Transfer of Sustainable Energy Technology to Developing Countries as a Means of Reducing Greenhouse Gas Emission: The Case of Bangladesh

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Abstract

Over the last two decades the world has been becoming increasingly concerned about greenhouse gas (GHG) emissions, global warming, unsustainable development, and poverty in the developing countries. The most acceptable way of mitigating GHG emission is the use of sustainable energy technology (SET) instead of fossil fuel. SET is available in the global market, but is outside the scope of availability for many developing countries. Due to the lack of economic and technical capabilities and wide-spread poverty, developing countries are unable to introduce SET independently, hence a need for appropriate assistance from developed countries. The case study was conducted in Bangladesh, one of the poorest countries in the world, with acute shortages of energy and largely disadvantaged rural population.

The study assessed three energy technologies—biomass, solar, and wind—to identify the most viable options of SET for the rural Bangladesh. The appropriateness of the proposed SETs is assessed on the basis of certain criteria: availability of resources, cost-effectiveness, degree of technological complexity, matching demand and supply, and contribution to reducing GHG emission. It has been found that each SET taken separately, has its limitations. The main barrier for biomass energy technology is the availability of biomass due to scarcity of land, and hence, producing food is preferable to growing trees for fuel. The major limitations for solar and wind energy technologies are high levels of capital investment and technological complexity.

The study proposes a combination of biomass, solar, and wind SETs as a long-term solution of energy crisis in the rural Bangladesh. It suggests relevant policy and types of assistance in the form of investment in education and training, machinery, spare parts, know-how etc. A brief proposal for capacity building has been prepared. It is expected that the proposed SETs will benefit sustainable development, poverty alleviation of rural Bangladesh, and the national socio-economic conditions. The study findings contribute to general knowledge, and are especially useful for developing countries.

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List of Acronyms and Abbreviations

AC	Alternating current
ACRE	Unit of land (1 acre=100 decimals)
ADB	Asian Development Bank
ADP	Annual Development Programme
BBS	Bangladesh Bureau of Statistics
BCIC	Bangladesh Chemical Industries Corporation
BCSIR	Bangladesh Council for Scientific and Industrial Research
BFIDC	Bangladesh Forest Industries Development Corporation
BIDS	Bangladesh Institute of Development
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power development Board
BRAC	Bangladesh Rural Advancement Committee (NGO)
BRDB	Bangladesh Rural Development Board
BREB	Bangladesh Rural Electrification Board
BSCIC	Bangladesh Small and Cottage Industries Corporation
BTC	British Tobacco Company
btc/year	Billion tons per year
BTV	Bangladesh Television
BUET	Bangladesh University of Engineering and Technology
BUP	Bangladesh Unnayan Parishad
BWDB	Bangladesh Water Development Board
CMI	Census of Manufacturing Industries
CO_2	Carbon dioxide
DC	Direct current
DE	Department of Environment
DESA	Dhaka Electric Supply Authority
DESCO	Dhaka Electric Supply Company
FCCC	Framework Convention for Climate Change
FFYP	Fourth Five-Year Plan
FFYP	Fifth Five-Year Plan
SFYP	Sixth Five-Year Plan

GHG	Greenhouse gas
GIIP	Gas Initially In Place
GJ	Gigajoule, Energy unit of 10*10
GOB	Government of Bangladesh
GTCL	Gas Transmission Company Limited
Ha	Unit of land measurement
IFAD	International Fund for Agricultural Development
IOC	International Oil Company
IPCC	Inter-Governmental Panel on Climate Change
Kg	Kilogram
LGED	Local Government Engineering Department
LPG	Liquid Petroleum Gas
ME&F	Ministry of Environment and Forestry
MEMR	Ministry of Energy and Mineral Resources
MLR	Multiple Linear Regression
NEP	National Energy Policy
NGO	Non-Government Organisation
OECD	Overseas Economic Cooperation and Development
PC	Planning Commission of the Government of Bangladesh
PJ	Peta Joule, energy unit of 10*15 joules
PRA	Participatory Rural Appraisal
PSC	Production Sharing Contract
PSMP	Power Sector Master Plan
PV	Photovoltaic
REDB	Rural Electrification Development Board
RES	Rio Earth Summit
RISP	Rural Industries Study Project
SET	Sustainable Energy Technology
SFYP	Second Five-Year Plan
SPSS	Statistical Package for Social Science
sq.km.	Square kilometre
tcf	Trillion cubic foot
TFYP	Third Five-Year Plan
TGL	Titas Gas Limited

TOE	Ton of Oil Equivalent
UNDP	United Nations Development Programmes
WAPDA	Water and Power Development Authority
WB	World Bank

Energy Conversion Factors

1000 cft of gas	=	6.4 gallon of crude oil
1000 cft of gas	=	6.5 gallon of furnace oil
1000 cft of gas	=	6.1 gallon of kerosene
1000 cft of gas	=	6.1 gallon of diesel oil
1000 cft of gas	=	6.1 gallon of gasoline oil
1 ton crude oil	=	40 MCF of gas
1 gallon of kerosene oil	=	164 cft of gas
1 gallon of diesel oil	=	164 cft gas
1 mound firewood	=	572 cft gas
1 ton firewood	=	15.5 MCF gas
1 ton coal	=	28.00 MCF gas
1 hectare	=	2.471 acres
1 acre	=	4,046 sq.m
1 acre	=	100 decimals
1 bigha (l0cal unit)	=	33 decimals
1 BTU	=	1055 J
1 calorie	=	4.184 J
1 foot	=	0.3048 m
1 sft.	=	0.092903 sq.m
1 yard	=	0.9144 m
1 toe	=	42.7 GJ
1 PJ	=	10 E15 J

Chapter 1

INTRODUCTION

1.1 Introduction

Over the last two decades, there has been a great concern about ecological changes in the world, caused by global warming, greenhouse gas (GHG) emissions, and deforestation. There has also been a concern about poverty alleviation and sustainable development in the developing countries where energy use is a crucial issue. In fact, energy is a common factor, both at production and consumption levels, for many of the observed global environmental problems.

According to the International Panel on Climate Change (IPCC), energy sector has been responsible for 46% of the increase in the GHG effect up until the last decade. Currently, CO_2 emissions contribute to 55% of the increase in GHG effect in two major ways:

- deforestation (for meeting energy demands) - 1.6 btC/year;
- energy use - 5.15 btC/year.

It is expected that energy demand will increase steadily to meet the needs of nations around the world, as industrial activities expand and the standards of living improve. If nothing is done, by the year 2025, energy sector will have been responsible for 65% of the increase in GHG, with CO_2 emissions in the range of 12 btC/year, about double the present volume (Barfield, Clarke and Leower 1994; Chabot 1994).

This factor is of more importance because, although developing countries are currently responsible for less than 16% of CO_2 atmospheric concentration, the dimensions of future emissions are expected to change. It is expected that a higher per capita energy demand will be observed in the developing countries as their population continue to grow and they try to achieve a higher rate of economic development.

To meet their energy demands, the developing countries currently resort to deforest and rely on fossil fuel, thus following a historical development path of today's developed countries. At the same time, struggling to enhance their agricultural production through use of fertilizers, irrigation, or improved mechanisation, they cannot possibly reduce GHG emissions by themselves alone.

Energy-related GHG could be mitigated by three approaches:

1) reducing energy demand through minimising energy-intensive economic activities;
2) improving the end-use energy efficiency; and
2) using sustainable energy technology (SET) instead of fossil fuel (ibid 1994).

In reality, though, modern mechanised economy of developed world, and fast-growing economies of the developing countries will demand a higher energy consumption level necessary for sustaining and driving their economic activities – which will result in higher GHG emission. Therefore, the first approach cannot be feasible due to its potential negative impact on the expected economic growth in the world, especially in the developing countries.

Furthermore, the more energy is consumed, the more CO_2 is emitted. By improving end-use efficiency, energy consumption in a particular economic activity can be reduced. The same result can be achieved by consuming less energy due to increasing efficiency of energy consumption devices and resulting technological improvement. In other words, GHG emission can be reduced through the improvement of energy technology (Sims 2001).

However, as all economic sectors in the developed countries and some economic sectors in the developing countries have for a long time been almost entirely dependent on fossil fuel as a source of energy, the infrastructure necessary for operating and maintaining relevant devices is already in place there. Therefore, it would not be feasible and economical to replace or modify the already established current technological infrastructure for improving end-use energy efficiency. In this context, it is worth noting that energy infrastructure in the developed countries is much older than that in the developing countries. Hence, it might be relatively easier to improve the technological status in the developing countries as compared to developed ones.

Improvement of energy technology includes increasing the efficiency of existing energy devices, and moving from fossil fuel to sustainable energy sources. In fact, fossil fuel and sustainable energy devices might complement each other.

The above approach raises two concerns: techno-economic viability of modification or replacement of present technological status, and the fact that efficient energy devices also use fossil fuel which emits GHG, though to a lesser extent as compared to older technologies. This implies that the second approach may reduce GHG emission under certain conditions.

With regard to the third approach, recent developments in technological areas of energy supply make it necessary to consider diversification of energy sources and stabilisation of energy supply, in order to prevent energy shortages. After the oil shock of the early Seventies', diversification has largely contributed to exploring renewable sources of energy supply. The development of solar, hydro, tidal, wave, wind, and biomass renewable energy sources is potentially quite effective for achieving new objectives (Ogimoto 1994; Heaton 1994). But these technologies are still mostly used by the developed countries, and are not yet readily available to prospective users in the developing countries (Jaffe et al 1999).

The situation can be described in the following way: on the one hand, the developing countries seriously lack economic and technological capabilities, particularly in the energy sector; and on the other hand, they need more energy to achieve their desired sustainable growth in rural and urban sectors. Sustainable rural development is also a precondition of keeping environment friendly, and an option of reducing GHG emission. The latter demands effective SET transfer.

Effectiveness of SET transfer involves the technology appropriateness for recipients' conditions, and the recipients' ability and willingness to adopt and use that technology according to their needs. Thus, the most feasible SET should be transferred to the developing countries as a means of controlling GHG, taking into account the respective country's social attitude, economic ability, and technical capability.

About 80% of population of the developing countries live in rural areas. The economic activities of rural population are focused on rural development, which takes place at a faster rate as compared to the developed countries. Hence, the developing countries need sustainable energy sources for sustainable rural development. In fact, considering its economic growth and the trends of energy demand, the developing world needs such a source of energy that meets its energy demand, is environment-friendly, and uses available technologies. In this context, SET transfer feasibility needs to be examined.

Furthermore, as the diversity, variability, availability, and density of renewable energy resources vary from region to region and from country to country, the technology might need modification to make it appropriate for a particular country. Alternatively, not all types of available renewable energy technologies might be sustainable for a single developing country.

For instance, according to energy professionals, biomass could be used as a sustainable energy source in developing countries. Yet, biomass production requires vast land areas, which could not be affordable for a particular country like Bangladesh due to a very low land-man ratio (roughly 0.001 sq.km per capita, BBS 1999). Bangladesh would need to choose between food production and biomass production. In contrast, the majority of African countries (Ghana, Nairobi, Kenya, and Sub-Saharan block) own abundant land resources suitable for biomass production. Thus, opportunity cost of resources is a prime factor in choosing energy technology in developing countries.

Again, the diversity and availability of resources might also vary from one region to another within a country. For example, in Bangladesh the wind speed of Eastern (coastal) belt is higher than that in the North. Similarly, the density of forestry in the Southern belt is higher than the same in the North. Therefore, the option of using wind power might be appropriate for the population of the Eastern parts of the country, but not in the North. The nature of energy consumption and the end-use energy devices are also contributing factors in choosing the most appropriate and sustainable energy technology.

Hence, to enhance the use of renewable energy, the appropriate technology must be provided to the users at an affordable cost. It is also important to ensure that technologies on offer are effective in developing countries; that the countries are able to operate them and meet the capital requirement. In other words, the ways and means of SET transfers to the developing countries, in accordance not only with demand, but also with technical and financial capabilities of recipient countries, need to be appropriately worked out.

1.2 The Bangladesh Context

Bangladesh became independent in 1971. Since independence, energy experts and donor agencies have expressed their concerns over multifarious energy problems facing the country. In this context, on numerous occasions energy issues and recommendations have been raised, considered, and observed. The major studies to this effect are Bangladesh Energy Study (GOB, BES 1976); UNDP and World Bank Joint Report (World Bank/UNDP 1982); Impact of Biomass Energy on Rural Development by Professor Nurul Islam (Islam 1981); Bangladesh Energy Planning Project (GOB, BEPP 1985); and Taskforce Report on Energy (Taskforce 1991).

Although the recommendations made by these studies might be controversial, the information and suggestion for improving Bangladesh energy sector form an important background framework for the present study. Moreover, although these reports are critically reviewed in the literature review of this thesis (Chapter 2), it could prove useful at this stage to discuss their major concerns about the consequences of energy problems in Bangladesh.

Bangladesh has a very low per capita energy consumption rate compared to other developing countries. In 1980/81 total per capita energy consumption was 6.24E-6PJ, with the commercial energy sector contributing 1.06E-6PJ (17%). The remaining 83% originated from traditional biomass fuel types. In 1998 per capita consumption increased to 9.67E-6PJ, with the commercial energy sector contributing 3.19E-6PJ (33%) (ADB 2000, p.34).

The higher per capita consumption rate is not only much lower than the corresponding parameter for developed countries, but is also among the lowest for Third World countries. According to the World Bank statistics, Bangladesh's commercial energy consumption is less than 15% of the average of the 34 "low-income countries".

Bangladesh is densely populated (over 800 people per square kilometer), the population is predominantly rural, and more than one-third of the population live below poverty line. Even in good years, 90% of the population consume less than 85% of the required daily food intake of about 2100 calories (Assaduzzaman and Chowdhury 1986). With arable land limited to about 13.1 million ha there is a population of about 130 million (January 2001 census) with a growth forecast of 2.4% p.a. during the period to 2010, two consequences are inevitable.

- In order to increase food production, intensive agricultural methods (mechanisation, irrigation pumping, fertiliser application, and cropping intensity), and associated social and institutional changes will have to be introduced. This will affect the climate due to land and forest (biomass) over-use. The impact would include sea level rise[1] (ADB 1994) and natural disasters (GOB, ME&F, NEMAP 1996).

- Employment opportunities in agriculture will be limited, and new jobs for a growing population will be city-based and industry-centred. This is likely to cause rapid migration from rural to urban areas, increased demand for transportation, air pollution[2], and pressure on housing and public health.

These factors will lead to an increase in energy intensity of the economy—in particular, to greater demands for commercial types of fuel. Undoubtedly, Bangladesh energy resources are too small to meet these huge demands.

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[1] ADB 1994 has found that sea level will rise about 1/3 area of Bangladesh will be under water due to the sea level rise. The two scenarios (at low growth rate and medium growth rate) of the sea level rise, are presented in Annexes 1 and 2, respectively. According to ADB, by the year 2070, sea level will rise about 45 cm at low growth rate and that about 1 metre at medium growth rate.

[2] As an example of the seriousness of air pollution, a photograph is presented as Annex 3.

Energy resource base demonstrates limited potential of hydropower due to the river characteristics, despite the fact that there are 230 rivers in the country (GOB, Power Cell 1997). The oil reserves are insignificant. Coal is mined at Jamalpur (approximately 1 billion tons), but the reserve's depth (over 1,000 metres) limits the recoverable quantity to less than 50 million tons, making exploitation expensive and problematic (Aziz 1999). Coal has also been found in Dinajpur at a much shallower depth, but the extent of the field has yet to be established (government is currently negotiating with a Korean company to find a way of exploring this reserve, GOB, ADP 2000/2001). Before performing any significant exploitation of available peat reserves (estimated at 600 million tons) in the South-West region (including 8 million tons in Khulna, and 125 million tons in Faridpur), a number of technical and economic problems must be resolved.

Natural gas is the only potential energy source for Bangladesh. In 2000, gas reserves amounted to 23 tcf (Aziz 1999; and ADB 2000, p.35). Details of the natural gas potential will be discussed in Chapter 4, but it is worth mentioning here that due to huge opportunity costs (producing fertiliser from gas) there is a question of choice, and hence, it would not last for long. Furthermore, as no gas has yet been found in the Western zone of the country, that region is at a disadvantage. Similarly, rural population is unlikely to benefit from the gas energy because it would hardly be possible to extend gas pipelines to rural areas in the near future.

The situation with the availability of traditional energy resources (such as biomass) is even less promising. The amount of traditional fuel energy in the unorganized sector grew at a rate of less than 1% p.a. between 1976 and 1982 (GOB, BEPP 1985a). This relative stagnation, compared with the commercial energy consumption growth (about 8% p.a.), has serious consequences because of the large share of traditional energy sources in total energy demand.

For instance, a 5% increase in total energy demand results in about 15% increase in commercial energy demand, with traditional energy supply remaining constant. An important factor here is the role of tree biomass, where over-extraction significantly affects the environment and the energy sector (The Daily Observer 2001; Islam 2001).

Moreover, as the main sources of biomass are agriculture, livestock, and forests, the multifarious use of these residues have made biomass scarce as an energy source. For instance, green sugar cane leaves are used as cattle fodder, and dry leaves are used for thatching roofs, and as fuel in rural areas. Similarly, crop residues are used as cattle fodder, fertiliser, and fuel. As a consequence, for rural energy sources, opportunity costs become very high. This situation has created further disadvantages for the poorer groups of the society, as agricultural residues comprise their main energy source.

Furthermore, with the gradual increase in energy demand, the volume of imported fuel is increasing too. Consequently, Bangladesh has to spend about two third of its export earnings to pay for fuel import. A scenario of the net costs of importing commercial fuel against export earnings is presented in Table 1.1.

Table 1.1: Percentage of Export Earnings Spent for Fuel Import of Bangladesh

Year	1981/82	1985/86	1990/91	1995/96	1999/00
Percent of export earnings	45	55	57	64	67

Sources: BBS 1996, 1997, and 1999; GOB, Ministry of Finance Economic Review 2000

The above illustration of Bangladesh energy situation can be summarised as follows:

I. The current rate of per capita energy consumption is very low, and hence there is a high possibility of an expansion of energy demand in the future.

II. There is a pressure in the economy to increase food production, create more employment, accelerate the pace of urbanization, and provide for more housing—which will lead to a sharp increase in demand for energy intensity.

III. The country will have to pay a large portion of its export earnings for importing fuel.

IV. Natural gas development may reduce the pressure on energy demand, but that might not last long due to its opportunity costs. In addition, because of capital requirements, the possibility of rural population benefiting from the use of natural gas will hardly rise to a realistic level in the near future.

V. Rural population will have to depend largely on traditional sources of fuel (biomass, solar, wind etc.). Hence, the main thrust of energy policy and programmes of Bangladesh should be towards increasing use of traditional sources wherever technically and economically viable.

VI. As the per capita income of rural population is very low (national level is also low), every conceivable effort should be made to ensure that the energy is supplied at affordable costs, and in the technology used is sustainable.

1.3 Energy Demand and Supply Scenario of Bangladesh

The demand for energy in Bangladesh is growing rapidly. The country is projected to have an ever-increasing energy deficit over the next 20 years. The demand and supply scenario is presented in Table 1.2. In 1990, the energy deficit was 74.2PJ, which would rise to 1640-2640PJ by the year 2020. This excessive demand would have to be met almost entirely by import. In terms of oil, the deficit would rise from less than 2 million tons (in 1990) to 38-62 million tons (in 2020), depending on the chosen scenario (GOB, National Energy Policy 1995; ADB 2000).

The demand and supply have been estimated based on two scenarios: low- and medium-growth-rate. The economic growth rate under the low scenario (4.44% in 1990) would rise to 6.65% by the year 2020, while under the medium-growth-rate scenario the figures are 5.0% and 8.0%, respectively. It is clear from the table that continued dependence on imported fuel would be a matter of greater concern for Bangladesh, unless an alternative is found.

Table 1.2: Energy Demand and Supply Scenario of Bangladesh

Description	*1990*	*1995*	*2000*	*2005*	*2010*	*2015*	*2020*
Demand							
Low-growth scenario	256.0	342.0	512.0	769.0	1025.0	1537.0	2050.0
Medium-growth scenario	256.0	362.0	531.0	827.0	1314.0	1979.0	3055.0
Supply	182.83	276.71	412.53	412.61	421.51	421.51	421.51
Deficit							
Low-growth scenario	74.17	65.29	99.47	356.40	612.48	1124.49	1637.49
Medium-growth scenario	74.17	85.29	118.47	414.40	901.49	1566.49	2642.49

Note: Figures in petajoules (PJ)
Sources: Government of Bangladesh, National Energy Policy 1995;
ADB 2000.

1.4 Research Problem

Bangladesh is an agricultural country with a very low land-man ratio (more than 800 per sq. km). The country's economic activities are mostly focused on rural development. Except natural gas, no other energy resources have yet been found recoverable. The country has been suffering from the constraints of meeting energy demands for its development growth. Therefore, as we have mentioned earlier, like many other developing countries, it would not be possible for Bangladesh to solve its energy-related problems (and hence GHG emission problem) on its own.

The main objective of the study is to investigate the prospective impact of three sustainable energy technologies (biomass, solar, and wind) on energy markets and rural development in Bangladesh. Biomass technology entails plantation of trees along riverbanks, fallow lands, and rural roadsides, as a source of firewood. Solar energy technology involves lighting, heating, drying, cooking etc. Wind energy technology involves using wind-driven water-pumping for irrigation and rural water supply.

There are a number of research papers on the use of sustainable energy sources and level of sophistication of these technologies, as well as on energy and environment-related problems of the developing countries (Nakiecenovic 1994; Ogimoto 1994; Amsalem 1993; Ali 1993; Edmonds and Reilly 1985; Clarke 1991, Read 1994, 1996, 1997, 2001; Jaffe et al 1999, Shyestha 1998.)

The major findings of these studies are that developing countries are responsible for less than 16% of CO_2 atmospheric concentration. More developed countries have a much higher share in global gas emission, while enjoying the benefits of higher energy consumption due to an early start in using commercial fossil fuel. Because of a long period of using exhaustible fossil fuel, they have achieved a higher level of economic growth.

Consequently, developing countries which are struggling with poverty, deforesting to meet their energy needs, and trying to grow more food through the use of fertilisers, irrigation, or enhanced mechanisation, cannot possibly reduce GHG emissions by themselves. Therefore, from a historic perspective, the responsibility for higher GHG atmospheric concentration clearly rests with the industrialised countries.

This concern was expressed in the Rio Earth Summit, as well as in the resolution adopted in the UN General Assembly in 1998 on Sustainable Development (Bebbington 1999). Consequently, there is a need for technology transfers from the North to the South. It has also been argued that many developing countries may not be able to concentrate on reducing GHG emission immediately because of their preoccupation with fighting poverty and solving other local environmental problems. This brings forward the issue of co-financing in technology transfers.

Although the above-mentioned studies argued in favor of assigning the responsibility for GHG emission reduction to the developed countries, they did not elaborate on transferring energy technologies to developing countries. Moreover, the issues involved with technology transfer (the recipient's ability to pay for new technology, mode of resource flow, impact of new technologies etc.) have not been addressed in these works.

Therefore, it can be said that the above-mentioned studies are limited in scope within the concept of using renewable energy sources, and, in some cases, transferring these technologies, but—in general—the issue of transfer mechanism(s) has been omitted from their discussion. In other words, such questions as the extent of the benefit of the new (proposed) energy technology to the users, their affordability, appropriateness to the users' socio-economic conditions, long-term potential of proposed technology etc. have not been addressed in previous studies.

Indeed, factors that make technology transfers socially and economically viable are yet to be examined. There is also a question of the appropriateness of methodology used by previous studies. Finally, previous researches have analysed technology transfer issue from a supplier's point of view ignoring user's choices and preferences This study will attempt to fill this gap by using the data from Bangladesh, a developing country.

The objective is to examine and identify the most viable option(s) of SETs for rural Bangladesh that is capable of meeting energy demands in the rural communities. A technology that is affordable, environment-friendly, understandable and easy to operate and sustainable in the long-term. Three energy technologies (biomass, solar, and wind) will be examined under certain justification criteria (discussed in detail in Chapter 8): availability of resources, cost-effectiveness, degree of technological complexity, ability to match with demand and supply, contribution to reduce GHG. In addition, we will also examine major constraints (if any) associated with the proposed energy technology.

Apart from solving energy crisis and contributing to carbon-saving in Bangladesh, the proposed SET transfer will also assist in implementing the commitments of Rio Earth Summit that might be expected from the North, as a way of discharging FCCC Annex 1 Party commitment under the Kyoto Protocol. In fact, this study analyses feasibility of SET in rural Bangladesh, linking it to the reduction of GHG emission in the atmosphere, the objectives of the Climate Change Treaty, and the development aspirations of the rural population.

The specific research questions that the present study would attempt to resolve are:

(a) Assessment of the resource base in relation to the biomass energy supply, including existing and future technological capabilities. For example, how feasible is the use of riverbanks for plantation? How much land the rural population can (and would be willing to) devote to tree plantation? We should once again iterate that, due to the low land-man ratio, the food production is still a crucial factor, so—the rhetorical question is: what will they do with a tree plantation when the population doubles in 50 years?

(b) Would the proposed energy technology be affordable for the rural population of Bangladesh? In other words, if the cost of the proposed energy technology is too high, it might be hard for rural communities to afford it given their current level of low income.

(c) Would the proposed energy technology be able to serve the specific needs of rural population? For example, they need energy for cooking, lighting, and irrigation: would the proposed energy technology meet these demands or not?

(d) What are the factors that can motivate the rural population to participate in the diffusion of the above-mentioned energy technologies? What support do they need and expect from the developed countries? And finally,

(e) What are the demand components? For instance, what will happen if sufficient energy is supplied? What will be the impact of additional energy on the development process?

This research intends to answer these questions in a systematic way, to pinpoint the benefit of a meaningful international transfer regarding the exchange of SETs between the countries. The results might be useful for policy makers, strategists, decision-makers, professionals, and other groups interested in the environment, economics, and energy technologies in the developing countries. The outcome of the study might benefit both developing (e.g. Bangladesh) and developed (e.g. New

Zealand) countries as technology-importing and technology-exporting countries, respectively.

1.5 Objectives of the Study

The major objective of this study is to investigate and identify SET option(s) most feasible for rural Bangladesh, one of the poorest countries in the world. This objective, if achieved, will assist in reducing GHG emissions, and meet developmental aspirations in a cost-effective manner.

The specific objectives of the study are:

(a) to assess the indigenous technological capabilities so far achieved by the recipient countries in sustainable energy technology areas;

(b) to examine the availability of desired technologies; and

(c) to examine whether SET transfer should be backed by resource flows from developed countries.

(d) To assess the perception of and attitude to SETs among the rural communities in Bangladesh.

1.6 Sustainable Energy Technology

Sustainability enables the programmes and activities currently undertaken to meet the needs of current generation, without compromising the needs of future generations. In this context, the concept of SET refers to the energy technology that is capable of providing energy to meet consumers' needs (demands) at an affordable cost on a long-term basis without disturbing (compromising) ecological balance. That means SET is environment-friendly and cost-effective. However, the viability of SET transfer depends on the socio-economic and technical background of rural population in Bangladesh.

1.7 Importance of the Study

Over the last two decades energy-related environmental problems and SET transfer have become topical issues in academic, political, and professional fields. There is now a growing body of theoretical literature and research on SET transfer, its relationship to efficiency, and its implication for environment. Previous researches dealt with the usefulness and success of energy technologies, their implications for the environment, and even the necessity of their global transfer. However, the ways and means of SET transfers, their suitability, types and scales according to recipient's choice, and affordability have generally been ignored. The present study will attempt to fill this gap. The contributions made by the present thesis are important for several reasons:

a. The fundamental aim of this research is to investigate the nature and types of SETs appropriate for meeting energy requirements for sustainable development of rural Bangladesh, one of the poorest and densely populated countries in the world. The theoretical framework of the present study is based on prevailing literature and available professional knowledge. The outcome is backed by secondary and primary information.

b. The country and sectoral focus of this thesis is unique. Whilst there have been plenty of case studies on analysis of energy technology and its transfer, and a few on sustainability in rural Bangladesh, there has been very little application of the international literature on SET transfer. Existing relevant research and rural energy balance in Bangladesh have largely been undertaken from a socio-scientific perspective. There has been a paucity of socio-scientific research, including technological aspects of sustainable rural development, and GHG emission reduction. The originality of the work could also be attributed to the characteristics of a broader economic environment (economy in transition), political environment (authoritarian regime), geographical location (lower flood plain land), international trade, and GHG emission reduction strategy.

c. Many analyses of SET transfer have been descriptive in nature, with the theory often based on stylized facts. Not surprisingly, some authors (e.g. Read 1994, 1997, 2001; Jaffe et al 1999) have argued for the adoption of more empirical investigative techniques, which allow the falsification of hypotheses derived from existing theory. This thesis, through its methodological approach, takes up this challenge.

d. The study is based on multi-dimensional methodological techniques, including the use of primary and secondary sources. The approach followed in this study involves the use of traditional survey technique, i.e. pre-designed questionnaire, with participatory rural appraisal technique and the use of existing secondary information.

e. Following from above, the thesis should contribute to the theoretical literature on rural energy technology in developing countries, through its implications for efficiency and equity, the role of national and international bodies in sustainable development through ensuring environmental quality for future generations, and the relationship among technology transfer, rural development, and clean development mechanism.

f. Finally, the thesis is focused on investigating the ways and means of meeting rural energy demands for sustainable growth, particularly in the developing countries like Bangladesh. The recommendations and analysis are intended for researchers, professionals, academicians, policy-makers, politicians, and public at large, while simultaneously contributing to the general body of knowledge on the subject.

1.8 Scope and Limitations of the Study

1.8.1 Scope

The scope of the study encompasses:

a. Discussion of global warming and related issues, SET, and its potential for application in the developing countries.

b. Evaluation of the current energy situation in Bangladesh, covering the agencies engaged in various segments of energy sector in Bangladesh.

c. Examination of the rural population's attitude to, and perception of SET, its desirability, and an appreciation of the reasons why some of their problems are linked to energy.

d. Analysis of alternative SET, and evaluation of context to determine the appropriateness of the proposed SET.

1.8.2 Limitations

The major limitations of this study are:

a. This study was not aimed at quantifying the potential demand for and supply of energy in Bangladesh. Making an accurate economic forecast was beyond the scope of the study.

b. We did not estimate the dollar value of the cost of introducing SET in Bangladesh. We do however, assert that the proposed SET would be cheaper than other options.

c. This study is focused on conceptual evaluation of the current energy consumption and production in Bangladesh. It provides a policy direction that could be used to alleviate the current energy crisis facing the country, in a sustainable manner.

d. At the initial stages of the research, we have faced significant logistical problems involving unavailability and poor quality of data and virtual inaccessibility into Bangladesh energy sector database.

e. This study would greatly benefit from an extensive field survey, but the funds shortage proved a constraint for carrying out fieldwork on a larger sample size.

1.9 Structure of the Thesis

Having discussed the fundamental issues relevant to global concern about environmental problems, GHG emission, SET transfer, and having outlined the basic research questions and objectives in the preceding sections, this section shows how the rest of the thesis has been organised to answer these questions, achieve research objectives, and outlines the structure of the thesis.

Chapter Two provides review of the literature on potential SET transfer as a means of mitigating GHG emission, and preserving sustainable development within the rural community of the developing countries, such as Bangladesh. A global concern about the rate of increase of GHG emission in the atmosphere makes it evident that it could be reduced through the use of SET rather than fossil fuel. Though SET is available in the global market, it is yet far from the reach of developing countries, which necessitates SET transfer from the developed to the developing countries. However, there is a gap between reality and the ways and means of SET transfer suggested and discussed in the earlier studies. This study attempts to fill that gap.

Chapter Three describes methods and techniques used in this study. Methodology is an important means to obtain goal-specific information. Secondary data are not always sufficient to examine the real situation of SET transfer. This has become even more critical, as we are dealing with Bangladesh, one of the most densely populated countries in the world. Therefore, the study uses both secondary and primary data. For primary data, we have carried out a field survey in four sampled villages of Bangladesh, through a structured questionnaire. In addition, in two villages, we conducted a participatory rural appraisal. Secondary data created a framework for investigating the problem, while primary data gave insight into the perception and attitude of energy users in rural Bangladesh.

Chapter Four analyses energy scenario of Bangladesh, presenting and discussing the major relevant issues: historical background of energy management institutions, their strengths and weaknesses and existing supply and consumption networks. In addition, this chapter describes the resource base of energy production and distribution in Bangladesh. Bangladesh has been suffering acute energy shortages, the gap between demand and supply is sharply increasing and it is clear that the country will not be able to solve its energy crisis in a conventional way, unless some alternatives are found. In Bangladesh, rural population is at a relative disadvantage.

Chapter Five examines such issues as the SET status and resource base, the nature of energy demand, energy-consuming activities, and the potential for introducing SET in rural Bangladesh. This chapter also deals with issues such as how much rural population can afford to pay for energy, why they use particular source(s), how do they strike the balance between energy demand and supply. A potential for introducing SET in rural Bangladesh is further emphasised by the fact that the rural energy sector is unorganised, sourced largely from the biomass energy.

Chapter Six presents the discussion and analysis of the findings of a household survey carried out as part of this study. The analysis here helps in understanding such issues as the energy demand, rural activities most affected by energy shortages, options relating to extra energy, attitude of a rural community toward SET etc. Rural communities are aware of their losses due to energy shortages, and Bangladesh rural population has a positive attitude towards participating in the SET transfer and its implementation.

Chapter Seven provides statistical analysis of background variables for the energy users of the rural Bangladesh. The analysis has been performed using Statistical Package for Social Science (SPSS) software. Means, Mann-Whitney, correlation and regression analysis have been performed. A positive correlation has been found between energy source used and socio-economic characteristics (income, ownership of assets etc.) of rural population.

Chapter Eight examines the feasibility of SET. Three energy technologies (biomass, solar, and wind) have been examined under certain criteria with the aim of defining the most viable option for rural Bangladesh. As none of the proposed SETs are free from limitations, a combination of three SETs has been proposed as a means of meeting energy demands, alleviating poverty, making energy supply affordable and sustainable with environment.

Finally, *Chapter Nine* summarises thesis discussions, and draws possible conclusions.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews relevant research in the field of SET transfer, aimed at mitigating GHG emissions and meeting energy needs, taking into account sustainable development and poverty alleviation in rural communities. The main focus of analysis is the relations among the nature of energy demands, feasibility of SET in view of specific needs to maintain sustainable development, and the people's perception of acceptability of the proposed SET in the developing countries, with special emphasis on Bangladesh.

The review is organised into three sections. The first section covers the studies relevant to global concerns about environmental effects of the use of fossil fuel (GHG emissions, ecological changes etc.). The second section covers studies that have examined and proposed the possibility of introducing SET as a means of providing a sustainable energy source and alleviating poverty in the developing countries. The third section covers the studies on Bangladesh energy sector.

In addition, to understand the role of SET for poverty alleviation in the developing countries, we review the conceptual debate on the relationship among poverty, environment, and sustainable development. Finally, based on the above-mentioned reviews, we present implications and conclusions for the present study.

It is worth noting that issues of environmental degradation, energy use, sustainable development, poverty alleviation, and technology transfer are so inter-related that it is very difficult to differentiate them in absolute terms. Therefore, in some instances, analysis might be presented on a broader scale rather than pinpointing microscopic details.

2.2 Studies Relevant to Global Concern about Environmental Effects

Although the issue of climate change has been discussed since the beginning of the 20th century, the last two decades saw a universal concern about the threat of ecological change, environmental damage, and overall global warming, caused mostly by the current pattern of energy production and consumption (Fleming 1998, Vakalyuk et al 1994).

It is argued that the earth cannot withstand the constant and irrepairable damage to the ozone layer, and the effects of increasing global warming. It is also argued (Thompson 1996) that as a result of using environmental resources in an unsustainable way, the grass root population of developing countries cannot come out of the vicious circle of poverty.

It is opined (Cavendish 2000) that the results of development programmes financed by developed countries have not reached their target groups. The gap between the rich and the poor is becoming wider and the environment is being degraded at a rate greater than the earth can afford (Prakash 1997). Such concerns have forced the United Nations as well as the leading countries in the world to take a serious note of climate change and take measures to address the problem. One such major international effort was the Rio Earth Summit 1992.

The major outcome of Rio Earth Summit was the recognition of global environmental threats as a common problem, irrespective of the countries' socio-economic status, by the heads of leading countries and international forums (Bebbington 2000).

Rio Earth Summit adopted the following important resolutions: (1) signing of two legally binding conventions (Framework Convention on Climate Change (FCCC)) and Convention on Biological Diversity; (2) statement on Principles of Forest Management; and (3) Rio Declaration on Environment and Development (Bebbington 2000, p.8). Indeed, while Brundtland Report brought the sustainable development concept into the wider world, Rio Earth Summit has formed a platform for the policy on sustainable development (Grubb et al 1993).

Rio Earth Summit recognised that the main reasons for increasing CO_2 concentration in the atmosphere are the use of fossil fuel, performing economic development activities in an unsustainable way, and the poverty of the Third World population. In fact, Rio Earth Summit (Grubb et al 1993) attributed the Third World poverty to its unsustainable development programmes, and the way energy is being used, emphasising that the above would pose a threat to future environmental degradation, increase GHG in the atmosphere, raising the issue of SET transfer.

Nakicenovic (1994) studied the perspectives of GHG emission on a regional basis. He stated that the developing countries are responsible for less than 16% of the CO_2 concentration due to their past consumption of fossil energy. The developed countries have a much higher share in global emissions than the developing ones.

In other words, GHG concentration is an exhaustible resource used by the industrialised countries to achieve their current levels of development. Therefore, relevant historical responsibility clearly rests with the industrialised countries. The global community is concerned that future emissions are expected to increase mostly in the developing countries, as the size of their population continues to grow, and per capita energy consumption increases due to the fast rate of economic growth.

Nakicenovic further states that the developing countries, struggling with poverty, currently have to deforest to meet their immediate energy demands, which in turn changes the land-use pattern, negatively influencing the natural environment. They are also using fossil fuel, thus following the historical development path of today's developed countries. At the same time, as they are struggling to grow more agricultural produce, they cannot reduce GHG emissions by themselves because of their economical and technical incapability. This causes a growing concern about global environmental degradation in which the current energy consumption pattern is a major contributing factor.

The findings of Nakicenovic's study are based on secondary data, and the methodology of his research is limited to literature review only. Moreover, although his study recommends the use of renewable energy technologies instead of fossil fuel for mitigating GHG emission, and advocates the need for technology transfers supported by resource flows (wherever applicable) from the North to the South, it does not elaborate on other conditions associated with the transfer of technologies to the developing countries.

In addition, his study does not address the issues of available technological options, their effectiveness in reducing GHG emissions, the costs of reducing emissions, and the requirement of adapting technical options to the users' choice, abilities, and demands.

Edmonds and Reilly (1985) carried out an assessment of the global energy for future use. Their analysis focuses on the issues of the quantity of energy to be produced and consumed in the world in the next century, impact of the energy transformation on environment, and long-run economic behavior in production and consumption sectors of the global energy market.

Their analysis recognises the global interdependence in exporting and importing energy resources (and/or services). According to them, energy problems should be viewed from two angles - energy production and energy use.

For simplicity of analysis, based on energy resources and energy use pattern, they have classified the world into nine regions: the USA, OECD West, OECD Asia, centrally planned Europe, centrally planned Asia, the Middle East, Africa, Latin America, and South and East Asia.

They found that the global use of energy is largely influenced by the five determinants: demographics, labour productivity, income, energy prices, and energy productivity. In other words, they recommend the use such parameters as population, economic activity, technological change, prices, and energy taxes and tariffs as inputs in determining global energy demands. Further, they have classified energy supply technologies into three generic categories: Resource-Constrained Conventional Energy, Resource-Constrained Renewable Energy, and Unconstrained Energy.

However, their assumptions are limited to the analysis of the current state of available energy technologies. Consequently, the issue of technological growth and changes has been omitted. However, technological growth and its dynamics strongly influence economics of technology transfer.

Furthermore, Edmonds and Reilly's analysis of energy forecast, based on secondary information, does not account for the informal sector, though their research includes most of the variables related to the energy demand. It is a widely-known fact, though, that informal sector such as unorganised rural communities not only consumes large quantities of energy but also significantly contributes to the national gross domestic product (GDP) (Cavendish 2000).

For example, in Bangladesh, 48% of its GDP (BBS 1999) comes from the agricultural sector, but energy sources of the rural population are unorganised and informal. Informal sector has not been accounted for in their analysis of the supply side, either. For example, rural communities derive most of their household energy requirements (cooking, heating etc.) from the abandoned forestry and livestock sources. In the developing countries such as Bangladesh, the informal sector plays a very important role (both in supply and demand).

Similarly, in forecasting global energy demand and supply, they have accounted for population size parameter, subdividing it into two categories: workforce and non-workforce. But in the developing countries, under-employment in workforce population is an important factor, and hence, while considering the productivity as a variable of energy consumption, the question of under-employment can hardly be ignored.

Furthermore, as a means of reducing CO_2 emission, the authors recommend the use of mixed energy technologies (fossil fuel and renewable sources), but it is not clearly stated whether fossil fuel would largely be replaced by renewable energy sources. In addition, the issue of natural CO_2 absorption has not been raised, hence the recommended way of CO_2 emission reduction might be far from reality.

Barfield, Clarke and Loewer (1994) conducted a study on the long-term effects of the biomass energy in reducing CO_2 emission in the atmosphere. They state that, as the use of fossil fuel is the main reason for the increase of GHG atmospheric emission, the use of biomass-derived fuel may be an alternative to its reduction. They substantiate their viewpoint with the following reasoning: a completely biomass-derived fuel system is carbon-neutral over a long period of time, thus biomass fuel production and use do not contribute to the accumulation of GHG. The quantity of the gas consumed in producing the biomass is equal to the quantity generated in conversion and combustion. If such biomass system is to have an impact, it must be used on a global basis.

However, Clarke in his earlier studies (1991), states that the use of biomass could be the largest single source of fuel in the 21st century. He also states that, although biomass energy system is carbon-neutral, it is not necessarily totally environmentally neutral. To make it environmentally sustainable and neutral, environmental neutrality needs to be analysed (p.383), i.e. the technologies available for energy production and supply need to be modified and renovated according to the users' demand.

They also state that environmental sustainability of the use of biomass system as an energy source should resolve the following questions: under what conditions would a global biomass production system be economically viable? What would be the demand and supply costs for the biomass-derived fuel? What would be the characteristics of such system? And could such system be environmentally sustainable in real terms? To make the biomass energy system sustainable, they suggest that it return all by-products of conversion back to the land.

In another study, Ahmad et al (1999) characterises the global energy system on the basis of three elements important for determining future environmental effects. These elements are: the amount of carbon emitted per unit of consumed energy, the amount of energy used to produce a unit of GDP, and the amount of GDP per head of population (also see Jaffe et al 1999).

It follows that the amount of emitted carbon is the proportion indicator of fossil fuel use in the system of energy sources; the amount of energy used per unit is the indicator of the energy efficiency in the economic activities; and the GDP per capita is the measurement of public welfare. This analysis bears a strong similarity with that of Edmonds and Reilly (1985). However, the dissimilarities lie in the methodology of estimating CO_2 emission.

For example, Ahmad et al mention only fossil fuel as a source of CO_2 emission, while Edmonds and Reilly state that the use of both fossil fuel and renewable energy may result in CO_2 emission, and do not specify that renewable energy sources are free from CO_2 emission.

Johansson et al (1993) state that as the global economic aspirations increase rapidly, energy demand will also increase irrespective of the energy efficiency mechanism used. Given the necessary support, the renewable energy system can meet that growing demand with lower prices than conventional fuel (also Sims 2001; Howarth 1997, p.1).

According to them, by the middle of the 21^{st} century, renewable sources can meet 60% of the global electricity demand, and 40% of the market demand for the direct energy use system, i.e. the transition from fossil fuel to renewable sources could benefit the environment through reducing CO_2 emission.

For example, by increasing energy efficiency and using renewable energy sources it would be possible to reduce the CO_2 emission level by 25% as compared to 1985. They also argued that due to the relative novelty of renewable energy technologies, it would be possible to supply and modify SET at the lower costs (pp 3-5), because fossil fuel energy infrastructure is older, well-founded, and faster, while the infrastructure of renewable energy technologies is still quite young. Therefore, the renewable energy system must be looked at in a global integrated context. Similar recommendations for modification of energy technologies and reducing GHG emission can be found in Hijikata (1994), Barefield, Clarke and Loewer (1994), Preece (2000), and Chakravorty et al (1997).

Read (1994) in his *Responding to Global Warming* says that, as per FCCC resolution, measures should be taken to control the possible problem of global warming due to GHG emission; and this problem can be solved at a much more affordable cost than we think, in ways that would motivate energy suppliers, and assist the process of economic growth and development in the Third World countries.

He says that the energy policy must be approached in an integrated and multidisciplinary way, through 'Tradable Absorption Obligation', to manage sustainable energy suppliers, along with the global reinvestment into advancing sustainable energy technologies, particularly biomass and wind power energy technologies. He argues that the benefits of transition to biomass fuel from fossil fuel are the certainty of undisturbed long-term energy supply, reduction of CO_2 emission, and the increase of natural CO_2 absorption.

Furthermore, according to Read, as the use of fossil fuel is one of the major contributors to the CO_2 emission in the atmosphere, an attempt to keep the former at a level of 1990 by the year 2020, as estimated by the FCCC, would not be possible unless a mechanism of natural absorption of CO_2 is introduced, through globally rebuilding forestry in an integrated way.

His model is based on the following main parameters: land use pattern, ratio of fossil fuel use to the biomass fuel use, rent (cost of land use) of land, long-term level of energy supply, incentives for energy suppliers, and taxation and tariff. His "ECLAM- Energy Carbon Land Allocation Model" shows that, with time derivatives[3], due to the use of land for biomass plantation, there will be no conflict with food production, particularly in the developing countries, struggling to produce more food. Read has pointed out that, although land is a major factor of tree plantation, forestry, and food production, there might be a choice to use land for tree plantations or for food—by planting trees for fuel instead of food-growing, land owners can earn more money in exchange for fuel. In this case the real-terms return from the use of land for bio-fuel would be much higher.

The above-mentioned studies can be classified into three groups, according to the time of their publication: pre-1980, 1980-1990, and post-1990. Pre-1980 studies mainly focus on managing energy supply sources in accordance with global demand (Flemming 1998). In addition, after oil shock in the 1970's, the issue of increasing energy efficiency was gradually coming into the public focus. The environmental issue, though, was relatively less important at that time.

During the 1980's research was mostly concerned with energy efficiency, GHG emission, and management of energy demand and supply. This brought into focus issues of energy export and import both nationally and internationally. Particular attention was paid to finding alternative energy sources, and the relations among energy supply and demand parameters.

After 1990, particularly after Rio Earth Summit and FCCC convention, energy professionals became concerned about CO_2 emission, and the balance between energy supply and demand in performing economic activities at a desired level. This group attached significant importance to renewable energy sources.

It appears from the above analysis that there is a growing concern about the increase of GHG emission in the atmosphere, with fossil fuel use being the major contributing factor. It also appears that there is a global attempt to control CO_2 emission, for which the need for SET becomes essential.

The above analysis also argues that CO_2 emission problem needs to be, and can be controlled by (a) reducing the use of fossil fuel, (b) increasing energy use efficiency, and (c) increasing the use of renewable energy sources, i.e. replacing fossil fuel with renewable energy sources. In other words, the means of reducing CO_2 emission is the transition of energy technologies from fossil fuel to renewable energy sources. But the mechanism of technology transition is left out in the above studies. Moreover, the concept of net CO_2 emission is also unclear.

Finally, the above review shows that, although the global concern about CO_2 emission and replacement of fossil fuel use by SET is well-pleaded, there is a clear gap in the research on SET in the developing countries. No study has examined whether SET will be socially accepted in rural communities of developing countries such as Bangladesh.

2.3 Studies Relevant to Availability of SET

Various issues of SET are covered in numerous researches, but the availability and the applicability of SET are discussed only in a few of them. This is because the general availability of SET does not mean that all types (especially in view of their technological complexity) are applicable for everything. This situation becomes even more critical when considering a particular SET for a particular user. For example, though biomass or solar energy technology is available in the global market, it might not be suitable for use in the rural Bangladesh communities.

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[3] 'Time derivative' means that implementation of proposed technology will take longer where time duration is a major parameter, and the benefits will increase gradually over time.

Jaffe et al (1999) studied the global issues and options of energy efficiency technologies and climate change policies. They stated that although GHG emissions are the product of human behavior, per capita economic activity, and energy use per unit of economic activity, the main contributor of carbon intensity is the use of energy technology (p. 1).

They further stated that GHG emission is growing at a rate that exceeds the metabolic capacity of this planet, and is increasingly accumulating in the atmosphere, raising the possibility of global warming and other climate changes, which—in turn—could have a devastating effect on human activities in the near future. As the CO_2 emission, mainly caused by burning fossil fuel, is the main contributor to increasing GHG in the atmosphere, it could be reduced either by increasing the energy end-use efficiency, or by moving energy technology from fossil fuel to renewable energy sources. They consider the appropriate energy efficiency a means of controlling GHG emission (pp 2-8).

This study emphasises that fossil fuel technology can gradually become substituted by renewable energy technology, with the result of improving energy end-use efficiency. As part of this programme, users, producers, and other associates might be given relevant financial incentives, such as tax credit (p. 8).

The authors advocate transfer of energy technology as an effective instrument of reducing CO_2 in the atmosphere (energy-efficient technology), and state the importance of technological invention, innovation, diffusion, and use of transferred technology in this regard. They recommend that everybody—from manufacturers to users of the proposed technology—should intervene to protect the market failure (pp 8-13).

They have used data from the UK sampled survey of household appliances, in which the efficiency of energy consumption is measured in terms of energy units and corresponding price per unit. They argue that an appliance consuming less energy for performing a specific activity, is efficient, and hence emits less CO_2 into the atmosphere.

Howarth (1997) has countered this idea with the following argument: as a result of increased technological efficiency of energy use, the ultimate energy demand might increase and cause the supply shortage. He stated that although the technological improvement would make energy more cost-effective, unless its cost dominates the price of product or service, energy demand growth would not be dependent on the increased energy productivity.

Ogimoto (1994) researched a possibility of exporting SET from developed to developing countries. He recommends to use SET (under the condition of its global availability) instead of fossil fuel to keep CO_2 emission rate within the desirable limit. The study further suggests that more resource-based countries should participate in the SET transfer so that it becomes available to the less developed countries. His work, though, does not address such issues of technology transfer as the recipient's choice, ability, demand etc.

Amsalem (1983) in his work *"Technology Choice in Developing Countries"* illustrates that technology transfer in developing countries should be based on the recipient's choice. He presents the mechanism of technology transfer, but does not address the issues of the required resources flow, and technology exports, which might be essential for mitigating GHG emission.

Ali (1993) states that a country might be in an "aid trap", if the technologies are not assessed according to the recipient's choice, i.e. technology transfer backed by the resources flow is still not sufficient to reduce GHG emission unless the technologies are matched with the recipient's demands.

For example, it is recognised that solar energy is good for environment. But if solar energy technology is transferred to Bangladesh where the population cannot operate it due to the lack of technical know-how, such technology transfer would hardly contribute to reducing GHG emission.

Similarly, if ethanol production technology used in transport sector is transferred from developed countries to the rural Bangladesh, but its population suffers shortages of energy used for cooking, and historically, cooking is one of the most important components of their livelihoods. To iterate, this technology would not correspond to the nature of energy demand of the rural population, and would hardly be effective for reducing GHG emission.

Hijikata (1994) states that the most important factor for managing future demand and supply of energy consistently with the desired environmental quality, is energy conservation through adjusting energy technologies. According to him, energy can be saved by changing national industrial bases (from producing high-energy goods to producing low-energy goods), and by making cheaper, smaller, but higher-quality electrical equipment. That is why all energy-saving initiatives should originate from economically and technically sound countries irrespective of their location.

As a means of reducing CO_2 emission, Hijikata recommends modification of the current energy technological structure in accordance with the environment, but does not discuss the issue of costs, and its impact on the global economy. Here, it is worth noting that renovation and modification of existing energy infrastructure is much easier to perform in developing countries as compared to developed ones—energy infrastructure of the latter is mostly based on fossil fuel whereas developing countries are still on their way to building it or developing the already existing infrastructure.

Hijikata further states that solution of global environmental problems, and SET transfer (including necessary technical know-how and capital) from developed to developing countries are very important. Environmental and energy problems cannot be managed by an individual country, they should be looked at as a globally integrated issue. It implies that transfer and management of energy technology is an international issue, requiring positive cooperation among the nations involved (pp 359-70).

The above review suggests possible reduction of GHG through using SET instead of fossil fuel, together with the relevant global initiatives. In other words, the required environment-friendly technology, which would meet energy demands, is available in the global market but no study has yet examined socio-economic acceptance of SET by the rural population in developing countries.

2.4 Conceptual Debate

The conventional literature in the field of sustainable development, poverty, and environment claims that the poorer classes of society are more responsible for environmental degradation because they use resources in an unsustainable way. However, some recent studies have shed some doubt on this conventional view.

2.4.1 Sustainable Development, Poverty, and Environment

In the modern world it is almost impossible to ignore the concept of sustainable development and its various derivatives (sustainability, sustainable growth, ecological sustainability etc. (Bergh and Straaten 1994)) It is not exactly clear, though, what these various terms mean, how they relate to each other, and to what extent they contribute to an understanding of sustainable development. And proper understanding of sustainable development is crucial when dealing with energy –a key factor of the society's production and economic development.

Bebbington (1999) states that Brundtland report is often quoted as the first to introduce the notion of sustainable development into the political arena (p. 4). But sustainable development debate has originated much earlier than acknowledged by Brundtland commission (Lele 1991, p.609): the concept of 'ecodevelopment' was proposed to describe the process of ecologically-sound development with positive management of the environment for human benefit, protecting environment 'for future generations'; in the 1972 Stockholm Conference (Holdgate et al 1982, pp 7-10, McCormick 1986, p.182).

