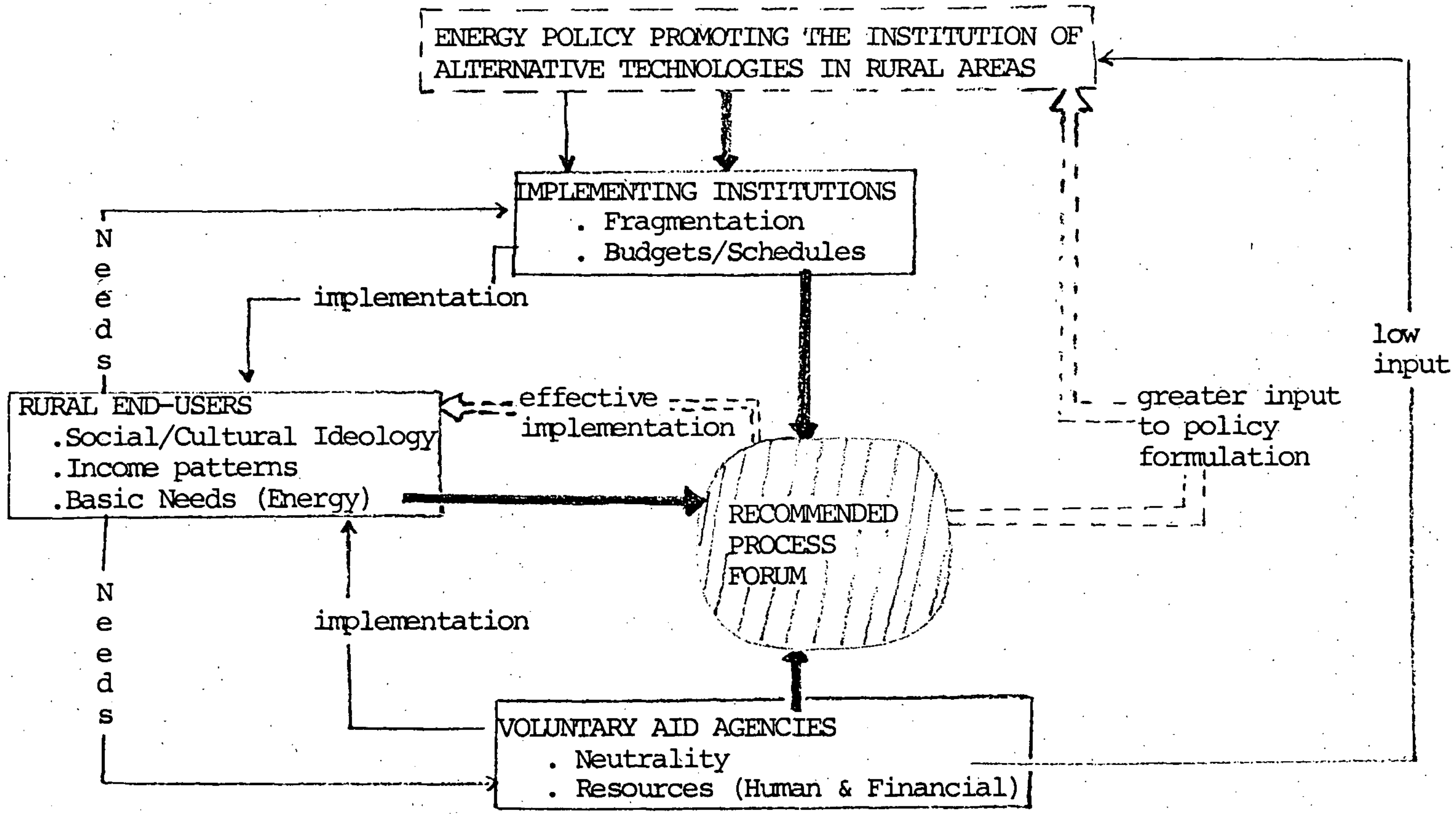
	SHORT-TERM	MEDIUM-TERM
MICRO LEVEL	. FOCUS ON ALTERNATIVE TECHNOLOGY IN BASIC NEEDS STRATEGIES . MINIMIZE SOCIAL AND POLITICAL CONSTRAINTS TO TECHNOLOGY DIFFUSION AND UTILIZATION	. PROMOTE CHANGE IN SOCIAL NORMS AND TRADITIONS (eg. through Organizational development and Education) . IMPROVE RURAL INCOME
MACRO LEVEL	. IMPROVE EFFICIENCIES OF CONVENTIONAL ENERGY TECHNOLOGIES . IMPROVE EQUITY IN THE DISTRIBUTION OF COMMERCIAL ENERGY TO RURAL AREAS . MANAGE URBAN ENERGY DEMAND . BALANCE COMMERCIAL AND NON-COMMERCIAL ENERGY SUPPLY TO RURAL AREAS	. IMPROVE MACRO-ECONOMIC CONDITIONS AND THE SETTING