Brundtland report defines sustainable development as "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UNWCED 1987, p.8). However, although Brundtland report recognised the concerns of sustainable development and environment, it did not facilitate understanding of poverty and environment.

Redclift (2000) states that the life style of rural classes of a society changes because of environment change (Chapter 2). In his earlier study (1987) he states that "*development be subjected to redefinition, since it is impossible for accumulation to take place within the global economic system we have inherited without unacceptable environmental costs. Sustainable development, if it is to be an alternative to unsustainable development, should imply a break with the linear model* *of growth and accumulation that ultimately serves to undermine the planets' life support systems"* (p.3-4; also cited in Bebbington 1999).

Reviewing the literature on sustainable development, Lele (1991) states that, as a result of inadequacy and lack of understanding of the relations among sustainable development, poverty, and environmental degradation, the policy and programmes undertaken so far cannot really improve the welfare of the poorer classes of the society (p.1, also Buttel and Gillespie 1988, Conable 1986, Bergh and Straaten 1994). However, Lele's findings do not specify whether it is poorer classes of the society who degrade the environmental quality because of their poverty, or it is the already degraded environment that makes them poor.

Broad (1994) carried out a research on the relationship of the poor and the environment. His case study was undertaken in the villages of Philippines. He argued that the deterministic view of the relevant conventional literature is far from reality. His study established that the rural population is poor because they do not have enough resources for their economic development, with the environment having already been degraded.

Broad's hypothesis further shows a positive correlation between the level of poverty and care for the environment, as the poorer layers of the society are aware of the direct dependence of their sustainability and survival on the environment. For example, the rural population of Philippines (p.812) are very careful in using their limited resources such as land, forests, fish etc. (pp 811-815).

The above considerations imply that despite inter-relationship of sustainable development, poverty, and the environment, poorer groups of the society should not be blamed for today's environmental degradation. In other words, the developed world can hardly avoid the responsibility of alleviating poverty in the developing countries.

In Bangladesh, the resources are very limited compared to population. The rate of resource exploitation is higher than what the ecology can bear. The current situation is the result of the development programmes which were undertaken in an unsustainable way, thus causing environmental degradation.

For instance, since its independence, about 70% of Bangladesh annual development budget has come from foreign aid (GOB, MF, Economic Review 2000) of which more than 80% has been invested in urban-based development programmes such as construction of urban roads and housing, flood protection dams, fuel import etc. (CPD 2000). Unfortunately, investment for the benefit of rural communities (rural development, fishery, river drainage, irrigation etc.) has been largely ignored. As a result, the gap between the resources demand and availability is gradually increasing, mostly affecting rural population.

Therefore, in Bangladesh, the SET should be able to provide energy on a long-term basis as per villagers' needs, and at affordable costs, without disturbing the ecological balance. SET should be environment-friendly and cost-effective.

2.4.2 Alternative, Renewable, and Sustainable Energy

Alternative energy sources with the potential for application in rural areas, are neither commercial (gas, electricity, or kerosene) nor traditional (wood, dung, and animal waste). The list includes renewable and non-renewable sources, with some sources applied commercially in urban areas (GOB, BEPP 1985b vol.1 pp. 1-29).

Renewable sources of energy have potential for long-term regeneration (in most of the cases, for an unlimited period of time). Apparently sustainable energy sources belong to this category. Sustainability, though, can be applied in a broader context, as it is related to long-term socio-economic goals and aspirations of a particular society (ibid). That is why, for a particular society, an energy resource could be renewable but might not be sustainable.

For example, hydropower electricity generation could be renewable but not sustainable in a country with different river characteristics (e.g. silted river beds due to water block). Similarly, biomass energy is renewable through replantation, but it might not be sustainable in a country with scarce land. Hence, there is a need for a clear understanding of every source and their potential applications.

2.4.3 Difference in Gross and Net Reduction of CO_2 Emission

Concepts of CO_2 gross emission reduction and net emission reduction are different. Most authors mentioned earlier argue in favour of gross reduction, when in the future the atmosphere will lose its capacity to absorb CO_2. On the contrary, net reduction is the only option to reduce CO_2 emission to a 1990 level as per FCCC resolution. Vakalyuk et al (1994) suggest that FCCC resolution can only be implemented if we use energy from a source allowing for the absorption of CO_2. Indirectly they recommend using renewable energy sources, particularly biomass.

Read (1994, 1996, 1997) defines net emission as gross emission minus gross natural absorption. He focuses on recycling CO_2 (emission/absorption process), through the use of the biomass fuel: "*a reduction in net emissions means lower gross emissions or increased absorption, and leads to lower level of pollution, possible after the passage of time in the case of a stock pollutant*"(Read 1999).

As a mechanism of controlling emission, Read proposes to use market opportunities where TAO is applicable. He defines TAO as follows: "energy sellers, at the wholesale level, are required to absorb some proportion of the carbon that is emitted when their product is used by the purchaser or to contract with other firms to carry out this obligation". However, his analysis is based on a perfect competition market situation in the ideal world. A limited number of energy professionals have been working in this context (Vakalyuk et al 1994, Edmonds and Reilly 1985, Read 1996, 1997, Senelwa 1997, Senelwa and Sims 1998, 2001, and Neij 1997).

Furthermore, energy use is an indicator of public welfare (Assaduzzaman 1998), as well as one of the main production components of the development process. Developing countries are struggling to achieve their economic development and public welfare goals, meet their development targets within a specified time period. Thus, they require an energy source which would be able not only to meet their short-run energy demand, but also be sustainable in the long-run. In short, they need energy from such a source, and in such a way as to meet their development aspirations. Energy policy, planning, and production framework for the developing countries must fit these criteria.

In this context, policy definition or planning energy supplies in developing countries should be considered from the users' rather than suppliers' perspective. In other words, the analysis should evolve from the bottom up (Senelwa 1997). The above-mentioned studies have approached these problems in the reverse order, from the suppliers' point of view. That implies a gap between the previous studies and the energy requirements criteria for achieving development aspirations of developing countries.

Furthermore, the pattern of energy use in developing countries differs from that of developed countries, due to the differences in the nature and type of their respective developmental activities. The nature of energy demand also varies due to the differences in technological levels, socio-economic structures, and resource bases. For example, energy demand in most developed countries is related to the industrial demand and public welfare, as their economy is mostly based on high technology, is mechanised, and capital-intensive. On the other hand, in the developing countries the economy is mainly agriculture-based, with a small share of primary products industry (Edmond and Reilly 1995, Karim 1997).

Moreover, in the Third World, economic development is mostly focused around rural areas. Hence, the criteria of assessing energy demand and supply would be quite different for the developed and developing countries (Islam 2000). As the sustainable energy supply is a precondition for sustainable development, energy supply technology and conditions must fit the rural development processes of the developing countries (Ahmad et al 1984; Ahmad et al 1999; Khan 1989; Khan 1991; Ali 1992b). This issue has been ignored by previous studies.

The outcome of a research largely depends on its methodology. Most of the previous studies analysed secondary data while few of them analysed both secondary and primary data. Recent studies show that the findings of a research based on secondary sources might not be sufficient to represent the real demand or supply situation. Particularly in developing countries, where the large portion of the population is far from being aware of their rights and obligations, and prevailing socio-economic constraints, any policy formulation should be based on primary data (Chambers 1997; Senelwa 1997). Hence, the methodology used in previous studies is far from being ideal.

Based on the above analysis, we can present the following interpretation:

a. GHG emission is globally increasing very rapidly, with fossil fuel use being one of the main contributing factors.

b. In the next 20-30 years, energy demand increase rate in the developing countries will be much higher as compared to the current rate in the developed countries. And if the developing countries continue their fossil-fuel-based economic activities, it will threaten environmental quality. Hence, there is a need to intervene in the energy production and distribution processes in developing countries.

c. Energy availability to meet global demand, particularly for developing countries, depends on the diversity of energy resources. Hence, developing countries need adequate technological support in meeting their energy requirements.

d. The technologies required for environment-friendly energy production and distribution to meet global energy demands, are available in the market, but they are mostly contained within developed countries. This implies the necessity for SET transfer (Newell et al 1999).

e. Developing countries cannot solve their energy problems alone, due to the lack of physical, human, and natural resources. Even though some developing countries have a higher population density than developed countries, there is still a shortage of skilled manpower, which requires assistance (capital and technical) from the developed countries (Assaduzzaman 1998; Nakicenovic 1994).

f. In developing countries, energy shortage problems are much more severe in rural areas than that in the urban centres. The consequences of energy shortages, to name a few, are fast urbanisation rate, deforestation, natural disasters, sea level rise etc. In fact, as a consequence of energy shortage, rural population in the developing countries finds itself in a vicious circle of poverty, feeling an urgent need to make a breakthrough (ADB 2000, Karim 1997).

g. Methodologies used in the above-discussed studies are far from being perfect.

2.5 The Bangladesh Context

It has already been mentioned in the previous chapter that Bangladesh has been suffering multifarious problems in the area of its energy supply and demand management. The situation is aggravated by the fact that, on the one hand, the country does not have adequate energy resources, and on the other hand, its economical and technological abilities are very limited. Moreover, its geographical location makes it more vulnerable, as it is situated in the lowest part of South Asian region.

In the rural areas of Bangladesh (with 85% of the national population), agriculture is virtually the only form of employment. Large seasonal variations in demand for labour contribute to a significant level of under-employment and unemployment. There are a few middle-class farmers and even fewer large farmers, but the majority of the population is represented by small farmers, marginal farmers, and landless labourers.

Although the majority of the rural population is very poor, it does not necessarily comprise a homogeneous group. Landless laborers, small farmers, sharecroppers, and other distinct groups all have different interests. Middle-class farmers are usually the most dynamic group, as they work on their own land, are interested in developing it, and have an access to capital subsidies, as opposed to the poor who only have a limited access to them. Large farmers are often not personally interested in agricultural progress, as they do not cultivate their land by themselves, but lease it out to other farmers (Hossain and Sen 1992; Hossain 1988). Therefore, in order to achieve positive long-term sustainable rural development, effective SET transfer (CPD 2000) should take into account the interests of all above groups.

Of a significant number of researches on sustainable energy resources and their transfer, there is only a limited amount related to Bangladesh. Moreover, the scope of research and development programmes in Bangladesh is also very limited due to its economic and technical capacities.

The major studies of Bangladeshi energy sector carried out so far (since 1971) are: World Bank and UNDP-sponsored study (World Bank/UNDP 1982); FAO-sponsored study by Professor Nurul Islam (1981); Bangladesh Energy Planning

Project (GOB, BEPP 1985a,b.c,d,e,f,g,h); APDC Kuala Lumpur sponsored by Assaduzzaman and Chowdhury (1986); Taskforce Report (1991); Asian Development Bank-sponsored report (ADB 1994, 2000); World Bank-sponsored report conducted by Prokoushali Sangstha Limited (2000); and CPD 2000.

Apart from above, some semi-government organisations and private institutions have conducted limited and not comprehensive research of the Bangladesh energy sector: Assaduzzaman 1998; BIDS, RISP 1980; Atomic Energy Commission (Karim 1993, 1996); BIDS (Khan 1989, 1990, 1991); Hossain 1995; GOB, Ministry of Energy and Mineral Resources (GOB, Power Cell 1997); Aziz 1999; Petrobangla 1999; World Bank Environment Sector Study 1997; Haque 1998, 2000; BUP-sponsored Ahmad et al 1997 and 1999. In addition, a few reports, mostly by multinational companies, present results of feasibility studies of agreements related to gas exploration.

Common weaknesses of these reports are as follows:

First, the scope of work and their terms and conditions were purposive as the studies were financed through foreign aid (e.g. World Bank, UNDP, ADB, OECD etc.). The studies were mainly focused on assisting in energy management planning. The recommendations were centred around the amount of deficit energy, and the amount of import energy required to cover that deficit. The recommendations were limited to the mechanism of importing liquid fuel, and coal and gas exploration. In spite of the relative insignificance of these reports' contribution to the development of energy technologies in Bangladesh, their recommendations have influenced national energy policy.

For example, in the North of Bangladesh there is no gas, and, as a consequence there is an acute energy shortage. To solve this problem, World Bank (1980) has recommended to build a power generation plant on imported diesel. Accordingly, at present, country imports diesel at a cost of Taka 74 per unit, and earning Taka 54 in revenue from selling the electricity produced from that diesel (ADB 2000). Apart from other technical, environmental, and production losses, there is a direct revenue loss of Taka 20 per unit of energy. Ironically, the feasibility study of these diesel power plants was conducted by the World Bank experts, and the plants were built with the financial assistance of the World Bank. This is the reality of the Third World politics, as is demonstrated by Ali (1992a)—a country can fall into an 'aid trap' if technology transfer does not happen according to the users' choice. Unfortunately, very little attention has been paid to the needs and prospects of the rural areas' energy problems.

Second, these studies have made a very small contribution to exploring rural energy resources. Moreover, government has withdrawn subsidies in the form of fertilisers, diesel, and high-yielding variety seeds, which caused a major problem for small and marginal farmers in the crop production. Since 1960's rural farmers have been purchasing diesel and fertilisers at a subsidized price, being motivated to produce more food. But, as per recommendations of the above-mentioned energy reports, government has cancelled that programme. As a result, small and marginal farmers have been facing numerous constraints in meeting production costs, while large farmers have benefited from this policy.

Finally, these studies have made only a minimal contribution to developing energy technology of Bangladesh. Expatriate consultants, and their local counterparts limited their activities to producing a report, without arranging training programmes to build skilled manpower or efficient management. As a result, the country did not receive any technological support apart from having a collection of such reports. Ashugonj power plant is a typical example of the above scenario.

World Bank/UNDP (1982), and to some extent, GOB, BEPP (1985f,g) also argued that, due to the Bangladesh need to develop its economy at a faster rate than the population growth, it needs rapid industrial growth, and renewable energy sources cannot meet its heavy industrial energy demands. Hence the necessity to import liquid fuel. In fact, these studies either misunderstood the concept of renewable energy or simply ignored it. Indeed, the potential for using renewable energy in Bangladesh is very large.

The biggest study in Bangladesh energy sector carried out so far is the Bangladesh Energy Planning Project, (GOB, BEPP 1985a,b,c,d,e,f,g,h,i). This report consists of nine volumes; Volume 4 deals with the rural energy sector. Although its recommendations primarily focus on estimating energy demand and the required amount of fossil fuel (especially oil and coal) to import, this study has covered a wide range of variables in the energy field. For example, this is the first study to have included environmental issues in the Bangladesh energy policy and planning.

The major limitation of this study is contained in its methodology. This study has used data both from secondary and primary sources (four major divisions), collected through a pre-designed questionnaire. The questionnaire was sent to different local government administrative units to be distributed among interested (identified) local leaders and get their feedback on the policy in the areas of energy demand and supply. As a result, the real beneficiary (the focused group) has not been consulted. Moreover, this study estimated energy demand on the basis of economic growth rate. It implies that the study recommendations might serve the short-term goals rather than long-term aims of sustainable energy management policy. In addition, the rural population's choice has been ignored in the data collection process.

Taskforce (1991) presented a brief but comprehensive report of energy sector of Bangladesh. It recommended the authorities to take strong remedial actions aimed at alleviating environmental degradation, in particular the air pollution of urban areas due to the use of fossil fuel. However, the scope of this study is also limited due to its use of secondary data, and hence it is questionable whether it presents the real picture of energy crisis in rural communities. It is opined that the recommendations of this study are 'slogan-based' only. The study recommends moving from fossil fuel to renewable energy technology.

Aziz (1999) studied the potential of renewable energy technologies in Bangladesh. This study is mostly devoted to forecasting the demand and supply of natural gas. Although it contains the analysis of the potential of solar and wind power in Bangladesh, it is limited to the number of plants in Bangladesh. The major contribution of this study is the identification of failures of biogas plants in rural Bangladesh.

Islam (1981, 1983, 1984a, 1984b) and others have discussed issues of rural energy, but only regarding biomass fuel, and leaving out other forms of sustainable energy. Their methodology could raise certain doubts as to sample and survey area selection.

For example, in each of his studies, Islam (1981, 1983) conducted field survey in only one village (Mymenshigh Zone). Based on such restricted and isolated data, it is hard to generalise, and extrapolate recommendations, especially for a country where agricultural practices differ from one region to another (Karim 1997).

ADB (1994, 2000) focuses on environmental issues, while highlighting the consequences of using fossil fuel. These studies are the first of its kind in Bangladesh—it has introduced the estimation of GHG emission (methane and carbon dioxide), due to the use of fossil fuel, paddy fields, and livestock waste. In fact, it is recognised that ADB has made a significant contribution to raising environmental awareness in Bangladesh.

2.6 Conclusions

On the basis of the above review, we can produce the following interpretations and conclusions:

a. Research and development programmes in the Bangladesh energy sector are very limited, with rural energy sector being severely neglected.

b. The recommendations on the choice of energy technology for Bangladesh, particularly those for rural Bangladesh, have not been made, as they should have been.

c. Most of the rural energy sector studies discuss biomass energy, leaving outside their scope other renewable energy sources.

d. There is a gap in understanding the concept of renewable, alternative, and sustainable energy sources applicable to rural communities.

e. There is a gap between understanding SET and sustainable development.

f. The pattern of energy demand and its appropriate sources have not been addressed.

g. Methodologies used are not sufficient for analysing rural energy scenarios, and they do not reflect the real choice of rural population.

h. Energy requirements and potential demand have not been addressed properly.

On the basis of the above, the present study will attempt to fill those gaps by:

1. critically evaluating options of using energy resources for the needs of present and future generations, through an appropriate methodology;
2. evaluating the type and potential demand for energy use in the Bangladesh rural communities;
3. estimating SET potential for rural Bangladesh;
4. identifying the best energy technologies for the rural population of Bangladesh—environment-friendly, effective in reducing CO_2 emission, appropriate for sustainable rural development, available in the market, and cost-effective;
5. identifying motivational factors to ensure the diffusion of SET in rural Bangladesh, based on the need for support from the developed countries in the SET transfer.

Chapter 3

METHODOLOGY

3.1 Introduction

The main thrust of this study is to assess the best possible options for SET so that the rural population of Bangladesh can achieve their desired development goals in a way that minimises environmental damage. The study was heavily dependent on both primary and secondary data, and particularly field survey. It is notable here that one of the bases of formulating objectives and research questions of this study, as described in Chapter One, was direct experience of rural life of Bangladesh, and the perceived needs and problems associated with meeting their energy needs.

The way these needs and problems relate to the existence of locally available energy sources, including biomass, solar, and wind power technologies, and the way people view them, formed the main purpose of information collection. The methodology was developed and, as much as possible, used in a manner so that rural people feel comfortable to participate with the data collection team, so that their social attitudes, economic circumstances, technical skills, and cultural behaviour were taken into account during the data collection. This chapter describes the methods and techniques used for conducting this research.

Throughout the study the methods appropriate for collecting information from primary sources were largely dependent on the socio-economic and cultural background of the respondents. In other words, before applying any particular method, it is very important to consider who the respondents are, what their cultural background is, and what their economic circumstances are. For instance, data gathered by using a structured questionnaire through door-to-door interviewing methods in a developed country would be different from that of data collected using the same questionnaire in a developing country's society.

Let us consider an example to explain the situation more clearly. If we ask respondents in New Zealand about their annual income, they may be able to give the correct, or very close to the real figure of their annual income—or they would refuse to answer that question. That means the collected data would be reliable. On the other hand, the same question in Bangladesh or any other developing country is very likely to lead to an exaggerated or biased response. This is because the socio-economic and cultural backgrounds in the two countries are different. A respondent from Bangladesh is used to seeing corrupt practices in their every-day lives, where making a biased statement is not considered to be a major issue.

Indeed, the social values, education level, cultural norms, and economic freedom of the two societies are different, which influences the respondents' choices. That is why there must be a consistency between the ontological query, epistemological environment, and the survey method (Fredrick 1998, Shiijun 2000).

There are several issues relating to the country and its history that might affect the context of research in Bangladesh. First, Bangladesh was a British colony for more than 200 years, until 1947. During the period of integration in Pakistan (1947-1971), and even after independence (in 1971), the country was ruled by military governments. Second, about 70% of its annual development budget comes from foreign aid. Third, people are relatively conservative due to lack of education.

Finally, in the rural Bangladesh, 35% of population live in absolute poverty (BBS 1999). As a result of these factors, it is necessary to devise research methodologies that are culturally appropriate, for example, appointing local interviewers and applying more than one method of data collection.

The main research methodologies adopted involved several stages:

1. Identification of the variables and their definitions
2. Determining methods of data collection
3. Sampling
4. Questionnaire design
5. Interviewing, and
6. Data analysis

This study required data from both primary and secondary sources. Very few studies have been carried out in the energy sector of Bangladesh, and sources of data are very limited. Furthermore, energy-related studies in Bangladesh are mostly concerned about the demand and supply of energy from a static point of view. The issue of potential demand has not been addressed in these studies. That means there are some limitations in data available from secondary sources, and new sources of primary data need to be developed. Moreover, this study on the transfer of SET for the betterment of the rural Bangladesh is a new concept where users' opinions are critical if likely success is to be ascertained.

3.2 Identification of Parameters and Their Definitions

Definitions of variables are directly related to the purpose of data analysis. In other words, objectives of the study indicate what type of data is needed and whether data would be required from secondary sources, primary sources, or from both sources (Ranjit 1996, p.7).

The main objective of the study is to assess the best options for SET for the rural Bangladesh. The thrust is to assess the long-term socio-economic and technological viability of three energy technologies (biomass, solar, and wind power). The study is involved in analysing the following:

a. Current state of commercial energy supply and demand in Bangladesh;

b. Description of present energy management;

c. Critical evaluation of current energy management;

d. Critical evaluation of future energy supply and demand in the rural Bangladesh;

e. Critical evaluation of energy resources of Bangladesh;

f. Assessing the feasibility of SET in the rural Bangladesh; and

g. Identifying the best SET for the rural Bangladesh.

Task (a) involves looking at the present supply and demand scenario of energy sector of Bangladesh. To achieve that, we used data on the quantity of energy produced and consumed nationally, major sources of energy supply and production, the pattern of energy distribution with respect to both rural and urban sectors, deficiencies in supply, relationship of economic growth with investment in energy sector, and the historical background of energy demand and supply of the country as a whole.

To perform this task we have used data mainly from secondary sources. The main sources were the published documents, research reports, annual and perspective development plan documents, energy policy of the government, statistical year book etc. The main agencies that have been consulted were Ministry of Energy, Power Development Board, Bangladesh Council for Scientific and Industrial Research, Petrobangla, Bangladesh Bureau of Statistics, Bangladesh Institute of Development Studies, libraries, universities etc.

Tasks (b) and (c) have also been performed by using secondary data of the above-mentioned types, but special attention was given to the contemporary energy policy, institutional arrangements, production and delivery networks, type of grid lines used, power distribution policy etc., with regards to the rural sector. The main focus of these tasks was to identify the weaknesses and shortcomings of current energy management. In so doing the energy management data from neighbouring countries, and some global data have also been used as a basis for comparison.

Task (d) involves having an insight into potential energy demand and supply scenario in the rural Bangladesh. To achieve that, we have used data on the potential future sources of energy, looking for the sources that would be sustainable for long-term use, other impacts of using the resources in the future etc. We have also used data regarding current and future energy-consuming activities, relevant impact on the socio-economic life etc.

Task (e) involves critical assessment of energy resources of the country. For this purpose, we have used data regarding the types and availability of different energy resources, their quantities, their future sustainability, the cost and benefit of using those resources, their financial and technical feasibility etc.

Tasks (f) and (g) involve assessment of appropriateness, and identifying the most viable SETs in the context of socio-economic factors of the rural Bangladesh. For doing that, we have used data resource base of producing energy, degree of technological complexity of SET, levels of technical know-how (e.g. education and training), attitude of people towards SET (e.g. willingness to participate in SET transfer), etc. In this context, we have also used data regarding the impact of SET on the environment, poverty, and future lifestyle of rural population of Bangladesh.

Considering the above tasks, the major parameters for investigation of this study were the sources available for energy supply, nature of energy consumption, potentiality of sustainable resources (sunlight intensity, wind speed, biomass production etc.), income, land ownership with type, education, attitudes of prospective consumers towards accepting the SET etc.

3.3 Nature of Demand and Supply of Energy

Identifying the most feasible SET for the rural Bangladesh is a vital component of this study. For achieving the study objectives, it is necessary to have a clear understanding of the concept and nature of demand and supply of energy and SET so that necessary data could be gathered accordingly.

3.3.1 Demand for Energy

This study aims to assess energy demand in the years 2010, 2020, and 2050. The bases of choosing the above-mentioned time span were two folds. First, the similar time span has been used in Read (1997 and 1998) for forecasting biomass production as an energy source at the global scale. Second, according to Kyoto Protocol the global aim is to keep the CO_2 emission rate in 2010 as it was in 1990.

According to economists, the Demand for Energy (DE) is the will to consume a certain amount of energy of a specific nature at a particular point of time backed by economic ability. According to this definition, the components of DE are the price, type of energy available for use, and the consumers' purchasing power used to procure that energy.

This definition is valid at a static point of time, and is bound to be misleading because the ability to use energy is a dynamic variable. Ability of energy use varies with time. For example, even if all the determinants that consume energy directly or indirectly remain unchanged, the need for energy might change because of the change in the population standard of living. It implies that the demand for energy is a function of the state of the national economy.

Economic growth of a society is directly related to the growth of population, housing, urbanisation, electrification, industrialization, climate etc. which are not static, but continuous with time. That means the need for energy is always changing with time, and hence DE is dynamic. Keeping that reality in mind, this study includes the factors of DE, which somehow influence the energy requirement. In Bangladesh, these factors are mainly agriculture, household, industry, production of energy, transport, commerce, service sector, and technological base of energy production, distribution, and end use.

Since its independence, Bangladesh has experienced an enormous rise in energy demand because of:

a. A process of transformation from predominantly rural to urban society,

b. Large scale rural to urban migration,

c. A high rate of industrialization,

d. Infractructural developments,

e. Transformation of agricultural sector from manual to mechanised (limited),

f. Growth of rural industries,

g. Expansion of the service sector,

h. Tremendous growth in the transport sector,

i. Rural electrification (limited), and

j. Use of natural gas as an input in the fertiliser and power industries.

Hence, the estimation of demand for energy in Bangladesh would refer to the demand for energy at present and potential demand from all sectors of the economy. But it is evident that as a result of huge energy demand, the present energy management is mostly concerned with the supply of energy in the urban sector where the rural sector has been neglected.

Moreover, it is also evident that in the rural economy, energy demand for household purposes and agriculture is a prime need for the rural population. Hence, this study must consider the present and potential demand for energy in these two sectors of the rural Bangladesh. This study refers to the potential demand as the expected demand for energy as a result of the changes in the state of the economy and living standards.

However, we have estimated the demand for energy as the sum of energy to be used for different activities by a particular consumer. For example, demand for energy of a household is the sum of energy used for cooking, plus lighting, plus heating, plus drying, plus entertainment etc.

3.3.2 Supply of Energy

Generally, energy supply implies the amount of energy that would be available from different energy sources for particular purposes. But issues such as energy required for energy production and energy losses from distribution channels are associated with the energy supply management. The amount of energy produced from a generator is not the same as the amount of energy available to the end-users. Therefore, the total demand for energy in a country is much higher than the net demand for energy from the end-users. It is evident that this issue has generally been ignored in energy management of Bangladesh (Karim 1996).

For instance, in 1991, the demand for energy in Bangladesh was 682PJ, out of which energy locally supplied by biomass and natural gas was 400PJ. Hence management would import 682-400=282PJ-equivalent fuel (GOB, Power Cell 1997). This demand was calculated as the sum of expected need of energy for different sectors (e.g. domestic, industrial etc.). In the following year it was found that a reasonable amount of energy (more than 50PJ) was spent as transmission loss, conversion loss etc. The need for energy to convert the imported fuel into local usable energy form was not shown in the total energy demand figure. This misleading calculation creates a false picture of energy supply in Bangladesh.

Further, as the urban sector is the privileged beneficiary from imported fuel, the net shortages create multiple effects on rural community. However, for the sake of simplicity this study would refer to energy supply as the amount of energy that would be available for end use by all consumers.

3.4 Households as a Unit

As in other societies, 'household' and 'family' are important basic economic and social units in the rural Bangladesh. They combine production, consumption, service, and social functions. Most traditional rural households in Bangladesh produce their own food, and their houses are built from naturally available materials such as wood, bamboo, and straw. Tools and utensils are usually self-produced (e.g. clay-made pots/plates, bamboo-made spoon etc.), as are sometimes clothes.

The connection of the farmers (especially small and marginal farmers) to the market is weak, and their purchasing power is limited: a small surplus of production is sold in the market, and a few items such as salt, kerosene, matches, or medicine are bought there. Sometimes, if there is an extra surplus, it is saved to meet the expenses of children's marriages, especially to give dowry to a daughter's husband. Community services and social identifications are also centred on the household.

Furthermore, rural households are the major consumers of energy. Most of the studies referred to earlier, have mentioned that the main demand for energy in the rural Bangladesh is for cooking, crop processing and lighting. But it was found in our survey that, apart from these needs, some other types of household activities such as farming, washing, entertainment are also important for rural households—to some degree at least. Interestingly, although the demand for these types of activities is low compared to cooking, the trend is increasing.

The reasons might be changing social attitudes and lifestyles. It is notable that this finding of our survey confirms that the pattern of energy demand is not static, and hence dynamic with socio-economic factors of a society. Hence, the SET programmes should be based on a sound understanding of the changing nature of households in rural communities.

3.4.1 Family Size

Family size is directly related to energy consumption. In general, a large family consumes more energy than a small family. However, this hypothesis might not be always true. For instance, if a four-member family consumes 20E-6PJ energy a year, a two-member family should consume 10E-6PJ in that same year. But in reality, energy consumption is not as linear in relation to family size as that.

A bigger family does not consume energy in direct growing proportion to a smaller one. In fact, a large family consumes less (saving) energy per capita compared to the smaller family. However, although GOB, BEPP (1985c,e), Taskforce (1991), Islam (1983), Hossain (1995) have used an average of family size 5.69, the average family size is getting smaller in Bangladesh as time goes on as a result of population control measures. According to a government document, the average number of persons in a family was 5.6 in 1998 (BBS 1999, p.76). Hence this study has considered an average family size of 5.6.

3.4.2 Joint Family

Understanding the nature of family is essential for analysing energy issue in the household sector. Generally, the number of family members in a joint family is more than the number in a single family. Moreover, members of a joint family are not limited within one relationship. For example, in a joint family, parents, children, grandparents, grandchildren or even distant relatives live in a household. Most household and commercial activities are run and managed under a common leadership in a joint family. The most important characteristics of a joint family is the sharing of resources by all family members. Therefore, it is very difficult to differentiate who uses how much resource.

For example, an adult son of a joint family is married and father of a child, lives with his wife and child in a separate house but within his parent's premises. Sometimes they cook food by themselves, and sometimes they cook their food on the parents' stove. Or even, although their child lives with them, they use light for his/her study in their grandparents' room. Indeed, joint family is a part of culture and a very common practice in rural Bangladesh, and this situation complicates the analysis of the issues of energy demand and supply in the household sector of rural Bangladesh.

3.5 Background Characteristics of Energy Users

The demand for energy, the type of sources used, and overall the acceptance of SET socio-culturally depends on the background characteristics of the energy users. The background variables are the land ownership, income, education, awareness of environment, and the attitudes towards sustainable energy sources. A clear understanding of these variables is essential so that data could be gathered accordingly.

3.5.1 Land Ownership

Land ownership refers to the quantity of land a household owns legally, irrespective of their uses. The term 'legal' refers to the relevant law of the country. The fact is that a household might own land under the ownership of different family members. Also, that family might have different categories of land such as cultivable land, fallow land, forestry etc. But as the analysis of biomass production is directly related to land, forestry, and agriculture, this study has collected data on land owned by a household by legal title into different categories, then added them together to find out the total land.

3.5.2 Household Income

Generally, a household might have income from different sources, for example, from service, business, investment, interest etc. Also, there might be more than one income-earner in a household. Considering the physical constraints of investigating all types of income separately, this study defines the income as the sum of annual income from different sources by different income-earners in a household. Also, as the tax deduction rate is different for different countries, it might be difficult to estimate disposable income for a particular household. Therefore, this study considers income as the household total annual gross income from all sources.

It is notable that some of the respondents were reluctant to disclose their income-related information due to fear of taxation or general suspicion. In those cases, we have estimated the income of a particular household as the sum of annual expenditures for different activities plus the savings in that year.

It is also notable that in few cases, respondents were reluctant to disclose their savings-related information. In those cases, we asked a question in a different way such as 'what they would do if there was an accident or disaster, how they would manage their money'. Our field survey experience is that by applying more than one approach desired data can be collected.

3.5.3 Education

Education is another important component in analysing the background characteristics of the energy consumers in the rural Bangladesh. This is because, as we have mentioned earlier, in the year 1998, the overall literacy rate in Bangladesh was 32.4% (BBS 1999, p.3), where that of rural population would obviously be much less. We have measured education level according to the approved academic qualifications of the country.

It is possible that a person might not have a formal academic degree or qualification but be able to read and write: will s/he be considered literate or illiterate? The answer is illiterate. This has been done for two reasons. First, for the sake of simplicity, and second, it would be difficult to justify her/his depth of academic knowledge. That is why this study has categorised education levels as illiterate, primary, secondary, higher secondary, bachelor and masters and above.

3.6 Environmental Awareness

Environmental awareness is a key factor for transfer, diffusion, and sustainability of SET. This is more important in the rural Bangladesh because of the socio-economic conditions of potential SET users. This study refers to environmental awareness as the knowledge of energy users (rural population) towards environmental quality, reasons for environmental degradation, effects of environmental damage on their lives, and the attitude towards protecting environment.

Respondents were asked whether they are aware of the possible reasons for frequent flooding or drought in Bangladesh, whether they know what causes air or water pollution, and whether they know that deforestation harms the environment. If they could answer these questions correctly or reasonably correctly, they were considered to be environmentally aware. Otherwise, they were classified as environmentally unaware.

3.7 Willingness to Participate in SET Transfer

Willingness to take part in the SET transfer is another major parameter in this study. This is simply because SET transfer would not be effective unless the potential energy users are willing to accept, learn, and use it. This study has measured this parameter by asking question whether and how the respondents would participate in the SET transfer, in what form they would contribute to making SET successful in their locality etc.

3.8 Methods of Data Collection

The methods included in this study were questionnaire survey, participant observation, and participatory rural appraisal techniques.

3.8.1 Questionnaire Administration

After completing sample selection, the appropriateness of the draft questionnaire was tested by conducting a 'pre-test' survey. The questionnaire was drafted on the basis of the objectives and theoretical frameworks set out for the study. After pre-testing, the draft questionnaire was modified accordingly. That modification involved the inclusion of some new ideas, as well as exclusion of some prior assumptions.

In the sample, 100 households from each village were selected for interviewing. Originally it was planned to interview 50% of households from large holdings group, and 50% from the small holdings group, but after completing and facing selection series, the final distribution was 54% from large holdings, and the remaining 46% from the small holdings category. Similarly, it was intended to survey approximately 50% male and 50% female, but the end result was 60% male and 40%

female respondents. These changes were made due to physical limitations, and different response rates in survey areas.

Finally, a total 303 questionnaires were found usable, and were analysed in the study. Although detailed characteristics of sampled respondents are described in Chapter 6, a brief of selected households in the sample is presented in Table 3.1.

Table 3.1: Number of Sampled Respondents by Sex, Land Ownership, and Divisions

Division	*Large land holdings*	*Small land holdings*	*No of male respondents*	*No of female respondents*	*Total*
Khulna	37 (53)	33 (47)	42 (60)	28 (40)	70
Rajshahi	39 (53)	35 (47)	45 (61)	29 (39)	74
Dhaka	45 (54)	38 (46)	50 (60)	33 (40)	83
Chittagong	40 (53)	36 (47)	44 (58)	32 (42)	76
Total	161 (54)	142 (46)	181 (60)	122 (40)	303 (100)

Source: Field survey

Note: 1.Figures in parentheses represent %age of total respondents surveyed in the village

2. One village represents one division.

3.8.2 Participant Observation

The participant observation method was used to fill the gaps apparent in the interview method. There are some socio-economic and cultural issues where better results can be obtained by observing the respondents' behaviour rather than asking questions in a straightforward way. In the participant observation process interviewer observes the respondents' behaviour, and takes note of the relevant information, in addition to asking questions while interviewing. Hence, interviewing through a pre-designed questionnaire together with participatory observation produces better-quality data.

The use of two techniques together in data collection can be seen in a good number of researches. For instance, Senelwa (1997) has used the questionnaire as well as participant observation methods in his energy study. Ranjit (1996), Senelwa and Sims (1998) have also put positive comments in favour of using joint techniques in their article on the methodology of energy planning. Jurgen and Harmut (1975 cited in Hossain, 1995) state that the use of two techniques together can give a better-quality database.

In fact, the use of more than one method in data collection always compensates for one another's deficiency, and provides a better scope of investigation, especially in social science researches. From this context, this study, in addition to interviewing and participant observation, has also used Participatory Rural Appraisal (PRA) technique in data collection.

3.8.3 Participatory Rural Appraisal

There is a wide range of methods used to engage communities to participate in development programmes. PRA is a methodical framework for understanding and assessing rural (and urban) situations, and planning development. They are based on attitudes, methods, and exchange. The knowledge of local people is taken as the starting point, and visiting planners or administrators learn from them, by using many different locally adapted methods. The ultimate goal is to identify possible concrete actions, based on shared understanding of the situation at hand (Jegillos 1997, p.5).

The PRA philosophy is based on the principle that development should not be imposed, people's felt needs and aspirations must be focused, local people know more than we do, and rural people should be regarded as partners in the development process. They can not only provide information, but also analyse it effectively. This mechanism can ensure sustainability of the project because of the local people's involvement right from the beginning of the project until its end (ibid, p.2).

The pioneer of PRA, Robert Chamber said that "*PRA is a growing family of approaches and methods to enable rural people to share, enhance and analyze their knowledge of life and conditions, and to plan, act, monitor and evaluate. Intensive and growing many of methods include visuals such as mapping and diagramming.*

Practical applications have proliferated, especially in natural resources management, agriculture, health and nutrition, poverty and livelihood... PRA methods and techniques present alternatives to questionnaire surveys in appraisal and research and generate insights of policy relevance. PRA approaches and practices enable lowers to express and analyze their multiple realities. Many poor people realities are local, complex, diverse, dynamic and unpredictable. For farming, forest based and pastoral livelihoods they often seek security by complicating and diversifying activities, and multiplying linkages and support to exploit varied and varying local resources and opportunities" (Chambers, 1997).

It is notable that the aim of the present study is to assess the appropriate SET for the rural Bangladesh where the recipients' attitude and reaction have a strong role to make the option viable. Data collected from secondary sources or by using a pre-designed questionnaire administration or participant observation technique would not be sufficient for knowing the recipients' ability, knowledge, and the reality. The issue might be more serious if the prospective users of the transferred technology are low-educated and suffer from poverty as is the case with Bangladesh.

One of the limitations of interviewing by a pre-designed questionnaire is the gap of understanding. Understanding gaps may arise either from interviewers or from respondents. To overcome this situation, this study has used the PRA technique in data collection, in addition to the questionnaire survey and participant observation method.

It has been mentioned earlier that we have surveyed four villages from four divisions. The PRA method was used in two of the sampled four villages. Two villages were Kutubdia of Chittagong division, and Loxmikola of Khulna division. These two villages were surveyed before by questionnaire interviewing.

The procedure that have been followed in PRA was as follows:

I was accompanied by an assistant, who worked in these villages before for the questionnaire survey, and stayed five days in each of the above-mentioned villages. As this was the second visit for data collection purposes, most of the localities and some of villagers were already known to us, and we to them, and it was relatively easy to introduce us to the villagers. But once they came to know that we would stay for a few days, some of them became a little anxious.

Anyway, we explained our motive and purpose of a second visit to the village leader, and requested him to call villagers at a common place. It was found that the number of villagers who participated in our programme was not the same as for everyday discussions.

For example, some people who attended the first-day's discussion, did not attend the second-day's programme. Moreover, some of the participants left the programme halfway through the discussion. Sometimes, a few people joined the discussion while the discussions were already underway. However, on average, the number of participants varied from 20 to 25 each day in each village, of which female participants were by and large 40-45%. Photographs of female and male participants, their activities, and living conditions of focus group have been presented as Annexes 4, 5, 6, and 7.

It might be argued that the irregular and unorganized attendance of villagers was the result of a failure to motivate villagers to participate in the discussion. But in reality, it was the freedom of unorganized pattern that has made the survey successful because villagers did not feel under any influence or pressure either from us or from the village leader. As a result, they expressed their opinions in a bias-free environment. These characteristics have been noted in other PRA work (Chambers, 1997).

The data collection technique applied was a simple focused informal discussion. The environment was created so that every one was encouraged to speak. Particular attention was given to women so that they could share and contribute in the discussion. One thing is worth mentioning: in the first day of gathering in Loxmikola village, discussion was held with male and female participants together.

In this case we observed that female participants generally spoke less than their male counterparts due to shyness or fear of their male relatives who were present there, although we encouraged them to speak freely like male participants. Therefore, from the second day onwards we have done PRA with male and female groups separately.

In a separate group, the female participants spoke more freely, and gave us realistic information relevant to this study.

Much information came out during the informal discussions. Some of them are relevant to this study; some are not. The information collected using PRA is often different from that collected by questionnaire interviewing. For example, by interviewing we asked respondents about the need for windmills. The reply was that they need windmills for irrigation. But during PRA, they told that they would cultivate wheat, potatoes, and also different types of winter crop if they could manage irrigation facilities.

Similarly, the second question asked was about the location of that mill, if it were built. During PRA, the participants were requested to draw a map of the proposed windmill location, which they did. Interestingly, in response to a questionnaire survey, the village leader informed our interviewer about a tentative location of the proposed windmill, justifying his opinion by the potential general benefit for the community due to the installation of the windmill according to his choice. But during PRA method, when villagers drew a map of the location of a windmill (Annexes 8 and 9), it was found that the location identified by villagers was different from that proposed by the village leader.

The village leader enthusiastically supported the earlier location. But that location was close to his land, and it would be easy for him to use that water pump for irrigating his own land. Moreover, the land required for the mill as a site belonged to a poor neighbour of that leader. That means that the previously identified location for installing a windmill was not appropriate for common villagers. Hence, the focus group can find best options independently.

Our survey experience demonstrates that PRA method for collecting data like why rural people need energy, what they would do with excess energy, what would be the best technological option for the future, how they would participate in technology transfer process etc., would provide the real picture of rural energy situation of Bangladesh.

In fact, the use of PRA method, in addition to interviewing and participant observation methods, has overcome the shortcomings of interviewing system, and has provided an extra layer of better-quality data.

3.9 Sampling Design

Ecologically Bangladesh is divided into four regions. Although the country as a whole is flood-prone plain land, the regions differ significantly according to land type, population density, literacy, agricultural pattern, and availability of natural resources. For example, all natural gas wells identified so far are situated in the Eastern zone of Bangladesh (Petrobangla 1998, also see Ali 1993, Khan 1991). Similarly, agricultural cropping patterns differ in the Eastern, Western, and South-Western zones. Due to these agro-ecological differences, the pattern of energy consumption and energy sources used also differed from region to region (Karim 1993, 1996, 1997).

Administratively, six divisions represent four regions in which two divisions (Barishal and Sylhet) have been newly formed - a separate database is yet to be established for them. Therefore, primary data of this study have been collected from the four villages sampled from four old divisions (Dhaka, Chittagong, Rajshahi and Khulna) so that the result of the survey is representative of the country as a whole. The number of sampled villages was:

(6-2) Divisions X 1 Upazilla X 1 Village = 4 Villages

The criteria of selecting four villages from four divisions were location, remoteness, population, their near-absolute dependence on traditional energy sources such as biomass, and their related needs. Although the exact location of these villages can be seen in Map 6.1 (Chapter 6), some topographical features of the sampled villages are presented in Table 3.2.

Table 3.2 Major Topographical Features of Sampled Villages

Village	*Division*	*Population (in '000')*	*Agro-ecological zone*	*Major tropical features*	*Percentage of total land*
Loxmikola (Daulatpur)	Khulna	26.2	Padma River flood Plain	High Land Medium High Land Medium Low Land Low Land Very Low Land Water	10 43 36 5 1 5
Nandigram (Nandigram)	Rajshahi	17.3	Chalan Bill flood Plain	High Land Medium High Land Medium Low Land Low Land Very Low Land Water	2 10 40 28 12 8
Savar (Savar)	Dhaka	32.2	Turag River belt	High Land Medium High Land Medium Low Land Low Land Very Low Land Water	20 35 14 15 12 4
Kutubdia (Kutubdia)	Chittagong	13.1	Bay of Bengal Tidal flood plain	High Land Medium High Land Medium Low Land Low Land Very Low Land Water	1 2 25 45 20 7

Source: BBS (1999), BUP (1989)[1], Hussain (1995).
Note: Word within parenthesis represents the upazilla, the Local Government Administrative unit in which the village is located.

The sampled villages did not have any natural resources like oil, gas or any other forms of fossil fuel. They were also free from government or semi-government sponsored forests or any other forms of energy production plants. The population of these four villages were largely dependent on different forms of biomass energy sources to meet their energy requirements. The procedures of selecting households for data collection along with some of their socio-economic characteristics are as follows.

[1] Study on the National Resource of Ganges and Brummaputra River Basins conducted by Bangladesh Unnayan Parishad (BUP) funded by Ford Foundation. This study was carried out among three countries (India, Nepal, and Bangladesh). The author of the present study is also a contributor to that project. It is notable that the recommendations of that study have influenced the water resource policy of Bangladesh.

A three-fold procedure was employed for data collection. First, a 100%-census of all households of the four villages was conducted to collect the basic statistics of physical, social, economic, demographic, and energy resources (forestry, livestock, sunshine, wind flow etc.). Also, some other basic information about these four villages (geographical location, land areas, land types, agriculture cropping pattern, sources of energy supply, nature of energy uses, existence of energy production plants, fallow lands etc.) was collected from the documents available in respective upazillas. The households were categorised on the basis of this information.

Categorisation was done according to the Bangladesh Bureau of Statistics definition of land holdings: landless (owning no land at all), small holders (owning up to 1.0 ha), medium holders (owning 1.0-3.0 ha), and large holdings (owning over 3.0 ha) (for details see GOB, Planning Commission, Second Five Year Plan 1980- 1985).

As the main thrust of the study was to identify appropriate options for sustainable energy supply in rural households, the landless and small land holdings households were grouped together in one category. We renamed this category as 'small holding households'. This is because it was seen from the basic data that the households who own less than 0.08 ha of land are also almost landless. And the nature of energy use and consumption are functionally very close. Similarly, as the use of energy sources and consumption pattern in medium and large land holdings households were very similar, these two groups were regrouped in one, and renamed as large land holdings households.

Hence, instead of the four categories used by the Bangladesh Bureau of Statistics, this study has divided the respondents into two groups in terms of land ownership pattern. The households who owned up to 0.08 ha of land have been considered small, and those who owned more than 0.08 ha, have been considered large. This type of categorisation of households in terms of land ownership has been used by Khan (1995), Karim (1995), Ahmad Q.K. et al (1984). Hossain (1995) also categorised land ownership into three categories instead of four.

The second part of the survey was conducted on the basis of the land holding categorizations, following a proportionate stratified sampling technique. Due to the limited nature of the representation of interviews of this study, purposive samples were drawn for the large land holding households where their numbers were found to be small. Similar sampling strategy and techniques can be found in Hossain (1995) and Islam (1983).

3.10 The Questionnaire

As this study was heavily dependent on primary data, the questionnaire was designed in a manner sufficient for gathering adequate and correct field information, to achieve the research objectives. In designing the questionnaire, the first task was to make a list of issues relevant for our analysis. The thrust of designing the questionnaire was directed at the types of necessary data and the reasons for their choice, and alternative ways of collecting that information.

The draft questionnaire was pre-tested in the field, and adopted necessary modifications on the basis of pre-testing experiences.

The questionnaire consists of five sections. The first section regards the background characteristics of respondents (name, sex, size of household, occupation, quantity of land owned and its types, number of cattle owned and their variety, income etc.) This information was needed to identify 'who is who' in the rural society, and the respondents' basic socio-economic characteristics.

The second section regards the sources of energy supply available in the respondents' society. This included all available types of energy sources (electricity, dung, trees, leaves, gas, kerosene, wood, gas cylinder, petrol, diesel, LPG etc.). For example, we have asked the respondents to mention what sources they had used.

The question about the pattern of energy demand and the nature of energy consumption was included in the third section. We asked the respondents what they do with energy, recording all possible types of consumption. The main variables of energy demand were cooking, lighting, washing, entertainment, security, machine operation, heating, air conditioning, fan operation etc. For simplicity, this section was divided into two parts: household and commercial consumption.

The next section includes the present state of energy technology of the locality. In this section main questions were asked about the existence of solar, wind, biogas, or any other forms of energy production plants in that locality. The potential demand for energy questions were included in the following section. In this section, particular emphasis was given to what they would do if more energy were available. Alternatively, which of their activities had been suffering from energy shortages.

Information about management of technology transfer was included in the last part of the questionnaire. Respondents were asked whether they would prefer to use the SET individual ownership or co-operative system of management. In this section, questions were asked about the types and nature of resources they would suggest for establishing the energy plant(s). In fact, the information on the respondents' attitudes, ability, and willingness regarding SET transfer were included in this section. Ability was measured in terms of investment capacity of land, labour, entrepreneurship, and capital. Information regarding the respondents' environmental awareness and knowledge of sustainability were also included. The last part of the questionnaire was kept open for respondents' comments.

It is notable that we have used two types of questionnaires for this study: a questionnaire for households and another for the leadership opinion survey. The respondents of the latter were local leaders, politicians, school teachers, local elite, religion leaders etc. A total of 31 of such leaders from four sampled villages were interviewed under this category. The questionnaires are presented as Annexes 10 and 11.

In addition, semiformal discussions were conducted with the energy management officials, to find out the prospects and problems in the energy sector of Bangladesh. Much interesting information emerged from those semi-formal discussions, which would not be possible to unfold through formal interviews. Of course, participating officials were given assurance that the information they gave us would not be used for any purpose except for this academic research.

It is relevant to note that we were interested in using a tape recorder while interviewing high officials and senior professionals. But, as some of the information and opinions that they gave us, was unofficial and confidential, and it could pose potential threat to their jobs if leaked, the respondents insisted on not using the tape recorder or quoting their names in any form of evidence related to the information given. Therefore, I conducted the interviews myself, and care has been taken to protect their identity.

3.11 The Interview Team

Fieldwork for this study was carried out in 1999 and 2000. Four interviewer teams conducted this survey, one in each village. Each team consisted of two interviewers. Survey was carried out in one village at a time under my supervision. During field survey the Chief Supervisor, Dr. Peter Read, visited Bangladesh more than ten times and monitored the performance and progress regularly. The Chief Supervisor's comments and feedback have significantly improved the quality of survey. From sampling to the end of data collection, we visited each village several times.

Interviewers were recruited from either the surveyed or a nearby village. Most of them were college or university students. Proper training was given to the interviewers after recruiting them. Careful attention was given to the use of the language and the research objectives so that they realised the importance of quality data and were committed to their job. Interviewers were instructed to use the Bengali language, if necessary, while interviewing. This was done to minimise misunderstanding.

There were a number of advantages in recruiting interviewers from individual local villages. They facilitated our entry to the village, as they were known to the locality and aware of the socio-economic and cultural background of the villagers. Thus, they provided basic information about the respondents and the locality. Without that assistance, it would be difficult for us to find out 'who was who' in the village, and whom we could ask for co-operation.

And finally, being local, it was easier for interviewers to make us trustworthy to the villagers and get the responses effectively. Sometimes, interviewers corrected the respondents' answers if they provided absurd information due to fear or lack of knowledge. This has happened many times, especially when asking about land ownership and income. It was found that villagers had their own ideas about each other's property, assets, occupation, and hence income.

Our experience from this study confirmed that recruiting local personnel for interviewing provides better results, especially where information is of confidential nature. Other than household survey, the interview team also interviewed local elite, teachers, politicians, and relevant officials of that locality. But I personally interviewed high officials, renowned academicians, senior politicians, or professionals.

It may be questioned whether the interviewers recruited from local villages were biased in administering the questionnaires. The answer is, that although the interviewers were recruited from local villages, necessary training was given to them in relation to the purposes and use of field survey data. It is believed that they realised the importance of their role in the data collection.

Moreover, I personally monitored and supervised the interviewers' work regularly. Finally, the filled-in questionnaires were edited and cross-checked immediately after completion of interviews, for consistency. Corrections have been made by physical verification, if any anomaly was found.

3.12 Data Analysis

The data were analysed in accordance with the study objectives. Necessary tabulations were prepared by using SPSS software. The following steps have been followed in analysing data:

a. Filled-in questionnaires and information recorded through observation techniques were edited. That helped to maintain the consistency of data.

b. Data were transferred from questionnaires to a spreadsheet; and

c. Necessary tabulation was prepared by using SPSS software.

There were 303 correctly filled-in questionnaires from four sampled villages. At the first stage, respondents' socio-economic background and related information were tabulated. These tables helped us to identify the nature and background of respondents in the rural Bangladesh. They also helped to find out the relationship of the nature of energy needs and types of resources used and the respondents' land ownership, education, income etc.

At the second stage, the data on various available energy resources for future energy sources were tabulated. The tables on environmental awareness, attitudes, and the respondents' ability to use SET, have also been compiled. Finally, using non-parametric tool "Mann-Whitney", we tested the results' validity. Moreover, statistical tests have been carried out using regression and correlation.

3.13 Conclusions

Based on the above discussion, it can be concluded that to achieve this study objectives, the data from both primary and secondary sources were necessary. Fieldwork was conducted in four villages of four divisions in 1999 and 2000. Primary data were collected using three methods: pre-designed questionnaire administration, participant observation, and PRA. PRA was conducted in two villages.

The main parameters of investigation were: pattern of energy consumption, potential demand, availability of energy resources, respondents' ownership of resources (e.g. land, forest, cattle etc.), their income, education, environmental awareness, attitudes towards SET, ability to contribute to SET etc. Information from secondary sources provided the basis for investigation, while that from primary sources has added an extra layer to the study findings.

Chapter 4

Bangladesh Energy Scenario

4. 1 Introduction

The aim of this chapter is to analyse the current energy scenario of Bangladesh. The relevant issues associated with the energy scenario are the major resources available for energy production and distribution in urban and rural areas, institutional arrangement for energy management, supply and consumption networks, and the status of SET with special emphasis on the rural energy sector. However, before going into any relevant details it is worth visualising the Bangladesh at a glance.

4. 2 General Features of Bangladesh

Geographically Bangladesh is located in the southern region of Asia, and surrounded by India from three sides, Myanmar in the South-East, and the Bay of Bengal in the South. The country lies between the latitudes of 24.34'- 26.34'N, and longitudes of 88.01'- 92.41'E, with a 724km long coastal belt. The average temperature varies from 9 degrees C to 34 degrees C, humidity ranges from 36% to 99%, average rainfall during the monsoon season is 120–345cm. The land area is mostly flat plain. There are a number of islands both in the offshore and the deep areas of the sea.

The area of Bangladesh is 148,393 sq.km. A network of 230 rivers and their tributaries, with a total length of about 24,140km cover the country down to the Bay of Bengal (GOB, Power Cell 1997,Sec. 13.0). Cyclone storms with high tides in the Southern zone and wide-scale floods are a regular phenomenon in the country. Geographically, Bangladesh is a natural disaster-prone area. The map of Bangladesh showing geographical location is presented as Annex 12.

The present population of Bangladesh is about 130 million, of which about 85% live in the rural areas (Census January 2001, official results are yet to be published). The average density of population is more than 800 people per sq.km (BBS 1999), one of the highest in the world. The rural population mostly live on agriculture, forestry, and fishery. Most of the population is directly or indirectly dependent on agriculture as a profession.

People in Bangladesh get energy from commercial and traditional sources. The types of commercial energy are electricity, natural gas, coal, and petroleum products, while traditional energy types are represented by biomass, animal power etc. The production and distribution of commercial energy is under public-sector management, its market is organized, while that of traditional energy is under private sector, and its market is unorganised.

In Bangladesh, per capita energy consumption rate is very low compared to other developing countries. In 1980/81, the total per capita energy consumption was 6.24E-6PJ, of which 17% (1.06E-6PJ) was consumed from commercial sources, and the remaining 83% (5.18E-6PJ) was used from traditional biomass fuel. In 1983/84, the per capita energy consumption to 6.27E-6PJ, of which the contribution of the commercial energy was 1.14E-6PJ (18%), and the remaining 5.13E-6PJ (82%) came from traditional biomass fuel (GOB, BEPP 1985b). In 1990-1998, the per capita energy consumption rose sharply to 9.67E-6PJ, of which 33% (3.19E-6PJ) came from commercial energy, and the remaining 67% (6.57E-6PJ) came from traditional biomass fuel (ADB 2000, p.34).

Even this relatively high per capita consumption rate is not only much lower than that of the developed countries, but is also one of the lowest among the lowest energy-user countries of the Third World. According to a World Bank statistics, Bangladesh's commercial energy use stands at less than 15% of the average of 34 "low-income countries". A comparison of Bangladesh per capita energy consumption with some neighbouring countries is presented in Table 4.2.1.

The total forest area covers about 14% of the officially designated land area (GOB, Power Cell 1997, Sec.5.1), but practically its tree-covered area is 6-7% only (GOB, ME&F 1993).

Table 4.2.1: Comparison of Per Capita Energy Consumption of Bangladesh and Some Neighbouring Countries

Country	*Energy consumption PJ/cap*	*Country*	*Energy consumption PJ/cap*
Bangladesh	9. 67E-6	Nepal	6.42E-6
India	11. 16E-6	Sri Lanka	17.91E-6
Indonesia	13. 80E-6	Thailand	20.80E-6
Pakistan	11. 57E-6	Singapore	260.88E-6

Source: Compiled from ADB (2000), Karim (1996), GOB, BEPP (1985b).

4. 3 Background of the Energy Sector

Bangladesh has reserves of natural gas, coal, and an insignificant amount of oil. The present pattern of energy supply is a mix of electricity, natural gas, liquid fuels, and biomass. Among these, biomass is the main source of energy for cooking (100% for the rural households, and 70% of urban households), and kerosene for lighting (ADB 2000). Because of inadequate supply, even the upper-class households still have either no or limited access to non-renewable energy sources. Lower-income group is a long way away from reaching the fossil fuel market.

According to the National Energy Policy (GOB, NEP, 1995, p.1) of Bangladesh, in 1990, only 2.2% of households (all urban) had natural gas pipeline connections for cooking; 10% of rural and semi-urban households had electricity connections; and only 3.9% of households (all urban) used kerosene for cooking.

Bangladesh is an agro-based country, and any policy on sustainable energy supply should be based on locally available resources that fit with the ability, desire, and lifestyle of the rural population. It is also understood that geographical location of Bangladesh (see Map of Bangladesh, Annex 12) makes it vulnerable with regard to the issue of the sustainability of energy supply and SET transfer.

4. 4 Institutional Arrangements

In Bangladesh, energy production and distribution infrastructure is not very old. Although the country came out of the British rule in 1947, until the mid-Fifties' the country (the then East Pakistan) was almost entirely dependent on imported petroleum products for its commercial energy. In the late Fifties' the then Pakistan Government established Water and Power Development Authority (WAPDA), responsible for managing national water resources, and power production and distribution—mainly from hydro sources (GOB, ME&MR Annual Report 1979).

WAPDA was accountable to the Ministry of Water Resources and the Ministry of Energy and Power. As a result, although it was set up as an autonomous body, its success was limited due to the dual administrative conflict. However, the major result of WAPDA activities was the building of a hydropower dam on river Karnofuli of Chittagong division in the early sixties. It is notable that it is the only hydropower plant in Bangladesh till today.

After gaining independence in 1971, WAPDA was split into two organisations: Bangladesh Power Development Board (BPDB), and Bangladesh Water Development Board (BWDB). BPDB is responsible for power generation and overall management of power in the public sector. BWDB is responsible for national water resources, including river basins. In 1981, another organization, The Rural Electrification Board (REB) was formed to provide electricity in the rural areas of the country.

There are few other organisations, apart from the Ministry of Energy and Mineral Resources, such as Bangladesh Petroleum Corporation (BPC), Titas Gas Limited (TGL), Dhaka Electric Supply Authority (DESA) are mainly responsible for energy distribution. Bangladesh Petroleum Corporation is solely responsible for natural gas management.

In addition, to promote rural energy, the government has set up Power Cell, mainly for policy formulation, under direct supervision of the Ministry of Energy and Mineral Resources. During field survey we were told that the government is planning to establish two more organisations: The Rural Energy Development Board (REDB), instead of REB, and Dhaka Electric Supply Company (DESCO), instead of

DESA. A summary of the main organisations and their responsibilities is presented in Table 4.4.1.

Apart from the above-mentioned organisations, Bangladesh Rural Development Board (BRDB) and Local Government Engineering Department (LGED) are partly involved in promoting solar power (photovoltaic) and biogas energy technology in the country. A few non-government organisations such as Bangladesh Rural Advancement Committee (BRAC), Proshika, and Grameen Shakti are also partly involved in marketing solar energy technology in the rural Bangladesh (CPD 2000).

Table 4.4.1: Organisations Involved in Energy Management, and Their Responsibilities

No	*Name*	*Responsibilities*	*Areas of work*
1	Ministry of Energy and Mineral Resources	Overall administration, coordination, and policy formulation	Whole country
2	Bangladesh Power Development Board (BPDB)	Power generation and grid building	Whole country
3	Bangladesh Petroleum Corporation (BPC)	Liquid fuel import and natural gas exploration	Whole country
4	Dhaka Energy Supply Authority (DESA)	Distribution of electricity	Only Dhaka city
5	Rural Electrification Board (REB)	Distribution of electricity	Semi-urban and rural areas
6	Meghna Oil Ltd.	Import and distribution of liquid fuel	Urban
7	Jamuna Oil Ltd.	Import and distribution of liquid fuel	Urban
8	Padma Oil Ltd.	Import and distribution of liquid fuel	Urban
9	Atomic Energy Commission	Research	Not applicable
10	Bangladesh Council for Scientific and Industrial Research (BCSIR)	Research and development of energy	Not applicable
11	Power Cell	Policy formulation	Not applicable

Source: compiled from different published materials. For details see GOB, Power Cell (1997), GOB, Planning Commission, SFYP (1980), and Taskforce (1991).

4. 5 Energy Supply Networks

The pattern of energy supply in all urban areas in Bangladesh, except Dhaka City, is very similar. There is a grid system power supply in all urban areas (district towns), although there is an acute shortage of electricity.

Due to acute shortages of power, electricity is supplied for a limited number of hours during the day. In Dhaka City, the supply mode is different: gas is supplied for household cooking and washing, while electricity is supplied for lighting. Transport is run on petrol and diesel, while human-pulled rickshaws and horse-pulled carts use kerosene for lighting if driving at night. Thus, the energy supply system in rural areas is different from that of the urban areas.

The rural community has a very limited access to the electricity supplied by REB. Even the high-income households of rural communities have either limited or no access to the grid power supply. In 1990, REB covered 10% of households under grid connection (ADB 2000, p.34), increased to 15%[2] in 1997 (GOB, Power Cell 1997, Sec. 1). Although REB was established about two decades ago, its distribution capacity is entirely dependent on the amount of power received from BPDB.

BPDB's electricity production capacity is very insufficient compared to national demands. So it delivers its maximum generated product to the DESA, which provides power supply in the capital city.

The second reason for a limited access to the grid power supply by rural population is the requirement of significant investment required for the installation of power grid in rural areas, which depends on its affordability to and relevant decision of the government. A summary of energy sources, and the location of their supply areas is presented in Table 4.5.1.

[2] The figure representing the number of households connected to power grid in the rural areas, is controversial, e.g. GOB, power cell (1997) shows 15%, while Azzaduzzaman (1998) shows 12%, and ADB 2000 shows 10.5%.

Table 4.5.1: Energy Supply Networks in Bangladesh

Energy sources	*Urban areas*	*Rural areas*	*Comments*
Electricity produced & supplied by BPDB	yes	No	BPDB supplies power in urban areas only.
Electricity supplied by REB	Partly yes	Yes	Limited access for rural population
Natural gas	yes	No	Gas is limited in Dhaka and Chittagong cities
Petrol	yes	No	No use of petrol in rural areas
Diesel	yes	Yes	Diesel is used for irrigation machinery operation in rural areas
LPG	yes	No	LPG is available in urban area only
LPG cylinder	yes	No	LPG is available in urban areas only
Firewood	yes	Yes	Firewood is used in households and for industrial activities
Animal dung	no	Yes	Large portion of the rural population uses dung
Leaves	no	Yes	Large portion of rural population uses leaves
Solar photovoltaic	no	Yes	Very few, still in demonstration stages
Windmill	no	Yes	Only a few in the coastal belt
Biogas	no	Yes	Very few in operation
Agriculture waste	limited	Yes	Large-scale use in rural households and industry
Timber waste	yes	Yes	Used in both rural and urban areas
Coal	yes	No	Not available in rural areas

Source: Compiled from PSL 2000, GOB, BEPP 1985e Vol. IV, Islam 1983, GOB, PC, FFYP 1990-95.

4. 6 Energy Consumption Networks

A summary of energy consumption networks has been presented in Table 4.6.1.

It is seen from Table 4.6.1 that in rural Bangladesh, people need energy mainly for cooking, lighting, washing, food processing, irrigation, and agriculture. Among these, cooking is the most essential source of demand (GOB, Power Cell 1997; also GOB, BEPP 1985a,d,e, Assaduzzaman and Chowdhury 1986). Table 4.6.1 also shows that biomass is the main source of energy for meeting different needs of the rural community. On the other hand, in urban areas, people consume energy from different sources depending on the type of needs and availability of energy sources.

For example, in urban areas, people have an option to use electricity for ironing or lighting, and gas for cooking. They can also use kerosene for lighting. However, in rural communities, people have no alternative but to use biomass for cooking, and kerosene for lighting.

With rural population, the choice of energy sources according to the type of users' needs is very limited. This situation has led to an increase in the dependency of rural community on biomass fuel. Therefore, given the question of affordability, the lack of alternative energy sources has made the issue of deforestation or environmental degradation less important to rural population in Bangladesh.

Table 4.6.1: Energy Consumption Networks in Bangladesh

No	***Rural Sector***		***Urban Sector***	
	Consumption	***Source***	***Consumption***	***Source***
1	Cooking	Biomass*	Cooking	Gas/electricity/firewood
2	Washing	Biomass	Washing	Gas/electricity/firewood
3	Lighting	Kerosene**	Lighting	Electricity/kerosene
4	Drying	Sun heat***	Drying	Electricity/sun
5	Heating	Biomass	Heating	Electricity
6	Entertainment	Moonlight/ Kerosene	Entertainment	Electricity/dry cell
7	Fan	Manual	Fan	Electricity
8	Air conditioning	Not applicable	Air conditioning	Electricity
9	Security	Kerosene	Security	Electricity/kerosene
10	Ironing	Biomass	Ironing	Electricity
11	Irrigation machine operation	Diesel	Irrigation machine operation	Electricity/diesel
12	Irrigation manual	Manual	Irrigation manual	Not applicable
13	Transport	Manual	Transport	Petrol/diesel
14	Small Business	Kerosene/ biomass	Business	Electricity/gas/firewood
15	Food Processing	Biomass/ Manual	Commercial	Electricity/gas
16	Agriculture	Animal power/ manual	Agriculture	Electricity/petrol/diesel
17			Industry	Electricity/diesel

Source: Compiled from PSL 2000, GOB BEPP 1985e,Vol. IV, Islam 1983, GOB,PC FFYP 1990-95.

Note: * Biomass includes firewood, animal dung, leaves, agricultural waste, food waste, and forest waste.

** Few households have access to electricity, with most of them (88.5%) using kerosene. Also, a few houses in the Eeastern zone have been using solar photovoltaic for lighting.

*** Drying includes all types of drying activities (agricultural, commercial, and household).

4. 7 Major Weaknesses of Energy Infrastructure of Bangladesh

It appears from previous discussion that the energy management system of Bangladesh is mainly limited to the management of energy supply in urban areas. It also appears that production and distribution capacity of electricity is limited to meeting urban population demand; the supply of and demand for energy for rural community has largely been ignored by the authorities. Karim (1996) has identified some problems associated with current energy management infrastructure.

On of the most significant problems is lack of efficiency. The country has too many institutions and organisations involved in energy production and distribution, but they hardly perform their responsibilities as per the objectives of their establishment. The practice of performance evaluation of energy sector in Bangladesh is quite scenical. Once an organisation under review is found inefficient, they tend to establish a new one with similar terms and conditions. In most cases, this is done without any serious consideration to the fate of the existing one. This leads to overlap of organisations and institutions theoretically performing the same or similar job.

The new organisation is found to inherit the same resources (human and physical) and problems as the previous one, instead of rectifying them. Hence, unfortunately, the reasons of inefficiency or poor performance of the previous organisation remain unraveled. The results of our interviews with higher officials show that the main reasons for inefficiency and poor performance in the energy sector of Bangladesh include a lack of accountability, corruption, and shortages of capital.

System loss, the amount of energy lost in the process of its production and distribution, is found be the next most severe weakness of energy management. GOB, BEPP (1985b) found that system loss is directly associated with corruption. In 1985, system loss comprised 42% of total energy production. In our survey, officials opined that the percentage of system loss rose from 42 to 47% in 2000. In Bangladesh, system loss occurs due to illegal sale of power in exchange for bribes. ADB (2000) mentions that half of system loss in the power sector of Bangladesh is attributed to theft.

The lack of coordination is another shortcoming in the energy management of Bangladesh. In spite of a significant number of organisations, which perform either similar or close to similar activities, there is a minimum coordination (sometimes no coordination) among them.

For instance, there are two power transmission lines from Puthia to Taherpur (Rajshahi division), one of which was built by BPDB, and another - by REB. In 1986, BPDB constructed an 11KV transmission line from Puthia to Taherpur to supply electricity in that area (GOB, ADP 1986-87). In 1992, REB extended its activities in that area, and as part of its development scheme, constructed another transmission line from Puthia to Taherpur (GOB, ADP 1992-93). Two transmission lines are parallel. Now, as the REB is responsible for distributing electricity in that area, its transmission line is in use. The BPDB line is not in use, leading to direct resources wastage.

This situation occurred due to the lack of clear definition of responsibilities and authorities of the two organisations. It is notable that although there is a specific procedure of undertaking any development scheme under public funding (with the inter-departmental understanding of a particular project being essential), it is most often being ignored by the relevant agencies. In this case, although BPDB built its transmission line earlier, REB did not consult with BPDB while preparing and implementing its transmission line development project. It is opined that internal conflict between two organisations is also a reason for this situation.

Similar evidence can be seen in the repair and maintenance activities of transmission lines, where more than one organizations are involved in the same job. Indeed, the lack of or weak coordination has made the management even more inefficient.

Lack of cooperation among the institutions and organisations is also a problem for Bangladesh. According to our survey, 65% of higher officials stated that they did not cooperate or were reluctant to cooperate with the relevant organisations in performing their tasks, as they did not want others to see that somebody might do a better job.

However, the most vital problem of the energy production and distribution system in Bangladesh is the limited capacity in production and distribution. It is opined that the main reason of limited capacity of production and distribution of power is the shortage of investment capital.

Location of power plants is another reason for the inefficiency of the energy sector. In the year 2000, the total number of power plants was 18 (10 use natural gas as a raw material to generate electricity, and 8 use diesel). Category-related locations of the plants is presented in Map 4.7.1. It can be seen that all gas power plants are located in the Eastern belt of the country, while diesel-based plants are situated in the Western zone.

This can be explained by the location of the gas fields in the Eastern zone: establishing power industry close to raw materials is cost-effective. However, that argument might become questionable when justifying the location of a gas power plant near Dhaka, with no gas wells in that district.

A similar situation is observed in finding the location for diesel plants in the Northern or Western zones. It would be cost-effective to build plants close to the bulk diesel unloading port or oil tankers such as Baghabari oil depot. Indeed, the choice of the location for power plants has been influenced by political interests rather than by the national interests as a whole. Ali (1993) has found similar situation with locating fertiliser plants.

Furthermore, in 1995, the power production capacity of Bangladesh from 18 power plants was 19.4PJ (19.4%) against the estimated energy demand of 682.9PJ for that year. The electricity produced at that period, constituted 3.3PJ (0.40%) (GOB, Power Cell 1997). It shows that electricity is a small component of energy supply in Bangladesh. Furthermore, interviews with power management officials have demonstrated that some power plants have suffered serious maintenance problems.

For example, Ghorashal Power Plant has been waiting for its burner to be repaired since 1997. Due to this, the production capacity of this plant has dropped from 80% (normal time) to 27%. Similarly, Bheramara Power Plant stopped its operation in July 2000 due to absence of spare parts (ref. Field Survey).

Maintenance problems have become so severe in Bangladesh that at certain points in time more than 67% power plants (13 out of 18) had to either shut down or cut their production target (The Daily Ittefaq 28 July 2001, The Daily Prothom Alo 27 July 2001).

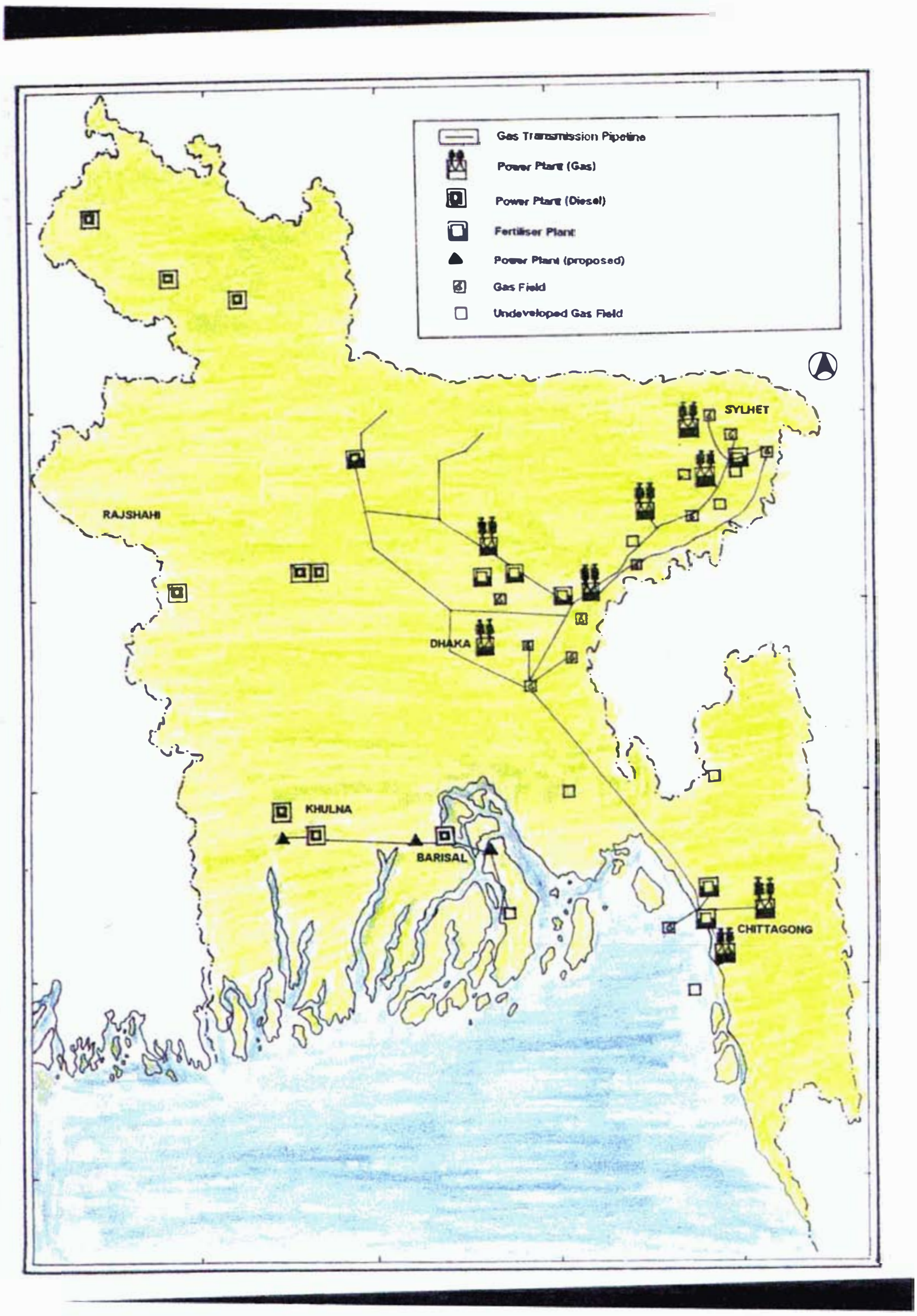
Regarding the investment for repairs and maintenance of power plants, it has been observed that foreign investors are more interested in building new plants than upgrading or rehabilitating the old ones. It has also been observed that the authority is also keen to invest in new plants at new locations.

Establishing a power generator takes 2 to 3 years (sometimes more) to complete all formalities, including negotiations with donors. So, there is no need to make payments immediately after announcing a new plant. Therefore, it is easier for political leaders to commit a new plant in a new location to serve their political interests. Interestingly, once the commitment is made, the plant had to be built (in most cases) due to the popular demand, irrespective of whether the then political leader is still in power or not. This situation has contributed to building a number of power plants in inappropriate locations of Bangladesh.

Lack of training and learning facilities, and obsolete technology is another problem in the energy sector of Bangladesh. For example, until 1995, power sector employed a total of about 10,000 staff, of which 40% were technical staff. Out of these 40%, on average only two or three employees a year had an opportunity to get higher education either at home or abroad (GOB, ME, 1991). Furthermore, as some of the staff were appointed without proper recruitment procedures (by nepotism), their qualifications and performance are questionable (Sirajuddin 1988), requiring further essential training. Obsolete machinery and equipment present a serious barrier for the energy sector of Bangladesh in achieving its desired goals.

Hence, it is clear that although a large number of organisations are involved in energy production and distribution system in Bangladesh, they have been suffering severe weaknesses such as lack of coordination, cooperation, training, shortage of capital, technological obsolescence etc.

Map 4.7.1 Category Wise Location of Power Plants in Bangladesh



4.8 Non-Renewable Energy Resources in Bangladesh

It has been mentioned earlier that Bangladesh is not rich in energy resources. This study has found two types of energy resources (natural gas and coal) discovered in the country. The discovery of natural gas has played a vital role in the energy sector, and positively influenced economy on the whole. Therefore, any policy-related analysis of the energy sector of Bangladesh needs an in-depth analysis of the gas sector.

Coal has not yet been explored due to technical and economic reasons. Hence, although this study is aimed at analysing rural energy, it is looking at gas as a sustainable source of energy supply in the rural Bangladesh. In this context, it is also worth discussing the potential for oil and electricity supply for the rural population.

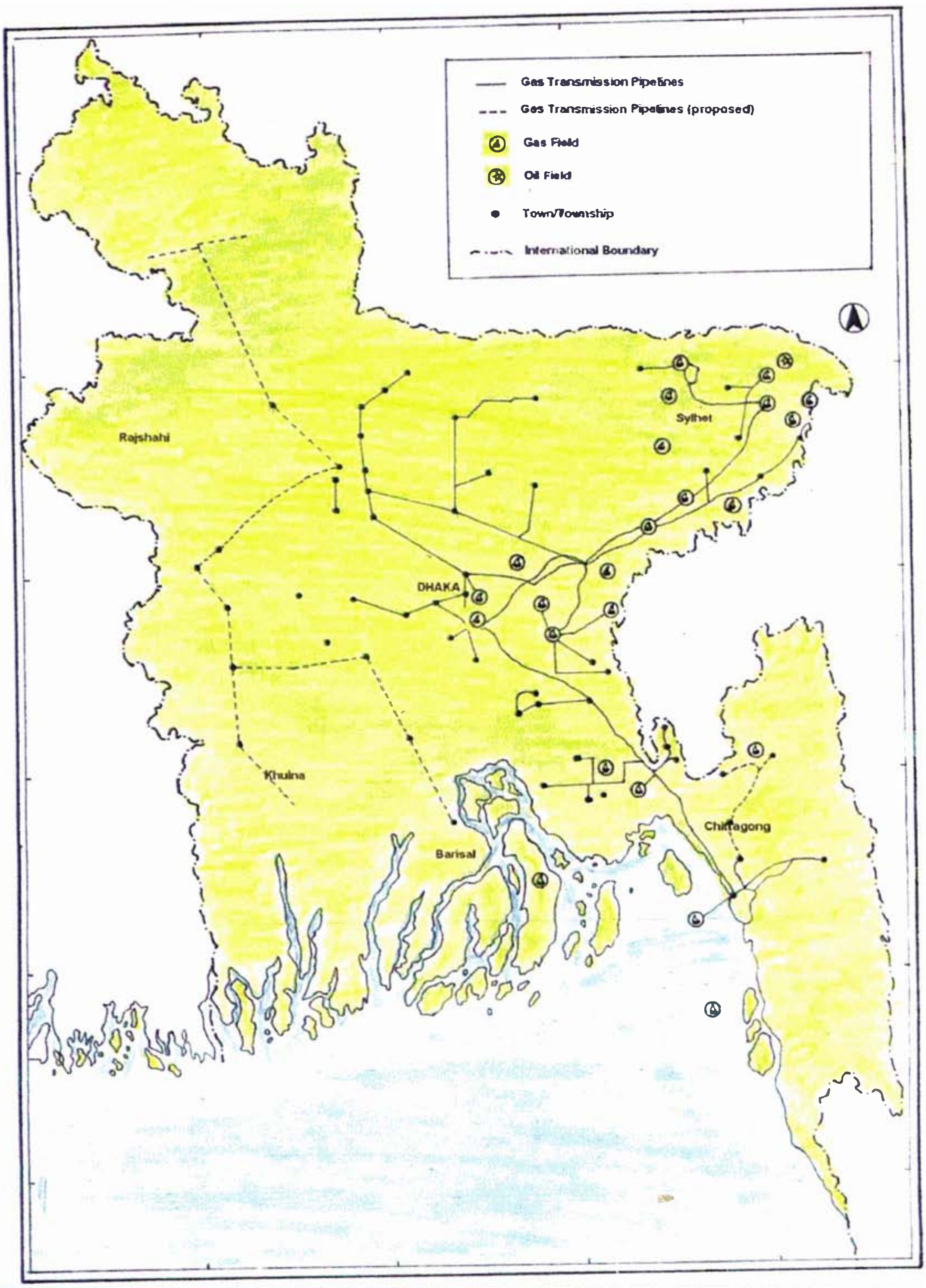
4.8.1 Natural Gas

The discussion in this section is focused on gas exploration, activities in the gas sub-sector, gas reserves, consumption trends, and options for future exploration and development of natural gas resources in near future. The location of gas wells and existing and proposed gas pipelines in Bangladesh are presented in Map 4.8.1.

Natural gas is an endogenous hydrocarbon resource and a predominant fuel for power generation. Government of Bangladesh (GOB), Petrobangla and International Oil Companies (IOC) dominate oil and gas exploration in Bangladesh. GOB and Petrobangla (nationalised sector) jointly serve as the regulatory body, whereas IOCs only produce gas.

The contractual framework under which these two entities operate is known as Production Sharing Contract (PSC) that gives private sector the provision to produce and market natural gas domestically, under a profit split of 60/40 after cost recovery. Presently Bangladesh is divided into 21 blocks (15 onshore, 6 offshore) for PSC to involve IOCs. Gas blocks are mostly concentrated in the eastern part of the country (Ali 1993, Khan 1991).

Map 4.8.1 Location of Gas Wells, Existing, and Proposed Pipelines in Bangladesh



During the early Seventies', 7 blocks were awarded to 6 IOCs. Now there are 8 blocks under contract with 4 IOCs (Unocal, Shell, Okland, and UMC). However, the politico-economic situation in Bangladesh has created a controversy in reserve estimation and parameters of demand estimation, in setting assumptions for gas demand forecast and actual long-term gas utilization. Therefore, in this context there is a paramount need for a correct assessment of gas reserves and future demand.

4.8.1.1. Gas Resource Classification and Reserve Estimation

The resource base of gas in Bangladesh can be divided into 3 main categories: discovered field, field growth, and new field discoveries.

Field Discoveries

At present, Bangladesh has 21 discovered gas fields of various sizes. Of these, the latest discovery in Bibiyana is still under appraisal, but is expected to be a major field. The other 20 gas fields have a total Gas Initially In Place (GIIP) of about 25 Trillion Cubic Feet (tcf). Of these 20 gas fields, 4 major fields in Kailashtila, Rashidpur, Habigang, and Titas contain 13.7tcf or 55% of the total GIIP. Detailed background information of discovered gas fields is presented in Table 4.8.1.

Mid-Term Gas Projection of Petrobangla presents rather a conservative estimate of these reserves. Under their estimates, the total recoverable reserve is 9.030tcf, of which previously estimated reserve of Habigang and Rashidpur is expected to downscale. Due to excessive water and sand production in the Bakhrabad field, it has produced only 39% of GIIP. Petrobangla thinks that reserve potentials of these fields need to be reassessed, and the new estimate would reflect even smaller reserves of gas in Bangladesh (Personal Communication with Sk Sirajuddin, Joint Chief, Planning Commission, also Petrobangla Annual Report 1998).

Table 4.8.1: Information of Discovered Gas Fields

Name of field	*Year of discovery*	*Company*	*GIIP (tcf)*	*Recoverable reserve (tcf)*	*Remaining recoverable reserve*
Gas fields currently in production					
1. Bakhrabad	1969	PSOC	1.432	0.867	0.307
2. Habigang	1963	PSOC	3.669	1.895	1.208
3. Jalalabad	1989	Scimitar	1.500	0.900	0.900
4. Kailashtila	1962	PSOC	3.657	2.529	2.360
5. Mehna	1990	Petrobangla	0.159	0.104	0.094
6. Narshingdi	1990	Petrobangla	0.194	0.126	0.091
7. Rashidpur	1960	PSOC	2.242	1.309	1.170
8. Saldanadi	1996	BAPEX	0.200	0.140	0.136
9. Sangu	1996	Cairn	1.031	0.848	0.836
10. Sylhet	1955	PPL	0.444	0.266	0.104
11. Titas	1962	PSOC	4.132	2.100	0.533
Sub-Total					**7.739**
Gas fields not yet developed					
1. Beanibazar	1981	Petrobangla	0.243	0.167	0.167
2. Begumgonj	1977	Petrobangla	0.025	0.015	0.015
3. Bibiyana	1998	Oxydental	U/A		
4. Fenchugang	1988	Petrobangla	0.350	0.210	0.210
5. Kutubdia	1977	Union	0.780	0.468	0.468
6. Semutang	1969	OGDC	0.164	0.098	0.098
7. Shahbazpur	1996	BAPEX	0.514	0.333	0.333
Sub-Total					**1.291**
Grand Total					**9.030**
Gas fields abandoned depleted/suspended after production					
1. Chhattak	1959	PPL	1.900	1.140	1.114
2. Kamta	1981	Petrobangla	0.325	0.195	0.174
3. Feni	1981	Petrobangla	0.132	0.080	0.041
Total Suspended			**2.357**	**1.415**	**1.329**

Source: GOB, Planning Commission (2001).

Field Growth

Field growth includes probable reserves due to the application of new technologies to the existing fields after evaluating risk/success ratio for Bangladesh. So far, Unocal claims 12.9tcf of probable reserves, whereas Shell's estimation is 9.38tcf against Petrobangla assessment of 9.030tcf of gas. The main technology drivers are thin-bedding pay analysis, 3D-seismic analysis, reservoir management, and compression. IOC claims that the new technology would reduce uncertainty, justify better estimation, and improve ability to extract.

New Field Discoveries

The Hydrocarbon Resource Assessment used by IOC is based on a probability approach (using Monte Carlo simulation), integrating the uncertainty and risks inherent in the potential reserve ranges due to sparse technical knowledge database. The mean or average estimation is 13.2tcf.

4.8.1.2 Differences in Opinions on Gas Reserve Records

It is assumed that Bangladesh has substantial gas reserves (12-80tcf). No scientific reserve data estimating actual recoverable gas has been collected since 1993. In the absence of proven data on gas reserves, some of the studies may seem superfluous. IOC thinks that the estimation of the unidentified potential is extremely important in assessing the entire national risked resource base.

A major part of the resources is yet to be discovered, and ignoring its potential will lead to sub-optimal planning. Unocal expects gas reserves of Bangladesh to be in the range of34.3-51.6tcf, of which technical estimate of the reserve quantity is 42.5tcf. Official information on gas reserves in Bangladesh is presented in Table 4.8.1.2.

Table 4.8.1.2: Announced Gas Reserves in Bangladesh

Announced Gas Reserves	(Trillion Cubic Feet)
Known discovered	21.0
Proven recoverable	12.6
Less already used	-3.0
Plus newly discovered	5.5
Total recoverable	**15.1**

Source: Field Survey

Bangladesh has discovered about 21tcf of gas, of which 12.6tcf is proven recoverable, i.e. could be extracted and used for domestic benefit. About 3tcf of the above gas has already been consumed. However, another 5-6tcf of gas are expected to be produced by Unocal from the Bibiyana field, amounting a total of 15tcf of gas as recoverable reserve. This reserve is expected to last for 45 years at present consumption rate, but might last for about 17 years if annual consumption growth rate becomes 10% (Aziz 1999).

4.8.1.3 Projection of Gas Demand

The data necessary to assess the current scenario of gas demand and supply, are mostly collected on the basis of historical demand, current production capacity of different fields and their technical linkages, and mid-term demand projection performed by Petrobangla. Data have also been collected through interviewing mid- and top-level management by using a semi-structured questionnaire. During the interview, the management was assured that the collected information would only be used for this research.

In Bangladesh, gas is used in industrial, commercial, and domestic activities. In industry, it is used for producing fertiliser and fuel. In commerce and households, it is used for cooking and heating. Projections have been made in accordance with National Energy Policy (NEP) and Power System Master Pan (PSMP) as the basis for demand forecast of power sector.

The fertiliser sector demand growth forecast is calculated on the saturation threshold of fertiliser plants across the country, based on the Bangladesh Chemical Industries Corporation (BCIC) surveys. Industrial gas demand projection identifies major gas users (direct users only) under the classification of Census of Manufacturing Industries (CMI).

Minor adjustments are based on the economic input-output table of goods constructed by Bangladesh Institute of Development Studies (BIDS), to exclude the intermediate users. Commercial and domestic sectors' future demand estimates were taken from the Bangladesh Statistical Yearbook (the total number of subscribers and approximate monthly usage of gas).

4.8.1.4 Projection of Gas Supply

Natural gas supply scenario has been constructed on the basis of existing fields number, and their production and transmission capacity. Supply situation during summer peak of the year 2000 is taken from BPDB as a reference. The IOC field reserves have been taken from their internal sources on the proven gas reserves in Bangladesh. Differentials have been made in terms of gas initially in place, recoverable reserves, and proven reserves, in order to assess cumulative production.

Gas supply is regulated by three factors: forecast of gas field production capacity, life cycle of reserves, and demand.

The demand and supply analysis accelerates growth in various sectors reliant on gas. Long-range forecast until 2005 made by different regulatory bodies or operating entities has also been discussed for better understanding and predicting the future demand scenario for gas supply, as the supply capacity depends on the existing fields' production capacity and future development plans.

The current peak gas supply capacity from the 12 producing fields (with a total of 44 wells drilled so far) is 1,077mmcfd as shown in Table 4.8.1.4. Note that it is limited by the well-head capacity of the Petrobangla fields and limited gas infrastructure. Capacity could be increased with more efficient high-tech operation management.

Table 4.8.1.4: Gas Production Capacity of Bangladesh as of 2000

Gas Field	*No of Wells*	*Capacity (tcf)*
Titas	11	300
Habigang	7	195
Narshindi	1	21
Bakhrabad	4	30
Mehna	1	20
Salda	1	15
Sylhet	1	6
Kailastila	4	110
Rashidpur	4	85
Beani Bazar	2	35
Sangu	4	160
Jalalabad	4	100
Total	**44**	**1077**

Source: Petrobangla 1999

4.8.1.5 Existing Gas Pipelines

Gas Transmission Company Ltd (GTCL) was created to enhance gas transmission activities in support of the formation of National Gas Grid in Bangladesh. GTCL is currently responsible for establishing the high-pressure gas and condensate pipeline. Information on existing and proposed gas pipelines is presented in Map 4.8.1.

4.8.1.6 Projection of Gas Production Capacity in Bangladesh

In order to eliminate the shortages of supply, 10 production wells with a capacity of 300mmcfd have been planned, along with processing and transmission. A mid-term supply projection of Petrobangla shows that production capacity would increase to 1300 mmcfd, and remain static until 2005. This projection shows strong dominance of PSC over private sector. The production forecast is presented in Table 4.8.1.6 and Figure 4.8.1.1.

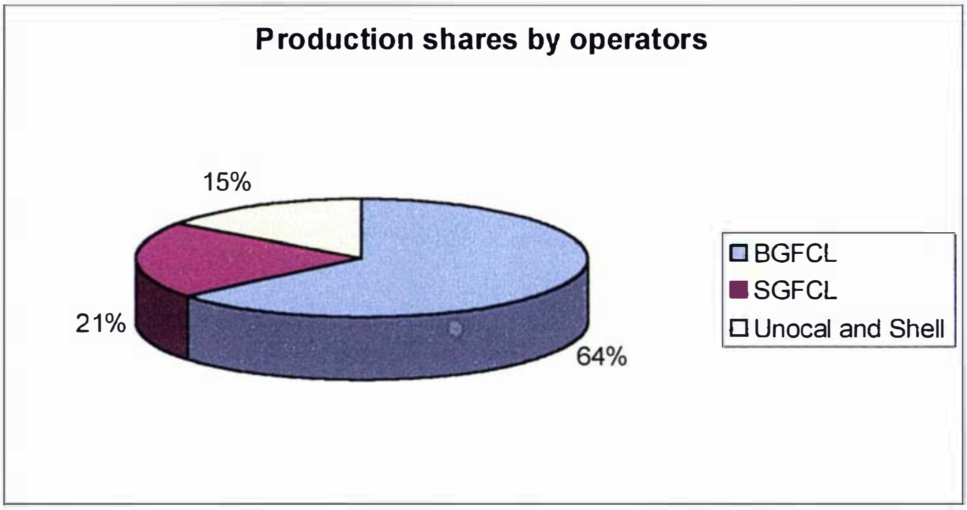
Table 4.8.1.6: Production Forecast Till 2005 of Gas Fields

Gas Fields	*Wells*	*1999-00*	*2000-01*	*2001-02*	*2002-03*	*2003-04*	*2004-05*
Public Sector							
Titas	14	390	390	390	390	390	390
Bakhrabad	5	45	40	35	35	30	30
Habiganj	10	280	280	280	280	280	280
Narshingdi	1	20	20	20	20	20	20
Meghna	1	20	20	20	20	15	15
Saldanadi	2	25	22	20	20	18	18
Sylhet	1	6	6	6	6	6	6
Kailastila	4	110	110	110	110	110	110
Rashidpur	7	150	150	150	150	150	150
Beanbazar	2	35	35	35	35	35	35
SubTotal	**14**	**1081**	**1073**	**1066**	**1066**	**1054**	**1054**
Private Sector							
Cairn: Sangu	5	130	130	130	130	130	130
Oxy: Jalalabad	4	100	100	100	100	100	100
Subtotal	**9**	**230**	**230**	**230**	**230**	**230**	**230**
Total	**56**	**1311**	**1303**	**1296**	**1296**	**1284**	**1284**

Source: Petrobangla 1999; Haque 2000; Aziz 1999

As shown in the table, BGFCL operates 6 fields producing approximately 64%, and SGFCL operates 4 fields producing close to 21% of total gas production in Bangladesh. Other than the public sector, Unocal and Shell produce approximately 15% of country's natural gas.

Figure 4.8.1.1: Gas Production Shares by Operators



Source: different published materials

4.8.1.7 Would Natural Gas be a Sustainable Source of Energy for Rural Bangladesh?

At the beginning of this section it has been mentioned that considering the reserve volume and the present demand, it is necessary to assess whether natural gas can be a sustainable source of energy supply for the rural Bangladesh. In this regard, we have analysed several issues. First, the volume of gas discovered so far is limited, and would one day be exhausted. Second, although the use of gas is less harmful for environment than that of coal or oil, it is not totally free from GHG emission. Third, based on a 10% annual growth rate, it has been projected that there is enough supply of gas for the next 17 years (on the upper side).

Until 2000, gas has been distributed only in the capital city, and the gas demand has been estimated based on current gas users. Also, until 2000 the country had a pipeline covering only 2.2% of the urban households (ADB 2000). Moreover, the extraction, distribution, and searching of new wells are entirely dependent on foreign aid (and foreign countries).

Finally, all gas wells are located in the Eastern zone of Bangladesh, which makes it geographically difficult to construct distribution pipes to the other parts of the country, particularly in the Western zone. It implies that considering economic ability, technical capability, and practicability, it would be easy to say that gas supply would hardly be a sustainable source of energy for the rural population in the near future.

4.8.2 Coal

4.8.2.1 Coal Use

At present, Bangladesh imports coal, but the import volume has been gradually decreasing. Coal is used almost exclusively in brickworks, having been displaced by oil or gas in nearly all other end uses. Present indications are that mainly as a result of import problems, coal use is diminishing, being displaced by gas or firewood, and possibly—to some extent—by coal washed into Bangladesh by rivers. Coal imports have declined in recent years—from 240,000 tons in 1980/81 to 130,000 tons in 1982/83, and to 47,000 tons in 1993/94 (BBS 1997). In terms of energy, it was

6.48PJ in 1980/81, 3.51PJ in 1982/83, and 1.27PJ in 1993/94, respectively. On the other hand, the use of gas has increased from 4,350 mcm in 1994/95 to 5,902 mcm in 1998/99 (BBS 1999, p.222).

The importance of coal could increase in future. As domestic gas reserves become depleted, coal may emerge as an important fuel, particularly for power stations and large industries. It could be imported or come from known but unexplored indigenous reserves in Jamalgonj and Dinajpur.

4.8.2.2 Jamalgonj Coal

Geological Survey of Bangladesh (GSB 1991, Part I for Jamalgonj and Part II for Dinajpur) has studied the economic and technical feasibility of developing Jamalgonj and Dinajpur coal resources. The main conclusions of that study are summarised below.

a) It is believed that coal reserves at Jamalgonj occupy a total area of approximately 18.75sq.km, in 7 seams at depth of 640m-1050m, with a total thickness of around 65m. The coal occurs at a depth more than 900m.

b) The exploration data available to date are inadequate for justifying very large capital expenditures on a mine development without further test drilling, and associated technical and economic studies.

c) The risk factors and uncertainties associated with a mine development are numerous, since the resource is located in completely virgin ground, in an area with no previous experience of coal mining.

d) A summary of a typical coal seam section at Jamalgonj is presented in Table 4.8.2.1.

Table 4.8.2.1: Summary of a Typical Seam Section of Jamalgonj Coal Reserve

Coal Seam	Depth of Roof of Seam (m)	Seam Thickness (m)
I	904	2.1
II	924	6.7
III	978	25.3
IV	1038	12.2
V	1074	10.1
VI	1134	8.8
VII	1154	25.3

Source: GSB 1991 (Part I & II), also Robertson Research International 1976

According to GSB, a full economic appraisal of the Jamalgonj coal reserve cannot be undertaken until a further in-depth technical study by expatriates. However, the study has made some tentative and approximate costing of future development.

It is worth emphasising that these costs should only be treated as indicative, be used for guidance purposes only, and could be subject to large variations in light of further exploration information. The cost estimates for three levels of output indicate that Jamalgonj coal would cost over US $150 per ton (GSB 1991). This is considerably higher than the cost of imported coal.

This situation implies that without further technical investigation it is hard to comment on the viability of extracting coal from this mine. Until 2000 no action has been undertaken to explore the feasibility of this extraction (GOB, ADP 1999/2000, ADP 2000/2001).

4.8.2.3 Dinajpur Coal

In Dinajpur, the deposit of coal seems to be significant, though until 2000 it has not been possible to announce its exact volume. However, the Geological Survey of Bangladesh has announced that two substantial seams of high-quality coal have been found in the village of Baropukuria near Dinajpur in the North-West of the country. Seam I is about 10m thick, and occurs at a depth of 160m. Seam II is about 40m thick, and occurs at a depth of 330m.

GSB suggested that further exploratory drilling was needed to ascertain the extent and technical characteristics of the Dinajpur coal. If a substantial reserve of coal is confirmed at that site, the development costs would be considerably less than in Jamalgonj, where the coal seams are over 900m deep.

This study has found in field survey that Government of Bangladesh has been trying to reach an agreement with a Korean Drilling Company in exploring the reserve in Dinajpur. A relevant significant amount of money has been included in the development budget of the year 2000/2001 (ADP 2000/01) for finalising the agreement.

4.8.2.4 Peat Reserves

Historically peat has been used as fuel for domestic purposes and in small rural industries in many countries, although the advent of coal, oil, and natural gas has greatly reduced its use, because the former types of fuel are more convenient and cheap, particularly for industrial applications. Recent years have witnessed a revival of interest in peat stimulated by the oil price rises of the seventies. A number of peat-fuelled power stations have been built in Ireland, Finland, and the Soviet Union. Studies of peat utilisation are in progress in several countries, including Canada, Brunei, Senegal, Sweden, and the US. The world peat reserves are estimated to be around 100 billion TOE.

In Bangladesh, there are two regions (Faridpur and Khulna) with major peat deposits, with a total estimated reserve of about 133 million tons. A number of smaller deposits exists in other parts of Bangladesh. Total peat reserves in Bangladesh are estimated at around 600 million tons. Apart from some small-scale use for domestic purposes and a few brick factories, no significant use of peat reserves has so far been made. No recent study has been carried out on the feasibility of its commercial use, either.

However, according to Taskforce (1991), the peat of Bangladesh is of the sedimentary, plastic or pulpy type, not woody or fibrous. It is marsh or swamp peat as opposed to the raised or blanket bogs of northern countries, and has a much higher ash content. Exploitation of the peat is considered technically feasible, but requires the construction of embankments. The availability and suitability of impervious clay to build the embankments would need to be confirmed.

Moreover, pilot tests are required to ascertain how the peat could best be extracted, and assess any possible reliability problems associated with its large-scale production, transport, and delivery. However, the most important practical problem might be the high flood risk rate of the sites of two main peat reserves. In Bangladesh, no programme has been yet undertaken to ensure technical and economic feasibility of peat extraction.

4.8.2.5 Would Coal Be a Sustainable Source of Energy for the Rural Bangladesh?

It is seen from above discussion that the reserves of coal and peat are reasonably sufficient in Bangladesh, and a major portion of its energy demand can be met by these resources. Nevertheless, physical depth of coal layers, and other technical considerations do not support such suggestions.

Hence, although it seems that coal could be a better source of energy supply in the country, the exploration of coal would not be possible in Bangladesh due to the lack of capital and know-how. Moreover, the use of coal would not be environment-friendly. Therefore, coal would not be a sustainable source of energy for Bangladesh.

4.8.3 Electricity

In Bangladesh, electricity is produced from hydropower, natural gas, and furnace oil. In the financial year 1998/99, the total amount of electricity generated in Bangladesh was 13872KWh, of which 89% was produced from natural gas, 7.5% from hydropower, and the remaining 3.5% from furnace oil (BBS 1999, p.219, GOB, MF, Economic Review 2000 Chapter 3). There are 8 power generation facilities run by furnace oil, 10 power generation facilities run by natural gas, and only 1 hydropower generation plant in the country. Natural gas is supplied from domestic sources, but furnace oil is imported and used as raw material for producing electricity. It has been mentioned earlier that the production costs of electricity produced by furnaces are higher than the revenue earned.

For instance, the cost of a unit of furnace oil is Taka 74, while the electricity produced by that furnace oil is sold for Taka 54 only. Indeed, the electricity and all imported fuel are sold in Bangladesh at a heavily subsidised price. The location of power generators run by furnace oil and natural gas is presented in Map 4.7.1. Installed and production capacities of electricity from different sources in 1995-1999 are presented in Table 4.8.3.1.

Table 4.8.3.1: Installed and Production Capacity of Electricity in Bangladesh

Electricity	*1995/96*	*1996/97*	*1997/98*	*1998/99*
Installed Capacity (MW)	2908	2908	3091	3603
Maximum demand (MW)	2087	2114	2136	2449
Power Generated (10E6KWh)	11474	11858	12882	13872

Source: BBS 1999, p. 219

It can be seen from the table that the installed capacity of electricity production in Bangladesh was 2908MW in 1995/96, increased to 3603MW in 1998/99 (23.9%). In the same period, the demand for electricity has been increased by 37.2% (BBS 1999, p.219). It is notable that this demand has been estimated on the basis of the existing grid connection: if potential power connections were added at the level of the present demand, the gap between supply and demand would increase. The utilisation of installed capacity of power plants in Bangladesh varies from 60 to 80%, which is very low (Assaduzzaman 1998). One of the reasons is that the plants have been suffering from lack of maintenance and related management problems noted previously.

4.8.4 Hydropower

After natural gas, hydropower represents the second most abundant indigenous commercial energy source used in Bangladesh. Although production of electricity from hydro source has been decreased compared to that of natural gas, in 1991/92, out of 3,433GWh of electricity generated, about 850GWh (nearly 25%) was generated by 3 hydro-units at Kaptai (BPDB, Annual Report 1995). In total, prospective hydro sources are much more limited than those of the natural gas, and the recently published Power System Master Plan (PSMP) estimates that the annual limit of hydropower-generated energy is around 1500GWh.

Presently Kaptai has 2 units with the rated capacity of 40 and 50MW. In the mid-eighties, a programme was undertaken to build a second powerhouse, with two 50MW units, with provision for additional two units of 50MW each. Thus the planned capacity of Kaptai would increase to 492MW. It is found, though, that even with the most favourable reservoir rule curve, the maximum additional energy would amount to 1,050GWh per year (ibid).

However, due to the environmental consequences of an increase in lake elevation disrupting the agricultural activities on the shore, and the possibility of the lake extend into Assam (India), the plan to increase the lake elevation has not been implemented. Furthermore, although there are 230 rivers in the country, due to their characteristics and water current, the prospect of hydropower generation is strictly limited in Bangladesh.

4.8.5 Oil

We have mentioned earlier that neither oil reserves nor commercial accumulations of oil have so far been discovered in Bangladesh, despite the existence of considerable quantities of natural gas. There is no satisfactory explanation for this, as oil is usually found in comparable deltaic formations. It seems unlikely that the source rocks would have only gas-generating capacity, and it is considered that an increased exploration effort, especially in the delta area, might lead to the discovery of oil. It must nevertheless be reasonable to expect that there is a much greater chance of finding additional reserves of non-associated gas than of oil.

In meeting its oil demands, Bangladesh depends entirely on imported oil. Bangladesh imports two types of oil: crude oil and petroleum product. The large sectors of oil consumption in Bangladesh are transport, industry, and electricity generators. The volume of imported oil is annually increasing, mainly because of the tremendous growth of the transport sector. The amount of imported crude and petroleum oil in 1994-1997 is presented in Table 4.8.5.1.