end-user goals and objectives. In the long run, this could save unnecessary expenditures for both the implementing as well as the financing agencies.

Table XXI is a representation of a participatory process involving three major actors: the implementing institutions, the rural technology end-users, and, voluntary aid agencies, whose role has not so far been discussed in this thesis.

Voluntary aid-agencies have become increasingly active in the field of technology diffusion efforts. They have played an active part in providing software support acting as a link between implementing institutions and the rural end-user [Berg 1984, Adams 1985]. On occasion, they have conceptualized and run programs independent of supportive government policies, such as in the case of rural development in Papua New Guinea [Power 1980]. They have two major advantages over implementing institutions in that they have a greater measure of social and political neutrality without biases when compared with local institutions and, often, do not suffer the relative financial and human resource constraint problem faced by local institutions. Although this relative lack of constraint could be attributable to their smaller size and number, it has been argued that such agencies face less constraints because of their clarity of goals, strength of purpose and better ability to communicate with the grass-roots [Linear 1985, Berg 1984]. Given their potential, they could play a major part in defining implementing strategies, perceiving rural energy needs and rural information collection. Their input into this process, has however, been minimal for a variety of social and political factors. Both Adams [1985] and Linear [1985] in addition to other authors such as Lichtman [1983,1987] and Smil [1984], have identified local institutional political ideology and culture as major factors. A process such as shown in Table XXI would capitalize on the resources and neutrality offered by these agencies to interface between rural end-users and implementing institutions, as well as in formulating effective future policies and programs.

TABLE XXI A proposed Policy Process



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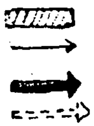

Process Forum
Past and present information flow
Suggested Inputs to process forum
Expected outputs from process forum

Institutions responsible for implementing alternative technologies in the Asia-Pacific are characterized by fragmentation in effort (Ch.VI). This is due to the following factors:

a. The large number of implementing institutions involved with conflicting institutional goals and objectives may lead to inadequate or conflicting perceptions of rural energy needs, preferences technology preferences, socio-cultural and political outlooks.

b. Implementation is often the domain of the policy maker without adequate input from the implementing agency regarding budgets and schedules. This is shown by both Smil [1984] in the Chinese case and Lichtman [1987] in the Indian one. For example, with the objective of diffusing a specified number of digesters within a specified time in China and India, cost over-runs in India and imperfect construction in China, ensued. There seems to be a relationship between budget limitations, an inadequate preception of costs, and cost over-runs, in the Indian case; and tight schedules and imperfect construction in China. A similar situation exists in the Asia-Pacific.

The incorporation of a participative process, as shown in Table XIX, should ameliorate both of these problems. Firstly, such a process could strengthen the interface between the implementing agency and the rural end-user leading to a better understanding of the social and political constraints to effective project implementation. Efforts could then be made to minimize these constraints. Secondly, grass roots cooperation could result from a process where agencies responsible for implementation discuss their budgeting and scheduling constraints with end-users.

From the perspective of rural end-users, this process has a major advantage in that it brings them into an empowered level of contact with agencies responsible for their welfare. In order to ensure representation, varied village interest groups and lobbies should be consulted and, mechanisms for encouraging participation should be incorporated into the process.