Table 4.8.5.1: Volume of Oil Import (in thousand tons)

Year of Import	*1993-94*	*1994-95*	*1995-96*	*1996-97*
Crude Oil	1239	1364	1141	1343
Petroleum Product	951	1165	1466	1581
Total	**2190**	**2529**	**2607**	**2924**

Source: BBS 1999, p.227

It can be seen from the table that the quantity of oil import has been increasing every year, which ultimately affects the country's economy. Obviously, the present pattern of energy import-dependent economy might not be sustainable for an agro-based country like Bangladesh.

4.9 Renewable Energy Resources in Bangladesh

Renewable energy resources in Bangladesh include biomass, solar power, wind power, and hydropower. As the purpose of this study is to analyse the rural energy sector, and the rural population of Bangladesh is mostly dependent on renewable energy, details of renewable energy resources and their technological applications are illustrated in Chapter 5. The hydropower has already been discussed in the previous section. The aim of this section is to give a brief idea of the status of renewable resources, to clarify the situation in the energy sector of Bangladesh.

Among the renewable energy resources, biomass is the dominant source of energy in Bangladesh. Out of the total supply, about 70% energy comes from biomass, though that percentage has decreased in the last decade (ADB 2000; ADB 1994; Taskforce Report 1991). Studies show that 100% of the rural households and 70% of urban households use biomass for cooking (ADB 2000).

The major sources of biomass are crop residues, firewood, twigs, branches, leaves, and animal dung. Crop residues are used as fuel either directly or in a processed form. Among the biomass-processed fuels, charcoal, charcoal cake, biogas from animal dung, dung cake, and dung sticks are the most common in Bangladesh. Apart from energy shortages due to over-use of biomass, country is facing many environmental problems such as deforestation, rise of the sea level, and natural disasters like flood and river erosion.

Some governmental organisations and a few NGOs are trying to promote solar and wind power energy. The application and diffusion of these technologies are still premature, but from the geographical and climatic point of view, there is a great potential for these two energy sources.

Animal power has been another energy source for the rural population since ancient times. Like in other countries, in Bangladesh animals are used to replace or supplement the need for human energy in transportation and food production. However, although animal power is the main source of energy in agro-based economy of Bangladesh, this area of the rural energy sector has been seriously neglected so far.

It has been observed that low animal nutrition, inappropriate technology, and inefficient management of animals cause inefficiency of animal power. An example of using animal power in inefficient way (ploughing with weak unhealthy cows) is presented in Figure 4.9.1.

Figure 4.9.1: The Use of Unhealthy Cows for Preparing Land

Source: personal collection

4.10 Pattern of Energy Balance

We Illustrated in Chapter One that the demand for energy is growing fast in Bangladesh, and it is expected that, unless alternative is found, excess demand will be met almost entirely from imported fuel. That means, the dependency on fossil fuel is increasing in Bangladesh. At this circumstance, it is worth to look into the pattern of composition of energy supply sources in the country. Table 4.10.1 shows the overall energy balance for Bangladesh in 1994/95.

It is seen from the table that 36% of the total commercial energy demand is supplied from petroleum products, 10% from electric power (generated by using hydropower,

Table 4.10.1: Bangladesh overall energy balance (1994-95, thousand tons of oil-equivalent)

Item	Coal	Crude oil	Condensates	Petroleum products	Natural gas	Hydropower	Nuclear	Electricity	Total
Indigenous production		1.01	9.18		6456.51	124.47			6591.17
Flare and loss									
Imports		1390.88		1187.95					2578.83
Exports				(160.10)					(160.10)
Bankers				(36.71)					(36.71)
Stock exchange		23.45		45.89					69.34
Primary energy requirement		1415.34	9.18	1037.03	6456.51	124.47			9042.53
Statistical difference				16.32					16.32
Oil refining		(1415.34)	(9.18)	1399.03					(25.49)
Gas manufacture									
Power generation:									
Fuel consumed				(261.04)	(2804.73)				(3065.77)
Power generated						(124.47)		929.32	804.85
Transmission and distribution loss					(342.87)			(277.95)	(620.82)
Energy sector's own use and loss					(4.61)			(55.04)	(59.65)
Net supply available				2191.34	3304.30			596.33	6091.97
Net domestic consumption				2191.34	3304.30			596.33	6091.97
Residential				442.55	474.68			231.97	1148.40
Commerce / services					95.86			56.33	152.19
Industrial				153.97	634.13			245.88	1033.98
Transport				1162.46					1162.46
Agriculture / others				432.36				62.95	495.31
Non-energy use					2099.63				2099.63

Source: BBS (1999), *Compendium of Bangladesh Environment Statistics 1997.*

natural gas, and fossil fuel), and the rest comes from natural gas (see 'net supply' row of the table). The table quotes the use of fossil fuel, hydropower, coal, natural gas, and electricity for generating the overall commercial energy balance of Bangladesh.

However, studies on consumption pattern (ADB 1994, Islam 1983) have shown that in 1981, 73% of energy consumption in Bangladesh used to be met from biomass sources.

Biomass energy was mainly consumed for cooking purposes, but by 1995 the share of biomass consumption has dropped to 55% (ADB 2000) due to expansion of the rural electrification programme. Other reasons include increase in the opportunity costs of biomass due to its multi-use. In addition, as nearby forests have already been cleared, collection of biomass from distant forests becomes harder.

It is clear from the table that although more than two third of energy supply of the country comes from biomass source, the contribution of this source has not been reflected in the energy balance table. In other words, the issue of rural energy sector and its management has been ignored in the national energy policy and planning of Bangladesh.

4.11 Conclusion

It has already been mentioned that Bangladesh is one of the most densely populated countries in the world, with more than 800 people inhabiting a square kilometer (BBS 1999). With this low land-man ratio, the per capita energy consumption in Bangladesh is also very low, compared to that of the neighbouring developing countries.

However, in 1990-1998 the per capita commercial energy (excluding the rural informal source) consumption has rapidly increased by more than 175% (ADB 2000, p.34).

It appears from our previous discussions that Bangladesh has been suffering shortages of energy where the condition of the rural population is worse. Lack of coordination, cooperation, and accountability has largely contributed to the inefficiency of organisations and agencies involved in energy management. Corruption and shortage of capital are the major problems in the energy sector of Bangladesh.

Bangladesh has very limited commercial energy resources, with natural gas resources being the most prominent. Although the reserves of natural gas seem good, the lack of proper policy and inadequate financial capacity are diminishing the beneficial effects of gas for the rural population.

The country has reasonable amount of coal reserves, but the technical and economic feasibility of its use is questionable. It has no oil reserves. Indeed, in meeting its energy needs Bangladesh largely depends on imported fuel. Currently Bangladesh used to spend about two-third of its export earnings to pay energy import bill and this trend is growing fast.

Among the renewable energy sources, biomass is the dominant one in Bangladesh. The major sources of biomass are crop residues, firewood, twigs, branches, leaves and animal dung. The supply of biomass is decreasing. The consequences of energy shortage, the country is facing many environmental problems such as deforestation, floods, drought etc.

Large portion of the country's energy supply comes from biomass but the contribution of this sector has hardly been recognised. Moreover, although more than 80% population live in rural areas, issues related to the demand and supply of energy for the rural population has largely been ignored in the national energy policy and development planning.

According to FAO, it is being increasingly recognised that the core of the energy strategy for increasing farm productivity in the developing countries depends mainly on appropriate combination of human, animal, and mechanical power for specific situations within the country, including technical suitability, and economic and social objectives (Kristoferson and Bokalders 1987, p.115).

Based on the above discussion, it can be concluded that there is an excess demand for energy in Bangladesh, but its local supply is restricted to natural gas and coal, due to technical and economic reasons, with the resultant disadvantageous position of the rural population. Therefore, we need to explore the SET, especially the types of energy appropriate for the mass of the population in the rural areas where energy is most deficient, and poverty is most wide-spread. The following chapters are devoted to identifying the best possible SET for the rural Bangladesh.

Chapter 5

SET Options in The rural Bangladesh

5.1 Introduction

We have discussed in Chapter 4 that the energy sector of Bangladesh has been suffering multifarious problems, where the rural energy sector has been almost completely omitted from the national policy framework and development plans. Accordingly, it appears that the rural energy sector is unorganised, and people are largely dependent on nature in meeting their energy needs.

The aim of this chapter is to analyse the state of SET in the rural Bangladesh. In this context, attempt would be made to explain the pattern of financial expenditures incurred by the rural population in their energy consumption; pattern of energy demand and supply; and the availability of energy technologies in rural Bangladesh.

It is also aimed at illustrating SET in the context of the rural energy demands and supplies scenario. The focus of discussion would be on analysing the issues of balancing energy demand with supply, reasons for using particular energy source, and the potential and limitations of SET in the rural Bangladesh. Indeed, the illustrations contained in this chapter would provide the theoretical basis for introducing SET in the rural Bangladesh.

5.2 Pattern of Expenditures on Energy in the Rural Bangladesh

Table 5.2.1 provides the pattern of expenditures incurred by rural population of Bangladesh in meeting their energy needs. It can be seen from the table that 55.57% of rural households spend between 134-260 Taka a month on energy consumption (equivalent to US $2.62-5.10 a month, or US $31.44-61.2 per year per household, or 9-12% of household income). In terms of the sources of rural energy, Table 5.2.1 further suggests that firewood represents roughly 34% of their total energy expenditure, while energy from other sources (mostly biomass energy from leaves, cow dung, jute sticks etc.) provides nearly 44% of the total energy expenditure. The

Table 5.2.1: Energy Expenditure Pattern in Rural Bangladesh

Monthly household income groups (in Taka)		% of household	Average monthly expenditure on fuel and lighting per household	Percentage of monthly expenditure on fuel and lighting							
				Total	Fire-wood	Kerosine	Gas	Electricity	Coal/Charcoal etc.	Jute Stalk	Others
1		2	3	4	5	6	7	8	9	10	11
RURAL											
	< 750	1.94	65.88	0.63	21.70	15.78				3.31	59.21
750	999	2.47	90.05	1.09	23.73	17.19		0.18		2.65	56.20
1000	1249	4.69	98.97	2.27	20.93	15.87		0.70		3.73	58.77
1250	1499	6.99	123.77	3.62	24.12	15.95			0.56	3.53	55.83
1500	1999	14.05	134.15	9.21	25.21	17.48	0.01	0.75		3.45	53.10
2000	2499	14.42	165.17	11.64	30.60	16.95		0.99	0.52	4.40	46.55
2500	2999	12.34	183.20	11.05	32.41	16.99	0.04	2.24	0.31	4.68	43.33
3000	3999	16.98	212.33	17.62	36.65	19.77	0.08	3.70	0.20	4.04	38.55
4000	4999	10.12	260.78	12.90	40.54	15.46		5.43	0.38	3.91	34.28
5000	5999	5.93	283.14	8.21	38.38	15.78	0.15	7.18	0.24	4.10	34.16
6000	6999	3.51	313.48	5.39	38.11	15.55	0.13	7.64		5.39	33.18
7000	7999	2.37	357.33	4.14	39.40	15.34		9.78	0.49	3.92	31.07
8000	8999	1.44	399.32	2.81	38.04	17.14	0.02	8.82		4.32	31.65
9000	9999	1.01	449.30	2.21	45.47	14.31		9.03		3.95	27.22
10000	12499	1.34	476.34	3.12	38.35	13.37		21.85		1.01	25.41
12500	14999	0.57	553.44	1.54	34.71	14.97		6.60		14.37	29.35
15000	17499	0.20	960.15	0.93	30.60	7.88		50.61		0.79	10.12
17500	19999	0.24	524.33	0.62	38.70	10.05		13.47		1.30	36.48
20000 +		0.38	541.74	0.99	34.95	20.06		27.23		1.70	16.07
ALL GROUPS		**100.00**	**204.61**	**100.00**	**34.41**	**16.19**	**0.04**	**5.27**	**0.24**	**4.11**	**39.75**

Source: BBS, HES *1995-96* Table 2.17

rural population spend about 22% of their total energy expenditure on commercial purposes, with kerosene being the most important source of energy in this respect. The rural population mostly depend on free or relatively cheaper energy sources such as leaves, cow dung, twigs etc. In Chapter 7, this relationship has been analysed in detail.

It is evident that roughly 79% of the total energy in rural areas is used for cooking (also see GOB, Power Cell 1997, GOB BEPP 1985e, Vol. IV). Kerosene provides energy for lighting in most rural households (approximately 15% of the total energy demand). Demand for other energy in rural Bangladesh is surpassed since electricity is not yet readily available in rural areas.

It is evident from Table 5.2.1 that firewood and biomass energy are the major sources of energy in rural Bangladesh. The implications would be important in terms of overall deforestation rate in Bangladesh, which has very little of its forest left (tree coverage in Bangladesh is only around 6-7% of the total land, while 14% of the total land area in Bangladesh is designated as forest land) (GOB ME&F; Forestry Master Plan 1993). The annual rate of deforestation in Bangladesh is higher than the world average (0.58%, Kristoferson and Bokalders 1987, p.4).

The high rate of deforestation is not only contributing to the environmental damage but is also a threat to the livelihood of the rural population of Bangladesh. However, unless rural population has an alternative source of energy it would be hard to control deforestation.

It is notable that the rate of firewood use in Bangladesh (34% of total energy) is much higher than that in Asia (17%) and Latin America (8%) but lower than that in Africa (58%) (Kristoferson and Bokalders 1987, p.4), partly due to a positive correlation between income and the use of firewood in a particular household. A detail of relationship between income and firewood use is illustrated in Chapter 7.

In Bangladesh, per capita income is US $369 (BBS 1999, p.271), and there is no equitable distribution of wealth. According to a study conducted by Bangladesh Institute of Development Studies (1986), about 50% of the country's population live below poverty line, a large part of which inhabits in rural areas. Although there is a controversy regarding the definition and concept of poverty (illustrated in this study), it would not be wrong to say that rural households have limited access to the firewood market due to their limited purchasing power. It implies that there is a need to explore the sources of energy supply that would be within the economic ability of the rural population, and facilitate poverty alleviation

5.3 Pattern of Energy Supply and Demand in the Rural Bangladesh

We have discussed in the previous chapters that in Bangladesh, rural community has a very limited access to grid-supplied electricity (ADB 2000, p.34). The main sources of energy in rural Bangladesh are biomass, solar power, wind power, and animal stock. We will see whether these sources are sustainable for rural population.

5.3.1 Biomass

In rural communities, 100% households use biomass for cooking purposes (as compared to 70% of urban households). A large portion of available biomass comes from agricultural residues. Major sources of biomass are presented in Table 5.3.1. It is seen from the table that crop residues (46%) play a dominant role in providing energy in rural community. Homestead forests also represent an important source of biomass production (12.9%). Hossain (1995) has illustrated in detail the role of homestead forest and energy sources in the rural Bangladesh.

More than 70% of timber, firewood, and bamboo come from privately planted and managed forests (Forestry Sector Study Mid-Term Report, cited in ADB 2000, p.35). Of forest products, 65% is consumed as firewood. In rural Bangladesh, although firewood is collected daily, it is often too costly for the poor households to burn—instead they collect it for resale later, while using cow dung, slash wood, and dry leaves to meet their energy needs such as cooking, washing etc.

Table 5.3.1: Major Sources of Biomass in Rural Bangladesh

No	*Sources of Biomass*	*Percentage*
1	Crop residues	46
2	Livestock dung	10.5
3	Community and homestead forest	12.9
4	Government forest	3.3
5	Other, including food processing	27.3
Total		**100**

Source: ADB 2000, p.35

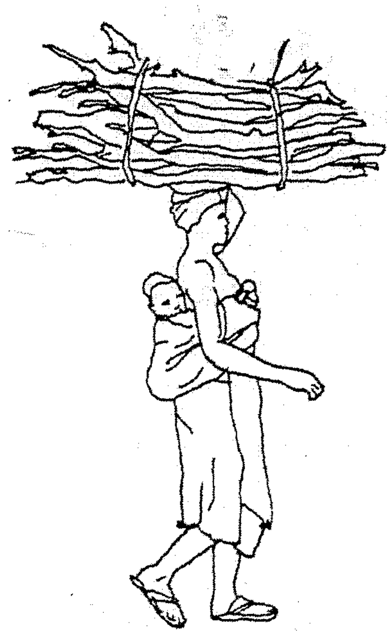
In rural societies, biomass is collected often by women or children. Poor people, on their way to and from work collect biomass (Kristoferson and Bokalders 1987). Children collect it in the daytime, instead of going to school. The field survey of this study has shown that fuel collection (due to lack of energy supply) is one of the main reasons of illiteracy in Bangladesh (also see Assaduzzaman 1998).

During the field visit, we have also observed that sometimes people collect and carry biomass to the distance of 10-20km. Moreover, they do it after completing their day labour. Figures 5.3.1 and 5.3.2 show the depth of necessity for energy for the rural population.

Biomass collection sometimes causes social problems and conflicts, especially when collection is performed by children. For example, a child left the already collected leaves in a pile, and entered the jungle to collect some more. After coming back with another batch, s/he noticed that the leaves left earlier has been stolen by an older/stronger man or another child.

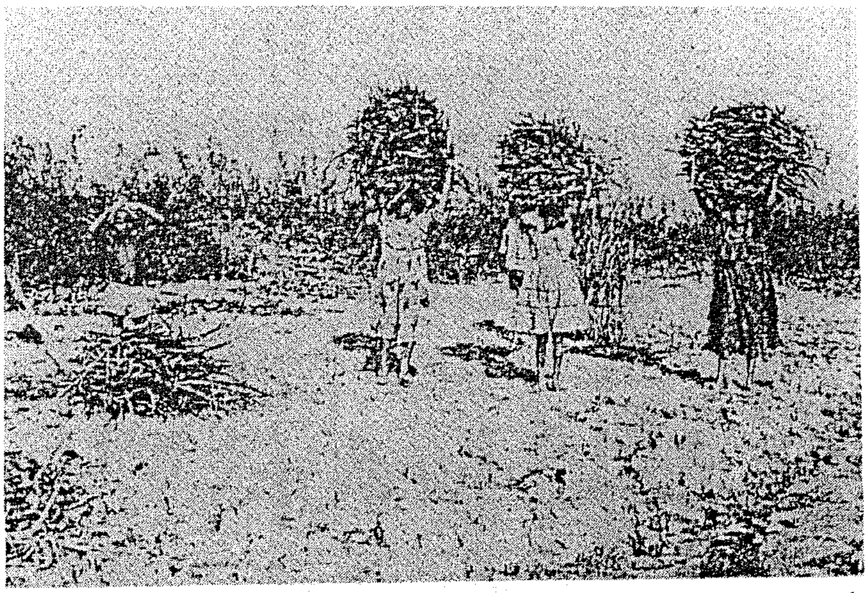
Furthermore, it has been observed in the field survey (PRA) that sometimes people, especially women and children, get assaulted by adult men or the owners of forests or jungle. Sometimes, they are even sexually assaulted or raped.

Figure 5.3.1: A Woman Carrying Firewood



Source: Kristoferson and Bokalders 1987.

Figure 5.3.1.2: Children Carrying Collected Biomass



Children collecting bio-mass for use as fuel in rural Bangladesh

Source: GOB, MEF, NEMAP 1995

The use of biomass depends on the type of technology and biomass used. For example, cooking in an open tri-pot clay-made stove, directly uses unprocessed crop residues, but requires processed firewood, i.e. dried and cut to size.

5.4 Available Renewable Energy Technologies in Bangladesh

This section illustrates the availability of renewable energy technologies in Bangladesh. Of the major sources of renewable energy technologies, biomass energy, solar energy, and wind energy are being used in Bangladesh either under pilot schemes or at individual or institutional levels[1].

According to one study[2], 71% of rural energy supply is used in cooking (mostly biomass), 2.2% in lighting (mostly kerosene), 17% in industries, except brick-making (mostly biomass), 0.3% in irrigation (diesel or electricity), 9.5% in fertilizer production (indirect use of gas). It is clear that biomass energy is the most dominant source of energy in rural Bangladesh, providing nearly 417.5PJ of annual 474.65PJ of energy in a year (1981 estimates).

5.4.1 Biomass Energy Technology

Biomass energy in Bangladesh includes agricultural residues, wood, leaves, and animal dung. On average, 12.5% of biomass energy comes from trees (woods and leaves), 62.5% from agricultural residues, and 25% from animal dung[3].

Most of the energy from these sources is used for cooking purposes (commercial or household).

In the rural Bangladesh, several processing techniques apply for using these residues (agriculture, tree, or animal) as fuel: charcoal (through briquetting), dung-cake, and dung-stick (through briquetting). The processing of charcoal and animal dung is common in all parts of Bangladesh.

[1] Aziz (1999)
[2] GOB BEPP 1985, P IV-2.25a
[3] ibid p.2.3a

5.4.1.1 Charcoal

Charcoal is the product of carbonisation of biomass fuel in the absence of air. This process is called pyrolysis. The raw biomass is heated in a kiln or retort. The volatile constituents of the biomass are emitted in the form of gas and organic liquid, mainly alcohol, oils, and acids.

The proportion of emitted and remaining products depends on time, temperature, pressure, type, distribution of air, and methods of operation. There are several recognised techniques available in the world. Nevertheless, the basic technology in making charcoal is kiln. In Bangladesh, earthen kiln (the cheaper one) has been used (Figure 5.4.1.1).

As the charcoal technology is convenient and not very complex, involving cheaper equipment for its gathering and use, historically it has become a popular fuel source in the developing countries including Bangladesh. Urban residents rely more on charcoal since it is more convenient, energy-dense, virtually smoke-free, and can be transported to urban areas relatively easily compared with firewood.

Fuel wood (due to its bulk) is more difficult and expensive to transport from distant plantations and open forests to urban areas, hence charcoal tends to dominate as urban fuel. Energy content of charcoal is about twice than that of air-dried wood.

However, three important issues are associated with using charcoal. First, the rural population more often uses leaves, twigs, branches, bush etc., which is collected from homestead, village forests, or outside large-scale planted forests. Nevertheless, charcoal-making requires the cutting of whole trees, which aggravates deforestation. Moreover, as the urban population of developing countries is increasing rapidly, unless alternative energy source is made available to them, the demand for charcoal will increase, thus causing more deforestation.

Second, charcoal is a wasteful fuel as compared to firewood, since conversion efficiency in terms of energy content rarely exceeds 25% when firewood is converted to charcoal in primitive earthen kilns used in Bangladesh. This type of kiln produces small amounts of charcoal at a time and needs more labour investment.

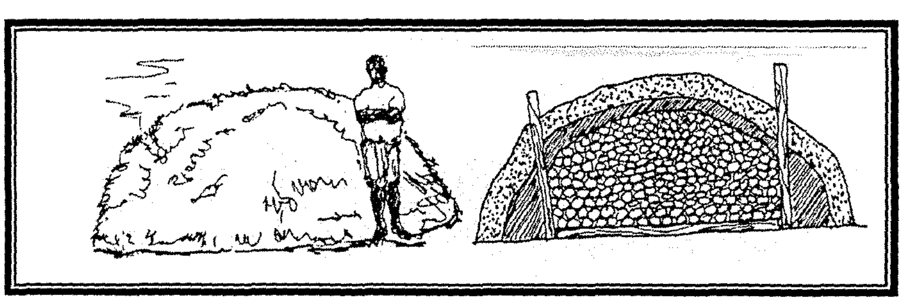
And third, the rural population uses open three-stone fireplaces in which the burning efficiency of charcoal is less than that of firewood. Burning efficiency in these fireplaces is 5% for charcoal, and 15% for normal firewood (Kristoferson and Bokalders 1987, p.52).

It is arguable that charcoal production might be a channel of resource mobilisation from rural to urban areas, and the rural population can benefit from this. The situation, though, is just the opposite: trees become more expensive for rural poor because most of them do not have their own forests or enough land to grow trees. In addition, marketing costs, including charcoal transportation, are higher than sales revenues. Moreover, shortages of capital are another factor to be considered for rural population.

The environmental impact of using charcoal as fuel is two-fold. On the one hand, charcoal production process needs heat, emits smoke and wood lots. Second, charcoal production causes a by-product, which requires careful handling. Thus, affordable charcoal production and use with the minimum disturbance to environment needs an in-depth technology-improving research, especially for the rural Bangladesh.

In Bangladesh, charcoal is used by blacksmiths and goldsmiths for metal and semi-metal works. It is also used for cooking and heating in some rural households. On a large scale, it is used as a fuel cement and steel-manufacturing agent.

Figure 5.4.1.1: Charcoal Production System in Rural Communities



Source: Kristoferson and Bokalders 1987

5.4.1.2 Charcoal Cake

The process of making charcoal-cake in Bangladesh is mostly used for recycling coal, and is relatively simple. Charcoal is smashed into grains, mixed with clay soil or rice husks, and then dried in the sun. Charcoal cake is a very cheap source of energy in rural Bangladesh, and is used in heating and in smoking huka[4]. Charcoal cake is mostly 'home-made', so only 0.04% of household energy expenditure is spent on this form of energy (Table 5.2.1).

It has been found during the field survey that rural people make charcoal cakes in dry season, and preserve it for use in the rainy season, when collection of biomass becomes difficult due to rain or flood, and the fact that biomass needs to be dried to remove its moisture content before use.

5.4.1.3 Animal Dung-Cake or Stick

Animal dung and crop residues are mixed to produce dung-cake or dung-stick, commonly used in rural households for cooking purposes. In rural Bangladesh, clashes over collection of dung are common due to the ownership issues. In absence of common pastureland, animals are allowed to graze in private croplands (after the harvest), and it is customary that the dung becomes property of the landowner who might prefer to use it as manure.

However, as more and more dung is used for cooking, livestock owners often collect it from their own livestocks. Consequently, land-owners often ban the cattle from grazing on their cropland. This situation is aggravated due to the price rise in chemical fertilizers. As a result, land-owners became more interested in using dung as a manure on their land.

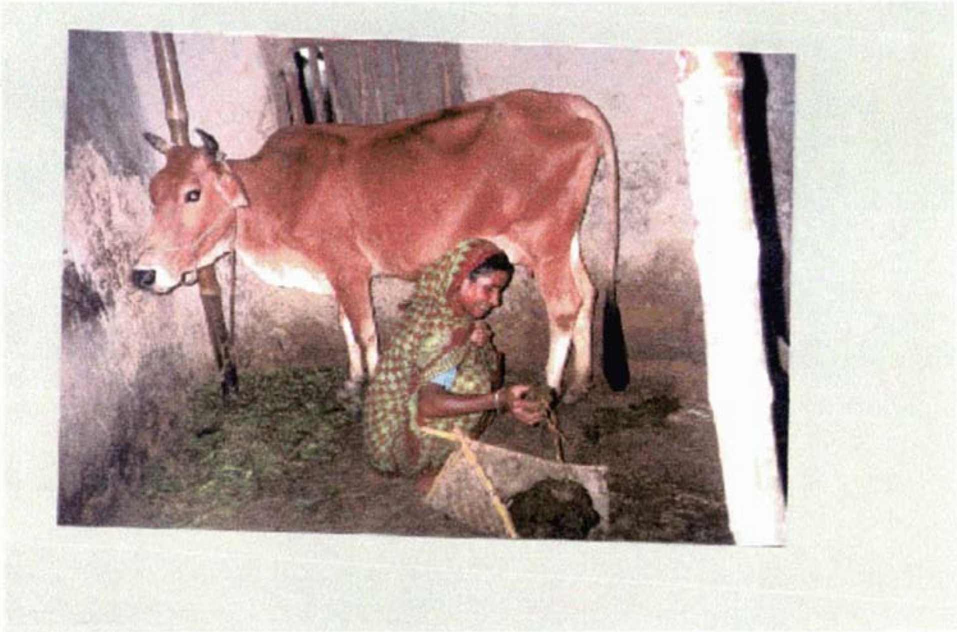
Three photographs of animal dung collection, and dung stick and cake making are presented in Figures 5.4.1.3a, 3b, and 3c respectively. These photographs have been taken in the sampled village Loxmikaola (Khulna division).

Dung cakes are usually processed and pasted on cottage walls or left the open air to dry in the sun. Drying usually takes 3-5 days to make it ready for burning. Drying

[4] A type of local smoking device, very traditional and popular in Bangladesh.

dung sticks takes a bit longer (about a week). Hygienic consideration and bad smell of dung can be a matter of concern, but rural women do not seem to be concerned about it.

Figure 5.4.1.3a: A Woman Collecting Cow Dung



Source: Field Survey

Figure 5.4.3.1.3b: A Woman Making Dung Sticks with Cow Dung and Jute Straws

Source: Field Survey

Figure 5.4.3.1.3c: A Woman Making Dung Cakes with Cow Dung

Source: Field Survey

It has been observed from relevant literature that most studies dealing with animal dung are concentrated on the use of dung in the form of biogas, but a very limited number of them address the issue of dung cake or sticks. Rural Industries Study Project (RISP) conducted by Bangladesh Institute of Development Studies (edited by Q.K.Ahmad BIDS 1981) identified that use of dung as an energy source in the form of cakes and sticks is very common in rural communities. The processed dung cake and sticks are convenient to use and can be stored easily. Indeed, the use of dung is a part of culture in rural Bangladesh.

However, the problems of using dung in the form of cake or sticks are two-fold: environmental and health-related. As dung cake is burnt in three-stone burners, it emits smoke. Moreover, its ignition requires a person to come very close to the fire (blow air from the mouth), which is likely to cause smoke, dust, and ashes get in to the eyes.

During PRA survey, it was found that a reasonable percentage of rural women were suffering from eye sight problems caused by the use of biomass (particularly crop residues, leaves, and dung) due to cooking in three-stone stoves or in open fires. Some public-sector organizations (e.g. BCSIR and BUET) have been working on the technological improvement of stoves since the mid-Eighties but with little effect.

The use of animal dung as a form of biogas is discussed further in this chapter.

5.4.1.4 Wood, Twigs, and Leaves

Wood, twigs, branches, and leaves are very common in rural Bangladesh. Studies have shown that richer households tend to use more wood, while poorer households mostly use twigs, trunks, and leaves (GOB, BEPP 1985e Vol.IV, p.3). Nearly 34% of energy expenditure of rural households is on firewood (a typical rural household monthly spends Taka 204 on energy, Table 5.2.1), 39%—on twigs, trunks, and leaves. It is mostly used for heating and cooking for commercial, industrial, and domestic purposes.

Since Bangladesh does not have much forestland (Map 5.1), the use of fuel wood in rural areas is blamed for rapid deforestation in many parts of the country. It is notable that the Northern part of the country (upper half of Map 5.1) has already been seriously affected by deforestation, though the land in Bangladesh is suitable for agriculture being either flood plain or delta land (Map 5.2). Therefore, potential for fuel wood production is very limited (BUP 1989; and also Pavallion and Sen 1994).

Map 5.1 clearly shows that forestland is almost non-existent. The only alternative is to use roadsides, flood embankments, and homestead areas for fuel wood production. The scope for this is also very limited given the alternative opportunities to use land in a densely populated country like Bangladesh.

For example, roadsides and flood embankments are now being leased out to the rural population (in-groups) under the 'social forestry' programme. Under some conditions, they can now use roadside land and the embankments to grow trees of their choice, and in return share the value of crops/woods with the Department of Forest. However, as there is a need to wait a period in order to get the return from planting fuel trees, and no incentive in the form of cash or immediate return from the promoters, in most cases, the road sides and embankments are being used to grow fruit and wood trees rather than grow trees for fuel wood production.

In addition, as about 50% of the rural population in Bangladesh live in poverty (35% live under absolute poverty level, BBS 1999), food production is more important to them than planting long-term trees. Further, the projects undertaken by the government and some multinational companies (e.g. British American Tobacco Company) are also inclined towards producing cash crop so that the country can repay the huge amount of foreign debt. This policy leads to discouraging biomass production, thus affecting landless population.

However, there is one more point worth mentioning here. In Bangladesh, there are 66,235 primary schools, 13,419 secondary schools, 10,259 colleges/madrasas, 93 professional training institutions, and 29 universities (BBS 1999, pp 340-344). All these educational institutions directly or indirectly receive financial assistance from the government. We have found in the field survey that the government can manage financial grants by introducing a precondition of planting trees on the premises of these institutions. In addition, there are more than 33,000 NGOs in Bangladesh, and most of them receive (directly or indirectly) foreign aid. The government can also intervene in channeling foreign aid provided to the NGOs towards planting trees. It is believed that if each institution/organisation plants 100 trees each year, it would result in more than 12 million trees every year. Some other incentives (e.g. tax exemption) can also be used to motivate growing more trees in fallow lands, riverbanks, premises etc.

5.4.1.5 Crop Residues

Agricultural residues may be used as building material, fuel, industrial raw materials etc. BEPP has estimated end-use coefficient of crop residues, which is shown in Table 5.4.1.5. It is clear that, except husk, most other crop residues have more than one use and as such, have opportunity costs. Crop residues such as straw and bran are also used as fodder in many parts of Bangladesh, and are available in the market. Of all the varieties of crop residues, only husk has no other alternative use in the rural Bangladesh.

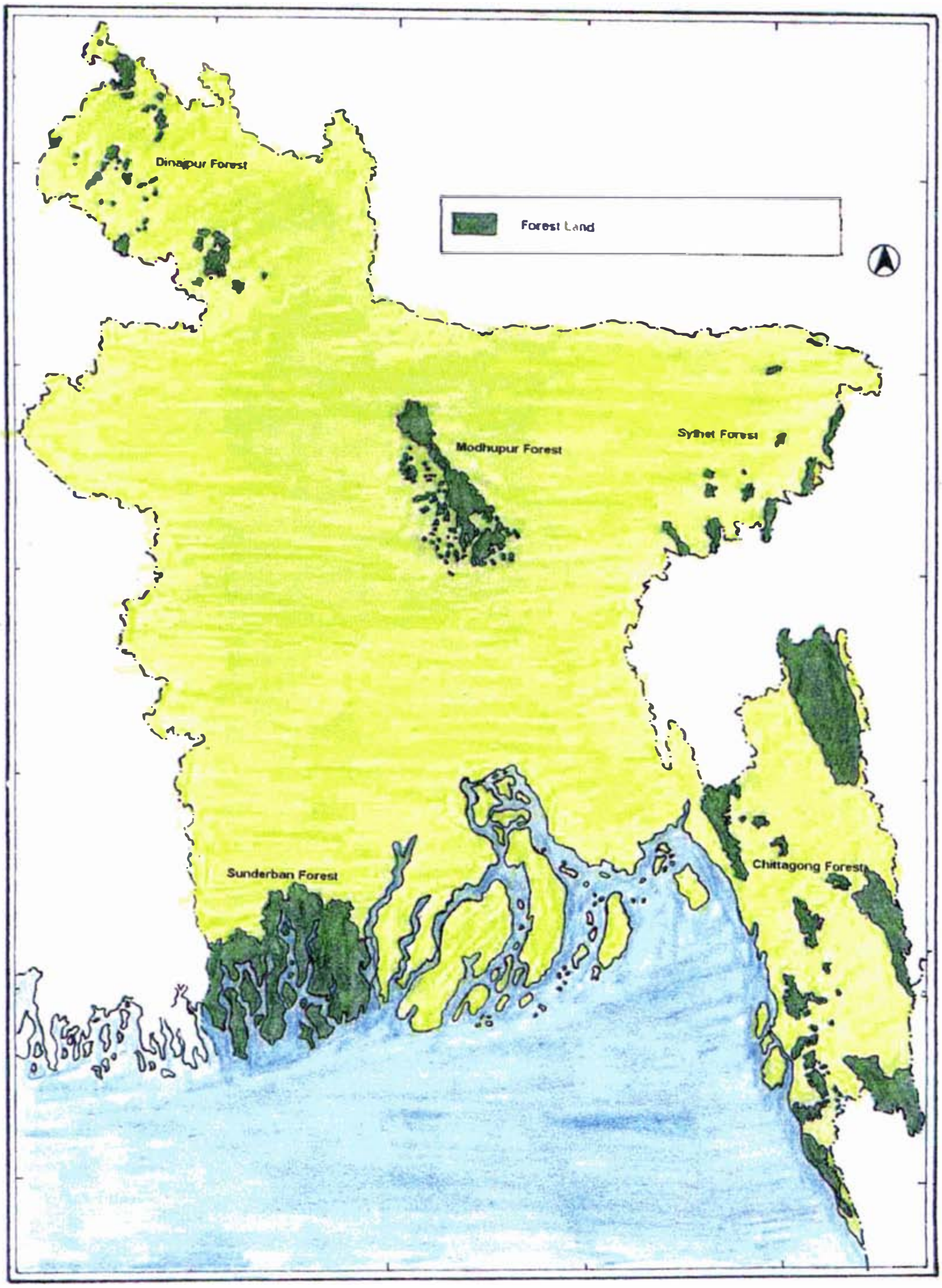
The landless population of Bangladesh historically meets their energy needs from the abundant leaves, twigs, crop residues etc. However, the multiple uses make crop residues costly, largely affecting poorer people. **Literally, the only sources of energy available to this group are the sun and wind.**

Table 5.4.1.5: Alternative Use of Crop Residues (%)

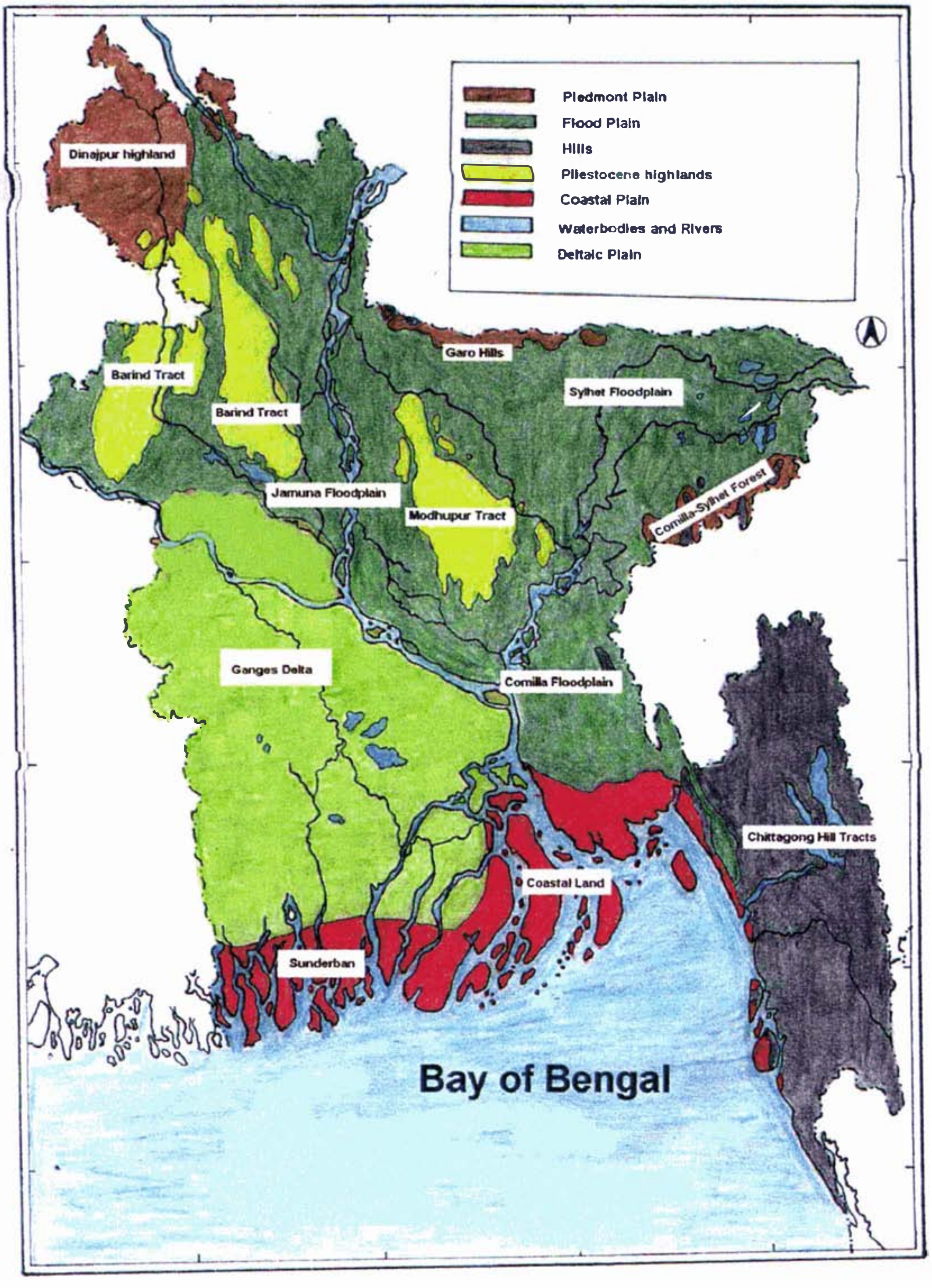
Residue	*Fuel*	*Building Materials*	*Industrial Raw Materials*	*Burnt in situ*	*Manure*	*Fodder*
Straw	17	51		11	21	2.56kg/animal
Husk		100				
Bran		21				79
Wheat Straw	28	52	20			
Bagasse	5	84	3		8	
Jute stick	27	58	10		5	
Others		24			26	50

Source: GOB, BEPP 1985e, P IV-3.58

Map 5.1: Forestland of Bangladesh



Map 5.2: Types of Land in Bangladesh



5.4.1.6 Biogas

Biogas is a newer source of energy in Bangladesh. It is produced naturally by certain bacteria on water-logged organic materials in the absence of air—a process known as 'anaerobic digestion.' About 60% of it consists of methane, while the rest is inert carbon dioxide. The main uses of biogas are cooking, heating water, and lighting (with gas lamps using incandescent mantles).

Current estimates of the number of biogas plants in the country are not available from any sources, but in 1985 nearly 250 biogas plants were operating in Bangladesh. Most of them were introduced by NGOs, and one was built by British Tobacco Company (BTC). BTC launched this programme with a view to motivate rural farmers to cultivate tobacco that would yield immediate cash returns and provide a solution to curing tobacco fuel.

The average cost of building a medium-sized biogas plant suitable for a 5-member family is approximately Taka 10,000, which is hardly affordable to a low-income farmer. In addition, a big part of rural population do not even own sufficient number of cattle for running a small-sized digester.

Moreover, a family that can afford installation costs and owns animals, can manage biomass fuel relatively easily (from forests or market). Furthermore, the majority of families owning biomass plants in Bangladesh are landlords.

Hence, they operate (filling slurry and extracting manure) their plants by paid labour. Servants are illiterate, lack technical knowledge, ignorant, and absence of earnestness is very common among them. This situation has contributed to presenting an unattractive picture of biogas plants to rural community. Until 2000, no biogas plant has been built under co-operative management.

The type of animal dung used is also a factor in a biogas plant's success. Ali (1992b) shows that for religious reasons, Muslims are not allowed to use or handle pig dung, which, in its turn, makes biogas programmes unpopular in the Muslim communities in China (partly) and Indonesia. This situation does not prevail in Bangladesh, as pigs are not generally raised in the country.

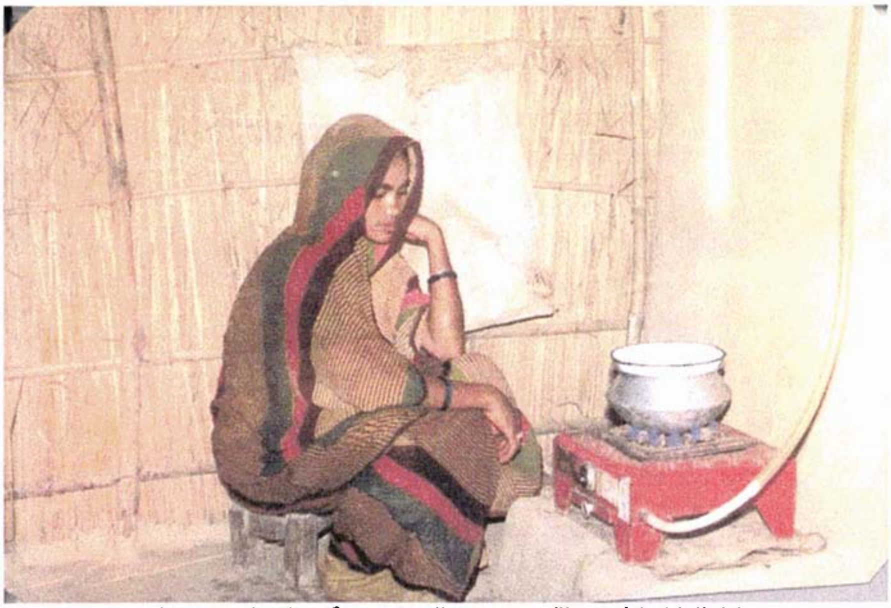
Two main types of small-scale biogas digesters (batch and continuous) were originally developed in China and India. A batch digester is operated with slurry under anaerobic conditions. Gas production starts after a few days of sealing the digester. Once the process is complete, the container is opened, emptied, and refilled with fresh slurry. It is normal to have several batch digesters (at least three) working in out-of-phase cycles so that at least one unit is continuously producing gas.

In case of a continuous digester, the slurry is added regularly, therefore, the gas pressure varies depending on the volume of the gas stored. In Bangladesh, biogas plants are not very popular, but some NGOs are trying to improve the situation. Two photographs regarding biogas plant and its use in rural Bangladesh are presented in figures 5.4.1.6a and 5.4.1.6b respectively. Figure 5.4.1.6a shows a biogas plant is under construction while figure 5.4.1.6b shows a woman is cooking with biogas.

Figure 5.4.1.6a: Biogas Plant Under Construction

Source: Photograph taken from Kapacia village, Dhaka.
This plant is sponsored by Grameen Shakti, NGO

Figure 5.4.1.6b: A Woman Cooking with Biogas



Source: Photograph taken from Nandigram upazilla, Rajshahi division

5.5 Other Renewable Energy Sources

Other renewable energy sources in Bangladesh include solar energy, hydro energy, wind energy, and geothermal energy. In rural Bangladesh, the use of these types of energy (except traditional use) is a new concept, and is yet to become popular. The following section presents only the current state of other renewable energy sources in rural Bangladesh.

5.5.1 Solar Energy

Solar heat has been used in Bangladesh for centuries in a variety of economic activities such as drying clothes, food grains, fish, raw jute, and evaporation of saline water for salt production. Long-term average sunshine data indicate that the period of bright (i.e. more than 200 watts/sq.m intensity) sunshine hours in the coastal region of Bangladesh varies from 3 to 11 hours daily. The daily global radiation varies from 3.8Kwh/sq.m to 6.4Kwh/sq.m.

These data indicate good prospects for solar thermal and photovoltaic (PV) application in Bangladesh. Table 5.5.1.1 shows the number of PV plants operating in Bangladesh, and their capacity. Map 5.3 shows geographic locations of these power plants in Bangladesh. The PV system is still running on an experimental basis, promoted by local NGOs or government research organisations. The power produced from PV plants is used by rural households in lighting and fans for both commercial and domestic purposes.

Annual solar radiation in Bangladesh has been estimated to be nearly 600 times the 1973/74 total annual energy consumption of 285PJ from traditional and commercial sources. There are various activities in rural Bangladesh which depend on the use of solar energy—and if these could be performed more quickly and efficiently by using simple devices, it would increase productivity, without making any demand on commercial energy sources. The use of solar radiation for heating and drying is common in all parts of Bangladesh, however, solar heating system using flat-plate collector is still unknown.

Table 5.5.1.1: Solar-Based Power Plants in Rural Bangladesh

Organization	*Energy Production (WP)*	*Location*	*Technology*
Bangladesh Council for Scientific and Industrial Research	Unknown	Joydevpur	Solar Hot Box (14 no.)
Bangladesh Rural Advancement Committee (a leading NGO)	Unknown	Kapacia	
Rural Electrification Board	62	Narshingdi	PV
Bangladesh Rural Advancement Committee (a leading NGO)	Unknown	Kapacia, Sreepur	Solar Hot Box (39 no.)
BGS (a local NGO)	96	Ukhia, Cox's Bazaar	PV (12), Solar Cooker
CMES (a local NGO)	100 50 WP	Dinajpur, Rangpur, Patuakhali, Tangail	PV (22)

Source: Aziz (1999)

5.5.2 Passive Solar Systems

There are also passive solar systems used to provide space and water heating for buildings. Passive solar systems rely on natural heat transfer forces of conduction, convection, and radiation to distribute the heat collected, e.g. south-facing glass to collect heat (depending on the location of the building), and heat-storing massive building materials within the building structure (brick concrete, stucco, tile, or water containers).

These massive materials have the ability to absorb heat and then slowly release it to the surrounding cooler areas. In rural Bangladesh, there is a tradition to build a south-facing house, but this tradition has not been supported scientifically. Introduction of this technology might save more energy in rural Bangladesh.

5.5.3 Solar Ponds

A solar pond is a body of water for collecting and storing solar energy. The pond (either natural or man-made) contains salt water, which acts differently than fresh water. In a fresh-water pond, sunlight entering the pond would heat the water, and by natural convection, the heated water would rise to the top, while the heavier cool water would sink to the bottom. Salt water is heavier than fresh water, and will not rise or mix by natural convection (Kristoferson and Bokalders 1987, p.205).

This creates a larger temperature gradient within the pond. Fresh water forms a thin insulating surface layer at the top, and underneath there is salt water, which becomes hotter with depth (as hot as 200 degrees Fahrenheit at the bottom) (ibid). However, this technology is totally unknown in rural Bangladesh. Moreover, as the rural population uses water from ponds and lakes for their daily activities, the effect of using salt with water needs to be examined before introducing this technology in rural communities.

5.5.4 Solar Drying

Solar drying refers to the method of using solar energy for drying. A wide range of products have been dried by the sun and wind in the open air for thousands of years—such as timber, tobacco, tea, and other food products. In the case of food, the purpose of drying is preservation for future use. One important advantage of solar drying is that the product is protected from rain, insects, animals, and dust.

The objective of drying process is to reduce the moisture content of the product to a specified degree. Air is drawn through the drier by natural convection. It is heated as it passes through the collector, then partially cooled as it picks up moisture from the product. An application of a solar dryer in rural Bangladesh is presented in Figures 5.5.4.1a and 5.5.4.1b. This plant has been built by Grameen Shakti (NGO), and used for demonstration purposes in a village near Dhaka.

5.5.5 Light Utilising Systems

Photovoltaics is the process of converting sunlight into electricity by means of a photovoltaic cell. The photovoltaic cell is a solid-state device composed of thin layers of semiconductor materials, which produce an electric current when exposed to light. Single cells are connected in-groups to form a module, and modules are grouped to form an array. The voltage and the current output from the array depend on the system configuration.

Photovoltaic cells produce direct current (DC) electricity, the type of electricity in batteries. Most appliances, however, are designed to use alternating current (AC) electricity, the type available from a standard wall socket. When AC current is required, an inverter is added to the photovoltaic system to change the current from DC to AC, but this incurs some loss of power output.

Photovoltaic-generated electricity has many applications. It has already become a permanent feature in the consumer market for products with small power requirements, such as solar calculators and watches. Other applications include water pumping, navigational signals, lighting, electric fence charging, vehicle battery charging, radio relay stations, and utility-scale electricity generation.

Solar energy may be either "stand-alone" or "grid-interactive" system. "Stand alone" system is not connected to an electric utility, while "grid-interactive" systems require the use of an inverter, but inverters are not required for stand-alone systems if DC appliances are used. Stand-alone systems may also include a backup system such as a diesel generator. Map 5.3 shows locations of PV-based solar energy generators in Bangladesh.

Prokowshali Sangsad Limited (PSL 2000) has conducted a study in the five villages of Narshingdi district, and concluded that the installation of grid interactive solar system plant might be a solution for providing electricity to rural households. However, that study has calculated that the unit cost of power would be Taka 115 per kwh, which could stretch the affordability of rural population. Our experience says that the unit cost of power production can be reduced by introducing co-operative system.

It is notable that the cost of producing electricity by using SET (e.g. solar or wind) is seemed to be higher in Bangladesh. However, in real terms it not. This is because in Bangladesh, most of the fossil fuel is distributed under subsidised prices. Cost is higher than the revenue it earns, i.e. the energy market in Bangladesh is not competitive. On the other hand, the estimated production cost of 1kwh electricity as shown above is unsubsidised.

Furthermore, the benefits of using sustainable energy sources are more than its financial costs. For example, such factors as environmental protection, consequences of climate change, freedom of users' choice, self-reliance, and long-term sustainability are to be included in the list of benefits. Therefore, the cost-effectiveness of sustainable energy sources involves the assessment of multidimensional benefits rather than production costs alone (Sims, October 2001).

It is seen from the map that most of PV plants are located near the capital, with some located in the coastal zone of the country. Because the NGOs are the promoters of this technology, they are less interested in working in remote villages due to costs and lack of urban facilities. It is notable that in Bangladesh, all leading NGOs are managed by the upper classes of the society.

Twenty five PV plants located in the coastal zone have mostly been installed by the Local Government and Engineering Department financed by International Fund for Agriculture Development (IFAD). The PVs were built on the roofs of cyclone shelters, special installations for protecting lives and resources from tidal floods and cyclones (GOB, Cabinet Division, IFAD Project Final Report 2000).

The idea of installing PVs on the cyclone shelters' roofs is justified by the fact that during cyclones or floods grid power lines get disrupted, and in the areas with no power line, kerosene also becomes unavailable. So during natural disasters, people in shelters can get power for lighting. As there have not been observed any major coastal disasters in the last 3-4 years, these PVs have been left unused, causing them to deteriorate due to lack of proper maintenance (ibid).

Sophisticated solar power technology is available in almost all parts of the developed world and some countries in the developing world. Some African countries like Ghana use this technology (Karekezi and Mackenzie, 1993). Thailand, China, and India have undertaken long-term programmes to promote this technology. In Bangladesh, the concept of this technology is still premature. However, as a symbol of the use of solar energy (use of solar cooker and solar dryer) in rural Bangladesh, two photographs are presented in figure 5.5.4.1a (and 5.5.4.1b respectively.

Map 5.3: PV System Used in Bangladesh

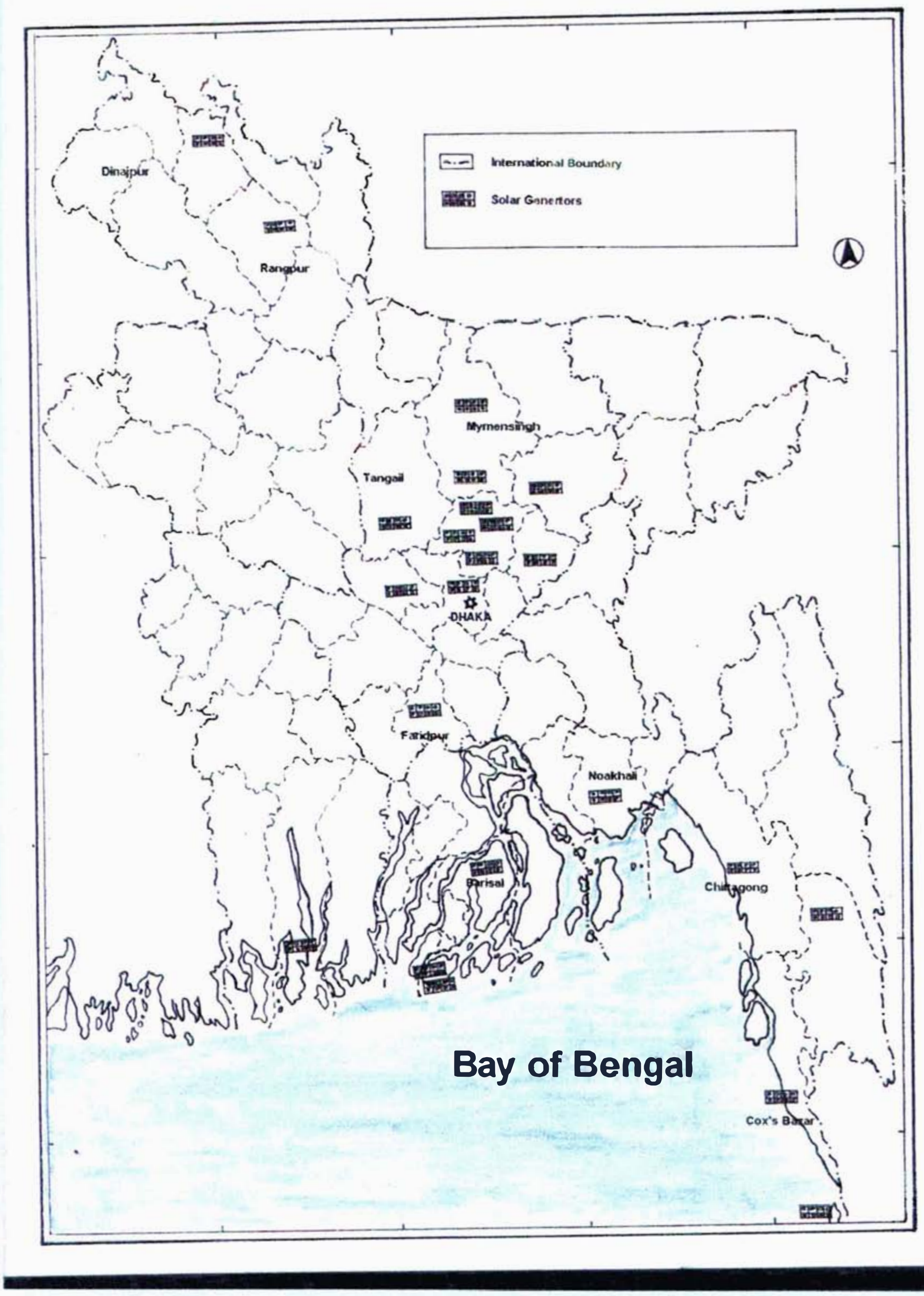


Figure 5.5.4.1a: A Woman is Cooking on a Solar Cooker

Source: Field Survey

Figure 5.5.4.1b: A Woman is Drying Chilli on a Solar Dryer

Source: Field Survey

5.6 Wind Energy

Bangladesh is situated in the latitudes of $20^{0}34'–26^{0}38'$N and longitudes of $88^{0}01'–92^{0}41'$E. The country has a long coastline where southwesterly trades and sea breezes blow in the summer months (March/April–August/September). Traditional meteorological data show wind speed in the coastal region range from only 2-4m/sec at the heights of 5-10m above the ground level. It is notable that these meteorological data were collected from the Meteorological Department of Bangladesh on 11 November 2000. Computer data sheet can be seen as Annex 13. The organisations involved with wind power promotion activities, technology types and locations are presented in Table 5.6.1.

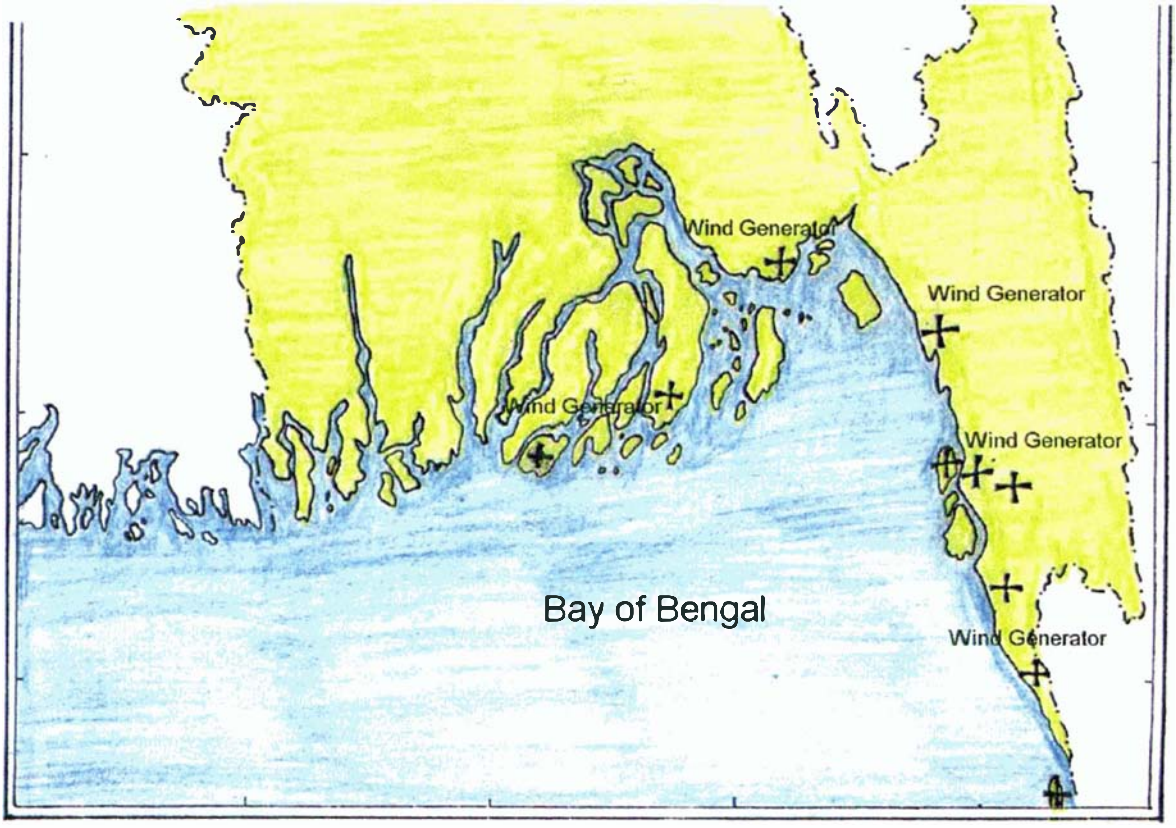
Table 5.6.1: Wind Power Generation in Bangladesh

Organization	*Energy Production (WP)*	*Name*	*Location*	*Technology*
Bangladesh Centre for Advanced Studies (an NGO)	Unknown	Wind speed and direction in 7 places in the coastal areas	Kuakata, Patenga, Noakhali, Kutubdia, Teknaf, Charfasion, Cox's Bazaar	Anemometer
Bangladesh Cottage and Small Industries Research (GO)	62	Monitoring	St.Martin Island	
Bangladesh Rural Advancement Committee (a leading NGO)	150	Pilot projects (11 wind turbines)	Cox's Bazaar, Banshkhali, Kutubdia, Pekua	Wind turbine

Source: Aziz 1999

The wind speed exhibits a diurnal cycle, peaking in the early afternoon and subsiding at night. There are many ways of using the wind energy, depending on the wind speed and its variation over the year. These include providing electricity to the national grid, stand-alone systems for home and commercial use, wind PV battery charger, hybrid system with diesel power, or a simple windmill to lift underground water for drinking or irrigation.

Map 5.4: Location of Wind Power Generators in Bangladesh



The application of wind energy technology for generating electricity in Bangladesh is still in its experimental phase of development, and no organisation has so far been engaged in commercial distribution of the system. Most organisations consulted during field survey were engaged in monitoring and gathering data on the wind speed, direction, pressure, and temperature at proposed sites. Map 5.4 provides the locations of wind-based power generators in Bangladesh. It is evident that wind power is mostly located near the coast, where it is most suitable. It is worth mentioning that although most of the land in Bangladesh is flood plain, some parts of coastal belt, particularly the South-Eastern parts (Chittagong, HillTract, and Sylhet regions) is relatively hilly. Therefore, these areas are more suitable for installing a wind power generator.

5.7 SET in the Rural Bangladesh

The discussions so far in this chapter on rural energy scenario of Bangladesh present a rather grim picture of the state of energy supplies. Biomass energy is in high demand in rural areas, being mostly used for cooking and heating purposes. In Bangladesh, biomass energy includes agricultural residues, dung-cakes, and firewood. Studies have suggested that the existing supplies of energy to rural households are used for cooking (87%), crop processing (10%), and lighting (3%).

The pattern of consumption is in no way sufficient to meet the needs of rural households. Alternatively, heavy dependency on biomass energy supplies in rural areas is also blamed for environmental problems. According to the World Bank (1997), ADB (1994), and ADB (2000), the rise of the sea level will cause about one-third of Bangladesh (Southern regions) to go underwater by 2020. However, although the sea level rise is a global problem, the rate of deforestation is another local cause of environmental damage, deterioration of living standard, poverty, and unsustainable way of development.

Deforestation is a major environmental problem directly related to the case of fuel wood for cooking and heating. The growth of rural population and increase in economic activities are mainly blamed for increased pressures on forestland. At the same time, deforestation is responsible for further deterioration of soil and water bodies.

Dung-cakes are also blamed for soil degradation in rural areas. The argument is simple: for many years, animal dung has been the main source of organic fertilizers. The shortages of biomass from agricultural and crop residues force many rural households to use dung as fuel. This leads to the increased use of chemical fertilisers for agricultural production, resulting in the disturbance of biodiversity.

The concept of energy sustainability is tricky, and refers to two fundamental elements of sustainable energy. First, it means aggressive pursuit of more efficient patterns of energy use (especially end-use) to get more energy services and higher benefits out of energy resources, which do exist. Second, it refers to a shift towards the use of new and renewable energy sources that, ultimately, are the only sustainable source of energy.

Considering these aspects of sustainable energy, we define SET as a technology that uses both renewable sources of energy and energy-efficient mechanisms to gain higher benefits out of existing energy sources, for example, energy-efficient bulbs to replace existing bulbs etc.

Government of Bangladesh and some NGOs have been working in this area for a long time. BCSIR has been working on developing improved stove for rural household to be used for cooking with biomass energy sources since the Eighties. BCSIR and Bangladesh University of Engineering and Technology have been developing solar stoves for many years. BCSIR researchers are also involved in developing biogas plants for households. All these projects and endeavours are meant to introduce SET in Bangladesh.

Some of the more publicised SETs in Bangladesh are:

1 Improved household cooking stoves (for commercial and domestic purposes)

2 Fluorescent lantern to be used with kerosene

3 Multi-burner cooking stove on fuel wood

4 Biogas plant

5 Solar cooking (using solar radiation)

These projects are mainly aimed at energy conservation, with less emphasis on developing energy supplies from renewable sources. In the Nineties, the government put forward a massive plan to provide electricity to rural household through Rural Electrification Board (REB).

An objective of this programme is to replace the current pattern of energy use with a 'cleaner' technology.[5] Introduction of electricity to rural households has opened a whole new world, which has been unknown hitherto. Energy demand has increased rapidly, and it has become diversified. This qualitative change in the energy consumption pattern is often underestimated and misunderstood, as the majority of the current analysis of energy demand in Bangladesh is based on existing pattern of energy use, ignoring future potential demand.

5.8 Conclusion

This study analyses the changing pattern of rural demand for energy, with the aim of determining most appropriate SET. The changes in the energy demand quality in rural households due to the introduction of electricity are likely to change the overall distribution pattern of energy consumption. Consequently, the pattern of energy supply might also need to be adjusted. SET in Bangladesh, therefore, refers to a set of technologies of energy supply and use, which would satisfy the needs of households, as well as promote efficient use of renewable energy supplies.

The nature of energy demand and supply from the users' point of view, and the attitude of the rural population towards SET will be discussed in the next chapter.

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[5] Electricity is mainly produced from natural gas in Bangladesh.

Chapter 6

Energy Use in the Rural Bangladesh

6.1 Introduction

The aim of this chapter is to present the discussion and analysis of the findings of the household survey carried out as part of this research. In order to understand the demand for energy, its availability, and sources, as well as to determine the level of acceptance of environment-friendly energy technologies in rural Bangladesh, a sample survey was conducted in rural areas of four major divisions of the country, between 1999 and 2000. A total of 303 usable responses to questionnaires were ultimately accepted for analysis in this study.

The questionnaire was divided in two parts: baseline information and perception of SET. In the baseline information, questions varied from basic household information (to understand the demand side) to availability of energy in rural areas. Questions also included information about the losses that the rural population currently incurs due to energy shortfalls in their locality. In the opinion section of the questionnaire, data were collected in terms of their acceptance of renewable energy technologies.

The result of this survey will be used to identify market and non-market sources of energy, understand energy collection mechanism, energy usage, energy types, and to link energy use to energy type. These would provide the basic information on feasibility of potential substitution of rural energy by SET.

Map 6.1 shows sample areas of data collection, while the number of respondents by division[6] is presented in Table 6.1.1. Numbers on the map show the actual size of

[6] Bangladesh is now divided in 6 divisions - Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet. The last two divisions have been separated from Khulna and Chittagong divisions respectively, since 1994. Aggregate data (time series) on these two divisions are not yet available from Bangladesh Bureau of Statistics, and so we excluded these divisions from the sample survey.

the population of a local administrative unit (upazilla[7]) where the sampled villages are located.

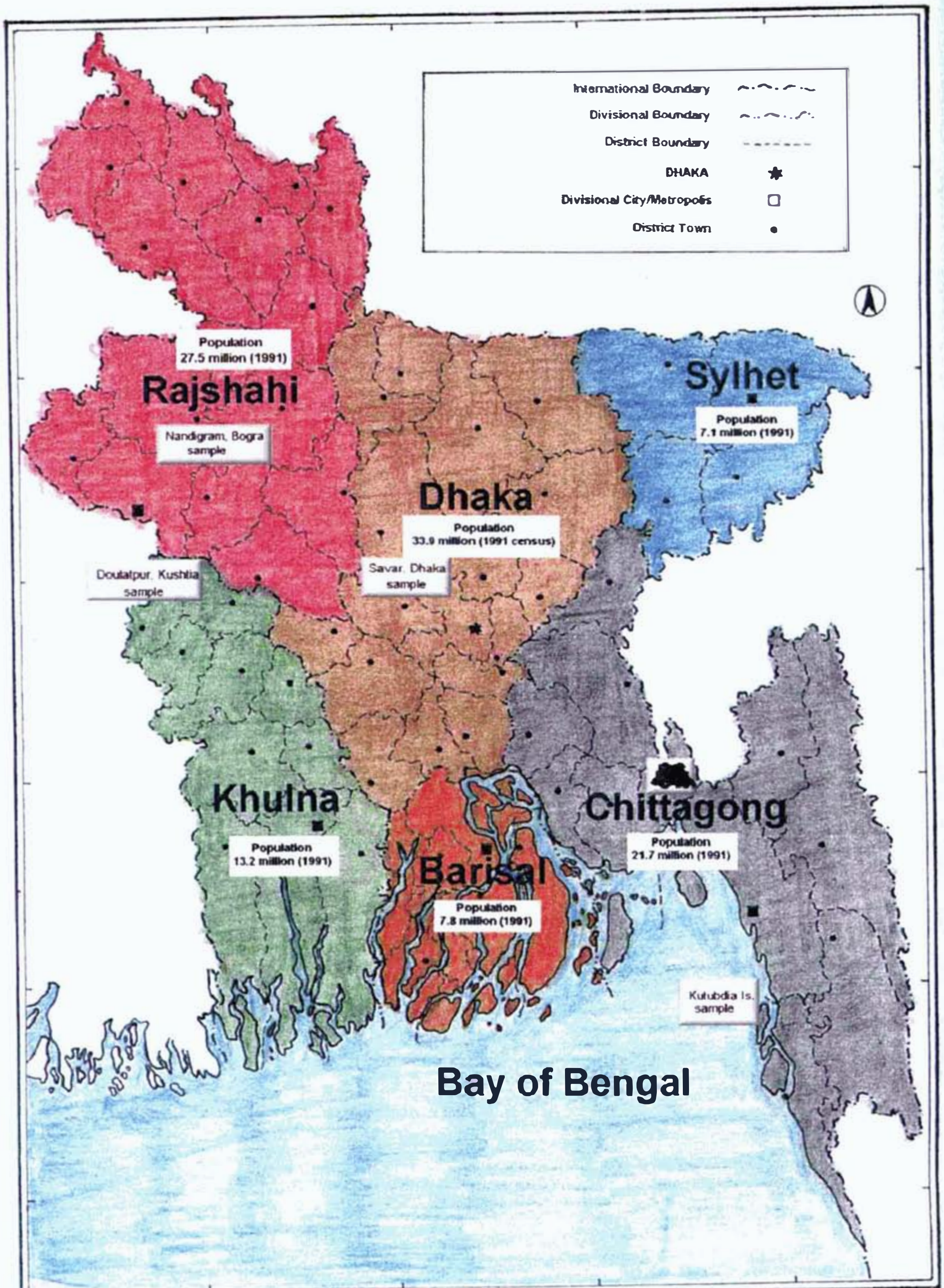
Table 6.1.1: Sampled Households Survey by Division

Division	*No of respondents*	*Percentage*
Khulna	70	23.1
Rajshahi	74	24.4
Dhaka	83	27.4
Chittagong	76	25.1
Total	**303**	**100**

Source: Field Survey

[7] Upazilla is a Bengali version of a local-level administrative unit of the Bangladesh. Formerly, it was a local police station. There are 460 upazillas in Bangladesh.

Map 6. 1: Sample Locations for Household Survey in Bangladesh



6.2 Characteristics of the Sample

Although the selection procedures in sampled villages and households have been discussed in Chapter 3, it is worth mentioning that the survey was conducted in four villages of four major divisions of Bangladesh. A total of 303 responses (60% male, 40% female) to questionnaires were finally used in the analysis (Table 3.1, Chapter3). Educational background of the respondents varied from illiterate to university degrees.

A disproportionately higher number of respondents (compared to national educational background) came from literate groups of people (267 of 303, about 88%, national literacy rate is 32.4 %; BBS 1999, p.3). Since educated people are the leaders in adopting new technologies in any society, we have deliberately created a bias in our sampling. It would give us a true picture of the feasibility of new energy technologies. In most cases, rural illiterate respondents follow the success of the educated people. Table 6.2.1 shows the distribution of respondents by educational background.

Table 6.2.1: Educational Qualification of Respondents

Educational level	*No of respondents*	*Percentage*	*National statistics (%)*[8]
Illiterate	36	11.88	67.6
Primary	84	27.72	16.3
Secondary	57	18.81	8.7
Higher secondary	78	25.75	4.0
Bachelor	36	11.88	2.6
Master and above	12	3.96	0.8
Total	**303**	**100.00**	**100.0**

Source: Field Survey

[8] We have used data from the draft report of ADB-funded Education Sector Reform 2000, prepared by M. Sirajuddin. The report is yet to be published.

The in-built bias in our sampling becomes clear when analysing occupational distribution of households. Households were selected at random, with one member of the family responding on behalf of the household. Table 6.2.2 presents occupational distribution of the respondents. Although most of rural households are engaged in agricultural activities, respondents were not necessarily farmers.

It is seen from the table that more than 18% respondents indicated their occupation as 'housewife'. This is unusual for the rural areas of a developing country such as Bangladesh. However, the benefits of having respondents from 'housewife group' are two-fold: first, in a male-dominated society of rural Bangladesh it is encouraging to see a good number of women coming forward to talk to us and express their views.

And second, although Bangladesh in general, and rural Bangladesh in particular, is considered to be male-dominated, we encouraged our field investigators to capture as many female respondents as possible because of the fact that women are the major energy consumers, being the ones who perform most of the household cooking, washing, lighting etc. Therefore, it was important to gather their perceptions of the environmental impact of the currently available energy sources and the benefit of introducing SET.

It may be noted here that in rural areas, the male family members hardly ever collect leaves, make dung-cakes, or do any cooking. But they are involved in chopping wood, cutting trees, and collecting firewood. The student respondents (24.8% in Table 6.2.2) are mostly school students. They took part in the study, when there were no other literate family members who could meet the interview demands. Culturally, in Bangladesh, when a stranger visits a household, it is usually a male who is asked to attend the visitor; but if there is somebody more educated, s/he is asked to talk to the guest. The same happened in the field survey.

Table 6.2.2: Respondents by Occupation

Occupation	*No of respondents*	*Percentage*
Unemployed	14	4.6
Student	75	24.8
Agricultural sector	11	3.6
Day labor	16	5.3
Service	90	29.7
Business	42	13.9
Housewife	55	18.2
Total	**303**	**100.0**

Source: Field Survey

The annual income of the sampled households is summarised in Table 6.2.3. It shows that a predominant majority of these households have annual income less than Taka 20,000 (equivalent to US $392). This income, extrapolated for a Bangladesh standard rural family with 5.6 members (BBS 1999, p.76), amounts to a per capita annual income of less than US $64, extremely low compared to the national per capita income of US $369 (BBS 1999). This reflects a highly skewed distribution of income in the country.

It is mentionable that agriculture, livestock, day labour, small jobs etc. are major sources of income for the rural households in Bangladesh. Table 6.2.3 shows that 42.6% of respondents belong to the lowest-income group of this study. In Bangladesh, income distribution is uneven. The gap between low-income and high-income groups is very large. It has been mentioned earlier that about 50% of the population live under poverty level, with 35% living below absolute poverty line. Therefore, our lowest-income group data is consistent with the national income distribution statistics.

It is also seen from the table that 57.4% of respondents are in the higher-income group. The deliberate bias towards literate sampling means that the average income in the sample is likely to be higher than the national average. But still, there is a significant portion of respondents without much income, which shows the general level of income of rural population in Bangladesh.

Table 6.2.3: Annual Income of Rural Households

Income level (Taka)	*No of respondents*	*Percentage*
Lowest-20,000	129	42.6
20,001-40,000	104	34.3
40,001-80,000	52	17.2
80,001-highest	18	5.9
Total	**303**	**100.0**

Source: Field Survey

Note: Taka 25=NZ $1

Table 6.2.4 shows the land ownership patterns of the respondent households. It is evident from Tables 6.2.4 and 6.2.5 that a large percentage of respondents do not have any excess land. This is the general characteristic of Bangladesh, one of the most densely populated countries of the world.

Table 6.2.4: Homestead Land Area

Quantity of land (hectre)	*No of respondents*	*%*	*Cumulative percentage*
Lowest-0.02	117	38.6	38.6
0.03-0.04	62	20.5	59.1
0.05-0.08	72	23.8	82.9
0.09-0.12	18	5.9	88.8
0.13-0.16	9	3.0	91.8
0.17-0.20	17	5.6	97.4
0.21-highest	8	2.6	100.0
Total	**303**	**100.0**	

Source: Field Survey

Land unit used in this study is hectare (1 hectare=2.471 acres; 1 acre=100 decimals). Most of the sampled households have both homestead land and arable land (Tables 6.2.4 and 6.2.5), and so they can buy energy as well as adopt new technologies. In terms of national land statistics, the percentage of population with less than 0.02 ha of arable land in the rural areas is 35.75% (BBS, HES 1995/96, p.237). Our sample conforms to this vital national statistics.

However, the ownership of homestead land (Table 6.2.4) shows that about 39% households have a very small household land. This reflects the relative scarcity of land for housing in Bangladesh. This is also consistent with the joint family culture in rural Bangladesh. When families grow, they may chose to add an extra house, but usually in the precincts of their paternal land. It could be explained by a number of reasons: sharing common facilities (tube well, pond, cattle yard, crop-processing yard etc.), acute shortage of high land suitable for building houses, historical tradition etc.

Table 6.2.4 further shows that 59.1% own less than 0.04 ha of homestead land, and 82.9% own less than 0.08 ha. This shows the density of population in the country overall. The other reason is that villages in Bangladesh are actually clusters of households. About 5-15 houses are commonly seen in just one cluster. So the average homestead land per household can be much less. The overall land ownership of the households is, however, not as low. That can be seen in Table 6.2.5.

The table shows more than one-third of respondents own less than 0.02 ha of land. These are virtually landless or marginal farmers. Over two-third own less than 0.20 ha of arable land. This means that the general land ownership is not very high in rural Bangladesh, which is not surprising.

Table 6.2.5: Cultivable Land Area

Quantity of land (ha)	*No of respondents*	*Percentage*	*Cumulative percentage*
Lowest-0.02	105	34.7	34.7
0.03-0.04	66	21.8	56.5
0.05-0.20	38	12.5	69.0
0.21-0.41	25	8.2	77.2
0.42-1.01	32	10.6	87.8
1.02-2.02	23	7.6	95.4
2.03-highest	14	4.6	100.0
Total	**303**	**100.0**	**100.0**

Source: Field Survey

6.3 Rural Energy Situation in Bangladesh

The above sample is used in this study to analyse the following aspects of rural energy situation in Bangladesh:

1. Sources of existing energy supplies
2. Energy usage by households and commercial enterprises
3. Methods of energy acquisition
4. Status of SET
5. Potential for sustainable energy use, and
6. Feasibility of producing sustainable energy.

6.3.1 Sources of Existing Energy Supply

Rural and semi-urban households use energy for multiple purposes from different sources. In our study on the existing sources of energy supply in rural Bangladesh, it has been found that rural households collect energy from various sources: animals, forest land or open land surrounding their villages, local retailers, local agents, wholesalers, and electrification boards (Table 6.3.1). Some of them also buy energy in the open market. These multiple sources of energy are used for multiple purposes: cooking, housekeeping, lighting etc. The nature of their demand for energy will be discussed later.

Table 6.3.1: Sources of Energy Supply in the Rural Bangladesh

Source of Energy	*No of respondents*	*Percentage of responses*
Own animals	83	27.4
Own forest/land	72	23.8
Local retailers	98	32.3
Local agents	14	4.6
Wholesalers	1	0.3
REB	6	2.0
Open market	29	9.6
Total	**303**	**100.0**

Source: Field Survey

6.3.1.1 Energy from Own Animals

Historically, in rural Bangladesh, most of the households own animals. The common animals are cows, buffaloes, goats, poultry, etc. The type and number of animals owned by the sampled households is presented in Table 6.3.2. Table shows that 76% households owned cows followed by 29% owned goats. Only 2% owned buffeloes. Table also indicates that a reasonable portion of rural households did not own any animals, although having animals in rural households is a common practice, especially an agro-based country like Bangladesh. The reason might be that a more than one-third of rural households in Bangladesh are landless so either they have very limited homestead land or no land at all. So they are unable to provide food and accommodation for animals. However, it is evident from the table that most of the rural households have cows as compared to other animals. Cow dung is a major source of energy in rural Bangladesh, as discussed in the previous chapter.

Table 6.3.2: Animals Owned by the Rural Households

Type of animals	*No of Owners*	*No of non-owners*	*Mean*	*Median*	*Standard deviation*
Cows	182 (76)	73 (24)	2.4478	2.0000	1.8701
Buffaloes	5 (2)	298 (98)	1.8000	2.0000	0.4472
Goats	87 (29)	216 (71)	2.2874	2.0000	1.2286
Other animals	57 (19)	246 (81)	7.5439	7.0000	5.2306

Source: Field Survey

Note: Figures in parentheses represent percentage

6.3.1.2 Energy from Own Forest/Land

Table 6.3.1 shows that 24% of rural households collect their supplies of energy from forests, including mainly biomass. The survey also revealed that they collect jute stalks, straws, leaves, and tree-branches from their forests and land.

6.3.1.3 Energy from Market-Based Sources

Local agents supply liquefied petroleum gas (LPG), diesel, cow dung (in the form of cake or sticks), kerosene, petrol, firewood, and even electricity to rural households. Wholesellers supply kerosene in the market, while retailers supply cow dung, electricity, biogas, kerosene, leaves, and firewood. This reveals the spread of market for energy in rural Bangladesh.

6.3.1.4 Electricity

BPDB produces electricity in Bangladesh. Except for Dhaka and some rural areas, it is also responsible for distributing electricity to end-users. BPDB is a public company, operated and managed by the Government of Bangladesh. In Dhaka, electricity is supplied to end-users through DESA, and in rural areas—by REB. Subscribers to REB units in each rural location form a society to manage REB. The name of the society is 'Palli Biddut Samity' (Rural Electricity Association).

6.3.2 Usage of Energy by Rural Households

Table 6.3.2.1 illustrates the pattern of energy use in rural households. It is evident that energy is used predominantly for cooking (98.3%) and lighting (82.5%) purposes. Nearly 66% use energy for washing (mainly to boil clothes for washing), 1% use energy to operate fans, and 10% use energy for entertainment (radio and TV). It is also clear from the survey that different types of energy are used for different purposes. For example, light and fan are operated on electricity, cooking—on biomass energy, and entertainment—on electricity or battery.

Does the fact that 98.3% households use energy for cooking, and 82.5% households use energy for lighting, mean that the rest of the households do not cook or light their houses at all? Every household has to spend energy for cooking and lighting. But the situation in rural Bangladesh is a bit different. Like many developing countries, in rural Bangladesh, joint families are culturally acceptable and are quite common.

For example, an adult son of a family separates from his parents, and lives with his wife (and/or child) in a separate room. Law of the land treats that new family as an independent tax-payer and independent household. But this new family enjoys (in most of the cases, but not always) the use of many facilities that belong to their parents. As the major part of rural households use collected (but not bought) biomass for cooking, the new family cooks their food on the parents' stove, using their biomass. And hence, they do not spend anything on energy. As a result, even occasional independent use of the stove is insignificant.

Similarly, in the case of lighting, because of a joint family culture, a new separate family usually lives most of the time with parents, they even study under their supervision. Hence they do not need extra energy for lighting in their own room.

It is notable that on average, rural households spend 3.2% of energy on entertainment (Table 6.3.2.1). Apparently, this quantity seems insignificant compared to other countries. But considering the income and standard of living, this quantity is consistent with their lifestyles. Rural households cannot afford to spend more on entertainment. In other words, the choice of energy use for the rural Bangladesh community is restricted due to limited purchasing power.

Table 6.3.2.1: Use of Energy by Rural Households

Purpose	*Frequency*	*Percentage of responses*	*Percentage of respondents**
Cooking	298	31.4	98.3
Entertainment	30	3.2	9.9
Fan	3	0.3	1.0
Ironing	137	14.4	45.2
Lighting	250	26.3	82.5
Security	32	3.4	10.6
Washing	200	21.0	66.0
Total	**950**	**100.0**	

Source: Field Survey

* Total number of respondents is 303.

6.3.3 Usage of Energy by Commercial Enterprises in Rural Bangladesh

Table 6.3.3.1 illustrates the pattern of energy use by commercial enterprises (e.g. shops, cottage industries, irrigation etc.) in rural Bangladesh. It shows that 45% of the surveyed enterprises use energy for irrigation purposes. Seventeen percent use it for fanning, 16% use it for lighting, while 12% (more than households) use it for entertainment (operating radio, cassette players, or TV for customers). It is also clear that while households use more than three sources of energy, diversity of energy sources is less significant in commercial areas.

It is mentionable that rural population in Bangladesh use large percentage of energy for irrigation (44.9%, Table 6.3.3.1). This consumption pattern is consistent with the agrarian society because the country is trying to shift its agricultural practices from traditional to semi-modern, which requires more energy. The increase of energy used for irrigation purposes implies a demand for energy to operate irrigation machinery. It also implies that additional energy in the agricultural sector might positively impact the rural economy and hence create further demand of energy.

Table 6.3.3.1: Use of Energy by Rural Commercial Enterprises

Purpose	*No of responses**	*Percentage of responses*
Air conditioning	1	1.0
Boiler	1	1.0
Entertainment	12	12.2
Fan	17	17.4
Irrigation	44	44.9
Lighting	16	16.4
Machine operation	7	7.1
Total	**98**	**100.0**

Source: Field Survey

* Total number of responses is not equal to 303 because not all sampled households used energy for commercial purposes

6.3.4 Reasons for Using the Existing Sources of Energy

The study also attempted to ascertain the reasons for which the users have chosen a specific type of energy for specific purposes. It is seen from Table 6.3.4.1 that 29% respondents do not have access to any alternative or cheaper source. So, they do not have much of a choice.

However, it is also revealed that when an alternative does exist, 25% prefer the current source of energy because of its relative cheapness. Eleven percent said that without the supply of electricity, they would have no option but to use this source, and 20% said that it is the only source they can use for this purpose. Overall, the picture is that the current pattern of energy use is mainly guided by two reasons: lack of alternative sources, and easy access to the existing sources.

The term 'easy access' refers to the fact that rural people can collect or buy specific type of energy within their affordable time and money. A large portion of rural population is unemployed. Moreover, a significant part of school-age children do not go to school because of their parents' low economic status. Hence, an unemployed member of a household can spend time to go to the market for fuel. Similarly, children who do not have much to do can collect biomass from nearby forests/land. The opportunity cost of collecting specific energy by unemployed people and children is insignificant.

Table 6.3.4.1: Reasons for Using the Existing Energy Source

Possible reasons	*No of respondents*	*Percentage*	*Cumulative percentage*
Easy collection	72	23.8	38.6
No other alternative	85	28.1	51.9
No electricity	32	10.6	62.5
Available source	30	9.9	72.4
Only source	58	19.1	91.5
Affordable	22	7.2	98.7
Others	4	1.3	100.0
Total	**303**	**100.0**	

Source: Field Survey

6.3.5 Energy from Home Sources

We know that several types of energy are being used by rural population in Bangladesh, and the questionnaire was designed to assist in understanding how energy like biogas, biomass, fuel wood, leaves, cow dung etc. is collected. Generally, rural households get their children collect biomass such as dung, leaves etc., while the adults collect market-based energy such as firewood, kerosene etc. It is found that 55.2% (Table 6.3.5.1) of rural households get their children collect leaves and cow dung, while the adults collect energy from marketplaces.

Table 6.3.5.1 also shows that cow dung, leaves, and firewood are collected from home sources in many rural households. It is also interesting to note that this energy is mostly used in household activities, and not for any commercial purpose. Table

6.3.5.1 further suggests that 22.7% of the sampled households collect cow dung, 40.6% collect leaves, and 53.5% (a majority) collect tree branches for firewood.

Therefore, the objective of rural energy policy should be providing access to rural population to alternative and environment-friendly technology. Table 6.3.5.1 shows that a huge percentage of people use firewood by chopping trees, which leads to massive deforestation (54.8%). So we need to reduce this 'wholesale' use of firewood. Indirectly, this is the same as destroying forests and jungle wood.

Table 6.3.5.1: Energy from Home Sources by Rural Households

Purpose	*No of responses*	*Percentage of responses*	*Percentage of total respondents**
Cow dung for household use	84	22.4	22.7
Cow dung for commercial use	2	0.5	0.7
Leaves for household use	123	32.8	40.6
Firewood for household use	162	43.2	53.5
Firewood for commercial use	4	1.1	1.3
Total	**375**	**100.0**	

Source: Field Survey

*Total number of sampled respondents is 303.

6.4 Potential for SET in the Rural Bangladesh

As the study is interested in finding the potential for SET in the rural Bangladesh where energy is in acute shortage, we asked questions on simple awareness (yes/no questions) and functional awareness (questions on the energy usage). While answering simple questions, 72% demonstrated awareness of the fact that their current pattern of energy use (Table 6.4.1) is not environment-friendly.

Table 6.4.1: Awareness about Environmental Pollution from Energy Use

Aware	*No of respondents*	*Percentage*
Yes	219	72.3
No	84	27.7
Total	**303**	**100.0**

Source: Field Survey

In explaining in some more detail the possible environmental consequences from their current pattern of energy use (mostly based on dung, leaves, firewood, and kerosene), a large majority of them (42.6%) quoted flooding as the main result of their current pattern of energy use (Table 6.4.2). About 63% consider that both flood and drought are consequences of their current energy use (mostly due to wide-spread deforestation). Only 2.3% could perceive that climate change is caused by the present pattern of energy use. This revelation is important both for finding an alternative to energy sources and analysing the pattern of adaptation to alternative energies.

Table 6.4.2: Knowledge of Environmental Consequences from Energy Use

Possible consequences	*No of respondents*	*Percentage*
Climate change	7	2.3
Deforestation	43	14.2
Drought	61	20.1
Flood	129	42.6
Ecological disturbance	6	2.0
Natural disasters – floods, cyclones	29	9.6
Natural calamities and deforestation	18	5.9
Smoke	4	1.3
Other	6	2.0
Total	**303**	**100.0**

Source: Field Survey

Table 6.4.3 demonstrates current knowledge of SET. It is observed that 96.4% of rural households could name at least one SET of energy production. Table 6.4.3 further suggests that in rural areas photovotaic (solar) and wind energy is mostly unheard of (3% and 9% of awareness, respectively), while nearly 75% of the people who could name SET know about solar, biogas, and biomass energy. This further suggests that biogas and biomass-based SET will be more readily acceptable in rural Bangladesh in the short run.

Table 6.4.3: Knowledge of SET

Type of SET	*No of respondents*	*Percentage*	*Cumulative percentage*
Biogas	78	25.7	25.7
Solar energy	78	25.7	51.4
Solar and biogas	72	23.8	75.2
Windmill, solar, and biogas	28	9.3	84.5
Photovoltaic	9	3.0	87.5
Wind power	27	8.9	96.4
No idea	11	3.6	100.0
Total	**303**	**100.0**	

Source: Field Survey

Table 6.4.4: Knowledge of Wind Energy and Use

Wind energy used as	*No of respondents*	*Percentage*	*Cumulative percentage*
Electricity	17	5.6	5.6
Windmill	153	50.5	56.1
Pollution- and fuel-free	7	2.3	58.4
Other	2	0.7	59.1
Don't know	124	40.9	100.0
Total	**303**	**100.0**	**100.0**

Source: Field Survey

To further examine the knowledge of SET, a second question asked respondents to identify some uses of wind energy. Table 6.4.4 shows that only 59% of the respondents had any idea about this technology. Out of a total of 303 respondents, a majority of 50.5% (153 of 179) mentioned windmill as the best use of wind energy, meaning that wind energy could be used for pumping water.

Our survey also showed that at present 45% (Table 6.3.3.1) of the commercial energy (diesel and electricity) demand in rural Bangladesh is used for running irrigation pumps. Given this, feasible wind energy may be a solution in some parts of the country. The scenario of Table 6.4.4 indicates that about 41% people are not aware of wind as an energy generator. This is an expected result in rural Bangladesh, as there is no wind turbine or windmill, which can generate electricity for commercial purposes.

Table 6.4.5: Knowledge of Biogas and Its Use

Biogas used as	*No of respondents*	*Percentage*	*Cumulative percentage*
Biogas	203	67.0	67.0
Biogas and fuel	8	2.6	69.6
Cooking	2	0.7	70.3
Fuel	1	0.3	70.6
Don't know	89	29.4	100.0
Total	**303**	**100.0**	

Source: Field Survey

In a similar question on biogas technology, 71% knew about some use for biogas (Table 6.4.5). Of these 98% (211 of 214) knew that biogas is mainly used for lighting and cooking. As for solar energy, 56% knew about solar power, and 95% of these knew that solar power is mainly used for lighting (Table 6.4.6).

Table 4.4.6: Knowledge on Solar Energy and Use

Solar energy is used as:	*No of respondents*	*%*	*Cumulative %*
Solar power	162	53.5	53.5
Fuel	4	1.3	54.8
Other	4	1.3	56.1
Don't know	133	43.9	100.0
Total	**303**	**100.0**	

Source: Field Survey

6.5 Perception of Producing Energy with SET

The survey revealed that only 2.4% of respondents could tell about existence of wind plants in their area (4.4% for biogas plants, 1.4% for solar photovoltaic, and 2.8% for windmill). Clearly, SET is not a popular item but it is not an 'alien species', either. It may not be popular because they do not know about this way of power generation. However, they have demonstrated knowledge of the dangers of the current energy technologies. Indeed, people in the rural Bangladesh know about it, and some have seen them being used. Consequently, to understand the future potential for SET in the rural Bangladesh we asked several questions.

Table 6.5.1: Will You Participate in Producing Energy by Using SET?

Will you participate?	*No of respondents*	*Percentage*	*Cumulative percentage*
Yes	208	68.6	68.6
No	94	31.0	99.6
Don't know	1	0.4	100.0
Total	**303**	**100.0**	

Source: Field Survey

Table 6.5.1 shows that a substantial proportion (68.6%) of the people are interested in participating in the SET production, and the rest have either no interest or are not sure about it. Of them, 29% (56 of 192) need more information about SET (Table 6.5.2). Fifty seven percent need money or some financial assistance, 1% need land,

and 10% need capital and labour to participate in producing energy, using SET. It is evident from this table that introduction of SET in rural Bangladesh would require some planning and establishing a mechanism. To introduce SET in rural Bangladesh, a mechanism to supply information and to provide financial assistance must be developed. In other words, rural population in Bangladesh need to build their capacity in regard to understanding the concept, and preparing and implementing the SET project proposal (Haque et al, 1999).

Guidelines for the capacity-building project proposal[9], with respect to SET transfer in Bangladesh is attached as Annex 14.

Table 6.5.2: What Do You Need to Participate in Producing Energy by Using SET?

Type of needs	*No of respondents*	*Percentage*	*Cumulative percentage*
Knowledge	56	18.5	18.5
Money	109	36.0	54.5
Land and money	7	2.3	56.8
Capital and labour	19	6.3	63.1
Land	1	0.3	63.4
Don't know	111	36.6	100.0
Total	**303**	**100.0**	**100.0**

Source: Field Survey

It is also evident from the survey that 14% of the respondents (Table 6.5.3) can supply some capital to establish energy-producing plants using environment-friendly technologies, and 31% are ready to provide labour for such a venture. This suggests that if SET is to be introduced in Bangladesh, it must be labour-intensive to ensure the population participation.

[9] This Project Proposal was prepared with the financial assistance of GEF fund. The leading implementing agencies were Massey University, Dhaka University, North South University, and other NGOs. North South University published this booklet, of which I am a co-author.

Table 6.5.3: Assistance Available from Rural Population in Establishing SET Plants

Assistance available	*No of respondents*	*Percentage*	*Cumulative percentage*
Capital	42	13.9	13.9
Labor	93	30.7	44.6
Service	21	6.9	51.5
Land and labor	18	5.9	57.4
Land, labor and capital	16	5.3	62.7
Land and capital	7	2.3	65.0
Land, labor and raw materials	20	6.6	71.6
Raw materials	6	2.0	73.6
Don't know	80	26.4	100.0
Total	**303**	**100.0**	

Source: Field Survey

6.6 Rural Energy Demand

Table 6.6.1 shows that 61% of the respondents in our survey mentioned short supplies of energy in their area, and the resultant vulnerability of economic and non-economic (social and cultural) activities. The table also demonstrates that 55% of the respondents mentioned that education is badly affected by the shortage of power necessary for lighting and—possibly—fans. Five percent named 'personal entertainment' (implying power for TV/radio/cassette players etc.). Nearly 9% mentioned that jobs were cut due to power shortages in their area. Other activities affected by energy shortages are small businesses, irrigation activities etc.

Table 6.6.1: Activities Suffering Due to Energy Shortages

Activities	*No of respondents*	*Percentage*	*Cumulative percentage*
Education	90	29.7	29.7
Personal entertainment	8	2.7	32.4
Business	4	1.3	33.7
Irrigation	7	2.3	36.0
Job	14	4.6	40.6
Education and irrigation	13	4.3	44.9
Irrigation and communication	7	2.3	47.2
Other	14	4.6	51.8
Don't know	146	48.2	100.0
Total	**303**	**100.0**	

Source: Field Survey

We further investigated the priorities for energy use in case of additional availability of energy for rural population of Bangladesh, and our results are quite illuminating. Table 6.6.2 shows that 58.4% of the 'new energy' will be used in education and entertainment, and 85% have some plan to use any extra energy that might be available to them. About 5% would use energy to improve their living. Clearly, energy is seen by many to serve three main purposes: education, entertainment, and lifestyle. Therefore, there exists a tremendous social benefit from supplying extra energy to these people.

Table 6.6.2: What Will You Do if You Have More Energy?

Activities	*No of respondents*	*Percentage*	*Cumulative percentage*
Education	87	28.7	28.7
Entertainment	81	26.7	55.4
Industry	16	5.3	60.7
Business	14	4.6	65.3
Improved living	16	5.3	70.6
Irrigation	4	1.3	71.9
Education and entertainment	9	3.0	74.9
Irrigation and business	10	3.3	78.2
More work	8	2.6	80.8
Protect environment	11	3.6	84.4
Other	3	1.0	85.4
Don't know	44	14.6	100.0
Total	**303**	**100.0**	

Source: Field Survey

Table 6.6.3 illustrates rural perceptions of the increased energy supplies. A large majority, 67%, think that it would increase economic activities, and create more jobs, 8% think that it would improve their lifestyle, 6% hope for more business etc. This finding implies that life in rural areas, both in terms of income, education, and entertainment, would change if more energy were made available. In the social context, it would reduce migration to urban centers, as well as impact on population growth.

Table 6.6.3: What Does More More Energy Mean?

More energy means	*No of respondents*	*Percentage*	*Cumulative percentage*
More work	180	59.4	59.4
More food	5	1.7	61.1
Improved lifestyle	24	7.9	69.0
More business	17	5.6	74.6
Education	6	2.0	76.6
Better environment	11	3.6	80.2
More work and food	17	5.6	85.8
Other	9	3.0	88.8
Don't know	34	11.2	100.0
Total	**303**	**100.0**	

Source: Field Survey

To elicit the opinion on direct benefits from increased energy supply in rural areas, we had designed a set of questions. On average, each respondent could name four benefits from more energy supply. It is evident from Table 6.6.4 that the largest benefit is considered to be education. This is followed by entertainment, more industry, better environment, reduced migration, better health, more jobs etc.

Table 6.6.4: Potential Benefits from More Energy in Rural Bangladesh

Future Benefits	*No of respondents*	*Percentage*	*Cumulative percentage*
Education	276	19.4	19.4
Entertainment	194	13.6	33.0
Food habits	79	5.5	38.5
More industry	128	9.0	47.5
More business	94	6.6	54.1
Reduction of population growth	98	6.9	61
More jobs	112	7.9	68.9
Reduction of rural-urban migration	121	8.5	77.4
Better communication	72	5.0	82.4
Better health	114	8.0	90.4
Better environment	137	9.6	100.0
Total	**1425**	**100.0**	

Source: Field Survey

6.7 Leaders' Opinions on SET

To identify the feasibility of introducing alternative energy technologies in Bangladesh, we conducted a separate survey among the social elite (school teachers, political representatives, religion priests etc.) in the survey area. This survey was essential because a large part of less educated rural population relies on someone who is better off or better educated. In this context, 'educated' does not mean having formal educational qualifications. The rural people tend to rely on a person who is relatively knowledgeable in their locality, considering him their well-wishing leader. In general, these leaders are religious priests, school teachers, political representatives, local elite, large farmers etc.

From sociological and cultural viewpoints, these leaders strongly influence the decision-making process of the rural society in a developing country, being able to motivate the focus group of the society. During PRA survey, we have observed that the involvement of local leaders forms an essential part of SET transfer in rural Bangladesh.

As a part of this study, leadership opinion survey was conducted in four sampled villages. Originally, there were 10 questionnaires for each village, but after a series of checking, a total of 31 were accepted for analysis. The number of respondents according to location is presented in Table 6.7.1.

Table 6.7.1: Number of Respondents According to Sampled Villages

Sampled Village	*No of respondents*	*Percentage*
Loxmikola	8	26
Nandigram	8	26
Savar	9	29
Kutubdia	6	19
Total	**31**	**100**

Source: Field Survey

Out of 31 sampled leaders there were 7 teachers, 4 religious priests, 5 large farmers, 5 local elite, and 10 were professional political leaders. The number of respondents in different occupations was selected randomly.

In most cases, the result is not expected to be much different from that of the household survey, but in terms of overall feasibility, their opinion would be of great weight. Of the 31 respondents, 73% had no idea about SET. Of those who knew about SET, only 3 could identify it with some details and names. This clearly suggests that SET is largely an unknown phenomenon in rural Bangladesh.

At the same time, it was found that 83% said that they would co-operate or assist in any endeavours to introduce SET[10] in rural areas. Moreover, 25% think that introducing such technology in rural areas would require some sort of financing. Forty one percent respondents in the leadership group also mentioned that they would provide land for installing SET facilities in their areas, and 90% said that they would use it, too.

6.8 Conclusions

Both household and leadership opinion surveys indicate that SET can be introduced in the rural Bangladesh to increase supply of energy. It is also clear from the household survey that energy for light, fan, and entertainment are of high demand and short supply. Survey further suggests that biomass energy is also short in supply, but can be usually collected from open access resources. At the same time, there exists a market for purchasing all types of energy supplies—from leaves to firewood.

Survey further points out people are aware of the 'cost' of energy shortfalls in their lives, and so are expected to be buying energy. It is also clear that one of the major reasons for using existing sources of supply is monetary cost, which will remain extremely important if we are to introduce new technologies. In other words, SET must be cost-effective. Both household and leadership opinion surveys revealed

10 SET in the context of Bangladesh includes solar energy, biomass energy, and wind energy.

existence of a strong positive attitude in rural Bangladesh to using and producing SET-based energy.

In the following chapter, we will evaluate the market potential for SET in rural Bangladesh in terms of demand, and in terms of SET-based energy production. People are aware of the possible benefits of SET, and they are overwhelmingly willing to help with such initiative.

Chapter 7

Analysis of Respondents' Background Characteristics

7.1 Introduction

The aim of this chapter is to carry out an in-depth analysis of the socio-economic characteristics of the sampled energy users in rural Bangladesh. It also aims at analysing the energy consumption pattern and energy sources used, and tries to link them to selected background variables of sampled respondents. The selected background variables include respondents' income, education, and land ownership. Overall, this chapter identifies the nature of the rural community in Bangladesh insofar as it is captured by this study. It is intended to analyse issues such as whether the knowledge about SET as well as environmental awareness of some respondents is different from others, and if so, what may have caused such difference.

Furthermore, as the main demand for energy is derived from cooking, lighting, washing, and entertainment, the relationship between the level of these forms of consumption and the background variables has also been analysed. The relationship of background variables with the pattern of energy sources used and consumption pattern would be an important basis for justifying SET transfer to the rural community.

It is understood from previous chapters that the main energy sources available in Bangladesh are animal dung, animal power, firewood, dry leaves, biogas, kerosene, natural gas, electricity, petrol, and diesel. Among these sources, survey results show that the significant energy sources available for the rural population of Bangladesh are firewood, leaves, animal dung, kerosene, electricity, and diesel. The rural community uses these energy sources for both household and commercial purposes (compiled from survey data, GOB, BEPP 1985e, and GOB, Planning Commission, Midterm Review Report 2000). Natural gas and gas cylinders containing LPG are not widely available in rural Bangladesh. The availability and use of petrol is insignificant. For instance, petrol is used mainly in the transport sector, but in rural areas the main modes of transportation are human-pedaled rickshaws, animal-pulled carts, and boats.

Although we have discussed in previous chapter, it is worth mentioning here that supply of electricity in rural Bangladesh is extremely limited. Out of 24 million households, until recently, only 12% (national statistics) have been connected with the power grid (Assaduzzaman 1998), and the supply of power in the grid involves either long-term shortages or no supply at all. Our survey found only 2% respondents had the grid connection for getting electricity (see Table 6.3.1). Moreover, whatever the supply, it is the rich class of the society who enjoys the benefit of electricity supply. This is because economically it is relatively difficult for low-income households to get grid connection compared to high-income households.

In addition, as the supply of electricity is extremely limited, there might be social and political influences in favour of rich households of the community to get grid connection. However, as electricity is used for lighting, security, entertainment devices operation, air condition etc., it can be assumed that the households with the electricity facility maintain better living standards in rural Bangladesh.

There are two other types of energy: sun radiation and human physical power. People use the sun mostly for drying, including agricultural and food processing. Human physical energy is used in all parts of the country, in almost all areas, including agriculture, industry, and commerce in rural Bangladesh. However, in some remote villages, where there is an extreme shortage of animal power, men pull ploughs in the harvesting season, but its impact is very insignificant. Hence, although this study has covered its data collection in all above-mentioned energy sources, the statistical analysis is undertaken only on the sources that are either currently being used or have the possibility of use in the future within the rural communities of Bangladesh.

The survey shows that dung, firewood, and leaves are mainly used for household purposes (e.g. cooking, washing etc.), and electricity and kerosene are used mainly for lighting. But sometimes, they are also used to meet all other household demands. For instance, firewood is used for cooking as well as lighting, washing, and even heating. Similarly, dung is used for more than one purpose. On the other hand, kerosene is used almost entirely for lighting. The use of diesel for household purposes is non-existent. Diesel is used for commercial purposes only. In this study, commercial purpose refers to the use of energy for rural industry or agriculture as well as in a rural business. It has been found in the survey that diesel is used only for irrigation (100%) in rural Bangladesh.