Past efforts at implementing these technologies have relied on policy often conceptualized by decision-makers and bureaucrats who have had little or no personal knowledge of the special needs and circumstances of rural dwellers [Harrison 1983, Linear 1985, Adams 1985]. In addition, little or no attempts have been made to solicit public input into formulating policy. Policies have therefore been inadequate. The process suggested here differs from the traditional approach in that it is a 'two-way' process, which serves both the functions of acting as a vehicle for soliciting public input into policy formulation as well as for implementation. The process should recognize all the actors including the different rural end-users, implementing agencies and often exogenous aid agencies. A self-explanatory relationship between the three actors is shown in Table XIX. As suggested by Islam [1984] it is necessary to recognize the diverse views and needs of rural end users, and, the need for more cohesive and less fragmented responsibility for implemention [IBRD 1984].

Processes should nevertheless be situation-specific. There are none that will work under all circumstances. A few that would appear to work well in developing countries are discussed by Boothroyd [1986] and Islam et.al. [1984]. Both stress the structure of the process and a role for a process facilitator. A detailed examination of these processes, their strengths and weaknesses, goes beyond the scope of this thesis.

7.2.2 The Macro-level

Within a well articulated policy framework, the following four issues concerning the continued use of conventional technologies need to be resolved over the short-term.

a. Improving technical efficiencies of existing conventional energy technologies and establishing new ones [IBRD 1983].

b. Improving equity in the distribution of secondary, commercial and renewable energy resources to rural dwellers through a reappraisal and continuous assessment of rural electrification programs [Pearce and Webb 1987].

c. Incorporating demand management techniques in the area of secondary, commercial and non-renewable energy resources in urban areas of the Asia-Pacific such as energy conservation in the various sectors of the urban economy. Urban Inter-fuel substitution is another item that has not been fully considered in many developing countries. The possibilities of fuel substitution in the transportation, industrial, and household sectors should be given greater consideration [Mulckhuyse et.al 1985, Siddayao 1985]. It is expected that a consideration of these items would in the long-run favor both decreases in energy consumption in urban areas as well as improve energy supply to rural areas. It is however not suggested that there ought to be a diversion of commercial fuels to rural dwellers at the expense of urban consumers. A middle-ground could be achieved.

d. Balancing non-commercial and commercial energy supply to rural areas. Processes for achieving this balance could be arrived at after consideration of the issues of demand management in urban areas, improving equity in rural areas and improving technical efficiencies of conventional energy technologies.

7.3 The Medium-term

7.3.1 The Micro-level

Two major areas of change are necessary over the medium term at the micro or village level in rural settlements of the Asia-Pacific region.

a. The first is a change in social norms and traditions. The incorporation of organizational development [OD] techniques could play a role in facilitating this change [Cummings and West 1986]. Organization development techniques adopt a systems approach to making clusters of people work better at a common task. There are several means through which this enhancement is achievable. Most of them focus on either improving the performance of components within the system or in the inter-relationships between the components.

Some manifestations of improving components include the formation of quality circles and self-regulating work groups. The removal of a hierarchical decision-making structure in favor of a matrix structure is another way of improving inter-relationships between components of the system, to make it work better. A good example needing further research is village level self-regulating work groups [SRWG's] to improve the environment for receiving appropriate technologies. Corporate experiments in OD have shown that the morale of employees improves with empowerment, innovativeness in task accomplishment is enhanced, employee turnover is reduced and cooperation between groups is enhanced. It is a possible that similar techniques in rural areas will enhance the morale of the rural dweller and thus minimize social constraints as well as increase innovativeness in task accomplishment, thereby leading to a higher level of 'work satisfaction'. Rural participation and cooperation should aid in creating an improved environment for appropriate technologies.

b. The second is identifying means of achieving an increase in rural income to improve energy affordability. Alternative strategies through which this could be achieved should be examined on economic development policy agendas. These could focus on traditional approaches to stimulating rural development through job creation and industrial development programs. Alternative energy technologies could themselves be used as means for generating employment if emphasis is placed on the indigenous nature of the effort at least at the management and operation phases.