The variables of background characteristics of the respondents have been analysed using SPSS. Particular techniques that have been used are means of variances, correlation, regression, and the Mann-Whitney test[1]. For the purpose of analysis, background variables have been categorised. Land ownership is divided into two groups: small and large holdings. Income is divided into two groups: low and high income. Education is divided into six categories: illiterate, primary, secondary, higher secondary, bachelor degree and masters and above. Environmental awareness is grouped as aware and unaware. Willingness to participate in SET transfer is grouped as willing and not willing. For energy sources use the respondents have been divided as users and non-users. These categories are explained in the next section.

7.2 Energy Users' Characteristics

7.2.1 Dung Users' Characteristics

This section takes a closer look at the dung users' background variables covered by the study. Dung users background variables are presented in Table 7.2.1. The table shows that 86.5% of respondents use dung for their household purposes. We are interested to know who these dung users are, what are their background characteristics, their level of environmental awareness, and willingness to take part in SET. We subdivide the dung users on the basis of income, literacy, land ownership, environmental awareness, and look at statistically significant differences among the categories of dung users. The degree of significance is examined by Mann-Whitney test. The household with the gross annual income of Taka 25,000 or more belongs to a higher-income group, while any annual income less than Taka 25,000 is grouped as low. Similarly, household with land ownership of 0.08 ha (20

[1] Mann-Whitney test is a non-parametric statistical tool used to determine whether significant difference exits between two categories of respondents while answering the same questions. For example, we can split the respondents into high-income and low-income groups, or small land holding and large land holding groups. Now, if we are interested in finding out whether they significantly differ with respect to the use of dung, a Mann-Whitney score of 0.005 or less would mean that there is a significant difference between the two groups. A brief explanation of Mann-Whitney Test program is presented in annex 17.

decimals) or more is categorised as large holdings while less than that is small holdings.

The reason for dividing land ownership into two groups is that in Bangladesh a typical household needs on average 0.08 ha of land, including homestead forestry. Above 0.08 ha of land is used as arable. In addition, the pattern of energy consumption as well as the use of energy sources may significantly vary if the land ownership is higher. This type grouping of land has been used in some studies (Hossain 1995; Khan 1995), and is available in neighboring countries such as India and China (Khan 1989). Similarly, to understand the degree of significance of differences, respondents have been grouped into two categories: users and non-users of selected energy source(s).

Table 7.2.1 examines selected background characteristics of dung-users by looking at their income, land ownership, level of education, environmental awareness, willingness to use SET, tendency (prevalence) of firewood use and prevalence of leaf use. From an income viewpoint, we wanted to know whether there is any significant difference between low-income and high-income groups in terms of dung use. The table shows that 86.5% of all respondents use dung as a source of energy in rural Bangladesh. However, the percentage of dung users in the low-income group is higher (92.3%) than that in the high-income groups (81.4%). We then wanted to know whether the observed difference (92.3% as compared to 81.4%) is statistically significant. Our statistical analysis shows that the difference is statistically significant at 0.6% level[2] (0.006).

Based on land ownership, the difference in use of dung between large and small land holdings households is not significant (0.573). It indicates that the prevalence of the use of dung is the same regardless of land ownership, or there is no statistically significant correlation between land ownership and dung usage. This reveals the fact that low-income and small land holding may not be analogous in the study sample. In fact, use of dung as a source of energy in rural Bangladesh is a common factor,

[2] A co-efficient of less than .05 indicates that difference is significant at 5% level and a co-efficient of less than .10 indicates that difference is significant at 10% level. A co-efficient greater than .10 indicates that difference is not statistically significant. Generally the lower the co-efficient, the greater the degree of significance. That is why a co-efficient of 0.000 indicates that difference is highly significant.

which depends on its availability, and it does not matter whether the user is a large or small landowner.

We further examined the sampled dung users on the basis of education, environmental awareness, willingness to participate in the SET transfer, and use of firewood and leaves. It is seen from Table 7.2.1 that, of the primary-level educated 95.2%, secondary level educated 97.4%, and of highly qualified level 50% respondents use dung as an energy source. The difference of dung use in these groups is statistically highly significant (0.000).

With regard to firewood users' and dung users' relationship, about 88% firewood users use dung, while 74.4% respondents who do not use firewood use dung. This shows a significant difference between the dung users who are also use firewood and the dung users who do not use firewood. Regarding environmental awareness, it is seen from the table that 85.6% of respondents who are aware of environmental pollution use dung, while 88.4% of who are not aware of environment pollution use dung. The result is statistically not significant (0.503). The reason behind the lack of awareness of a large portion of population may be that, as dung is used as a source of energy very commonly in rural population, and in the developing countries, the use of dung is inherited since ancient times, people do not consider it to be the environmental issue.

In relation to dung users and leaf users, it is seen that 96.8% leaf users use dung, and 69% respondents who do not use leaf use dung as a source of energy. The difference between these groups is highly significant. The table also shows that about 90% respondents of who are interested in participating in SET transfer process use dung while 79% of who are not interested in SET transfer process use dung. The degree of difference between these two groups is also statistically significant.

Table: 7.2.1 Dung Users' Characteristics

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Using Dung* (86.5)*	*Significance of Difference***
Income			Significant (0.006)
Low Income	142	92.2	
High Income	161	81.4	
Land ownership			Not significant (0.573)
Small Holdings	138	87.7	
Large Holdings	165	85.5	
Education			Highly significant (0.000)
Illiterate	36	83.3	
Primary	84	95.2	
Secondary	57	94.7	
Higher Secondary	78	82.1	
Bachelor	36	77.8	
Master and above	12	50.0	
Environmental Awareness			Not significant (0.503)
Aware	208	85.6	
Unaware	95	88.4	
Willingness to SET			Significant (0.010)
Willing	208	89.9	
Not Willing	95	79.0	
Firewood Use			Significant (0.018)
Firewood Used	264	88.3	
Firewood Not Used	39	74.4	
Leaf Use			Highly significant (0.000)
Leaf Used	190	96.8	
Leaf Not Used	113	69.0	

Source: Compiled from survey data

*Figure after decimal is rounded up.

**Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of dung.

7.2.2: Firewood Uses' Characteristics

Like dung users', the background characteristics of firewood users have been analysed in this section. The main focus of this analysis is to see the relationship of firewood use with land ownership, educational level, and the income of firewood users. It also aims to see the degree of differences in the use of firewood, as a source of energy, due to the change in background variables of the respondents. In addition, respondents' awareness about environmental pollution and the knowledge about SET in relation to firewood use also need to be assessed. Relationship of the variables in relation to firewood use is presented in Table 7.2.2.

It is observed from Table 7.2.2 that out of total, 87.1% respondents use firewood as a source of energy. In the low-income group 83.8% use firewood, and in the high-income group 90.1% use firewood. The degree of difference between these two groups in the use of firewood is statistically highly significant (0.000). This result shows the reality of rural community where the rich use more firewood than the poor do. From a sociological point of view, as firewood is a better quality energy source compared to dung and leaves, use of firewood carries a symbol of dignity for the richer family in rural Bangladesh.

However, based on the land ownership pattern, the degree of difference in the use of firewood is not statistically significant (0.703). This may be the result of the fact that large land holdings does not mean that the owner is rich, and hence not necessarily belongs to the high-use group in firewood. Another reason may be that, although generally the high income is highly correlated with large land holdings, this may not necessarily be always true. For instance, if the land is fallow, the income from that land may be less or even zero. This assumption is applicable for a country like Bangladesh where the land may be lost due to river erosion or natural disasters like flood. However, there might be some socio economic factors that have influence on this behavior of firewood users but not been covered in this study.

Table 7.2.2 also shows the significant difference in firewood use with the different level of educational background (0.002). Generally, the choice of firewood use depends on factors such as availability of resources, knowledge on environmental pollution, income level etc. However, an opposite relationship is found between environmental awareness and firewood use. The degree of difference is not significant (0.348). The most likely reason may be that though the rich use more firewood they are not necessarily knowledgeable about environmental pollution.

The table shows further that 88.9% dung users use firewood, while 75.6% respondents who do not use dung use firewood. The degree of difference is significant (0.018). Similarly, 94.7% leaf users use firewood, and 74.3% of who do not use leaves use firewood. The degree of difference is also highly significant (0.000). It indicates that the households who consume more firewood also use more dung and leaves, and vise versa.

It is also seen from the table that 92.3% of respondents who are willing to participate in SET transfer use firewood, while 75.8% of those who are not interested in SET use firewood. The degree of difference in these two groups is also highly significant (0.000).

Although there might have other socio economic factors in the population which have not been covered in this study, one interpretation can be made from the mentioned firewood behavior that the respondents who use firewood may have better access to occupy (use) dung and leaves compared to those who use less firewood. In other words, it would not be wrong to say that the households who can afford (use) for firewood have more access (control) over the energy market than who can not afford for firewood.

Table: 7.2.2 Firewood Users' Characteristics

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Using Firewood* (87.1)*	*Significance of Difference***
Income			Not significant (0.105)
Low Income	142	83.8	
High Income	161	90.1	
Land Ownership			Not significant (0.342)
Small Holdings	138	89.1	
Large Holdings	165	85.5	
Education			Highly significant (0.000)
Illiterate	36	66.7	
Primary	84	95.2	
Secondary	57	94.7	
Higher Secondary	78	89.7	
Bachelor	36	72.2	
Master and above	12	83.3	
Environmental Awareness			Not significant (0.078)
Aware	208	89.4	
Unaware	95	82.1	
Willingness to SET			Highly significant (0.000)
Willing	208	92.3	
Not Willing	95	75.8	
Leaf Use			Highly significant (0.000)
Leaf Used	190	94.7	
Leaf Not Used	113	74.3	
Dung Use Total			Significant (0.018)
Dung Used	262	88.9	
Dung Not Used	41	75.6	

Source: Compiled from survey data

*Figure after decimal is rounded up.
**Co-efficient less than 0.05 means the two categories significantly differ with respect to the use of firewood.

7.2.3: Leaf Users' characteristics

Table 7.2.3 represents the relationship of respondents' background variables and the use of leaves as a source of fuel. It is seen from the table that out of total, 62.7% respondents use leaves as a source of energy. Of the low-income group 54.9% are leaf users. Of the high-income group 69.6% are leaf users. The degree of difference in these two groups is significant. However, in relation to firewood users and leaf users, 68.2% firewood users use leaves, while 25.6% of respondents who do not use firewood use leaves. The degree of difference between these groups is also significant (0.000). This finding has a positive consistency with the relationship of firewood use versus income, which shows that rich households consume more firewood than the poor do.

The fact that in rural Bangladesh people who use leaves as an energy source means they have no alternative source or are economically unable to bear the alternative fuel costs, i.e. financially they belong to lower-income groups of the community. In fact, to some extent, the use of different sources of energy is a symbol of the users' social status in rural society of Bangladesh. In addition, the significant difference between low- and high-income group in the use of leaves also indicates that the high-income group is not dependent on leaves as much as the low-income group.

The use of leaves according to respondents' educational level reveals that about 25% of illiterate population use leaves, followed by primary-qualification-level family (78.6%). The degree of difference is significant (0.012). However, 65.9% of respondents who are environmentally aware use leaves, while 55.8% of who are not environmentally aware use leaves. The degree of difference is not significant (0.093). The reason may be the lack of knowledge about environmental quality or SET. About 75% of those who are interested to participate in SET transfer use leaves, and 36.8% of those who are not interested in participating in SET transfer use leaves as a source of energy.

The table also indicates that 70.2% of dung users use leaves, while 14.6% of those who do not use dung use leaves. The degree of difference is highly significant (0.000) in these groups. It indicates that a household, which depends on leaves, is likely to be dependent on dung too. That means there is a similarity between dung users' and leaf users' socio economic characteristics such as choice of energy sources.

The most interesting point is that, except for environmental awareness, the degrees of difference of analysed variables are significant. It indicates that use of leaves as a source of energy plays a significant role in rural Bangladesh, and hence any policy regarding the change of leaves use requires in-depth attention.

Table: 7.2.3 Leaf Users' Characteristics

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Using Leaf* (62.7)*	*Significance of Difference***
Income			Significant (0.009)
Low Income	142	54.9	
High Income	161	69.6	
Land Ownership			Significant (0.013)
Small Holdings	138	70.3	
Large Holdings	165	56.4	
Education			Significant (0.012)
Illiterate	36	25.0	
Primary	84	78.6	
Secondary	57	71.9	
Higher Secondary	78	64.1	
Bachelor	36	52.8	
Master and above	12	41.7	
Environmental Awareness			Not significant (0.093)
Aware	208	65.9	
Unaware	95	55.8	
Willingness to SET			Highly significant (0.000)
Willing	208	74.5	
Not Willing	95	36.8	
Firewood Use Total			Highly significant (0.000)
Firewood Use	264	68.2	
Firewood Not Use	39	25.6	
Dung Use Total			Highly significant (0.000)
Dung Use	262	70.2	
Dung Not Use	41	14.6	

Source: Compiled from survey data

*Figure after decimal is rounded up.

** Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of leaves.

7.2.4: Kerosene Users' Characteristics

Statistical analysis of background variables (respondents' income, land ownership, education, environmental awareness, and interest to participate in SET transfer) of sampled respondents who use kerosene as a source of energy for household and commercial purposes is presented in Table 7.2.4. It is notable here that in rural Bangladesh kerosene is used almost entirely for household purposes, for lighting only.

However, while conducting a participatory rural appraisal survey in Kutubdia village (Chittagong Division), we found a family which, sometimes in rainy season, uses kerosene as a facilitating agent for firing firewood or leaves for cooking or washing 2-3 times a year. For commercial purposes, kerosene is used for lighting in shops. Kerosene is used for cooking in some families in urban areas, including city slums. Hence, as the use of kerosene for other purposes than lighting is very insignificant in the rural sector, this study is limited to the analysis of kerosene for lighting purposes.

It appears from the table that out of total, 90.8% households use kerosene as a source of lighting in which there is a significant difference between low- and high-income groups in terms of their kerosene use (0.042). Of the low income group 94% are kerosene users. Of the high income group about 88% are kerosene users. It shows that high-income groups are not dependent on kerosene use as much as the low-income group. A contrasting picture is seen in the land ownership pattern. Of the small land holdings group about 88% are kerosene users, while of the large land holdings group 92.7% are kerosene users. But the degree of difference is not significant (0.197). One of the reasons might be that the large land holdings households need more kerosene to meet their lighting demand where other energy sources such as electricity is not sufficient enough.

In terms of respondents' educational background and kerosene use, it is seen that 90.5% of primary level educated, 93% of secondary level educated, 89.7% of higher secondary level, and 83.3% of master and above qualification level educated respondents use kerosene. The lowest use of kerosene is observed in illiterate group of the community (10%). The degree of difference among these groups is not significant. The reason might be that the households with students need/consume more kerosene. Similarly, households with members working/studying at night, consume more kerosene for lighting. Kerosene is the main (in fact only) source of lighting for study at night in rural Bangladesh. Obviously, illiterate households are largely disadvantaged group of the society, they consume lowest amount of energy for lighting purpose.

In response to a question of the field survey, respondents opined that their children's education has been suffering due to the lack of energy. A similar opinion was found during the PRA surveys. It was found that education suffers severely as a result of insufficient energy for lighting in rural Bangladesh.

It is also seen from Table 7.2.4 that of the respondents who are aware of environmental pollution 92.3% use kerosene, while that of who are unaware of environmental pollution 87.4% use kerosene. The degree of difference between these two groups is insignificant (0.169). The reason might be that the use of kerosene is such a common thing in rural communities that people do not think about environment when using it.

The table shows that about 92% firewood users use kerosene, while about 82% of who do not use firewood use kerosene. The degree of difference in these groups is significant (0.045). However, the degrees of difference between different groups of kerosene users with regard to leaf use and dung use are not significant (0.524 and 0.483, respectively).

Table: 7.2.4 Kerosene Users' Characteristics

Characteristics and Types of Energy Used	*No. of Respondents* (Total 303)	*Percentage of Respondents Using Kerosene* (90.8)*	*Significance of Difference***
Income			Significant (0.042)
Low Income	142	94.4	
High Income	161	87.6	
Land Ownership			Not significant (0.197)
Small Holdings	138	88.4	
Large Holdings	165	92.7	
Education			Not significant (0.599)
Illiterate	36	10.0	
Primary	84	90.5	
Secondary	57	93.0	
Higher Secondary	78	89.7	
Bachelor	36	83.3	
Master and above	12	83.3	
Environmental Awareness			Not significant (0.169)
Aware	208	92.3	
Unaware	95	87.4	
Willingness to SET			Not significant (0.107)
Willing	208	88.9	
Not Willing	95	94.7	
Firewood Use			Significant (0.045)
Firewood Use	264	92.1	
Firewood Not Use	39	82.1	
Leaf Use			Not significant (0.524)
Leaf Use	190	91.6	
Leaf Not Use	113	89.4	
Dung Use			Not significant (0.483)
Dung Use	262	91.2	
Dung Not Use	41	87.8	

Source: Compiled from survey data

*Figure after decimal is rounded up.

**Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of kerosene.

7.2.5: Diesel Users' Characteristics

This section shows the background characteristics of respondents who use diesel as a source of energy in rural Bangladesh. It is notable here that diesel is used in rural areas only for commercial purposes. In this study, commercial purpose refers to such diesel-using activities as operating deep tube well for irrigation. That means in rural areas there is no other use of diesel, except for machine operation for irrigation.

The main reasons might be the high cost of diesel for rural population, and the unavailability of technology for its alternative use. In urban areas, there are some uses of diesel in the transport sector, but these facilities are not available in rural communities. The relationship of respondents' background variables in respect of diesel use is presented in Table 7.2.5.

It appears from Table 7.2.5 that the degree of difference in using diesel with respondents' income, land ownership, education, and even with the combination use of firewood, dung, and leaves is not significant in all cases. The co-efficient of significance test is higher than 0.05 in all cases (see Table 7.2.5). The reasons behind it are mainly the very limited use of diesel (irrigation machines operation only), and it occurs irrespective of other factors. As there is no alternative source for machinery operation, diesel is treated as an essential commodity in rural Bangladesh where consumers' choice is strictly restricted.

Furthermore, it has been observed in the PRA survey that as diesel is the main (indeed only) source of energy for irrigation machine operation and its distribution (marketing) system in rural Bangladesh is controlled by the middlemen and large farmers, the small and marginal farmers are more disadvantaged from the benefit of diesel.

Table: 7.2.5 Diesel Users' Characteristics

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Using Diesel* (3.6)*	*Significance of Difference***
Income			Not significant (0.053)
Low Income	142	1.4	
High Income	161	5.6	
Land Ownership			Not signi icant (0.064)
Small Holdings	138	1.4	
Large Holdings	165	5.5	
Education			Not significant (0.931)
Illiterate	36	0.0	
Primary	84	4.8	
Secondary	57	3.5	
Higher Secondary	78	3.8	
Bachelor	36	2.8	
Master and above	12	8.3	
Environmental Awareness			Not signi icant (0.716)
Aware	208	3.4	
Unaware	95	4.2	
Willingness to SET			Not signi icant (0.716)
Willing	208	3.4	
Not Willing	95	4.2	
Firewood Use			Not significant (0.195)
Firewood Use	264	4.2	
Firewood Not Use	39	0.0	
Leaf Use			Not significant (0.485)
Leaf Use	190	4.2	
Leaf Not Use	113	2.7	
Dung Use			Not significant (0.661)
Dung Use	262	3.8	
Dung Not Use	41	2.4	

Source: Compiled from survey data

*Figure after decimal is rounded up.

** Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of diesel.

7.2.6: Environmental Awareness

This section deals with the relationship of environmental awareness and background variables of sampled respondents. Details are shown in Table 7.2.6. It is observed from the table that the respondents who have higher income are more concerned about environmental pollution than those of lower-income group (81.4% and 54.2% respectively). The degree of difference with respect to environmental pollution awareness between high and low-income groups is highly significant.

On the other hand, although respondents who belong to large holdings ownership are more aware of environmental issues than those belonging to small holdings, the degree of difference is not significant (0.240).

In relation to education, it is seen that relatively higher educated respondents are more aware about environmental degradation than less educated or illiterate. The degree of difference is significant (0.004). The table also shows that the degrees of differences of environmental awareness among the users and non-users of firewood, leaves, and dung are not significant (0.078, 0.093 and 0.503 respectively).

It is clear from the table that environmental awareness is a matter directly related with education and income of rural population of Bangladesh. In this case, education means knowledge, including technological knowledge and income means purchasing power of the respondents. **Ironically, these two sectors severely suffered due to the lack of sufficient energy in rural society of Bangladesh. This indicates that investment in education and employment sectors is the precondition of keeping environment friendly in Bangladesh. In other words, policy regarding education and employment is directly related with the effective transfer of SET to Bangladesh.**

Table: 7.2.6 Characteristics of Respondents about Environmental Awareness

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Aware of Environment* (68.7)*	*Significance of Difference***
Income			Highly significant (0.000)
Low Income	142	54.2	
High Income	161	81.4	
Land Ownership			Not significant (0.240)
Small Holdings	138	65.2	
Large Holdings	165	71.5	
Education			Significant (0.004)
Illiterate	36	13.9	
Primary	84	61.9	
Secondary	57	80.7	
Higher Secondary	78	80.8	
Bachelor	36	83.3	
Master and above	12	100.0	
Willingness to SET			Highly significant (0.000)
Willing	208	77.4	
Not Willing	95	49.5	
Firewood Use			Not significant (0.078)
Firewood Use	264	70.5	
Firewood Not Use	39	56.4	
Leave Use			Not significant (0.093)
Leave Use	190	72.1	
Leave Not Use	113	62.8	
Dung Use			Not significant (0.503)
Dung Use	262	67.9	
Dung Not Use	41	73.2	

Source: Compiled from survey data

*Figure after decimal is rounded up.

**Co-efficient less than 0.05 means the two categories significantly differ with respect to their environmental awareness.

7.2.7: Willingness to Participate in SET Transfer

The results of the respondents' interest towards participation in SET transfer in relation to their background variables can be seen in Table 7.2.7. It appears from the table that 53.5% low-income group respondents, and 82.0% high-income group respondents are interested in participating in SET transfer. The difference between these groups is highly significant (0.000).

Seventy nine percent small land holdings owners and 60% large land holdings group expressed their interest in SET. The willingness in participation gradually increases with the level of education of the respondents. That means, relatively higher educated people are more interested in participating in SET transfer process. Their percentage varies from 13.9 to 86%. A little variation is seen in highly qualified respondents (master and above 75%). The degree of difference among different groups in terms of education is significant (0.019).

The respondents who are environmentally aware, are more interested in contributing to SET transfer pr•cess. Of the environmentally aware group about 77% expressed their interest in SET, while of the environmentally unaware group 49.5% expressed their interested in SET. This result is consistent with analytical output of environmental awareness variable (section 7.2.6) which indicates that environmental awareness is a precondition for SET transfer process, which suggests the need for investment in education sector.

It also appears that the percentage of respondents willing to share in SET transfer process is higher in users of firewood, leaves and dung than that of who do not use these energy sources (non-users). The degrees of differences are significant for all cases, i.e. less than 0.05. This indicates that respondents are aware about the consequences of energy problems, and have shown their willingness to participate in SET transfer process irrespective of their background. That means there is a strong demand for SET in rural Bangladesh.

Table: 7.2.7 Characteristics of Respondents of Willingness to SET

Characteristics and Types of Energy Used	*No of Respondents* (Total 303)	*Percentage of Respondents Willing to Assist SET* (68.7)*	*Significance of Difference***
Income			Highly significant (0.000)
Low Income	142	53.5	
High Income	161	82.0	
Land Ownership			Highly significant (0.000)
Small Holdings	138	79.0	
Large Holdings	165	60.0	
Education			Significant (0.019)
Illiterate	36	13.9	
Primary	84	65.5	
Secondary	57	71.9	
Higher Secondary	78	85.9	
Bachelor	36	86.1	
Master and above	12	75.0	
Environmental Awareness			Highly significant (0.000)
Aware	208	77.4	
Unaware	95	49.5	
Firewood Use			Highly significant (0.000)
Firewood Use	264	72.7	
Firewood Not Use	39	41.0	
Leaf Use			Highly significant (0.000)
Leaf Use	190	81.6	
Leaf Not Use	113	46.9	
Dung Use			Significant (0.010)
Dung Use	262	71.4	
Dung Not Use	41	51.2	

Source: Compiled from survey data

*Figure after decimal is rounded up.

** Co-efficient less than 0.05 means the two categories significantly differ with respect to their willingness to participate in SET transfer process.

7.2.8: Energy Needs For Cooking

It has been explained in a previous chapter (Chapter 6 Table 6.3.2.1) that rural households spend 78.7% of their total consumed energy on cooking, lighting, and washing (31.4% for cooking, 26.3% for lighting, and 21% for washing). It is also seen from that table that more than 98% households spend energy for cooking in everyday life of rural Bangladesh. Further illustration of nature of energy needs for cooking and lighting in rural society of Bangladesh can be seen in Chapter 8 section 8.3.1.1. & 8.3.1.2 respectively. Hence, it is interesting to know whether there exists any variation due to different background characteristics of respondents in using pattern of energy for cooking and lighting purposes. Socio-economic variables of the respondents who use energy for cooking and lighting are presented in Tables 7.2.8 and 7.2.9, respectively.

It is seen from Table 7.2.8 that, of the low-income group households 95.8% use energy for cooking, while of the high-income group households 96.3% use energy for cooking. Based on land ownership criterion, 99.3% households of small land holdings group use energy for cooking, while 93.33% households of large land holdings group use energy for cooking. However, the degree of difference is not significant (0.825) for income variation, but significant (0.008) for land ownership. The degree of difference in energy consumption for cooking purpose in terms of educational level and willingness to take part in SET transfer is highly significant (0.000 and 0.040, respectively). On the other hand, the degree of difference with regard to environmental awareness and energy use for cooking is not significant (0.880).

In relation to firewood use and energy use for cooking it is seen that 97% firewood users use energy for cooking, while 90% of households who do not use firewood use energy for cooking. The degree of difference in these groups is significant (0.031). The degree of difference between users and non-users of leaves with regard to use energy for cooking is insignificant (0.354). It indicates that cooking is the main energy demand of rural communities of Bangladesh, and households consume energy for cooking irrespective of their social background. It implies that any policy formulation regarding the supply-demand management of energy for Bangladesh needs a clear attention of cooking factor of rural community of the country.

Table: 7.2.8 Characteristics of Respondents Who Used Energy for Cooking

Characteristics and Types of Energy Used	*No of respondents* (Total 303)	*Percentage of Respondents Using Energy for Cooking* (96.0)*	*Significance of difference***
Income			Not significant (0.825)
Low Income	142	95.8	
High Income	161	96.3	
Land Ownership			Significant (0.008)
Small Holdings	138	99.3	
Large Holdings	165	93.3	
Education			Not significant (0.528)
Illiterate	36	100.0	
Primary	84	95.2	
Secondary	57	93.0	
Higher Secondary	78	97.4	
Bachelor	36	97.2	
Master and above	12	91.7	
Environmental Awareness			Not significant (0.880)
Aware	208	96.2	
Unaware	95	95.8	
Willingness to SET			Significant (0.040)
Willing	208	97.6	
Not Willing	95	92.6	
Dung Use			Not significant (0.746)
Dung Use	262	96.2	
Dung Not Use	41	95.1	
Firewood Use			Significant (0.031)
Firewood Use	264	97.0	
Firewood Not Use	39	89.7	
Leaf use			Not significant (0.354)
Leaf Use	190	96.8	
Leaf Not Use	113	94.7	

Source: Compiled from survey data

*Figure after decimal is rounded up.

** Co-efficient less than 0.05 means the two categories significantly differ with respect to their need for energy for cooking.

7.2.9: Energy Needs For Lighting

We have mentioned in the previous section that energy spends on lighting is the second most priority in rural Bangladesh. Background characteristics of sampled respondents who use energy for lighting is presented in Table 7.2.9.

Table shows that about 54% respondents of the low income group use energy for lighting, while 76% respondents of the high income group use energy for lighting. The degree of difference between low income and high-income group respondents with regards to use of energy for lighting is highly significant (0.000). It indicates that high earners demand more energy for lighting than low-income earners.

The degree of differences with regard to use energy for lighting between users and non-users of leaves and dung is also significant (0.000 and 0.004). However, the degree of differences in relation to energy consumption for lighting among different groups of environmental awareness, attitudes towards SET transfer process and use of firewood are insignificant (see table).

The significance of differences among different groups in the use of energy for lighting indicates that the demand for energy for lighting varies from class to class within the community, depending on their background. In other words, the energy demand for lighting is a function of living style of the society. In PRA survey, it has been found that education is one of the most badly affected areas as a result of shortage of energy in rural Bangladesh.

Table: 7.2.9 Characteristics of Respondents Who Used Energy for Lighting

Characteristics and Types of Energy Used	*No of respondents* (Total 303)	*Percentage of Respondents Using Energy for Lighting* (65.7)*	*Significance of difference***
Income			Highly significant (0.000)
Low Income	142	54.2	
High Income	161	75.8	
Land Ownership			Highly significant (0.000)
Small Holdings	138	51.5	
Large Holdings	165	77.6	
Education			Significant (0.002)
Illiterate	36	94.4	
Primary	84	48.8	
Secondary	57	57.9	
Higher Secondary	78	65.4	
Bachelor	36	80.6	
Master and above	12	91.7	
Environmental Awareness			Not significant (0.874)
Aware	208	65.4	
Unaware	95	66.3	
Willingness to SET			Not significant (0.085)
Willing	208	62.5	
Not Willing	95	72.6	
Firewood Use			Not significant (0.114)
Firewood Used	264	64.0	
Firewood Not Used	39	76.9	
Leaf Use			Highly significant (0.000)
Leaf Used	190	56.8	
Leaf Not Used	113	80.5	
Dung Use			Significant (0.004)
Dung Used	262	62.6	
Dung Not Used	41	85.4	

Source: Compiled from survey data

*Figure after decimal is rounded up.

**Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of energy for lighting.

7.2.10: Energy Uses for Entertainment

The background characteristics of respondents who use energy for entertainment are presented in Table 7.2.10. It appears from the table that out of total, only 9.9% households spend energy for entertainment purpose in rural Bangladesh. In terms of respondents' income level it is seen that 7% respondents of low income earning group spend energy for entertainment, and 12.4% respondents of high-income group spend energy for entertainment.

Similarly, 5.8% respondents of the small land holdings group spend energy for entertainment, while 13.3% respondents of the large land holdings group spend energy for entertainment. The income-based degree of difference is not significant (0.118), but that of land-ownership-based is significant (0.029).

The degree of difference is insignificant between the environmentally aware and unaware groups of respondents who use energy for entertainment (0.509), and also insignificant between the users and non-users of firewood and leaves (0.937 and 0.056 respectively).

From the above data it is difficult to see what types of entertainment facilities people enjoy, or what types are available in rural Bangladesh. But it indicates that economically relatively well-positioned households consume more energy for entertainment where a source and adequate supply of energy is available.

It may be mentioned here that in rural Bangladesh the entertainment and recreation sector is affected most due to shortages of energy. It was found in PRA survey that 16 out of 20 participants (80%) revealed going to bed immediately after dinner because they had nothing to do in the dark.

It was also found that due to lack of money people could not afford individual facilities such as television or cassette player, which could be operated by a battery. Sometimes male members of a family can go out to socialise or walk or play cards in the moonlight, but for female members the situation is more critical.

During PRA survey, women were asked what they usually do in their leisure time. They could not think of anything except household work and providing services for their husbands, raising children, helping other family members. They seemed to indicate that they had no leisure time but this may be due to the inability to spend quality time after nightfall due to an absence of affordable lighting in the house. It implies that there is a tremendous demand for energy in entertainment sector of rural Bangladesh.

It is therefore hard to avoid the conclusion that lack of energy is one of the main barriers to improving the lifestyle of rural society. Moreover, our above-mentioned findings may confirm the argument that the failure of population control programme in rural Bangladesh is caused by energy shortages (GOB, MOHF 1994, Family Planning Project Evaluation Report).

Table: 7.2.10 Characteristics of Respondents Who Used Energy for Entertainment)

Characteristics and Types of Energy Used	*No of respondents* (Total 303)	*Percentage of Respondents Using Energy for Entertainment* (9. 9)*	*Significance of difference***
Income			Not significant (0.118)
Low Income	142	7.0	
High Income	161	12.4	
Land Ownership			Significant (0.029)
Small Holdings	138	5.8	
Large Holdings	165	13.3	
Education			Not significant (0.229)
Illiterate	36	16.7	
Primary	84	6.0	
Secondary	57	7.0	
Higher Secondary	78	15.4	
Bachelor	36	5.6	
Master and above	12	8.3	
Environmental Awareness			Not significant (0.509)
Aware	208	9.1	
Unaware	95	11.6	
Willingness to SET			Not significant (0.057)
Willing	208	7.7	
Not Willing	95	14.7	
Firewood Use			Not significant (0.937)
Firewood Used	264	9.8	
Firewood Not Used	39	10.3	
Leaf Use			Not significant (0.056)
Leaf Used	190	7.4	
Leaf Not Used	113	14.2	
Dung Use			Significant (0.006)
Dung Used	262	8.0	
Dung Not Used	41	22.0	

Source: Compiled from survey data

*Figure after decimal is rounded up.

**Co-efficient less than 0.05 means the two categories significantly differ with respect to their use of energy for entertainment.

7.3: Correlation Analysis

The interdependence of respondents' socio-economic background variables, sources of current energy use, pattern of energy use for main household activities, and knowledge of and interest in SET has been analysed in this section. The aim is to further justify our findings statistically. The variables that have been inputted in the analysis are respondents' land, income, education, use of firewood, dung and leaves for household purpose, awareness about environmental pollution, knowledge about SET and willingness to participate in the SET process. The results of correlation calculation are presented in Table 7.3.1.

Table 7.3.1 Correlation Output

	Land	*Income*	*Education*	*Fire wood*	*Dung*	*Leaf*	*EA*	*Know SET*	*Willingness to SET*
Land	1.000								
Income	.345**	1.000							
Education	.091	.087	1.000						
Firewood use	.019	.025	-.016	1.000					
Dung use	-.115*	-.169**	-.199**	.136*	1.000				
Leaves use	-.202**	-.065	.001	.295**	.393**	1.000			
Env. Awareness	.054	.133*	.402**	.101	.039	.097	1.000		
Knowledge about SET	-.096	.139*	.266**	.012	.093	.213**	.204**	1.000	
Willingness to SET	-.073	.008	.370**	.229**	.149	.361**	.279**	.245**	1.000

Source: Compiled from survey data

* Correlation is significant at the 0.01 level (2-tailed).
**Correlation is significant at the 0.05 level (2-tailed).

It is seen from the Table 7.3.1 that land has a strong positive influence on income but negative impact on the use of dung and leaves. Income variable has positive influence on environmental awareness issues and knowledge about SET but that is negative on dung use. It means that proper land use (e.g. scientific cultivation, agro-based programs etc.) might contribute to increase peoples' income which inturns reduce the use of dung and leaves because people may choose alternative sources of energy (including technological upgradation) instead of what they are using now in a traditional way.

Table further shows that education has a strong positive influence on environmental awareness, knowledge and willingness about SET but that is negative on dung use. Similarly, it is also seen from the table that firewood and dung uses are positively associated with the use of leaves. The reason might be that as rich class of rural community consumes large share of firewood compared to dung and leaves, the increase of firewood consumption might contribute to increase the dependency on dung and leaves for poor groups.

However, Although environmental awareness, knowledge and interests about SET are interrelated and each of these factors has a strong influence on others, an unexpected relationship (positive influence) is seen between leaves use and knowledge about SET.

It is clear from the above mentioned correlation analysis that there is a relationship between background characteristics of the energy users and the effective transfer of SET as a means of keeping environment friendly as well as meeting energy demands in a sustainable way for rural population Bangladesh. This relationship confirms our survey findings (Chapter 6) that rural people are interested to know more about SET and they are willing to contribute in the SET transfer process in appropriate form. It implies that, as part of SET transfer process, there is a need to educate rural population of Bangladesh and to create employment opportunity further.

7.4: Regression Test

We have tested, by using Means of Variance and Mann-Whitney techniques, whether there exists any significant difference among different groups of energy users in relation to the use of some selected energy sources and due to their different socio economic backgrounds. We have also used correlation method to testify our findings further. It is seen that the results obtained from Means, Mann-Whitney and correlation tests are consistent. Now we are interested to justify this observation with regression model.

We have observed in PRA survey that there is a positive correlation between the respondents' background characteristics and the SET transfer process. That means a strong influence of the respondents' background characteristics on the SET programme decision-making process. The success or failure of SET programme may largely depend on users' (respondents') choice.

Hence, it is considered important and interesting to identify respondents' background characteristics that influence their willingness to participate in the SET programme. The main determinants influencing the choice of SET, are the respondents' social, economical, technical, and cultural background as we have analysed earlier.

However, for the sake of simplicity, this study considers that respondents' education, income, land ownership, and knowledge about SET and environment are the most significant determinants to analyse in regression model. We have used Multiple Linear Regression (MLR) model. Two regressions have been analysed.

In the first one, awareness about environment pollution due to the energy use has been considered a dependent variable, and income, education, land ownership, and knowledge about SET are considered independent variables. In the second one, the willingness to participate in SET transfer process is considered a dependent variable, while income, education, land ownership, knowledge about SET, and environmental awareness are considered as independent variables.

While details of regression processes can be seen in table 7.4.1a and 7.4.1b (see annex 18a and 18b respectively), the results of two regressions are presented in equation 7.1 and 7.2 respectively. In both cases, t values are presented in the parenthesis of the respective equation. Adjusted R and F values are also denoted along with respective equation.

The equations are:

$$AEP = .324 + .348E + .090I + .014L + .136K \text{ ---------------------- (7.1)}$$
$$(6.200) \quad (6.221) \quad (1.598) \quad (.243) \quad (2.348)$$
Adjusted R Square = .176, F value = 17.119

$$PSET = .275 + .249E - .027I - .054L + .125AEP + .239K \text{ -------(7.2)}$$
$$(5.033) \quad (4.250) \quad (-.483) \quad (-.951) \quad (2.202) \quad (4.242)$$
Adjusted R Square = .204, F value = 16.446

Where, AEP = Awareness of Environmental Pollution; E = Education;
I = Income; L = Land; K = Knowledge about SET;
PSET = Participation in SET programs; and
.324 and .275 are constants.

It is notable that there are some other socio economic factors in the population which have not been considered in this study, generally these factors are denoted by 'U' in the regression model equation. But for simplicity we have excluded that 'U'.

Equation 7.1 shows that awareness about environmental pollution is highly positively influenced by education, which is statistically significant too. It implies that if education (including technological kn•wledge) increases by one unit environmental awareness will also increase by o.348 units.

Equation also shows positive relationship between knowledge of SET and environmental pollution. For example, according to model, if knowledge increases by one unit, awareness about environment will increase by 0.136 units.

However, although the rest two variables (income and land) have no significant influence on awareness of environment pollution, constant (0.324) is statistically significant (see Table 7.4.1a).

The adjusted R Square value (.0.176) and F value (17.119) are statistically significant which indicates that the influence of education and knowledge upon awareness is about 18%. Apparently it shows low influence but for a country like

Bangladesh where literacy rate is very low and knowledge about SET is extremely limited, this 18% influence is not less important in policy making process for rural population.

It implies that the education and knowledge of environmental pollution are the key factors to be considered in transferring SET from the developed to the developing countries like Bangladesh.

Similar interpretation can be made from equation 7.2. It is seen from the equation that education and knowledge about SET have strong positive influence on the interest of participation in the SET programs, which is statistically significant too. Environmental awareness has also influence on interest of participation but not strong like education and knowledge.

For instance, increase of one unit of education will increase 0.249 units of interest of participation in SET programs. Similarly one unit positive change of knowledge of SET will contribute to make a change of 0.239 units in the willingness of SET activities. However, influence of the rest three variables is not statistically significant.

It is seen from adjusted 'R' value that the influence of above mentioned variables, as estimated, is about 20%. Although it seems low, for a third world country like Bangladesh it is not less significant in the decision making process.

Therefore, it is found that results of regression model are consistent with the results we obtained from other statistical analysis and satisfy the findings of the study.

7.5 Conclusion

This chapter has analysed the relationship of respondents' socio economic background variables with sources and pattern of energy use in main areas of household activities. Respondents' socio economic factors that have been analysed are land ownership, income and education. Major sources of energy supply are dung, firewood, leaves and diesel. Major household activities that cause large portion of energy demand are cooking, lighting and entertainment.

In this context, we have grouped the respondents into two categories for each of the variables. These are large and small land holdings, high and low income, illiterate, primary, secondary, higher secondary, bachelor and master and above. Regarding energy sources use we divided respondents as user and non-user. We have used means of variance, Mann-Whitney Test, correlation, and multiple linear regression methods as analytical tools.

Dung users' characteristics show that about 85% rural population use dung as a source of their energy supply. The low-income group households are more dependent on dung than the high-income households. Moreover, use of dung in rural community is very common, and people are not aware about the consequences of dung use and environmental pollution.

Firewood use analysis shows that about 87% households of rural Bangladesh use firewood as a source of energy for household activities. Rich people consume more firewood than poor people do. The differences of use of firewood based on respondents' education level are statistically significant. People are aware about the consequences of firewood use and environmental problems.

Leaf users characteristics shows that 63% households use leaf as a source of energy. Small land holdings households are more dependent on leaf compared to large land holdings households. The use of leaf has a positive relationship with firewood use and dung use. For instance, households who use firewood and/or dung use more leaves compared to who do not use firewood and/or dung. The degree of difference between these two groups is statistically highly significant. The degree of difference with regards to leaf use and environmental pollution is not significant.

Kerosene users' characteristics show that about 91% rural households use kerosene as a source of energy for lighting. In large scale, kerosene is the only source of energy for lighting in rural Bangladesh. Low income group is more dependent on kerosene than rich do. Rural people use kerosene as an essential commodity and very little aware about the environmental consequences due to kerosene use.

Diesel is entirely used for irrigation machine operation in rural Bangladesh. Less than 4% households use diesel. Large farmers and distributors more benefits from diesel use than small and marginal farmers. Diesel is treated as an essential commodity whose demand huge but supply is restricted by the monopoly market. It indicates that the potential demand for energy in the agricultural activities is very high in rural Bangladesh.

The analysis of awareness of environmental pollution shows that there is a positive relationship between environmental awareness with users' income and education. That means high income and educated households are more concern about environmental pollution than that of low income and less educated (and illiterate) households. The degrees of differences in these cases are highly significant too.

Willingness to participate in SET programs analysis shows that the interest of participation among the energy users increases with the level of their education and income. In addition, the people who are aware of environmental pollution are also more interested to participate in SET programs compared to those are not aware. This analysis also shows that there is a strong demand of SET in rural Bangladesh and people are willing to participate in SET programs.

The analysis of energy use for cooking, lighting and entertainment shows that large portion of households' energy demand derives from cooking followed by lighting. Less than 10% households use energy for entertainment of which high income and large land holdings are privileged. Rural women are highly disadvantaged due to short supply of energy for entertainment.

In brief, the statistical analysis of this chapter confirms that:

a. The main sources of energy supply in rural Bangladesh are dung, firewood, leaves, wind, animal power, and direct sun heat. Electricity and diesel are used on a very small scale, mainly for lighting and irrigation machinery operation. That means biomass is the main energy source in rural Bangladesh.

b. There is a positive relationship between the type of energy source and the socio-economic background of the users. The relationship between environmental awareness and education, income and willingness to participate in SET transfer process is also positive.

c. Above findings have been confirmed by using Means Test, Mann-Whitney Test, Correlation, and Regression analyses.

Based on the above analysis, it can be said that rural community of the sampled villages depends on biomass, wind and sun heat for meeting their energy demands mostly in a traditional way. However, there seems to be great scope for adoption and transfer of SET. But, as the users' knowledge about SET is limited, and as there exists a positive correlation between energy use and socio-economic variables, the adoption of SET may not be a straightforward process.

This chapter has revealed much about the background characteristics of energy users in rural Bangladesh. In particular, people with low income, smaller owners of land, and less educated people are more likely to use dung, leaves, and to some extent firewood as their main energy source. On the other hand, people with higher income, more land, and more educated are more likely to afford firewood or to some extent, electricity.

In general terms, firewood is not a luxury item, but in the context of rural Bangladesh where forest land is increasingly disappearing, and plantation of trees has not been adequate for a long time, rural people find it hard to afford even firewood for cooking. In addition, they struggle to afford kerosene for lighting. Therefore, the poor people are becoming increasingly dependent on leaves and dung.

With these findings in mind, it is now possible to turn to the key issue of the search to the most appropriate form of SET for the rural poor of Bangladesh. It is this issue that we now address in the following chapter.

Choice of SET for Rural Bangladesh

8.1 Introduction

In the previous chapters (Chapters 4 and 5) it has been established that Bangladesh has been suffering from acute shortages of energy, with rural communities being in the most vulnerable situation. It has also been illustrated that the country is endowed with very limited natural resources with the exception of natural gas. It largely depends on imported fuel (Chapter 4).

The use of imported fossil fuel is not only damaging environmental quality and long-term economic sustainability but also makes it almost impossible for Bangladesh to extend fossil-fuel-based power distribution networks to rural areas in the near future. Moreover, the low purchasing power is also a limiting factor for rural population, preventing it from having an access to the organised energy market.

Therefore, it is of crucial importance to find the best possible options of energy supply for rural communities. In this connection, it has also been mentioned earlier that this study would consider the viability of three energy technologies: biomass, solar, and wind power (Chapters 1 and 2). The aim of this chapter is to justify the best possible technological options for rural Bangladesh in meeting its energy demand at affordable cost, in a sustainable and environment-friendly way.

The effectiveness of SET transfer largely depends on the recipients' environmental set-up, economic ability, levels of technical know-how, social attitudes, and cultural behaviour. Economic ability includes recipients' financial capability, and all natural and physical resources that the recipients can afford. Levels of technical know-how refer to the users' technical skills and knowledge to adopt and use the introduced technology.

And socio-cultural issues imply the societal attitudes towards accepting technological changes, and the degree to which a particular society is prepared to adopt changes. It is generally believed that introducing change is not an easy task. That means that transfer of technology will not be effective unless it fits with the recipients' demands; and serves relevant developmental aspirations. That is why the criteria of justifying the appropriateness of SET are vital.

8.2 Criteria of Justifying SET

The appropriateness of an individual technology or its application might be assessed by a multidimensional approach because of its diversified use and applications. And hence, the selection criteria might also be different in every concrete case. For instance, a particular type of technology that might be suitable from the suppliers' point of view, might not be justified from the buyers' point of view. Accordingly, selection criteria will be quite different. Therefore, it is worthwhile to assess technology transfer on the users' economic ability, technical capability, social attitudes, and the ability of that technology to perform the desired tasks. This is even more crucial in assessing SET for a rural community.

It is arguable that the recipients' cultural and religious issues are also vital factors in assessing the suitability of a particular technology for a particular community. This is logical because, if a technology is transferred to a society where it does not match the users' cultural and religious habits, the recipients will not be willing to participate in implementing that technology, or they might choose not use it altogether. Ultimately, technology transfer will be ineffective. An evidence of this occurrence can be found in Ali (1992b)[1] where it has been shown that the biogas programme in the Muslim community of Indonesia failed because of using pig dung as a raw material in the biogas plants. On the other hand, similar biogas plants have been successful in China.

Given the importance of religious and cultural issues in assessing technological options for a particular locality, this study takes into account the fact that in

[1] The article was selected for publication in Unnayan Bitorko (a quarterly journal) Dhaka in 1992, but due to unavoidable circumstances, its publication was stopped for two years. As a result, my article

Bangladesh, pigs or other animals not accepted for consumption by Islam are very rare. It is possible to remove the barriers of technology transfer by introducing appropriate means and ways, where the first step will be to educate the potential recipients of the technology.

Furthermore, it has been found that the failure of biogas plants in Bangladesh was caused by shortages of raw materials, and lack of capital and motivation (Aziz 1999, Tasksforce 1991). Indeed, constraints on the technology transfer might not be the same for every rural community, although their socio-economic and cultural status might look similar.

Therefore, as we aim at assessing SET from the users' perspective, the criteria for judging its appropriateness would be: (a) availability of resource base, i.e. how much resources will be available to supply that particular energy, and its long-term consequences; (b) degree of technological complexity, i.e. whether rural population would be able to adopt that particular technology, using their technical knowledge; (c) cost-effectiveness, i.e. whether the cost of production and distribution of a particular type of energy would be within the reach of the poorer classes of rural communities; (d) balance between supply and pattern of needs, i.e. whether the technology can supply the particular type of energy that the users need; and (e) contribution of this particular energy technology to reducing GHG emission.

8.3 Nature of Energy Needs in Rural Bangladesh

The aim of this section is to illustrate the pattern of energy consumption. The information and analysis contained here would be useful for matching technological suitability with the users' requirements. We will make a special effort to analyse an approximate range of demand for a particular activity, and—where possible—an approximate demand will also be estimated.

The need for energy in a particular community depends on the nature of its economic activities, the degree of mechanisation in the agricultural sector, industrial base,

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was not published. However, the copy of this article is available at IDTC library, University of production and distribution networks, consumption behaviour, and the standard of living and lifestyle of the community. These multidimensional factors complicate energy demand analysis.

In addition, where the resource is extremely limited, it is obvious that maximum efforts would be aimed at using it in diverse ways. This has happened in rural Bangladesh where almost each part of a biomass product is used.

For instance, the grain from rice crops is used for human food, husk - for fuel, bran and best straw – for animal fodder, and the rest is used as fuel, organic fertilizer, or construction material. Similarly, each and every biomass product has more than one use, which makes its opportunity cost high, affecting the landless population of the society (for details of alternative use of biomass see Table 5.4.5.1 in Chapter 5). Consumption patterns of using biomass as fuel also vary from village to village, even from household to household, where they either compete with or complement one another.

For example, a household without its own cattle and hence cattle dung, uses jute stick directly as domestic type of fuel whereas another household with an access to cattle dung, makes dung sticks of dung and jute sticks, and uses them as fuel. Dung sticks can be used in big fireplaces (industrial burners), and they are also easy to use and transport compared to jute sticks.

It has been observed in the PRA survey that relatively rich farmers enjoy the benefits of processed fuel, as they have more options to mix different forms of biomass. It follows that there is a positive relationship between the use of a particular source of energy by a specific community and the level of poverty in that community.

There might be a contradiction in definitions regarding the depth of poverty, but the fact remains that rural economy of Bangladesh is almost below poverty line. In 1991/92 the number of rural population under absolute poverty line was 44.8 million (35.6%), and that became 45.7 million (36.3%) in 1995/96 (BBS 1999, p.389). It

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Melbourne.

means that in 1991-1996 the number of rural population existing under the absolute poverty line, increased by 1%. The population is struggling for food and basic needs such as health, education, and shelter. They live on agricultural produce, with the land being the prime factor of production. Definitely, their first choice would be to use the land to produce food for consumption.

As long as the rate of food production equates the population growth, it is manageable. But on the one hand, population grows faster than food production, and on the other hand, land resources are limited, and there is no way to increase them. Hence, the country is required to produce more food in limited land area by increasing crop intensity which necessitates the use of more energy as the increased food production requires the use of mechanised agriculture and use of fertiliser.

The real situation is even more severe because first, the agricultural production system is still in a traditional stage of development, and is dependent on human and animal power, and solar radiation; and second, the land area for crop production is decreasing due to increased housing and related needs from the growing population. This situation has been contributing to less food for people, and hence the biomass.

According to Islam (1983, p.11), three stages of agricultural practices might be observed in some locations of Bangladesh: simple traditional, semi-mechanised, and modern mechanised stages. The simple traditional system is characterised by a very low degree of commercial energy input. Human and animal labour force and solar radiation are the main energy input factors in this system.

The semi-mechanised system uses some chemical fertilisers, pumped irrigation, pesticides, and improved seeds; fields are prepared either mechanically or by cattle, and food processing (thrashing or drying) is sometimes mechanised. In a modern mechanised system, all food production processes are mechanised to a maximum, with the high input of fertilisers and other chemicals.

The third stage is very rare, but the country is trying to change its agricultural production system from traditional to semi-mechanised form for which the energy other than biomass is a precondition. Change of a productive system needs energy for machine operation (tractors or irrigation pumps), which is not technologically viable through using biomass and chemical fertilisers. Hence, development of agricultural sector largely depends on either supply of fossil fuel or energy of a similar nature such as solar or wind power.

Another important feature of energy demand in rural Bangladesh is transfer of biomass (mainly firewood and timber) from rural to urban areas, and transfer of fossil fuel (mainly kerosene and diesel) from urban to rural areas. Although the transfer of biomass and kerosene between rural and urban areas is an important factor in analysing the nature of rural energy needs, due to physical limitations this issue has not been dealt with in this study.

It appears from the above discussion that the analysis of rural energy use pattern is complex. It becomes even more complicated when we differentiate energy use for different activities. For instance, it is quite often in rural communities for the members of a household to sit besides the cooking stove while the food is being prepared, and eat in the light of the cooking flame. Thus, extra energy for lighting is not used while having dinner. In a sense, an acute energy shortage has persuaded rural population in the necessity of saving energy thus forming a useful habit.

Categorisation of the energy use pattern in rural Bangladesh is also a complex task. Some literature sources have categorised rural energy consumption pattern into four groups (consumption in households, commercial units, agriculture, and industry (GOB BEPP 1985e)). Although this system seems logical, the associated problem is the difficulty in subdividing the energy used in industry, and energy used in households.

One of the examples is the use of biomass fuel for making gur[2] from date plum tree juice. It is quite common in rural Bangladesh to make gur and perform other household cooking activities in the same burner. Additional firewood requirements for cooking amount to zero in this case. Alternatively, while household members are cooking food or boiling dirty clothes for washing, they can also cook other food for their own consumption on the same burner (while the previous item is temporarily kept off the burner for processing or stirring), or cook some other product which could be sold in the shop or at the market at some other time of the day. As the

[2] A type of molasses made from date tree juice.

market structure and the household structure in rural communities are unorganised, this situation usually becomes more complex, and hence it is hard to estimate the amount of energy consumed for each activity separately.

Furthermore, sometimes, it is hard to differentiate how much energy is needed for household cooking and how much for commercial cooking purposes. For example, for a family of four when it cooks food for selling in a restaurant, and at the same time consumes it at home there is no additional consumption of energy for cooking food for household consumption in this case. Similar complexity might arise when water is pumped for irrigation (agricultural activities) but is also used for some household activities. Moreover, this situation is further complicated when the owner of the water pump sells part of the pumped water to other farmers with a commercial motive.

The above circumstances are quite common because of the very small land size and an unorganised land use pattern in rural Bangladesh. To avoid these complexities, this study agrees to the national energy policy of Bangladesh (GOB, National Energy Policy, 1995) where the energy consumption pattern has been divided into two categories: household consumption and commercial consumption. In this case, household consumption refers to that amount and type of energy which is used within the household for domestic purposes. Commercial consumption of energy includes energy used for commercial purposes (business motives), and in agriculture and industry. Another important reason justifying this classification is the fact that in rural Bangladesh about 90% of energy is consumed for household purposes, with cooking being a vital component of energy consumption.

8.3.1 Energy for Households

In rural Bangladesh, household sector consumes the largest share of energy (87.5% according to GOB BEPP 1985g, 90% according to Taskforce 1991, and 79% according to GOB Energy Policy 1995), and the smallest quantity of fuel is used in commercial sectors. Agriculture is an important productive sector, and in future, it will require increased level of inputs of energy for fertiliser, irrigation, machinery, and transport to ensure higher yield of food and cash crops. Biomass fuel is mainly used in industry for processing agricultural crops (making gur from sugarcane juice, tobacco curing). Industrial activities in rural areas are currently limited but are expected to grow in the future, needing more energy.

Further, although the man-pulled rickshaw, man rowed boat and animal-pulled cart are the main means of transportation in rural communities, there is a growing trend of using fossil fuel in transport sector (auto rickshaw). However, considering the need and importance of energy for household sector and the scope of work, this study excludes this issue from its analysis.

Household activities mainly use biomass fuel for cooking, washing, and heating; kerosene is used for lighting; and dry cell is used for entertainment (Tables 6.3.1 and 6.3.2.1).

8.3.1.1 Cooking in Rural Households

It has already been mentioned that in rural Bangladesh household activities consume the lion share of energy demand, where cooking plays a predominant role. It has also been shown that biomass is mostly used for cooking food (almost 100% in rural households, and 70% in urban households, ADB 2000). Our analysis of demand as a dynamic concept could not include detailed consideration of the amount of energy consumed per household and per person, due to limited scope of the study. Hence, it would be reasonable to analyse the demand through an assessment of relevant studies carried out earlier.

The amount of per capita energy consumption in rural households varies from location to location, region to region and the figures in individual locations greatly differ from the national average. Further, the estimated amount of per capita energy consumption is different from study to study, too. Per capita consumption of the biomass fuel for cooking as estimated by some studies is presented in Table 8.3.1.1.

The table shows that the variation of per capita biomass consumption in rural Bangladesh is very high. The reasons behind it might be that the consumption of biomass is related to the type of its availability, and biomass production varies from region to region (Quader and Omar 1982).

Table 8.3.1.1: Per Capita Biomass Fuel Consumption for Cooking

SL.No.	*Study*	*Per capita biomass fuel consumption (GJ/year)*
1	GOB, 1976	2.8
2	Tyers, 1978	5.0
3	Briscoe, 1979	6.8
4	Hughart, 1979	7.6
5	Islam, 1980	4.9
6	Dauglas, 1981	4.44
7	Rahman, 1982	1.6
8	Quader, Omar, 1982	8.1
9	Islam, 1982	4.46
	Average	***4.71***

Source: Islam 1984a, GOB, BEPP 1985e, p.IV-2.4

Furthermore, the results of our field survey show that the types of biomass used for household cooking positively correlate with the background characteristics of its users. For example, if the user is a large farmer, owns large land-holdings then that farmer would use, generally, more firewood (quality biomass) compared to tree branches or leaves than that small or marginal farmers (Dauglas 1981). Wealthy families use relatively more expensive biomass (e.g. firewood) than that of the poor.

It is worth investigating whether rural households in Bangladesh with equal number of family members have been enjoying the same amount of biomass energy as is available for consumption per person. The answer is negative for a two-fold reason. First, poor families have limited access to the biomass market due to their limited purchasing power. Moreover, although poor families collect biomass from nearby forests or abundant crop fields, this collection is sometimes controlled by rich farmers (land-owners) due to their intention to use it as a fertiliser on their own land.

Second, rich farmers usually have to cook food for their hired labour, which results in using more biomass energy. It follows that large farmers benefit more from the high per capita biomass energy consumption. This situation implies the necessity of sustainable energy supply in a manner providing the disadvantaged groups of population with the same access to energy as is being enjoyed by more privileged groups.

However, referring to Table 8.3.1.1, it is difficult to estimate the accurate annual consumption of biomass energy for cooking per person. One option of the safe analysis is to use the mean of the study results (4.71 GJ/year/person). Using this figure, we arrive at the following total amount of biomass energy consumed for cooking per year in rural communities:

Total population	=126.5 million[3]
Rural population	=126.5*0.80 (percentage is rounded)
	=101 million
Biomass required for cooking	=36.36 million tons
Biomass energy for cooking	=101E6X 4.71GJ/year
	=475E6 GJ/year

Similar calculation is presented in GOB, BEPP (1985, p.IV-2.5) where the annual consumption of biomass energy for cooking has been estimated as 4.44GJ/yr/person. This study argues that a single person annually burns about 360kg biomass fuel for cooking (3% firewood, 66% agricultural residues, 7% tree droppings, and 24%dung, resulting in 4.44GJ/yr/person).

Hence, a household with 5.95 members uses 26.42GJ equivalent biomass per year for cooking. However, as the average family size in Bangladesh is 5.6 (BBS 1999, p.76), this study will use this figure. Accordingly, the biomass energy for cooking stands at 26.38GJ/household/year.

It is notable that the calorific value and moisture content of biomass fuel depends on its density, weather, maturity of a tree, type of biomass etc. Moreover, energy need

[3] This is the estimated population of Bangladesh as of 1998. BBS estimated this population figure based on population census 1991. Population in 1991 was 111.45 million (BBS 1999, p 76). Census 2001 figure (130 million) not yet published.

for cooking also depends on the type of cooking and the device used for cooking. Therefore, like many other studies, this study does not claim the above estimation to be absolutely correct. The figure is useful for understanding the nature of demand and consumption pattern of using biomass fuel for cooking purposes in the Bangladesh rural communities.

8.3.1.2 Household Lighting

Energy used for lighting is the second biggest source of energy demand in rural Bangladesh, where kerosene is the main source of fuel. In rural Bangladesh 91.41% of households use kerosene for lighting, while 8.59% obtain light from other sources, mainly from rural electrification board (BBS 1999, p.138). Kerosene is bought from retail shops in rural localities. In general, there are two types of lighting devices used in rural Bangladesh: open-wick lamps, made of either aluminum or clay (kupee), and hurricane lantern fitted with chimney made of aluminum and glass.

As there are no recent studies on the number of kupees or hurricanes used in rural Bangladesh, it is hard to get current reliable data. But, according to Islam (1980), 85% of rural households use open-wick kupees, while 15% use hurricane lanterns. Kerosene is used as fuel for both types of devices. PRA survey discovered another type of kupee (in Kutubdia village), made of clay and edible oil used as fuel, but because this fuel is edible and inconvenient to use, the interest in this device was lost.

Two types of kerosene are available in rural market (white and reddish), but in view of the unavailability of information on their luminous intensity, it is impossible to define requirements for each type of kerosene individually. During PRA survey in Kutubdia village, we were told that reddish kerosene emits more black smoke from kupees than its white variety, which is harmful for eyes, as well as for the environment. However, as kerosene supply in rural markets depends on the sellers' choice, and the rural population has no alternative source of lighting, they are almost indifferent to which type of kerosene to use.

Total consumption of energy for lighting in rural Bangladesh depends on the number of households, number of rooms per household, number of kupees used per room, and the duration of lighting per night. Some literature sources state that rural population uses one kupee per room, and the duration of its use is on average 2.5-4.5 hours per night (BIDS, RISP 1981). We have been told during PRA survey that the households with students usually use kupees longer (up to 6 hours per night).

Our villagers (focus group) also opined that large farmers in the community generally use kupee (or hurricane) longer as compared to small households, because they spend more time preparing dinner for their labour, and entertaining guests at night. Our survey shows that a common household uses two kupees/hurricane lanterns for approximately 3 hours per night, consuming about half a gallon kerosene per year. In terms of energy requirements, this is approximately equivalent to 1GJ per year per household.

Hence the estimated consumption of kerosene for lighting in rural households:

Number of households in rural Bangladesh	=18 million[4]
Electricity connection available	=8.59% of households
Number of households using kerosene	=16.45 million
Total kerosene used	=352,000 tons
Energy consumption for lighting	=352E3GJ

Households with electricity connection also use kerosene due to the limited or no supply of electricity for days in a row. It must also be noted that the same amount of kerosene operates the improved kupee developed by BCSIR for 8–12 lamp-hours per night, more than double the previous duration. However, the introduction of this type of kupee in the rural communities is still at its initial stages because of bureaucracy and capital deficit (GOB, Planning Commission Energy Wing Report 1995).

Kerosene is also used for urban household lighting and for domestic cooking but this factor falls outside the scope of our study.

[4] Figure of household numbers has been rounded.

8.3.2 Energy for Commercial Activities

We have mentioned earlier in this chapter that the energy use in rural Bangladesh is so complex that it is almost impossible to differentiate the amount of energy used for one type of activity from another, particularly when dealing with the household energy consumption. To avoid this complexity, we define commercial energy as energy consumed for commercial or productive purposes irrespective of its place of use. For example, if energy is consumed for making gur or processing food from home, and that gur or processed food is used for commercial purpose, then that energy would be treated as commercial.

In rural Bangladesh, activities performed from household premises but with commercial purposes, are mainly making gur (substitute for sugar) from date tree juice, sugarcane juice, and through rice parboiling. However, the intensity of these activities varies from region to region.

For example, making gur from date tree juice, sugarcane juice, and through rice parboiling is very common in Rajshahi division and part of Khulna division (northern part of Bangladesh), while being relatively uncommon in Chittagong, Sylhet, and Barishal divisions. All these commercial activities use biomass energy, mostly agricultural residues, twigs, and rice husks.

In 1998/99, total production of rice was 19.9 million tons (BBS 1999, p.185). It is estimated that about 55-65% of rice is annually parboiled in households. Hence, if we consider that 60% of rice was parboiled in that year, its quantity would amount to 11.94 million tons (19.9x10E6x0.6).

According to BIDS 1981, about 400 kg of agricultural residues are required to parboil 1 ton of rice, i.e. approximately 1 ton of biomass is fueled for 2.5 tons of rice boiling. In 1998/99, the amount of biomass used for rice parboiling can be estimated as (11.94/2.5)=4.78 million tons. In terms of the calorific value, 1 ton of biomass equates 4.31GJ. Hence, biomass energy used for rice parboiling in 1998/99 in rural Bangladesh was (4.78xE6x4.31)=20.6E6GJ.

The parboiled rice can be preserved longer than non-parboiled ones. Therefore, farmers might have a better option of selling their rice during uncultivable seasons. Hence, the energy spent on boiling, is offset with the benefits it creates (Islam 1984).

Similarly, the consumption of biomass for making gur can be estimated as follows.

Three tons of biomass are required for making one ton of gur (Alif 1981). In 1998/99, the total production of gur was 90,200 tons (BBS 1999). Hence, the biomass consumed for making gur was 90200x3=270,600 tons (generally, in the form of agricultural residues, leaves, and twigs). In terms of energy, this equals to 270600x4.31=117E4GJ.

Based on the above facts, the energy consumption pattern in rural Bangladesh households is summarized in Table 8.3.2.1.

Table 8.3.2.1: Estimated Energy Consumption in Major Areas of Rural Households

Purpose of energy consumption	*Energy type*	*Quantity (million tons)*	*Energy unit in GJ*
Cooking	Biomass	36.36	475E6
Lighting	Kerosene	352E-3	352E3
Rice parboiling	Biomass	478	20.6E6
Making gur	Biomass	270E-3	117E4
Total		***514.98***	***497E6***

Source: Field survey

According to an official publication (GOB Power Cell 1997, Sec.5.4), 97.3% of rural energy were supplied from locally produced biomass, and used for cooking and food processing. The remaining 2.7% were supplied from commercial fuel, mainly for household lighting. Our survey confirmed that statistics: 97.3% of energy was supplied from local sources, and the remaining 2.7% - from commercial sources (Table 6.3.1, excluding REB supply). Our survey also confirmed that rural households use about 98% of their total energy consumption for cooking and food processing (Table 6.3.2.1), and commercial energy (kerosene) is mainly used for lighting.

One of the reasons for using less energy for lighting is that the data mentioned in the above table does not include electric lighting. In addition, some other energy-consuming household activities (washing, entertainment, ironing etc.) have not been included in the estimation. However, the amount of energy consumed for these activities is relatively insignificant. It is of note that 8.59%[5] of households have grid power connection, although the power supply is strictly limited for specific hours (BBS 1999, p.138).

8.3.3 Energy Demand in Agriculture

Agriculture is the predominant sector of Bangladesh economy. Majority of the rural population live on agriculture. We have mentioned earlier that the agricultural sector of Bangladesh is still at the traditional stage of its development, although maximum efforts have been invested to move agriculture from a traditional to a semi-mechanised stage, demanding particular type of energy. Hence, although the thrust of this study is to deal with energy-related household activities of rural Bangladesh, the nature of energy consumption in agriculture sector is worth mentioning.

The types and the amount of energy consumption in agricultural production vary from crop to crop, season to season, and even location to location. For example, wheat cultivation needs more fertilisers and less irrigation than paddy production.

Similarly, paddy production in Rajshahi region needs more irrigation compared to that of Mymenshigh region due to the type of land. Land in Rajshahi region is drier than in Mymenshigh. Therefore, the aim of this section is to illustrate the energy consumption pattern in agricultural sector instead of quantifying energy consumed in each component.

[5] We have mentioned earlier that the number of households with the grid power connection is controversial.

In Bangladesh, energy sources directly used for agricultural production are:

i. Human and animal muscle power for land preparation, planting, harvesting, and crops transportation;

ii. Human labour, diesel fuel, and electricity for irrigation;

iii. Indirect use of energy for agricultural production through chemical fertilisers and pesticides; and

iv. Energy in the form of heat and mechanical power for post-harvest processing of crops.

8.3.3.1 Human Labour

Human muscle power has been an important source of energy for agricultural production in rural Bangladesh since ancient times. The analysis of human labour contribution to the agricultural sector is related to the quantity of calories intake per capita, and the volume of work performed by the labor. Both these analyses are complex. In addition, very few studies of the relations of calories intake, manpower utilization, and energy consumption in rural Bangladesh have been performed so far. Assaduzzaman and Chowdhury (1986) have done a study in this area.

They have showed that the work output of human muscle energy depends on the calories intake of the labour force. In rural Bangladesh, the ratio of calories intake and work output is low. Unemployment and under-employment are related to the energy analysis in the rural sector, but this aspect has not been addressed in their study.

Furthermore, in the same way as differences in the calories intake, the use of equipment for performing similar type of work also differs from location to location. For example, equipment for cutting paddy in the Northern part (Rajshahi and part of Khulna division) is different from that used in the Eastern zone of the country. Hence, due to shortages of data and unorganised nature of energy sources and labour force market in rural Bangladesh, this study considers illustrating the human muscle energy situation in terms of employment only.

In rural Bangladesh, agricultural activities largely depend on nature such as rain and the sun. Accordingly, industrial activities and the related employment in agricultural sector are very seasonal. According to BBS (1997), labour force normally works for 185 days a year (62% direct agricultural activities, and 38% other activities). The number of hours worked does not follow the clock, generally it is from sunrise to sunset.

In 1990, the total number of population employed in agriculture was 34.35 million (17.37 million (50.57%) female, and 16.98 million (49.43%) male). In general, the percentage of female is higher than that of male workers in the agricultural sector of Bangladesh. However, this pattern has been changed in 1995 when the total number of agricultural workers was 34.86 million (16.42 million (47.10%) female, and 18.44 million (52.90%) male)) (BBS 1999 p.147).

In 1990, the number of female workers in the agricultural sector was higher than that of male workers, whereas in 1995 that ratio has changed. Generally, female workers can be hired for the same job with lower wages as compared to males.

Moreover, employers (usually large farmers) can also ask female workers to extend their working hours beyond the contract terms. Finally, male labour force can be easier involved in off-farm activities away from home. The above data also indicate that the increase of employment opportunities in the agriculture sector from 1990 to 1995 was only 1.48%, far behind the increased active labour force entering the labor market in that period.

Hence, due to the over-pressure of unemployment, male workers have taken the opportunity of employment. It is notable that absence of equal employment opportunity for both sexes in Bangladesh largely affects female population of rural Bangladesh.

The above illustrates creating employment and required food production definitely calls for energy, with the subsequent necessity to choose the technology for energy supply.

8.3.3.2 Animal Power

Animal muscle power is another important source of energy supply in rural Bangladesh. The purpose of this section is to describe existing and potential animal power scenario of rural Bangladesh, to clarify the pattern of energy consumption, and hence potential energy requirements.

In 1996, the total number of bovine animals in Bangladesh was 22.29 million (1.25 per holding, and 0.18 per capita) (BBS 1999, p.159). Relevant studies, although old, in this area (Jabbar and Green 1983; Gill 1981; McColly 1971; Hussain and Sarkar 1978) provide basic information on the status of animal power use in rural Bangladesh.

According to these studies, about 98% of animal power is used for crop production and post-harvesting crop processing, and the remaining 2% are used for other activities. These studies also indicate that in Bangladesh, animals engaged in the agricultural sector are small in size and over-stressed, with less weight, and poor health. The main reasons for that are low calories intake, weather conditions, inferior-quality nursing, and longer hours of work.

Generally, two oxen/cows can cultivate about 4-5 acres (0.4-0.5 animals/acre) of land. In 1996, the total arable land constituted 17.77 million acres (BBS 1997), with the requirement of 8.89 million of workable animals to maintain the existing level of cropping pattern. But due to sickness, underage, and milking, the number of workable animals is less than the total number of bovine animals. As a result, the shortage of workable animals in the agricultural sector in that year amounted to about 20%.

Our survey data have demonstrated that the density of workable animals is not the same in all regions of the country. For example, in Loxmikola village (Khulna division, Kushtia district), there is a tremendous shortage of bullocks, and hence some farmers use milk cows for ploughing land.

During PRA survey, we have observed a similar situation in Kutubdia village (Chittagong division, Cox's bazaar district), where due to shortages of bulls farmers employed more human labor force for land preparation. In fact, they have substituted animal power with human muscle power. The implication of using milk cows for crop production leads to further shortages of cattle, milk, and protein. Indeed, the use of animal power in rural Bangladesh is contributing to a vicious circle where the sustainable supply of energy might be a solution.

Based on the above analysis, the following comments can be made:

a. The increase of employment opportunities in the agricultural sector of rural Bangladesh has been very insignificant since 1990. This situation is a matter of concern for rural population due to very limited alternative scope of work.

b. The ratio of female and male workers in the agricultural sector has been decreasing since 1990.

c. Traditional agriculture largely depends on animal power. There is a shortage of animals required for agricultural activities in rural Bangladesh. The lower average sizes and weight of animals in Bangladesh causes lower efficiency and leads to further shortages of power in this sector. The population in some parts of the country uses milk cows to make up for power supply, thus creating a vicious circle in the agricultural sector.

d. Taking into account the size of arable land, population density, food production capacity, and energy use pattern, it becomes clear that there is an urgent need for energy supplies to sustain the agricultural sector in rural Bangladesh. But the question is: what type of energy can the population use and afford?

8.3.3.3 Energy for Irrigation

Irrigation facility is compulsory for increasing agricultural production. Without using other modern inputs such as chemical fertilisers and pesticides, the volume of food production might be tripled, if only irrigation facility were provided (Hossain 1988). This is even more critical for rural Bangladesh because of the need to produce more food in a limited land area.

In Bangladesh, irrigation in the agricultural sector started in the mid-sixties'. The then Pakistan government launched a very small-scale assistance programme with the financial aid from the USA (Kushtia and Jessore districts under the name of WAPDA canal). After independence, the programme acquired momentum, but still only 48.31% of arable land has been brought under irrigation in the last four decades (BBS 1999, p.158).

Two types of irrigation devices are used in Bangladesh: manual and power-operated. The available power-driven (diesel or electricity) irrigation devices are low-lift pumps, shallow tube wells, deep tube wells and submersible pumps. Traditional devices are manually operated, and their output is much lower than that of modern devices. The area irrigated by using different devices is presented in Table 8.3.3.3.

Table 8.3.3.3: Area (in thousands acres) covered by different irrigation devices in rural Bangladesh (1998)

Devices	*1994*	*1995*	*1996*	*1997*	*1998*	*Average annual growth rate*
Power pumps	1651	1623	1674	1718	1745	1.14
Tubewells	5199	5537	5823	6124	6515	5.06
Canals	383	383	388	395	402	0.99
Total Modern	**7233**	**7543**	**7885**	**8237**	**8662**	**3.95**
Traditional	**893**	**919**	**903**	**897**	**836**	**-1.28**

Source: BBS (1999 p.192)

Note: Traditional devices include doons (conical containers, 10x1 inches), swing baskets, and other manually operated devices.

It appears from the table that the areas irrigated by modern devices have been increasing each year (3.95%), while those irrigated by traditional methods, have been decreasing (-1.28% annually). It indicates a need for energy in the agricultural sector, and public willingness to consume more energy in this sector. The population is getting used to more mechanised cultivation processes. Hence, energy supply for irrigation should account for introducing modern irrigation devices.

The information on the amount of energy consumed for irrigation is not available, but in 1998, the total amount of energy consumed in the agricultural sector was 432 thousand tons of oil equivalents (BBS 1999, p.231). This amount includes energy consumed in irrigation and operation of the mechanized equipment directly involved in crop production, but does not include using fertilisers.

8.3.4 Energy for Rural Industries

In rural Bangladesh, the number of industries is insignificant. However, as the majority of rural industries is agro-based, they consume energy from locally available human and animal muscle power, biomass, sun, and wind. They also use commercial fuels such as diesel for operating machinery, but this amount is insignificant.

The major problem in estimating energy demand is the lack of systematic data on energy consumption in rural industries. Moreover, there is also a problem with the definition of rural industries. Generally, they are assumed to be small cottage industries, although there are similar industries in urban areas, too. However, for the sake of simplicity we would include energy consumed in rural industries and for commercial purposes together, classifying it as commercial consumption.

8.3.5 Summary

Based on the above discussion, the following comments can be made:

a. The demand, as estimated for some activities, might not be exactly the same, but it gives an idea of the nature of energy demand and current consumption behavior, which is an essential tool for balancing energy demand and supply.

b. Energy use is diversified, but its sources are limited, mainly biomass.

c. The devices of energy end-uses are not very complex, and hence matching alternative energy sources of supply with demand would be relatively simple.

d. The structure of energy supply and demand in rural Bangladesh is not well-developed, hence introducing the proposed SET would be easier, and the rural population might accept it.

e. Considering the pattern of energy consumption, it is evident that cooking, lighting, and irrigation are the most demanding areas. And hence, the sustainable supply of energy for these areas might bring positive impact on poverty alleviation of rural Bangladesh.

8.3.6 Justification of SET

The purpose of this section is to justify the proposed three energy technologies in terms of criteria mentioned at the beginning of this chapter. Each SET (biomass, solar, and wind) would be evaluated within each criterion (availability of resources, technological complexity, cost-effectiveness, matching with demand and supply, contribution to GHG emission reduction and major constraints, if any).

8.4 Feasibility of Biomass Technology

In this section, we will examine the sustainability of biomass energy technology by applying the above-mentioned criteria.

8.4.1 Availability of Biomass

In Bangladesh, the sources of biomass energy are agricultural residues, wood fuel (firewood, tree residues), and animal dung. The projection of biomass supply has been considered under two scenarios: business as usual and reference. Biomass supply in business as usual scenario is detailed in Table 8.4.1. This scenario refers to the situation that if nothing were done for further tree plantation or extension of forestry, then the biomass would be available for consumption, as shown in the table.

It appears from the table and its assumptions that the production of agricultural residues has been gradually decreasing. On the other hand, firewood supply and tree residues have been gradually increasing. The supply of animal dung has remained unchanged. This scenario shows that as the agricultural cultivation process is gradually shifting from a traditional to a semi-modernised stage, farmers are using high-yielding seeds, in addition to other modern inputs. High-yielding crops produce more crops but less straw (residues).

Regarding increased tree residues, since the mid-eighties' the country has tried to increase plantation on the fallow land such as roadsides and railway sides, under the name of developing social forestry. It seems that roadside trees do produce residues for fuel. But because of competition between using land for food production and fuel production, this programme has become unpopular with rural communities (GOB, MR&H 1999, Roadside Forestry Project Proposal: Phase 2)

Table 8.4.1: Projection of Biomass Fuel Supply in Business[6] as Usual Scenario (in Petajoules)

Fuel Type	*1995*	*2000*	*2005*	*2010*	*2015*	*2020*
Agricultural residues	382.5	369.5	356.93	344.80	333.07	321.74
Firewood	58.44	66.62	75.94	86.58	98.70	112.52
Tree residues	16.96	18.85	20.96	23.30	25.90	28.79
Animal dung[7]	77.78	77.78	77.78	77.78	77.78	77.78
Total biomass fuels	535.68	532.75	531.61	532.46	535.45	540.83
Population	121.4	130.0	144.11	159.74	176.64	195.81
Per capita supply (GJ/person/year)	4.41	4.10	3.69	3.33	3.03	2.76
Energy demand	362	531	827	1314	1979	3055

Source: GOB BEPP 1985h, pp. VII.4.1-14); GOB National Energy Policy 1995, Directorate of Forest 1999, BBS 1999, p.231

[6] The projection has been estimated with 1995 as base year.
[7] The amount of energy extraction has been kept equal throughout the time period, based on the assumption that the increase of number of cattle is almost insignificant. The data from PRA survey in two sampled villages also support this assumption.

Projection of the biomass energy has been estimated on the basis of the following assumptions:

a. 1995 has been considered as base year.

b. Agricultural residues included jute sticks, paddy straw, and bagasse because these three major crops produce residues for fuel in Bangladesh. Other crops have been ignored because of their insignificant contribution to fuel.

c. It is assumed that increase in number of animals will be offset by increased demand for meat, low fertility rate, and loss of lives due to natural disasters, hence the growth in the amount of animal dung has been kept unchanged. It is also assumed that 34%[8] of total dung will be available as fuel (77.78PJ/yr) throughout the planning period. Further increase in the percentage of dung is unlikely due to the following factors: dung produced during a rainy season cannot be dried, most of the dung will be used as manure by land-owning households, part of it will be used as building material, and part of it will be wasted at the time of grazing.

d. Population growth rate has been estimated at 2.17%, the population growth rate target of Bangladesh. For details see mid-term review of the Fifth Five-Year Plan (GOB, Planning Commission 2001).

e. For estimating the future growth rate, the quantity of actual production of each type of biomass in years 1995, 1996, 1997, 1998, and 1999 was recorded and converted into energy terms. Then the difference in each year was calculated. After that, weighted average of differences was calculated[9]. This procedure has been chosen because the value obtained by weighted average is more realistic than if it is obtained by normal mean.

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[8] For details see Jabber and Green 1983.

[9] Annual growth rate calculated by weighted average is: for agricultural residues 1.95%, rice straw 0.004%, rice husks 0.007%, bagasse (-0.009%), twig leaves 2.23%, other wastes 1.21%, jute sticks (-1.95%).

Firewood supply is gradually increasing because of over-cutting trees in all types of forests. This scenario can be viewed in the light of deforestation rate. In 1960, forest area comprised 25% of total land area. This figure dropped to 15% in 1977, and 7% in 1991 (GOB, MOEF 1993). Currently, the forest area comprises about 6% of the total land. For example, in 1991 the area of acquired forest was 496 sq.km, which dropped to 372 sq.km. in 1996 (BBS 1999, p.194). Hence, gradually increased supply of firewood originates from deforestation rather than newly planted forests.

Thus, the biomass fuel available per person dropped by 37% between 1995 and 2020. The projected total supply of biomass fuels increases but, because of the faster growing population, the estimated annual per capita supply of biomass fuel will decline from 4.41GJ in 1995 to 2.76GJ in 2020 (see Table 8.4.1).

Another important indication of the table is that per capita energy available from biomass has been decreasing. This implies that unless further biomass production arrangements are undertaken, biomass energy supply will be questionable. However, another way of reducing the rate of per capita biomass energy demand is by increasing the end-use efficiency of energy (see Chapter 1), i.e. improving biomass energy technology can reduce the pressure on biomass fuel.

In fact, joint efforts directed at the biomass production and technological improvement of energy efficiency can make biomass a sustainable source of energy. In other words, under the usual business scenario, biomass energy source is not long-term sustainable for rural Bangladesh.

In the reference scenario, the first question is how to increase forestry cultivation and the relevant supply of biomass. In Bangladesh, total land area is 147570 sq.km. of which 28038 sq.km (19%) is not usable because of roads, bridges etc. (BBS 1999). In 1991, the area of total operated land was 8,289,988 ha,[10] and total homestead land was 533,555 ha. Total arable land was 7,191,962 ha (BBS 1999). Per capita operated land was only 17 decimals. There is no alternative to increasing the operational land areas without deforestation.

[10] In Bangladesh, the unit of land measurement is acres. 2.471 acres=1 hectare.

The per capita and available land area data imply the necessity of making a choice: to use that land for food production or forestry. Food production is required for current population and for the future population growth. Moreover, the areas of operational land would decrease at a rate of increased demand for housing and other civil utilities. Our survey information shows that more than 85% of the respondents prefer to use the land for producing food rather than forestry. This is the reality of a subsistence economy.

Some energy professionals (Read 1994, 1997, 1998, Ahmad et al 1999, Senewla 1997) advocate biomass energy by arguing that biomass can be produced in fallow lands, roadsides, and riverbanks, without disturbing regular agricultural lands and food production. Other experts argue that excess biomass can be produced by multicrop cultivational methods. The counter-argument is that in Bangladesh, people are fighting for food, they are in need to grow more food, and also need more land for housing and civil utilities.

In 1990, non-arable land area was 3,150 thousand ha, increased to 3,751 thousand ha in 1998 (BBS 1999, p.182). The annual average growth rate was 2.38%, higher than the estimated population growth of the country (2.17%) (BBS 1999, p.135). Similarly, between 1990 and 1998, the area of fallow land decreased (from 1,087 thousand ha to 363 thousand ha). The annual average rate of decrease was 8.33%.

It is expected that the decreased amount of fallow land would increase the area of forestry or arable land. But data show an increase in overall arable land (from 14,063 thousand ha to 34,810 thousand ha from 1990 to 1998 (0.01%)). Forest area increased from 4,703 to 5,572 thousand ha (18.48%) (BBS 1999, p.182). The simple question is: where is the remaining area of the decreased fallow land?

Obviously, the difference has been used for other purposes such as housing, new roads etc. Due to this excess pressure on land use, the scope of using fallow or roadside land for forestry expansion would hardly be significant in Bangladesh.

As for the use of riverbanks, it is evident that in Bangladesh, a network of 230 rivers, canals, streams etc. (with a total length of 24,140km) covers the whole of Bangladesh down to the Bay of Bengal (GOB, Power Cell 1997). However, although there is a potential to use river water as a national resource, the characteristics of most riverbanks are not favourable for plantation due to erosion.

Moreover, where some parts of riverbanks are available, local muscle power groups occupy that land for agricultural (food) production (GOB, ME&F, Annual Report 1993a). The data on the width of the banks of major rivers in Bangladesh is presented in Annex 13. This implies that the feasibility of using riverbanks for forestry is not viable in Bangladesh.

Furthermore, from an agricultural economics point of view, it might be argued that the production of biomass would increase if agriculture shifted from a traditional to a semi-mechanised or mechanised stage: agricultural production such as crop yields, and growth of crops would increase as a result of mechanised cultivation and high-yielding seeds. But the problem is that high-yielding seeds produce more crops but fewer residues.

Moreover, mechanised cultivation itself needs further energy supplies, which might not be viable due to the impossibility of providing natural gas to rural areas in the foreseeable future, weak balance of payments, and lack of purchasing power of the rural population.

Land, manpower, animal, and water are major resources for providing food, fiber, fodder, and fuel to maintain rural production processes. With 60% of the total land area under agricultural production (BBS 1995), there is little scope to increase the land used for crop production or to re-allocate agricultural land for planting trees. The characteristics of cropping land in Bangladesh are presented in Map 8.1. It is seen from the map that arable land in Bangladesh is basically three types: about 1/3 most suitable, 1/3 medium suitable and the remaining 1/3 is less suitable for agriculture production.

Therefore, additional energy is needed to intensify land use through irrigation, and to power mechanical devices to provide the draught power necessary for land preparation beyond that available from bullocks. In addition, there will also be an increase in the demand for chemical fertilisers. Hence, use of excess energy in the agricultural sector can increase crops or crop residues only up to a certain limit.

Land is the key factor of biomass production. And Bangladesh has been suffering from the land scarcity. Hence, in response to the arguments of the above-mentioned energy professionals, it might be commented that the production of biomass as a source of fuel might be viable in the countries with abundant land, for example, Africa, Kenya, or even North America, but not in a country like Bangladesh.

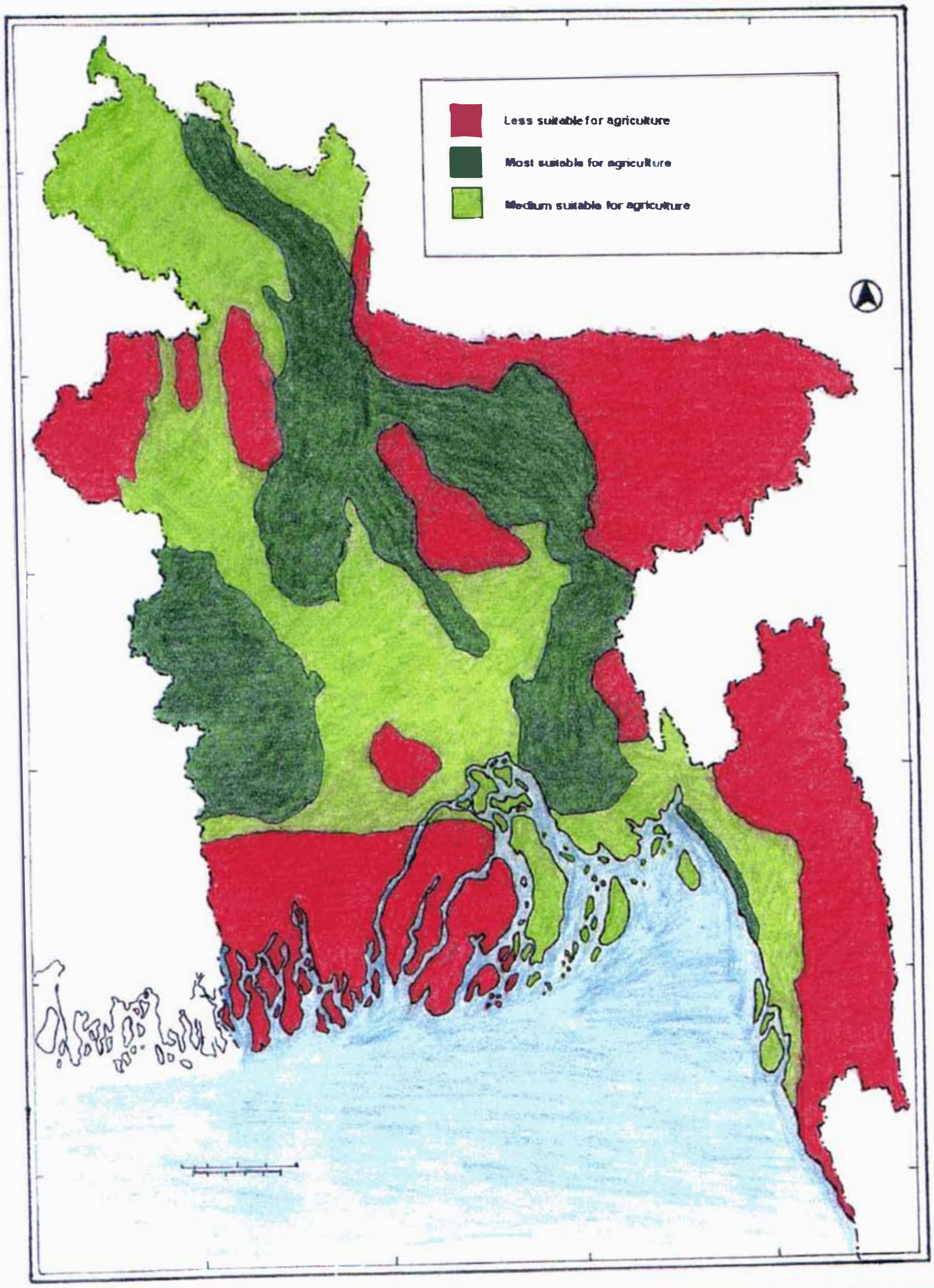
Furthermore, in rural Bangladesh household, commercial, and industrial activities all use biomass. Among these three sectors, in the future, the demands of the industrial and commercial sectors will be fully met because part of the industrial sector is likely to have a priority access to residues used in processing crops from which they are produced (e.g. bagasse for making sugar and gur, rice husk for rice processing).

The remainder of this sector and the commercial sector are likely to command greater purchasing power to gain access to the necessary fuels than the domestic sector. So, it is arguable that as the industrial and commercial sectors might have relatively better opportunities to shift from biomass use to fossil fuel, more biomass might be available for domestic use.

But this argument does not prevail because, first, although natural gas contributes to the major parts of electricity production, the country largely depends on imported fuel for its industry and transportation, such as imported diesel for irrigation. Second, due to economic and technical problems, the country will not be able to extend gas pipelines to the rural communities in the near future. Hence, rural households will get less access to the biomass market compared to the other sectors.

Thus, the deficit of biomass fuel for rural cooking signifies its physical shortage. The high proportion of agricultural residues used for domestic cooking signifies the scarcity of firewood. In addition, any scarcity of biomass fuel will not affect different socio-economic rural groups uniformly. It is the poorest sections of the rural community who will suffer most.

Map 8.1 Characteristics of Arable Land in Bangladesh



Average consumption of biomass fuel for rural domestic cooking has been estimated at 26.38GJ/household/year (see Section 8.3.1.1). Experience shows that there is little scope for reducing the existing per household consumption of biomass fuel without 'improving the performance' of stoves or severely degrading the quality of life. Considering the current estimated low level of per capita fuel consumption, it is likely that some people are already suffering due to the lack of fuel for cooking in rural Bangladesh.

'Improving the performance' of stoves refers to the fact that in Bangladesh, rural households use clay-made open tri-pot stoves for cooking, washing etc., where the biomass fuel energy efficiency is very low. According to BCSIR (1984), more than 29% of biomass fuel heating efficiency is a straightway waste because the cooking device (stove) is kept open. Moreover, as the pot is clay-made, it takes longer to heat it.

It is notable that BCSIR innovated a stove, making it closed (air-protected) and more efficient. It now requires less biomass for the same activities compared to the conventional one. The cost of each stove is Taka 700. Accordingly, BCSIR undertook a project to sell the improved stove to the rural population. Unfortunately, the programme failed due to lack of affordability of the price. It was opined that appropriate programmes like credit facilities and deforestation awareness could motivate rural communities to use improved stoves (ibid).

Based on the above analysis following comments can be made:

a. The projected demand for biomass fuels increases at a higher rate than the projected supply, resulting in a considerable deficit. This deficit will have to be met either by substituting fossil fuel or by an appropriate rural energy development programme such as solar and wind power.

b. If no policy intervention is undertaken to meet the fuel deficit, people will have no other choice but to meet the demand by further over-cutting trees. In order to avoid severe environmental and ecological problems and disruption of future social and economic welfare, it is considered highly undesirable to allow over-cutting of tree resources to make up for the fuel deficit.

c. Poorer classes of the rural society will become more vulnerable due to shortages of biomass supply, which ultimately will lead to further unsustainability of the development process, and hence, to poverty.

8.4.2 Technological Complexity of Biomass Energy

The degree of complexity of biomass technology depends on the type of device uses. For example, the biomass-based technology of producing ethanol for transport is more complex than producing biogas for cooking. However, the most common methods and techniques of biomass uses are direct burning in a fireplace, pyrolysis, briquetting, charcoal-making, biogas plants, dung cake etc.

In rural Bangladesh, most of the agricultural and forest residues are burned directly in a fireplace (details in Chapter 5). Animal dung is generally mixed with other types of agricultural residues to increase the burning efficiency and prolong the life of dung cake/ sticks.

Machinery and equipment for processing biomass into usable efficient form might be available in local markets. For instance, the machinery and equipment required for a biogas plant (brick, cement, wood, bamboo etc.) are all available in Bangladesh. Similarly, charcoal can be made in an earthen kiln process, and the materials for that technology are produced locally. However, people need training to use these technologies.

Although the technology itself is not very complex (in the case of biogas and charcoal), its adaptation and diffusion in rural communities might need training for users. Our survey has found that, in spite of some limitations in expansion of biogas plants, charcoal, and briquette production in Bangladesh, there is a bright potential for the relevant technologies in the rural energy market.

8.4.3 Cost-Effectiveness of Biomass Technology

Cost-effectiveness of biomass technology depends on the type of biomass, type of technology, and the purpose of energy use. For example, if unprocessed crop residues are directly used for cooking, the cost of that fuel will be insignificant because there will be no processing costs involved. Similarly, if residues are used to produce biogas as an energy source, then that energy will be more expensive than original residues' energy because of production costs (equipment, labour etc.).

As we have shown in Chapter 5, biomass can be used as fuel mainly (apart from direct burning) in the form of biogas, charcoal, dung cake, dung stick etc. These different forms of energy incur different types of costs.

8.4.4 Matching with Demand and Supply

Rural population of Bangladesh has been using biomass as a source of fuel since long. Biomass is used for most households and some commercial activities. However, biomass cannot be used for lighting unless some relevant technology is invented and introduced.

Currently, about 92% of households (details are presented in Chapter 6) use kerosene for lighting. Our field survey data show that about 28% of households think that they use kerosene for lighting because there are no alternative relevant sources of energy (details in Table 6.3.4.1). Similarly, about 11% of households have opined that they use kerosene for lighting because of no electricity supply in their locality.

This indicates that people are interested in changing their behaviour in energy consumption for lighting, if alternative source becomes available. But it is questionable whether biomass source can substitute kerosene in lighting? Therefore, we can only conclude that the supply of biomass energy will be able to fulfill the large part of demand.

8.4.5 Contribution to GHG Reduction

The contribution of biomass to reducing GHG emission is two-fold. First, biomass energy emits gases to the atmosphere (but less than fossil fuel), which ultimately increases the volume of GHG in the ozone layer. And second, trees absorb CO_2 from the atmosphere, which ultimately reduces the volume of GHG. In fact, the contribution of biomass to the GHG emission is a recycling process. However, the quantities of absorption and emission depend on the areas of deforestation and replantation.

In Chapter 2, we have mentioned that the energy-related studies and hence the data, are very limited in Bangladesh. The data on CO_2 emission or related information on GHG emissions such as country-specific parameters, are also extremely limited. Furthermore, there are various sources of methane emission, viz. paddy fields, livestock, biomass burning, land filling, termite colonies etc. And the amount of methane emission varies among biomass types.

For example, methane emission from biomass is different from that of cow dung, and different from the volume of methane emission from paddy fields. Therefore, it is hard to analyse the contribution of biomass to GHG emission in quantitative terms.

However, according to ADB 1994, in 1990, the estimated volume of CO_2 released from fossil fuel was 3,566 thousand tons, of which liquid fuel constituted 46%, solid fuel constituted 1%, and gaseous fuel constituted 53% (p.98). The above study also states that in 1990, 5.72 thousand tons of methane were emitted due to firewood burning, 5.75 thousand tons—from cow dung, 2,779 thousand tons—from paddy fields, and 504 thousand tons—from livestock (pp. 100-104).

In 1990, the total estimated methane emission from non-fossil fuel constituted 3,294 thousand tons. Although the methodology and parameters used in this study are not free from controversy, it appears that the quantity of methane emitted from fossil fuel is higher than that of non-fossil-fuel activities. Therefore, it is reasonable to expect that introducing SET will positively impact the reduction of GHG emission in Bangladesh.

8.4.6 Major Constraints of Biomass Technology

We have shown in Section 8.4.1 that the biomass availability is directly related to the land availability, which is scarce in Bangladesh. Presently, the per capita area of arable land is only 0.07 ha (17 decimals). Hence, the questions whether that land will be used for tree plantation or for growing agricultural produce for consumption.

8.5 Feasibility of Solar Energy

The feasibility of solar energy technology in terms of justification criteria such as availability of supply, technological complexity, cost-effectiveness, matching with demand, contribution towards GHG emission reduction, and major constraints if any will be examined in this section.

8.5.1 Availability of Solar Radiation

The raw material required for solar energy is basically solar radiation, which is abundant, particularly in Bangladesh due to its geographical location between the latitudes of '24.34'–'26.34' N and longitudes of '88.01'–'92.41'E (see annex 12) and structure of landscape (mainly flat plain).

Annual solar radiation in Bangladesh has been estimated at nearly 600 times the 1973/74 total energy consumption of 285 PJ from traditional and commercial sources (GOB, Power Cell 1997 Section 7.0). To understand the intensity and duration of sunshine in Bangladesh, we have collected relevant data from the Meteorological Department of Bangladesh (MDB) in November 2000. MD recorded intensity and duration of sunshine data for each month of 1997 to 1999 from the 14 selected places in Bangladesh. Copy of collected data is presented as annex 14.

The long-term average sunshine data indicate that the period of bright (more than 200 watts/sq.m intensity) sunshine hours in the coastal region varies from 3 to 11 hours daily. The global radiation varies from 3.8kwh/sq.m/day to 6.4kwh/sq.m/day. These data indicate that there are good prospects for solar thermal and photovoltaic applications in Bangladesh.

8.5.2 Technological Complexity of Solar Energy

Generally, the degree of complexity of energy technology depends on its applications. For example, if there are two technologies in use (solar photovoltaic system for lighting, and solar dryer for drying purposes), the technological complexity of photovoltaic system is higher than that of the dryer, simply because a photovoltaic system needs high-skilled trained personnel for its repair and maintenance (Grameen Shakti 1999). However, the operational complexity is almost the same for both devices. Users need minimum training and no formal educational qualification.

Kristoferson and Bokalders (1987) in their book *"Renewable Energy Technologies: Their Applications in Developing Countries"* mention a need for training and development programmes for the users to understand and feel comfortable with renewable energy technologies. Ahmad et al (1984)[11] mention that repair, maintenance, and training facilities are a prerequisite for introducing a new technology. It implies that as the Bangladeshi people (especially in rural Bangladesh) are relatively less educated and less skilled, they might require some sorts of training to participate in the solar energy process.

8.5.3 Cost-Effectiveness of Solar Energy

The cost-effectiveness of a particular energy technology involves calculating the cost of raw materials, machinery and equipment, labour, management, and some other utilities. The cost of producing one unit of energy is used as a criterion of applicability of a type of energy technology.

Two issues are associated with cost-effectiveness: the cost of energy itself and its affordability to the users. This study is more concerned about the latter, i.e. we are interested whether the rural people of Bangladesh can afford the cost of solar energy. And as the detailed estimation of costs involved in producing solar power needs an in-depth study, we only attempt to comment on the affordability issue.

Spare parts and all types of machinery and equipment for solar power are imported. So, it is hard to estimate the actual cost of a completed plant. However, as some organisations in public sector and some non-government organizations (NGO) are working on disseminating this technology, it is worth looking at the costs range provided by the above entities.

Local Government Engineering Department, Government of Bangladesh installed 25 solar photovoltaic plants in Chittagong and Coxs Bazaar districts, with a cost of

[11] The ILO, Geneva, has published this research report involved in evaluating Technology Adaptation and Employment Generation of Agricultural Tools and Implements Industries in Bangladesh (I am its co-author).

Taka 1,35,000[12] each (GOB, Cabinet Division, IFAD Project 2000). Each plant's capacity supplies power for lighting and water heating to about 1000 people simultaneously.

Grameen Shakti (NGO) installed 5 solar photovoltaic plants at Kapacia village (near Dhaka) with cost of Taka 35,000 each. Each plant's capacity supplies light equivalent to 3 60-watt bulbs, sufficient to light a 6-members' household in rural Bangladesh. It also installed 5 solar cookers in the same village, with a cost of Taka 15,000 each (Grameen Shakti, Annual Report 2000).

Prokowshal Sangshad Limited, with the financial assistance of the World Bank, produced a feasibility report for involving 5 villages into a grid-interactive system (as a joint programme with REB) for providing solar power supply. They estimated that one unit of electricity can be produced at a cost of Taka 115, a little higher than the cost of power based on furnace oil in the public sector of Bangladesh.

It implies that the cost of solar power in Bangladesh is more expensive than currently used energy. But does the current pricing of energy supplied in Bangladesh (e.g. electricity and petroleum products) reflect a real price?

The answer is negative, because, as we have already discussed, the cost of one unit of electricity produced by using furnace oil in 8 generators in the Northern part of Bangladesh is Taka 74, whereas the selling price of that unit is Taka 54. That means that the government subsidises Taka 20. Similarly, the opportunity cost of natural gas does not count while it is used to produce electricity.

Moreover, the externalities such as air pollution and other consequences of using fossil fuel have not been accounted for in the current energy pricing policy of Bangladesh. Although it seems apparent that the cost of solar power is higher than that of electricity produced by using gas or furnace oil, the real price might be much less if the energy market were allowed to function without government intervention.

As far as the affordability is concerned, we have mentioned in Chapter Five that a typical (landless or low-income) rural household's average monthly energy bill is Taka 134-260 (for detail see Table 5.2.1). It means that introduction of solar power

[12] US$ 1= Taka 56 as on 30th June 2001.

technology in rural Bangladesh might need a subsidy from the suppliers' part. The pattern and type of subsidy needs further in-depth investigation.

8.5.4 Matching With Demand and Supply

Solar power technology produces energy in the form of direct heat and in the form of electricity for lighting. Activities like cooking, lighting, entertainment, drying etc. (households or commercial) can be performed with the solar energy. At present, rural population of Bangladesh use mostly biomass burned in the open stove. The use of solar energy for the same activities will require modifying stoves (solar cooker), i.e. the matching of demand and supply of solar energy in the Bangladesh rural communities must be considered in adopting new devices such as solar cooker and dryer.

8.5.5 Contribution to GHG Reduction

Solar energy technology is free from environmental pollution because it does not use fossil fuel or any other materials harmful for the environment. But it does not absorb GHG such as CO_2, as opposed to biomass, which can recycle CO_2. However, solar energy is environment-friendly.

8.5.6 Major Constraints of Solar Energy Technology

The major constraints in transferring solar energy technology to rural Bangladesh are capital and knowledge. Our field data show that the majority of respondents need money and knowledge for participating in a SET transfer. It implies that a potential market for SET in rural Bangladesh is constrained by capital and know-how considerations. The form of capital or technical know-how transfer needs further in-depth investigation.

8.6 Feasibility of Wind Power

In this section, we will investigate the feasibility of wind power technology in rural Bangladesh. Like biomass and solar energy technology, wind power is also examined on the basis of justification criteria.

8.6.1 Availability of Wind

The long-term wind flow in Bangladesh (especially in the islands and the Southern coastal belt of the country) indicates that the average wind speed remains 3-4.5m/s (10.8-16.2 km/h) from March to September, and 1.7-2.3m/s (6.12-8.28 km/h) during the remaining period of the year. Wind speed related data were collected from the Meteorological Department of Bangladesh (MDB), Dhaka in November 2000. MDB recorded the duration and speed of wind from the 14 selected location of the country for the period covered each month of 1997 to 1999. Copy of collected data (location wise) is presented as annex 15.

The island and coastal areas present ample opportunities for applying wind mills for pumping water and electricity generation. But during the summer and monsoon seasons (March to October), there can be very low-pressure areas and storm wind speeds of 55.6-83.3 m/s (200-300km/h). Wind turbine must be strong enough to withstand these high wind speeds. Our field survey results show that wind resources appear to indicate the potential for wind energy use in the coastal areas of Bangladesh both for grid application and isolated village electrification.

Bangladesh is strongly influenced by the South-West monsoon winds in March-October. These winds are strengthened as they pass through the V-shaped coastline of Bangladesh. It is these monsoon winds that have enabled extensive wind-farm development in India, where, for example, more than 200MW operate in Tamil Nadu (GOB, Power Cell 1997, Section 8). Wind speeds are expected to be high enough for economic grid power generation to feed the main grid or isolated grids in wind-diesel hybrid configurations.

Patenga of Chittagong district is a potential location for a wind farm. In 1995, Bangladesh Atomic Energy Commission (BAEC) collected a series of data from Patenga, and recommended it as a good location for setting up a wind farm. BAEC report says that in Patenga, wind speed varies from 4.2 to 8.1m/s (15.12-29.16 km/h), average 6.5m/s (23.4 km/h) at 20m. Winds are strongest from March to October, but exceed 5m/s (18 km/h) at 20m for over 6000 hours per year (cut-in speed of large wind turbines is about 4m/s (14.4 km/h)). Preliminary estimate of the net annual output from a Patenga 500kW wind turbine with a 40m hub height is 1200kWh, which seems feasible. Wind potential at Patenga alone is about 100MW (BAEC 1995).

A number of windy locations along the coastline offer available land, and grid and road access. It is notable that other parts of the country, especially Northern and North-Western parts, are also suitable for windmills. That means that, taking into account wind speeds and ecological conditions, the wind energy technology has a great potential in Bangladesh.