Finally, education plays a major part in creating a suitable environment for new technologies. Ways and means of assessing its impact and recommending either structural or curricular changes should be on the agenda of agencies committed to social change in rural areas.

7.3.2 The Macro-level

At the macro-level, it is suggested that an improvement in the conditions of macroeconomic uncertainties will have a positive impact on the deliverability of commercial energy through the development of improved infrastructure to rural areas. This could play a part in ameliorating the less than ideal rural energy condition in both the Asia-Pacific region and in other developing countries. A further discussion on the relationship between an improvement in the macroeconomic setting and an improvement in the deliverability of commercial secondary energy to rural areas, however, goes beyond the scope of this thesis.

7.4 Research and Development needs

This thesis has identified technical, economic, social, cultural and institutional barriers to the effective dissemination of appropriate technologies, in particular, solar and biogas. It has been noted, in the course of conducting a literature review that there are information gaps in almost all areas and certain broad generalizations had to be made, in supporting the hypothesis and in the ensuing recommendations. These information gaps occur in the following areas.

1. Rural income-energy expenditure profiles are unavailable for most of the countries selected. Dated information was available for Thailand and the Philippines. Efforts should be made to carry out such surveys on a more regular basis and the information generated should be made available to the public.

2. Rural social and cultural profiles could be prepared using a broader set of indicators other than rural education, health, and availability of water and infrastructure. As part of the basic needs approach, multilateral agencies should establish a database on energy profiles as a subset of social and cultural profiles, and include information on rural preferences for energy types, energy consumed, rural commercial non-commercial energy

ratios, to facilitate focussed research.

In conclusion, six broad areas of research and further development are suggested:

1. Research into improving the technical efficiencies of alternative energy technologies. This could be undertaken indigenously in the research and development centers described in Chapter V.

2. Research into means to improve the economic viability of these technologies, taking into account the need for sensitivity analyses, different decision criteria and and elaboration on the types of imperfections in rural markets.

3. Research into means for removing institutional barriers to the effective dissemination and utilization of these technologies using institutional task groups and a more integrated and better accountable approach.

4. Research into means through which rural energy affordability could be improved.

5. Research into strategies for encouraging rural inter-fuel substitution using moral suasion, taxation and regulation instruments for minimizing the social, cultural and political constraints to technology diffusion. A specific project could be the articulation of means to encourage substitution from biomass (firewood) to other renewable resources such as wood waste and bagasse, biogas, passive solar and wind.

6. Research into placing rural energy development in the broader context of integrated rural development. Rural social and cultural forces affect all rural development programs and projects. Measures of success that effect one area of rural life, cannot be divorced from effects on other aspects of rural life. A project to emplace alternative energy technologies has an impact on the rural system as a whole, as Dandekar [1978] points out. A better place, for technology diffusion programs, may lie in integrated, systems approaches to facilitate rural development. Research into identifying the system's complex components and

their inter-relationships may facilitate not only technology diffusion but integrated rural development, satisfaction of rural basic needs and ultimately, an improvement in the quality of rural life.

As stated at the outset of this thesis, alternative technologies can play an important role in augmenting the supply of commercial energy to rural areas in developing countries. Unless steps are taken to remove the identified barriers to implementation in future technology diffusion efforts, this potential will not be realized. In this light, policy and planning process recommendations are made which could serve as a guideline for future decision-makers in the Asia-Pacific region, both for identifying the relevant problems and issues which create barriers, and for proposing ways to surmount them, taking into account the actors, roles and relationships in the rural Asian environment.

NOTES

Chapter II

(1) The exceptions being Malaysia which is a net oil exporter and Papua New Guinea with its negligible energy imports. The Asian Development Bank [1982] has classified Korea as a country with adequate non-commercial energy to meet rural energy needs but yet 51-75% of its commercial energy needs is met through importation. In a similar light, Papua New Guinea imports about 76-100% of its commercial energy needs. Both Thailand and the Philippines are countries with inadequate non-commercial energy resources to service rural areas as imports account for about 76-100% of their commercial energy needs.

(2) The conclusion that petroleum products are subsidized in Malaysia is drawn from a comparative analysis of actual and normative price indices for regular gasoline and kerosene. Actual prices are constantly below normative prices indicating a level of subsidization by government. In fact, in the case of Indonesia and Malaysia [ADB, 1982, p.156-7] actual prices appear to be decreasing in comparison to increasing normative prices.

(3) From a similar analysis supported by data on taxation levels on gasoline and kerosene direct government taxes on petroleum products increased from $.045 to $.168 between 1973-76 in the Philippines in conjunction with an increase in import duty of about 50% in the same period. In Thailand, direct government taxes on imported petroleum products increased about 20% in the period 1973-79 but import duties in the same period increases threefold from $.15 per US Gallon to $.54 per US Gallon.

(4) Usually as part of an energy demand management effort. Typical examples are strategies recommended by the World Bank [Mulckhuyse 1986], the United Nations [UNDNRE 1984], and the Asian Development Bank [ADB 1982].

(5) Edelman argues that increased costs of petroleum imports have played a significant role in fuelling the debt crisis. In his words [1978, p.15] "The increased costs of petroleum imports - a commodity often critically needed for planned growth and development - has caused severe economic distortions and balance of payments difficulties for many of the less developed countries".

(6) The Asian Development Bank [1985] estimates population growth in Korea at 1.9% per annum in the period 1975-80. In the same period population growth in the Philippines averaged about 2.8%. Between 1970-80, population growth rates in Papua New Guinea, Malaysia and Thailand averaged about 2.1, 2.8 and 2.5% respectively.

(7) Six reasons are often advanced for the institution of rural electrification programs: It is supposed to benefit the rural poor; it represents a replicable and well-tried solution to the rural energy problem; it acts as a catalyst to further rural development; it aids in reducing rural-urban migration; its prolonged usage aids in improving rural literacy, general education and rural health and therefore contributes to rural social cohesion and finally, rural electrification is supposed to promote political stability. Pearce and Webb [1987] in association with Nathan [1979], Tendler [1979], Mccawley [1983], Bijort [1974], Kessler [1981], Goddard [1981] and Samanta [1983] systematically critique each of the above six reasons and have pointed out that none of them are ever achieved through rural electrification programs.

(8) In the period 1980-83 the Bank made eight loans to Argentina, Bangladesh, India and Portugal for the installation of secondary conversion and energy efficiency facilities. The rationale for investing over $938 million in updating facilities at five refineries in India was

that, in the long run, it would result in a net foreign exchange savings of over $10 Billion [1981 prices] during the 12 years of the refineries' life. The term given to it was 'refinery rationalization'.

(9) The results presented in Figures 7 and 8 are aggregated from data presented in Islam et.al [1984]. They are results of surveys carried out by the National Energy Administration [NEA] in the case of Thailand and the Ministry of Energy in the case of the Philippines. In the case of the Philippines, the country was divided 12 regions ranging from the Ilocos region to Western and Central Mindanao, and the ratio of gross annual expenditures of non-commercial to commercial energy was determined for three income classes: less than 2500 pesos per annum; 2500-7999 pesos and finally, those households earning more than 8000 pesos per annum. This information is presented in figure 7. The Thai survey was carried out by dividing Thailand into five regions Northern, North-Eastern, Central 1, Central 2, and the Southern region. Net annual expenditures on commercial and non-commercial energy were then found for five income classes: below 25000 Baht per annum; 25000-48000 Baht; 49000-72000 Baht; 73000-120,000 Baht and finally, over 120,000 Baht per annum. Figure 8, however, aggregates this information for all the regions and presents net annual non-commercial and commercial energy expenditures by different income groups.

(10) In this context, studies have attempted to establish a correlation between hoarding and the price of commercial fuels in rural India. Though not directly applicable to the countries selected in the scope of this thesis, certain general conclusions, including a positive correlation between hoarding and the price of fuels, can be reached.

Chapter III

(1) This is not completely true, as assessment programs in the United States have shown that solar technologies do have negative impacts on the biophysical environment in terms of front-end ecological costs [Bronfman 1983].

(2) Some authors [Harrison 1983, UNESCO 1984] claim that sludge is actually enhanced by up to 50% compared to the fertilizer [NPK] value of applying wastes directly as manure.

(3) Some good examples are different modifications proposed by Demuynck et.al [1984] more from the urban, European context. UNEP [1981,1983] have suggested some modified designs for developing countries.

(4) This popularity is well demonstrated by the case of biogas digester emplacement in the Philippines and Korea. see chapter V.

Chapter IV

(1) In fairness it is worthwhile noting that Bhatia [1977], Moulik [1978,1982] and Santerre [1984] have made attempts to incorporate a sensitivity analysis into their benefit-cost valuations. What Lichtman suggests, is that the range of benefits and costs could be improved upon thus painting a more realistic picture on which a decision can be based.

Chapter V

(1) Marginal costs are used in this category as opposed to average costs because of the vulnerability of solar and biogas technologies to climate and natural factors such as the availability of dung and other socio-political constraints which act to increase costs of production and subsequently, the price of energy for household consumers [Dunkerley 1980, Taylor 1981].

(2) Gupta [1983] notes that two problems could arise in the collection of inputs for the digester; variability in the magnitude of inputs due to natural factors, and non-cooperation on the part of the villagers unless adequately rewarded. The Maya Farms serves as an example where adequate rewards (wages) are paid to the villagers for collecting inputs for the digester as compared to a government run and financed installation such as Fateh Singh ka Purwa, in India; see appendix.

(3) The criteria are: that whoever pays to install them also pays to operate and maintain them or pays a proportion of recurrent costs; the energy output is affordable without further subsidization to offset increasing marginal costs.

Chapter VI

(1) This is not always correct, given the success of private ventures in the Philippines; see p. 74-75.

(2) No specific information was available about the status of biogas digesters in Papua New Guinea. It is assumed from the appropriate technology literature that institutional efforts focussed on diffusing basic technologies to the rural dweller, in PNG, have been far from satisfactory [Mackillop 1980, Power 1980].

(3) Mr. Jose Parayno installed the plant in his piggery at Calasiao on complaints from his neighbors of a foul odor from his piggery. After its installation, notes Maramba [1978, p.146] "his neighbors stopped complaining. Now it is he who complains of too many visitors to see his biogas plant".

(4) The best examples of institutions where research is sponsored are the Korea Institute of Energy and Resources [KIER] and the Korean Institute of Science and Technology.

(5) Biogas technologies, under this plan, will share the total outlay with other proposals such as the establishment of village woodlots, improved rural furnaces and boilers, the establishment of rural energy centers and improved rural pyrolytic processes [UNESCAP 1981].

(6) The exact magnitude of the subsidies was unavailable. From literature on the Maya farms' experience it is estimated that the government subsidized the enterprise for about 30% of its installation expenses. As far as tax concessions are concerned, a private limited company is entitled to a higher rate of depreciation on capital costs (about 17%) for these technologies than for others (about 12%); they pay a lower rate of income and capital gains taxes for these enterprises than for other similar small-scale ones.

(7) Information as to whether this objective was fulfilled or not is unavailable at the time of writing this thesis.

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APPENDIX: TWO CASE STUDIES IN INDIA

Experience with biogas digesters in India reinforces the conclusions of this thesis. The purpose of this appendix is to elaborate on two case studies of biogas implementation in India. These descriptions are based on questionnaires sent to key informants in India and the United States. The informants were:

a. The Tata Energy Research Institute [TERI], N.Delhi;

b. The Center for Science and the Environment, N.Delhi;

c. Prof. H. Dandekar, The University of Michigan;

d. Volunteers in Technical Assistance [VITA], Wash.D.C.

Based on their perceptions, the following two case studies in India are described.

A case of failure: Community scale plants in Fateh Singh Ka Purwa

The name of the project was the "Implementation of biogas plants in Fateh Singh Ka Purwa". The biogas plant in this instance was a community sized 'wet' plant. The plants were set up by the Planning Research and Action Division [PRAD] of the Government of Uttar Pradesh with financial support from UNICEF. The stated objective for the project was to improve the village's energy supply through the installation of the digester. Contact between the proponents of the technology and the rural recipients was 'grass-roots' participatory in nature with the project managers acting as facilitators in village groups. State and local level planners were involved in planning and implementation. Planning and implementation occured over the period 1978-79. In November the first community scale plant went into operation with a second one following in January 1979. The decision to implement the technology was taken for the villagers: consultation through 'grass-roots' participation was seen as a means of legitimation. The villagers, however, appeared convinced of the obvious advantages that biogas technology represented. In addition, a local government officer played a major part in facilitating acceptance. Financial support for the project was provided through a coordinated effort of PRAD and UNICEF.

The villagers in Fateh Singh Ka Purwa recognized that biogas was safer than the firewood and kerosene that they normally used. Initially, they recognized its importance in providing a more convenient way of cooking, as it was easier to burn than firewood. Other benefits that biogas represented initially was in the operation of agricultural machines and the use of slurry fertilizer which was distributed to each household in proportion to the amount of dung that the household contributed.

Problems with using biogas began when the villagers recognized that they would have to substantially change their lifestyles to accomodate the flow of biogas for cooking purposes. Often, the gas would be provided at 3 a.m. inconveniencing a majority of the villagers. Another reason for failure that Gupta [1983] decribes is that the villagers felt they were not consulted at every stage of the project. They did not understand why they had to pay for the gas when they had always had the dung free of charge. As combusting biogas requires special burners which they could not afford, they did not buy them and instead improvised, creating further problems in gas flow.

The end result is that both the plants lie in a state of disrepair.

A case of limited success: Dhanawas

The setting up of biogas plants in Dhanawas formed part of an integrated rural development effort. Biogas implementation and improved cooking stoves formed a major part of the energy related development effort in the village. The Tata Energy Research Institute in conjunction with the Haryana State government initiated the scheme. The name of the project was "The implementation of biogas in village Dhanawas". The defined objective for the project was to develop the village by installing biogas plants as part of an integrated rural energy planning and development program. Contact between proponents of the technology and rural recipients was of a "grass-roots" participatory nature. The Haryana state government and TERI were the prime actors in the planning effort. Planning was initiated in February 1985, and implementation is ongoing. To date, six family sized 'wet' digesters have been installed. There are ongoing efforts to train masons, extension workers and plant owners.

The decision to implement the technologies was taken for the villagers by TERI and the Haryana state government. It could be construed that consultation with the villagers was a means for legitimation. The villagers however had an opportunity to see a project in the village and acceptance was, to a large extent, facilitated through the demonstration effect. From the questionnaire administered by TERI, it is seen that the villagers recognized that biogas was easier to burn compared to firewood and therefore represented a greater convenience in cooking. They rejected the notion that it was more economical and that it saved time. In addition, they recognized that biogas was not cheaper than other fuels but represented a good mechanism for disposing waste. A positive demonstration effect and an enhanced family status appear to be major factors facilitating the installation of family sized digesters from a social perspective.

There are problems with biogas in Dhanawas village. Further analysis of the questionnaire points out that most of the villagers recognize the bad odour around the plant and this fact, to a certain extent, undermines the importance that biogas represents as a source of fuel. In addition, cooking on dung-fuel represents a moderate cultural and psychological barrier which in part, defines the suitability of that form of technology to that particular environment. Technical problems with these digesters are mainly leakage and low temperatures in winter which affect gas production. There is however, no lack of skills to operate and maintain the plant.

In response to the questionnaire sent, TERI explicitly recognized that the ready availability of alternative fuels represents a major obstacle to the adoption of digesters in Dhanawas. In addition the high cost of installation, particularly without subsidies, requires a one time lump-sum investment putting it out of the reach of the very poor in Dhanawas and supporting the argument made in the thesis regarding economic appropriateness of the digesters. Finally, another very important reason for the less than ideal adoption of biogas digesters is less than ideal was because information about such innovations was not properly diffused to rural dwellers.