8.6.2 Technological Complexity of Wind Power

The degree of technological complexity of wind power is higher than that of biomass and even—to some extent—than that of solar power, depending on the types of devices used. For example, technology of a simple windmill used for water pumping is much simpler than that of a wind turbine used for producing electricity.

Some types of technological devices used for producing wind energy are already available in the global market, but their design is mostly suitable for the developed countries. Some designers in the developed countries consider that importing a more sophisticated wind energy technology might benefit the developing countries, but this assumption is far from reality, due to the importing country's (e.g. Bangladesh) inability to use and adopt that technology. Hence, the transfer of a more sophisticated wind energy technology might be unsuccessful.

Some of the wind power technology available in the global market are wind diesel hybrid power system, stall-regulated wind turbine (Hydro Tasmania 2001); Darrieus vertical axis rotor, small-wind turbine for battery charges, Danish 55kW wind turbine, Maglarp 3 MW wind turbine etc. (Kristoferson and Bokalders 1987, pp 274-281). However, as the main thrust of this study is to examine the feasibility of wind energy in the context of rural Bangladesh, the focus of technological complexity should be on the extent to which the rural population of Bangladesh is able to adopt the technological devices of wind energy.

PRA survey in Kutubdia and Loxmikola villages, investigated in detail the potential of wind energy for rural development, particularly for irrigation purposes. We have observed that the rural population will use windmills for irrigation, implying a large potential for a simple windmill in rural Bangladesh rather than a large-scale high-tech wind turbine. Furthermore, the level of technical skills and education in rural Bangladesh population indicates the possible viability of a small-scale windmill. On the other hand, a sophisticated wind turbine might be feasible for producing electricity at a national level.

8.6.3 Cost-Effectiveness of Wind Power

The costs of wind power technology vary greatly with its capacity of power production, quality of machinery, and other capital and organization-related costs. However, although a few windmills have already been set up in Bangladesh, it is hard to know their capital costs, and even variable costs, because these plants are in a private ownership, and are mainly used for demonstration purposes. Therefore the owners are not interested in disclosing their real price, in order to protect their future business investment.

The costs of a standard windmill in Bangladesh were discussed with the energy technology professionals of Bangladesh University of Engineering and Technology, Bangladesh Atomic Energy Commission, Ministry of Energy etc., and the results show that the tentative cost of a standard windmill with a capacity of water-pumping for 5 ha of land is Taka 55,000-65,000.

Considering the thrust of this study, it is questionable that whether this cost is affordable for rural population of Bangladesh who are mostly low-income earners, using either free or cheap energy sources. On average, they spend about 12% of their income on energy.

Furthermore, considering the per capita income of Bangladesh (US $369), a typical family of 5.6 members (Chapter 3) will have to invest about 52%[13] of its annual income into a windmill. From the point of individual family ownership, the financial viability of a windmill might be questionable for the rural communities in Bangladesh.

[13] US $1=Taka 56. So, annual income is 369*5.6*56=Taka 11,5718. An average cost of a windmill is (55,000+65,000)/2=Taka 60,000. Therefore, 60,000/11,5718*100=51.8%.

However, the scenario might be different if we consider the capital investment and management under co-operative system. Our field survey data show that 85% of respondents are aware that it is hard for an individual family to bear the capital costs of a windmill in their locality. Therefore, they are interested in sharing the investment and management on a co-operative basis. Respondents are also aware that a windmill might bring more benefits beyond the physical factors such as reduction of GHG emission.

In the PRA survey in Kutubdia and Loxmikola villages, we insisted on finding out the attitude to the windmill, and found out that villagers were very positive towards installing a windmill in their locality under co-operative system (PRA section of Chapter 3).

This situation indicates a need for further in-depth study assessing the cost-effectiveness of wind power technology for rural Bangladesh.

8.6.4 Matching With Demand and Supply

Consumption and demand pattern for a particular energy source is largely influenced by the availability of the relevant source. For example, people of rural Bangladesh are habituated to using kerosene for lighting, but once electricity is supplied to some localities, people become more interested in using it as an alternative source of lighting, i.e. supply creates demand.

Energy demand is dynamic and changeable with the change of the users' socio-economic and cultural status. At the same time, it is notable that the energy demand also depends on the purpose of energy use. For example, firewood can be used for cooking but it is inconvenient to use it for lighting. That is, more than one type of energy source is needed to meet more than one type of energy demand. This issue refers to matching demand with supply, requiring the need to investigate whether wind energy meets the rural population's demand.

Energy produced from wind is used as electricity, for machine operation etc. It means that the energy supplied by a windmill or other form of wind-power technology, can meet a large part of the energy demand of the rural communities of Bangladesh.

8.6.5 Contribution to GHG Reduction

The use of a particular type of energy technology might have more than one impact on GHG emission. For instance, fossil fuel emits CO_2, whereas biomass not only emits CO_2 but also absorbs it. In fact, biomass works as a recycling agent of CO_2 emission process.

However, as the production and distribution of wind energy is entirely free from the use of fossil or other biomass fuel, it does not pollute the air and hence, does not contribute to the environmental degradation.

8.6.6 Major Constraints of Wind Energy Technology

The technology of wind energy is relatively complicated, requiring sophisticated machinery and the need of training to understand and operate it. Moreover, as the wind power machinery has a longer all-seasonal exposure (at least 10 years) to weather conditions, its spare parts might be oxidised and damaged.

Another important constraint for wind power technology is the land requirement. In Bangladesh land is scarce. But, on the other hand, the land used for a windmill might be also used for other purposes, for example, crop production. Moreover, proper choice of location can minimize land waste.

8.7 Summary of SET Feasibility in Matrix Format

Based on the above analysis, the summary of feasibility of introducing SET in rural Bangladesh is presented in Matrix 8.7.1. Possible links between supply and demand related to household and commercial activities are presented in Models 8.8.1 and 8.8.2, respectively. The model shows that the energy demands of household activities and commercial activities are very likely to be met from the SET sources.

8.7.1: Feasibility of Introducing SET in rural Bangladesh

TECHNOLOGY CRITERIA[14]	*BIOMASS (traditional biomass technology, biogas)*	*SOLAR (PV,cooker, dryer)*	*WIND (wind turbine, windmill)*
Availability of Resources	Production and supply is gradually decreasing compared to demand.	Supply abundant for infinite future.	Supply abundant for infinite future. But depends on wind speed. Might not be available as and when needed.
Complexity of Technology	Simple to use. Needs little training. Rural population can operate once trained. Repair and maintenance simple.	Simple to use. Needs little training. Repair and maintenance require special skills.	Relatively complex to use. Requires training. Repair and maintenance require specialist skills.
Cost-Effectiveness	Installation cost of traditional biogas plant varies, Taka 5000-35,000. Raw materials are not free of costs. Opportunity costs of raw materials gradually increasing. Low maintenance costs.	Installation cost varies, Taka 10,000-175,000. Spare parts costly, maintenance costs reasonable.	Installation cost varies, Taka 35,000-250,000. Spare parts costly, maintenance costs reasonable.
Matching with Supply and Demand	Cooking, lighting, not irrigation or agriculture. Partly for industries.	Partly for households, and partly for commercial uses. Not for large machine operation.	Partly for households, and partly for commercial uses.
Contribution to GHG reduction	Much less, but not 100%-free from GHG emission. Helps CO_2 recycling. Net emission reduction not certain.	100%-free from GHG emission. Helps to reduce net emission. 100%-environment-friendly.	100%-free from GHG emission. Helps to reduce net emission. Little risk for birds' migration, otherwise 100%-environment-friendly.
Major Constraints	Long-term availability of raw materials uncertain.	No major constraints. Use depends on sunlight. Parts imported.	No major constraints. Plant installation depends on location. Use depends on wind speed. Parts imported.
Comments	Biomass might be feasible as a source of energy supply for both household and commercial uses in the short run. But it would	Solar energy might be feasible as a SET for household and partly commercial use in rural Bangladesh subject to proper training, supply	Wind might be feasible as a SET for irrigation and water supply both in household and commercial uses in rural Bangladesh subject to

[14] There are two types of technologies: 'traditional' and 'modern'. For example, producing ethanol from biomass is modern technology while biogas technology is traditional. There is a large variation in terms of usefulness, cost etc. between these two types of technologies.

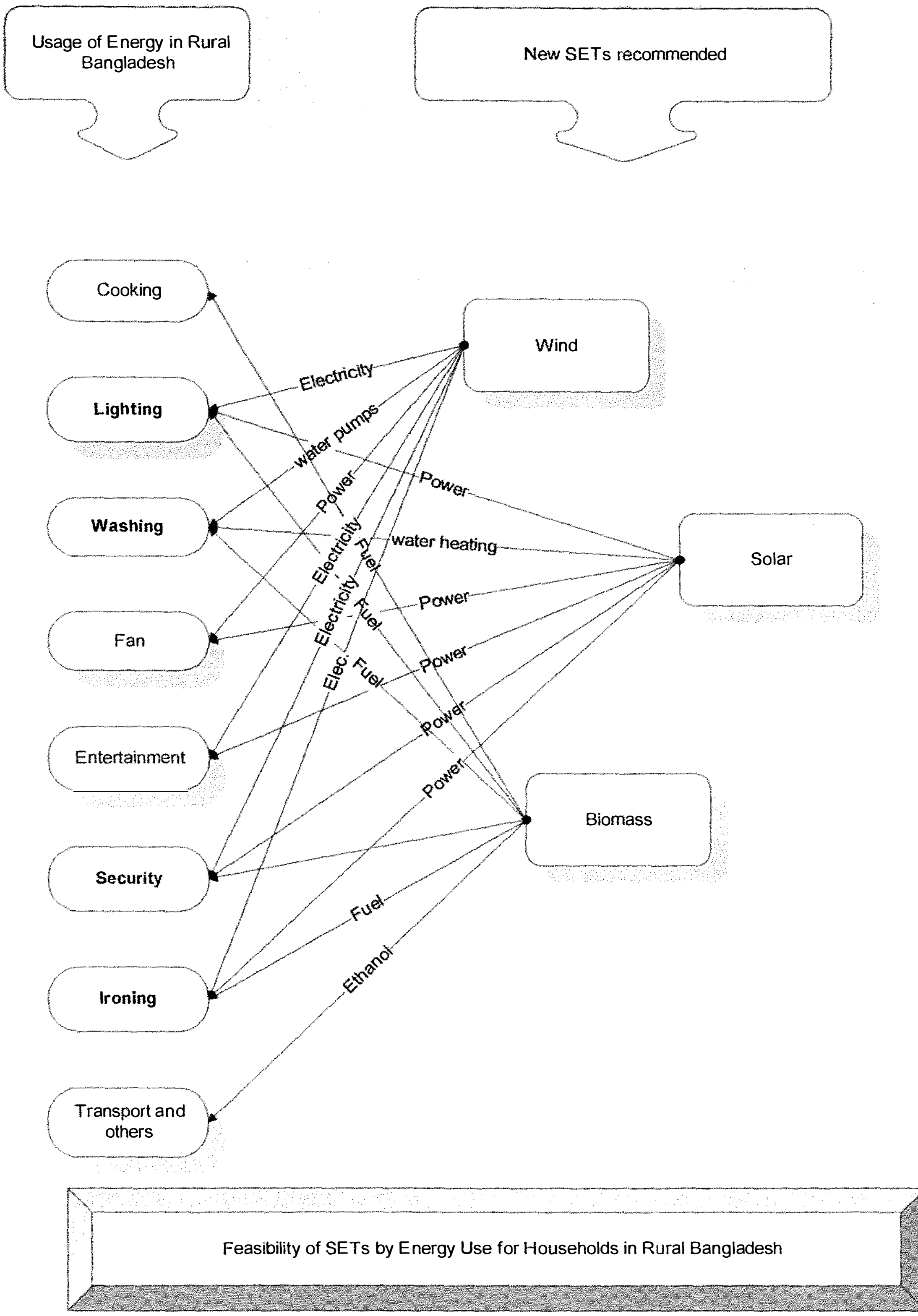
TECHNOLOGY CRITERIA[14]	*BIOMASS (traditional biomass technology, biogas)*	*SOLAR (PV,cooker, dryer)*	*WIND (wind turbine, windmill)*
	hardly be sustainable for rural Bangladesh in the long run.	of spare parts, and financial subsidy in installation.	proper training, supply of spare parts, and subsidy in installation.

8.8 Energy Supply and Demand Linkage Model

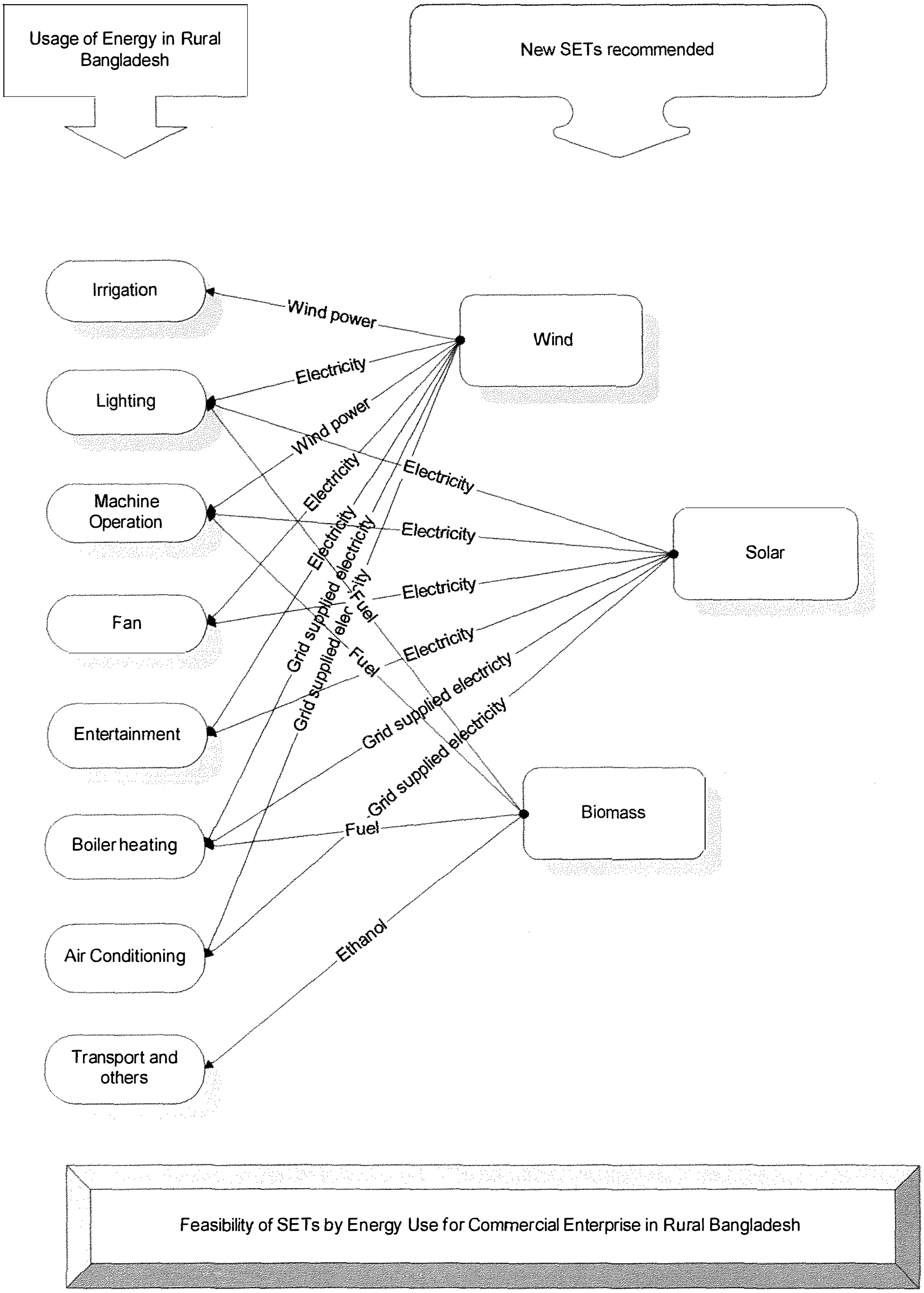
In our analysis, we have categorised the demand for energy in rural Bangladesh into two groups: household and commercial. Household activities include cooking, lighting, washing, entertainment, security, ironing, fan operation etc. Commercial activities include irrigation, machine operation, boiler heating, lighting, security, air conditioning, fan operation, entertainment etc. Available energy resources, feasible for rural community, are biomass (firewood, twigs, leaves, charcoal, dung, biogas), solar, wind, kerosene, electricity, and diesel.

Based on our previous analysis, a model of linking the demand for energy and the best feasible source of supply to meet that demand has been developed. Energy Supply and Demand Linkage Model (Figure 8.8.1) shows the feasibility of SET for household activities, while Figure 8.8.2 shows the feasibility of SET for commercial activities in rural Bangladesh. It is seen from the model that the rural population can meet their energy demand from locally available resources, if energy supply is properly planned and managed.

8.8.1: Energy Supply and Demand Linkage Model for rural Bangladesh



8.8.2: Energy Supply and Demand Linkage Model for Rural Bangladesh



8.9 Conclusion

Bangladesh has been suffering from acute energy shortages. The gap between demand and supply is gradually increasing. Although there are some reserves of energy resources (natural gas and coal), the country's economic and technical inability makes it hard to provide energy supply network to the rural population. The dependence on importing fuel is gradually increasing, where the rural population is largely disadvantaged due to their low purchasing power.

In rural Bangladesh, the major household energy demand is for cooking and lighting, while it is irrigation and crop-processing for commercial activities. Based on current and potential consumption patterns, economic ability and technical capability, some criteria are chosen to examine the feasibility of introducing SETs to rural Bangladesh: availability of resources, degree of technological complexity, cost-effectiveness, matching demand with supply, contribution to GHG reduction, and major constraints. Three energy technologies (biomass, solar, and wind power) are examined with the aim of finding the best possible options for rural Bangladesh.

Having analyzed the energy use pattern, energy sources, and costs and benefits of potential forms of sustainable energy, it appears that none of the technologies (biomass, solar, and wind) considered here would be fully implementable alone in rural Bangladesh. A combination of biomass, solar, and wind power energy technology is suggested.

Chapter 9

Conclusions and Policy Implications

9.1 Introduction

The purpose of this chapter is to summarise the major findings of the study, and draw a conclusion to the thesis. A brief summary of the major findings of each chapter is presented in the following sections, with a section showing the achievement of the study objectives. The last two sections point out the policy implications, and the directions of further new study research.

9.2 Summary of Previous Chapters

9.2.1 Background of the Study

Background, theoretical framework, scope, limitations, and the objectives of the study are discussed in Chapter 1. Energy is a common factor behind many of the global environmental problems observed today. Energy sector has been responsible for 46% of the increase in the GHG effects until the last decade, and GHG emissions would increase to 65% if the present pattern of consumption and supply is to be continued. There is a global concern about environment, and it is believed that one of the best ways to control GHG emissions is to generate energy from environment-friendly sources rather than use fossil fuel.

It is argued that, due to the wide-spread poverty in developing countries, and unsustainability of their development path, their economic activities might pose threat to environment, causing its degradation. So there exists a need for SET transfer to the developing countries. But the energy use pattern, its infrastructure, nature of energy demands, and even economic and technical strengths of each particular country are different.

This situation raises the following questions: What energy technologies are available in the global market? What technologies are feasible for a particular developing country? To what extent would the proposed technology be able to meet the demand for energy in relation to the developmental requirements of developing countries? etc. In fact, the problem is to find the most feasible SET for developing countries such as Bangladesh.

Bangladesh suffers an acute shortage of energy. Many socio-economic activities, including living standard and lifestyle have been affected by energy shortage. The country has very limited natural resources, and is very weak economically and technically. Furthermore, Bangladesh spends about two-third of its export revenue on meet energy import bill requirements. The dependency on imported fuel is gradually increasing where rural population is largely disadvantaged. The gap between demand for and supply of energy is gradually increasing, too. This situation is creating further disadvantage for rural society where poverty is wide-spread, and people have very limited purchasing power.

The main objectives of the study are: (a) to assess the existing indigenous technological capabilities of the recipient countries in SET areas; (b) to examine the availability of desired technologies; (c) to examine whether SET transfer should be backed by resource flow from the developed countries; and (d) to assess the perception of and attitude to SETs among the rural communities in Bangladesh.

9.2.2 Literature Review

In Chapter 2, we have reviewed the literature relevant to the SET transfer contribution to mitigating GHG emission, and meeting energy needs for sustainable development and poverty alleviation of the rural communities. The review covers the areas of global concern about GHG emission, availability of SET in the global market, and the studies on the Bangladesh energy sector.

Literature survey shows a global concern about the GHG emission due to the unbalanced use of fossil fuel. The concern is becoming more serious because of the trend to use fossil fuel, and the rate of depletion of natural resources (deforestation and land use) in the developing countries. Rio Earth Summit drew formal attention of the developed countries and relevant international agencies to this issue. Relevant sources state that GHG emission (particularly CO_2) can be mitigated by increasing the use of sustainable energy sources instead of fossil fuel, and the necessary technologies in this context are available in the global market.

We have also analysed the conceptual debate on some terminology relevant to this study. There is a gap in understanding poverty, sustainable development, environmental degradation, net and gross emission of GHG etc. The gap also exists in the concept of renewable, alternative, and sustainable energy resources.

Conventional literature holds a negative view that the poor population of the rural areas is mainly responsible for degrading the environmental quality, but this study has found that poorer class of the society are more careful in the use of natural resources. They protect the environment in the interests of their survival. Case studies in Philippines and Bangladesh have confirmed this finding.

It has been found that previous studies have addressed the energy demand and supply issues from the suppliers' point of view, while the issues of potential demand from the users' point of view have been left out. However, studies have argued that, as the developed countries are mostly responsible for today's environmental pollution while enjoying the benefits derived from it, they should come forward to co-operate with the developing countries in undertaking GHG emission reduction programmes.

It has also been found that the methodologies used in previous studies are not sufficient for analysing rural energy scenarios, and would not reflect the real choice of rural population.

In Bangladesh, research and development programmes in energy sector are very limited, and the issues relevant to rural energy have not been addressed. This study attempts to fill this gap.

9.2.3 Methodology of the Study

Methods and techniques of data collection and analysis have been described in Chapter 3. As the main thrust of the study is to identify the best possible options of SETs for rural Bangladesh so that rural population can achieve its development goals in an environment-friendly way, the study is heavily dependent on both primary and secondary data used.

Secondary data were collected from different published materials, while primary data were collected from the field survey. The field survey was conducted in four villages, one village from each region of rural Bangladesh. It used three methods: structured questionnaire, participants' observation, and participatory rural appraisal. A structured questionnaire was designed for interviewing sampled respondents, with special care for the socio-economic and cultural background of the respondents.

The questionnaire is focused on obtaining information on the sources of energy used by the rural population, the reasons for its use, major activities that consume energy, activities suffering from the shortage of energy, possible activities in the case of additional available energy. In addition, questions included the motivational factors in introducing SET in rural communities, types of required assistance, level of awareness about the relationship between energy use and environmental degradation etc.

A total of 303 responses to the questionnaire have been analysed, in which 60% of respondents were male, and 40%—female. The main parameters of investigation were: pattern of energy consumption, availability of energy resources, respondents' ownership of resources (e.g. land, forest, cattle etc.), their income, occupation, education, environmental awareness, attitudes towards SET, ability to contribute to SET etc.

In addition to it, we have also carried out another, leadership opinion survey, using a different set of structured questionnaires. The respondents were school teachers, local politicians etc. A total of 31 responses have been analysed from the four sampled villages.

In two villages, we have also carried out focus group interviews, using PRA technique. Information from secondary sources has provided the basis of investigation, while that obtained from primary sources has added an extra scope for the insight into the real situation addressed in this study.

9.2.4 Bangladesh Energy Scenario

In Chapter 4, we have analysed the current energy scenario of Bangladesh. The issues involving energy management in Bangladesh are: availability of resources in energy production and distribution; institutional arrangement for energy management; supply and consumption networks; and the status of SET with special emphasis on the rural energy sector.

Bangladesh is located in South Asia, and is surrounded by India on three sides, Myanmar in the South-East, and Bay of Bengal in the South. Its population is 130 million, the area is 148,393 sq.km. The population density is about 800 people per sq.km. About 85% of the population live in rural areas, mostly earning their living from agriculture, forestry, and fishery. Most of the population is directly or indirectly dependent on agriculture. The country has 230 rivers with a total length of about 24,140 km, and a 724 km-long coastal belt. Bangladesh per capita energy consumption is 9.67E-6PJ.

The first electricity supply system was introduced in Bangladesh in the mid-Fifties', and currently there are 11 organisations directly or indirectly involved in power production, distribution, and management. Among them Bangladesh Power Development Board (BPDB) is the largest responsible for electricity production and urban distribution. Bangladesh Rural Electrification Board (REB) is responsible for distribution of electricity in rural areas, purchasing electricity from BPDB. Dhaka Electric Supply Authority (DESA) is entirely responsible for distribution of electricity to the capital city. Titas Gas Supply Company supplies natural gas.

Until 2000, 15% of households have been connected to electricity supply networks, while 2.2% of households have been connected to gas supply networks. The electricity is produced from three sources: hydro, natural gas (87%), and furnace oil. The produced electricity meets about 34% of the country's current demand level.

Energy shortages in Bangladesh cause resource constraints, economic and technical incapability, and inefficient management.

Natural gas reserves comprise 25tcf. Gas is used for household consumption, producing fertilizers, and in electricity production. As a result, it is likely to be exhausted in the near future. Moreover, due to economic limitations experienced since the mid-sixties, the country has connected only 2.2% of urban households to gas pipelines. It means that in rural areas it will be almost impossible to supply gas from door to door in the foreseeable future.

Bangladesh has coal reserves of about 19 sq.km. in Jamalgonj, and close to that figure in Dinajpur. In addition, it has about 600 million tons peat reserve. But coal deposits lie at a depth of about 900–1000 meters. So, economic and technical feasibility of its use is doubtful. The country has no oil reserves. The characteristics of most Bangladesh rivers make them unsuitable for producing hydropower.

The management of energy production and distribution in Bangladesh has been suffering from multifarious problems: corruption, red tape, lack of co-ordination and co-operation, inappropriate policy, shortages of capital for investment, and system loss. About 50% of the system loss is attributed to pure theft. Hence, every year government is losing huge amounts of revenue. Bangladesh spends about 67% of its export earnings for importing fuel.

Indeed, there is a huge excess demand for energy in Bangladesh but its supply is restricted to local resources such as natural gas and coal, due to technical and economic reasons where the rural population is more disadvantaged. Therefore, there is a need to explore SET, especially those appropriate for the mass of the population in rural areas where energy shortage is most acute, and poverty is most wide-spread.

9.2.5 SET Options in Rural Bangladesh

Chapter 5 has analysed the state of the energy sector and SET in rural Bangladesh, particularly the level of financial expenditure for energy, pattern of energy demand and supply, and the availability of SET. In fact, it has examined how rural population meet their energy demand, why people use particular energy sources, potential and limitations of introducing SET in rural Bangladesh.

In rural Bangladesh about 56% of the population spend on average Taka 134-260 per month on energy (US $2.62-5.10 a month, or US $31.44-61.2 per year per household, or 9-12% of their income). Per capita annual income is US $369. Firewood meets roughly 25% of total energy demand, while other sources (cow dung, leaves, dried crop etc.) provide 50% of the total energy demand.

Basically, rural population largely depends on relatively cost-free or cheaper sources of energy such as leaves, cow dung, twigs etc. But due to alternative use, the opportunity cost of biomass is gradually increasing. In rural Bangladesh, people use energy for cooking (100% biomass), lighting (kerosene), washing (biomass), heating (biomass and sun radiation), irrigation (diesel), agriculture (human muscle power and animal power) etc.

In Bangladesh, rural communities have a very limited access to the grid-supplied electricity. The main sources of energy in rural Bangladesh are biomass, solar power, wind power, human labour, and animal stock. All rural households use biomass for cooking, with its large portion originating from agricultural residues, followed by forestry.

Poorer classes of the society make their children collect biomass fuel instead of going to school. Sometimes, women and children are physically or even sexually assaulted while collecting biomass in forests or jungles. Indeed, biomass collection becomes a social problem in rural Bangladesh.

The use of biogas, charcoal, solar, and wind power in different forms is very limited because of the limited awareness of these sources of energy among the rural population, resource constraints, and insufficiency of technology diffusion and motivational programmes. However, government and some non-government organisations have been promoting these energy technologies, and the potential for the use of SET in rural Bangladesh is very big.

9.2.6 Energy Use in Rural Bangladesh

In order to understand energy demand, its availability, and sources, as well as to determine the level of acceptance of environment-friendly energy technology in rural Bangladesh, a sample survey was conducted in four villages of four major divisions of Bangladesh. In addition, to learn the attitude of leaders who might be involved in decision-making of SET transfer, a separate survey (31 respondents) on social elite, school teachers, political representatives was conducted in the survey areas. The discussion and analysis of the findings of the household and leadership opinion surveys are presented in Chapter 6.

The survey results have been used in identifying market and non-market sources of energy, understanding energy collection mechanism, energy use, and classifying the energy use patterns. This information has provided us with a clear picture of the feasibility of potential substitution of rural energy with SET. A total of 303 usable responses (60% male and 40% female) to questionnaires were ultimately accepted for analysis in this study.

The surveyed villages, households, and respondents were selected randomly. The sampled respondents represented different backgrounds in respect of their education levels, income, sex, land ownership, occupation etc. It has been found that educated people are more concerned about the sources of energy, deforestation, and its consequences than illiterate people. More than 18% of respondents are housewives. It has been observed that as they are directly involved in energy use in household activities, they have strong influence in acceptance of SET in rural communities.

Survey findings suggest that the annual income of 43% of households is less than Taka 20,000 (US $357). Also, up to 5 decimals of arable land are owned by 34.5% of respondents who are considered landless (national statistics of landless is 35%). This indicates that in Bangladesh, especially in the rural areas, income distribution is uneven, and the poverty is wide-spread.

The sources of energy supply in rural Bangladesh are ownership of animals, forests, land, local retailers, local agents, wholesalers, REB, and open market. The use of energy in households involves cooking, lighting, entertainment, fan, ironing, security, and washing, with the largest amount of energy consumed by cooking, followed by lighting. In commercial activities, energy is used for air conditioning, boilers, entertainment, fan, irrigation, heating, curing, lighting, and machine operation, with the largest amount of energy consumed by irrigation.

The rural population uses current sources of energy because of easy collection, affordability, and absence of an alternative. A high number of respondents opined in favour of no other alternative source. In rural Bangladesh, children are used to collect leaves, crop residues, cow dung, twigs etc., while adults collect energy from market (kerosene and diesel) or buy firewood.

About 72% of respondents are aware of environmental pollution caused by free energy use. Forty-three percent of respondents believe that the unsustainable use of energy is one of the causes of frequent flooding followed by drought (20%) and deforestation (15%). In rural areas, solar and wind energy is mostly unheard of, while nearly 65% cited biogas and biomass as energy sources. It means that biogas- and biomass-based SET will be more readily acceptable in rural Bangladesh.

Introduction of SET in rural Bangladesh would require some planning and introducing a relevant mechanism. Clearly, it requires developing financial assistance mechanism and an information system. In fact, the rural population need to build their capacity in regard to understanding the concept, preparing the project proposal, and implementing SET. A guideline of capacity-building project, with respect to SET transfer in Bangladesh, is attached in Annex 16.

Due to energy shortages, the most vulnerable activities are education, irrigation, personal entertainment, businesses, employment, communication etc.

The survey results show that rural population is aware of the 'cost' of energy shortfalls, and so they are expected to be willing to buy energy. However, it is also clear that one of the major reasons for using the existing source of supply is its cost, and this factor is very important in introducing SET. Therefore, SET must be cost-effective. Both household and leadership surveys have disclosed a strong positive attitude to using and producing SET-based energy in rural Bangladesh.

9.2.7 Analysis of Respondents' Background Characteristics

Chapter 7 has carried out an in-depth statistical analysis of socio-economic characteristics of the sampled energy users of rural Bangladesh. It has also looked at the energy consumption pattern, energy sources, and found the corresponding link to selected background variables of sampled respondents. In fact, Chapter 7 has identified 'who is who' in the Bangladesh rural community within the limits of this study. We have analysed whether the knowledge about SET as well as environmental awareness of some respondents is systematically different from others, and—if so—how it is different.

Furthermore, as the main energy demand originates from cooking, lighting, washing, and entertainment, the relationship of the consumption level and the background variables has also been analysed. The selected background variables were respondents' income, education, land ownership etc. The relationship of background variables with the pattern of using energy sources and consumption behaviour has formed an important basis of justifying SET transfer to rural Bangladesh.

We have used SPSS software (Means test, Mann-Whitney test, Regression, and Correlation) for the purposes of statistical analysis.

The rural communities of the sampled villages depend on biomass and sun heat for meeting their energy needs in a traditional way. There is an acute shortage of energy for both household and commercial activities where women are largely disadvantaged.

Low-income population, small land-owners, and less educated classes are more likely to use dung, leaves, and—to some extent—firewood as the main energy source in rural Bangladesh. Similarly, higher-income population, larger land-owners, and more educated classes (or the population with a higher education) are likely to afford firewood or—to some extent—electricity.

Although firewood seems not too expensive, in rural Bangladesh, where forest land is disappearing, and plantation has not been managed carefully, it is becoming increasingly problematic for the population to afford even firewood for cooking, and kerosene for lighting. As a result, poorer classes in rural communities gradually become more dependent on leaves and dung.

9.2.8 Choice of SET in Rural Bangladesh

Taking into account socio-economic factors of rural population of Bangladesh, the best possible options of SET have been presented in Chapter 8. As this study is concerned with assessing SET transfer from the users' perspective, the criteria for justifying the appropriateness of the proposed SET for rural communities are: (a) availability of resource base, (b) degree of technological complexity, (c) cost-effectiveness, (d) balance between supply and demand, and (e) contribution of the particular energy technology to reducing GHG emission.

In addition, major constraints related to accepting the proposed SET have also been assessed. This study assesses the feasibility of three proposed energy technologies (biomass, solar, and wind) within each criterion.

The availability of biomass has been examined on the basis of its major sources of production (agricultural residues, firewood, tree residues, and animal dung). The supply of biomass was estimated for the period 1995-2020. It has been found that the annual per capita availability of biomass was 4.41PJ in 1995 dropped to 2.76PJ in 2020. Scarcity of land and the demand for more food production are major contributing factors of the decrease in biomass availability.

Biomass energy technology is simple and affordable. However, it is not 100%-free from environment pollution, although it works as CO_2 absorber, too. However, although it would be easier for the rural population to use, and hence accept, biomass energy technology, the major constraint here is the choice of land use—food production or tree plantation. Biomass technology is feasible in the short-term but is hardly acceptable in the long run in rural Bangladesh.

The environment-friendly sun radiation is suitable for solar power technology in Bangladesh. But the technology is relatively complex and is quite costly for individual households. Major constraints here are the technological complexity and costs. There is a need for training, and market availability of spare parts could be a problem. Solar energy technology might be unacceptable in the short run, but would be feasible in the long run.

Wind is suitable for producing environment-friendly wind power in Bangladesh. But the technology is relatively complex, and the cost is not affordable for an individual household. Like solar, wind energy technology might also be unpopular in the short run, but could be feasible in the long run.

A model linking available sources of energy supply with the pattern of consumption has been developed. It shows that the demand for energy in rural Bangladesh can be met from the local available resources, if proposed SETs are introduced, planned, and managed properly.

9.3 Achievement of Objectives

The aim of this section is to evaluate whether and how we have achieved the objectives and answered the questions of the study.

The objectives of the study were: (a) to assess indigenous technological capabilities of the recipient countries have so far achieved in SET; (b) to examine availability of desired technologies; (c) to examine whether SET transfer should be backed by resource flow from the developed countries; and (d) to assess the perception of and attitude to SETs among the rural communities in Bangladesh (see Section 1.5 of Chapter 1 for details).

The research questions of this study were concerned with biomass supply potential, cost-effectiveness of SET, its ability to satisfy specific energy demands, motivational factors of the rural population, and the nature of potential benefits of extra energy supply (see Section 1.4 of Chapter 1 for details).

In achieving the objectives and answering research questions, we have evaluated the energy demand and supply pattern, management structure, and the potential of energy resources in Bangladesh (Chapter 4). In this context, it has been found that Bangladesh has been suffering from the shortage of energy, the gap between demand and supply is gradually increasing, the resource base is limited, and that due to economic and technical limitations these resources can hardly be used in the near future. It has also found some serious weaknesses in the energy management system where the rural communities are largely disadvantaged.

We have also analysed the pattern of demand and supply of energy and resource base in relation to SET in rural Bangladesh (Chapters 5 and 6). It has been found that the rural population uses most part of energy for household activities, with biomass being the main source of energy supply. The availability of biomass might not be sustainable due to land scarcity. However, technological improvement might play an important role in sustaining biomass energy in rural Bangladesh. Resources base for solar and wind also looks promising.

Finally, we have assessed technological capabilities of rural communities in relation to SET, and identified the most feasible SETs for rural Bangladesh (Chapter 8). The study findings demonstrate the limited nature of capabilities (knowledge, technical know-how, and ability to use) in utilising SETs in rural Bangladesh. SET is available on a limited scale, and is unorganised.

Furthermore, SET transfer to Bangladesh needs to be assisted by the resource flow from the developed countries. Assistance might be in the form of education, training, import of machinery and equipment. There is a need for a further in-depth research identifying relevant actual needs and types of assistance.

9.4 Policy Implications

Facing an acute shortage of energy (fuel: electricity, gas, biomass, petroleum), Bangladesh is also plagued by its energy (supply and demand) management problems. They span institutional level, policy level, resource constraints, planning—in fact, they are present at each stage of the national energy production and distribution networks. This energy crisis has created multidimensional problems in the socio-economic life of the society as a whole, with rural communities being particularly disadvantaged. It is clear that the country is unable to solve its energy shortage problems in the conventional way.

The findings of this study, and the evidence gathered lead to a number of policy proposals:

(1) Conventional methods of energy augmentation are not going to work in solving Bangladesh's problems. First, due to its unique features (very high population density in a very small land area), Bangladesh is unable to import fossil fuel because of the lack of financial resources. Second, there is not enough current in the rivers to help generate hydro electricity at the required level. Third, Bangladesh does not have the capital to radically multiply its current energy generation capacity. Fourth, there is not enough forest left to supply firewood to meet even day-to-day cooking demands for a 130-million population. Fifth, there is a very insignificant quantity of mineral oil (potential) in Bangladesh. Finally, even if Bangladesh had enough money to import fossil fuel to meet its energy needs, it is clear that it would not be environmentally sustainable. Therefore, the only option for Bangladesh is to choose our proposed SETs, at least in the rural sector.

(2) Immediate measures should be taken to restore environmental balance by banning all deforestation. Possible means that we would like to suggest include: (i) cash incentives for plantation, (ii) systematic tree planting by all NGOs, schools, colleges, and other institutions, with cash incentives offered to schoolchildren and school management for plantations on school premises; (iii) part of government subsidies offered to schools, college, madrasa should be linked to their environmental performance.

(3) Immediate steps should be taken to involve rural community in planting trees on the roadside and fallow lands (where possible) as part of social or community forestry programmes. Certain motivational arrangements must be in place to incentivise people to plant trees, e.g. government buys all trees from the planter after a certain period of time. Moreover, rural communities should be assured of the ownership of the trees they planted.

(4) Immediate steps should be taken to reform the existing energy infrastructure. A medium-term plan could be taken to ultimately privatise BPDB, REB, and all other agencies in the energy sector, privatise distribution of electricity and gas. Most of the system loss arises from illegal connections provided by corrupt BPDB and DESA employees to the poorer layers of the society. It is notable that Bangladesh is one of the politically sensitive countries in the Third World. Most public sector organisations are dominated by a trade-union group with its vested interests, which—directly or indirectly—influences the government. So, it is very likely that privatisation of the power sector will be severely impeded by the concerned group, especially trade unions. An example of this kind is the failure to privatise the Bangladesh Telephone Board in 1998 due to massive trade union strikes. It is also notable that public sector employees do not feel a sense of belonging to their enterprises. Privatisation of the power sector should ensure that the utilities and services are paid for by the users.

(5) Immediate steps should be taken to educate rural population—through advertising, TV, radio, and newspaper campaigns etc. against environmental hazards caused by cutting trees for firewood, using fossil fuel etc. An example of a successful public campaign (amidst all of the country's problems) is the decreasing population due to the introduction of birth control. Part of school

curricula can also be changed accordingly. For example, secondary school students might be asked to educate at least one person as part of their curricula.

(6) Bangladesh does not have sufficient resources to undertake all proposed initiatives immediately. The process should take time and occur gradually, phase by phase. Moreover, as the large part of country's annual budget comes from foreign aid, it can be channeled accordingly, in favour of these programmes. For the pilot implementation of Phase 1 foreign aid could be channeled in the form of (i) capacity building, (ii) capital, machinery, equipment, and (iii) technical know-how for implementing the proposed biomass, solar, and wind power plants.

The benefits from our proposal are multidimensional. Some of them are the reduction of urban migration, creation of business opportunities and hence employment, growth of food production due to irrigation, birth control (introducing entertainment facilities), elimination of illiteracy (sending children to school instead of collecting fuel), and overall improvement of the standard of living. In fact, the implementation of our proposed SET will positively impact socio-economic lives of Bangladesh population, especially in the rural areas.

The technology proposed in this study is simple, relying on common sense and economic reasoning. It is not calling for high-tech or capital-intensive technology. The proposed technology is self-reliant, paid for by the users, and affordable to the rural community. At the same time, this low-cost energy technology will bring unlimited direct and indirect benefits to the rural population of Bangladesh, playing an especially significant role in alleviating poverty and keeping environment viable, while improving the lifestyle. The main thrust of the policy implication of our proposed SET is towards investing all efforts into creating a social movement for solving energy problems, thus saving our livelihood.

9.5 Directions for Further Research

This study has examined the energy scenario of Bangladesh, with special focus on the rural population, including patterns of energy consumption, types of available energy resources, status of SET etc., and made corresponding proposals. Three types of SET (biomass, solar, and wind) are feasible for rural Bangladesh, each with its own limitations. We suggest undertaking development programmes aimed at educating people, growing more trees, channeling foreign aid in favour of energy projects, privatising energy sector etc.

These suggestions have raised certain questions: What should be the form of investment in education sector? How much assistance is necessary? What trees are suitable for the particular land characteristics? How can the rural population prepare their project proposals? What will happen if more natural gas is discovered? Can Bangladesh use all of its land to produce more food and import energy? The answers to these questions can be found through further research on these issues.

9.6 Conclusion

It is clear that Bangladesh has suffered acute energy shortages. The gap between demand and supply is gradually widening. Although there are some reserves of energy resources (e.g. natural gas and coal), due to economic and technical inability, it is hard to provide energy supply network to the rural population. The dependence on import fuel is gradually increasing where the rural population is largely disadvantaged due to its low purchasing power.

In rural Bangladesh, the major energy demand in household activities is cooking and lighting, while for commercial activities, it is irrigation and crop processing. Based on the current and potential consumption pattern, economic and technical capability, some criteria are chosen to examine the feasibility of introducing SET to rural Bangladesh: availability of resources, degree of technological complexity, cost-effectiveness, matching demand with supply, contribution to reducing GHG, and major constraints. Three energy technologies (biomass, solar, and wind) are examined to find the best possible options for rural Bangladesh.

Having analysed energy use pattern, energy sources, and costs and benefits of potential forms of sustainable energy, it appears that none of the technologies (biomass, solar, and wind) considered here would be fully implementable alone in rural Bangladesh. A combination of biomass, solar, and wind power technology is proposed. The proposals of this study further suggest an urgent need for formulating policy, planning, and undertaking relevant development programmes. Implementing the proposed SETs will benefit socio-economic development of Bangladesh, especially its rural population.

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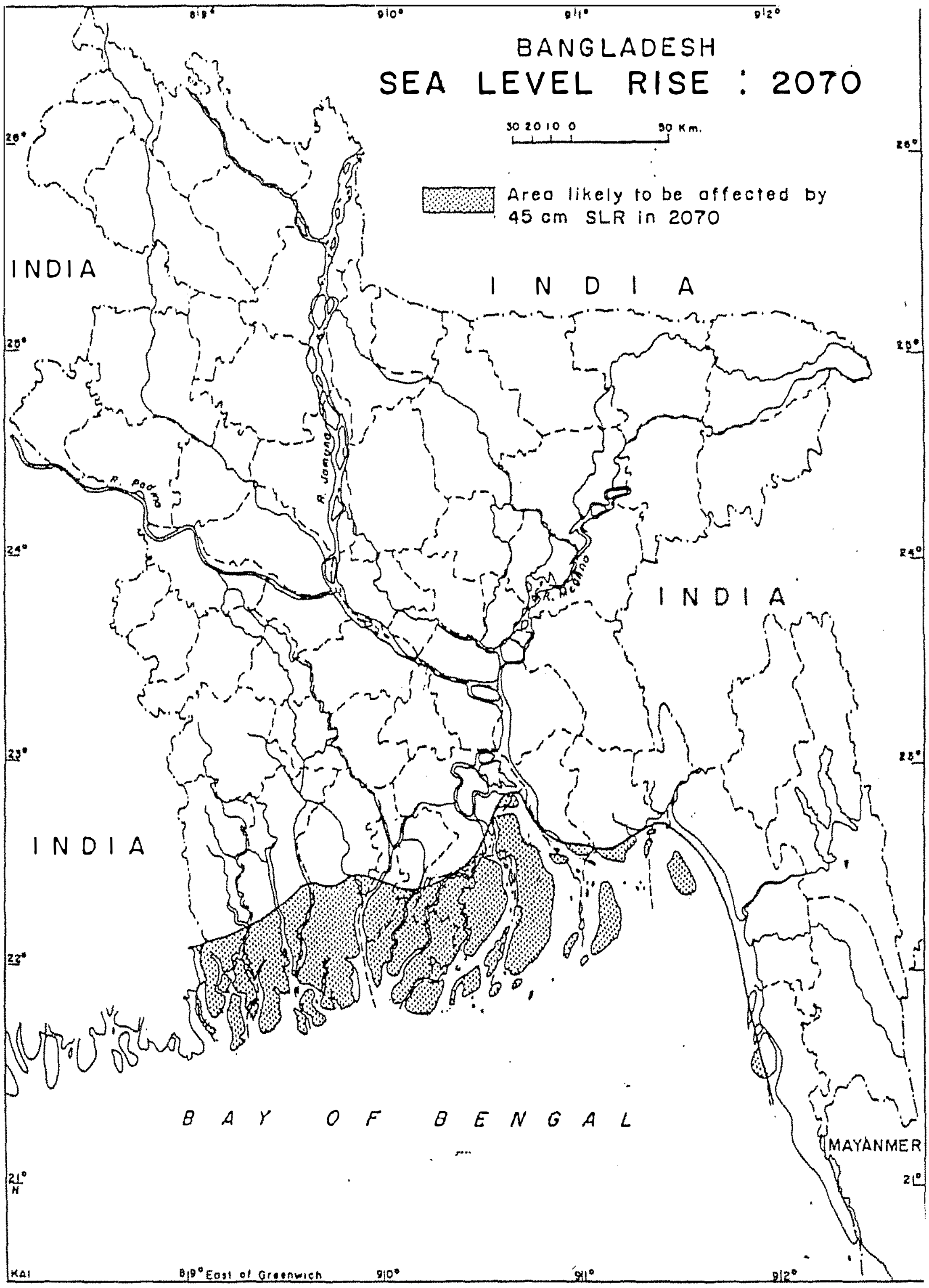
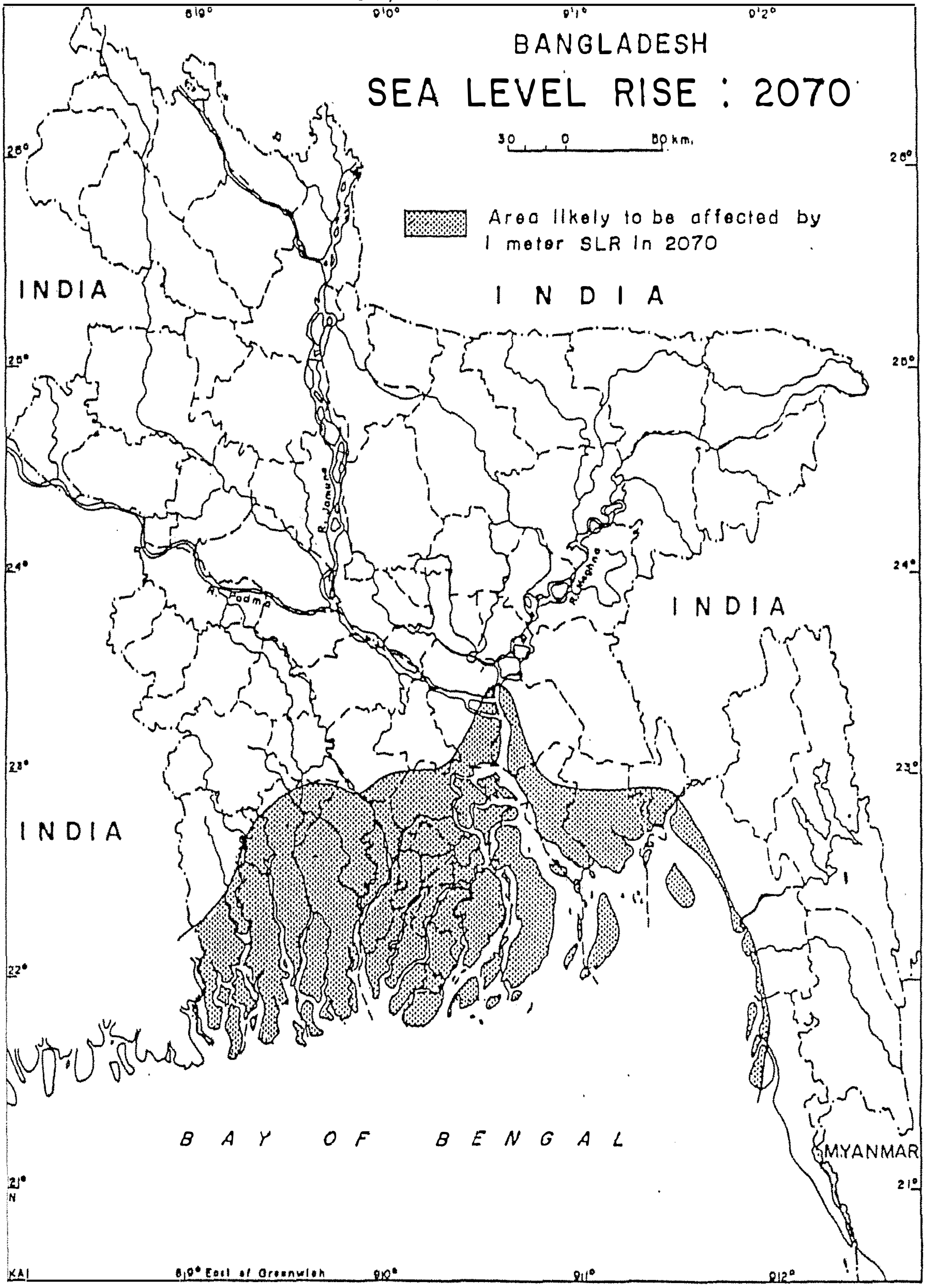
Annex 1

Sea Level Rise at Low Growth Rate



Annex 2

Sea Level Rise at Medium Growth Rate



Annex 3

Air Pollution: Photograph Taken from Dhaka city

Source: GOB, ME&F, NEMAP (1996)

Annex 4

Focus Group Interview:
Some of the Female Participants of Kutubdia Village

Source: Field Survey

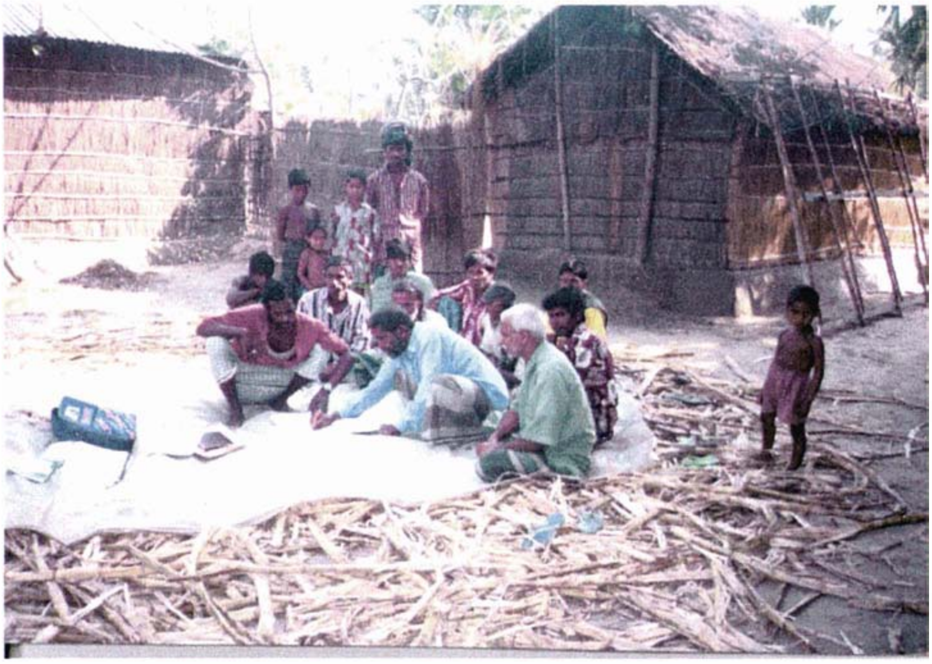
Annex 5

Focus Group Interview:
Female Participants Drawing Map of the Area to Suitable Location for Windmill at Loxmikola Village

Source: Field Survey

Annex 6

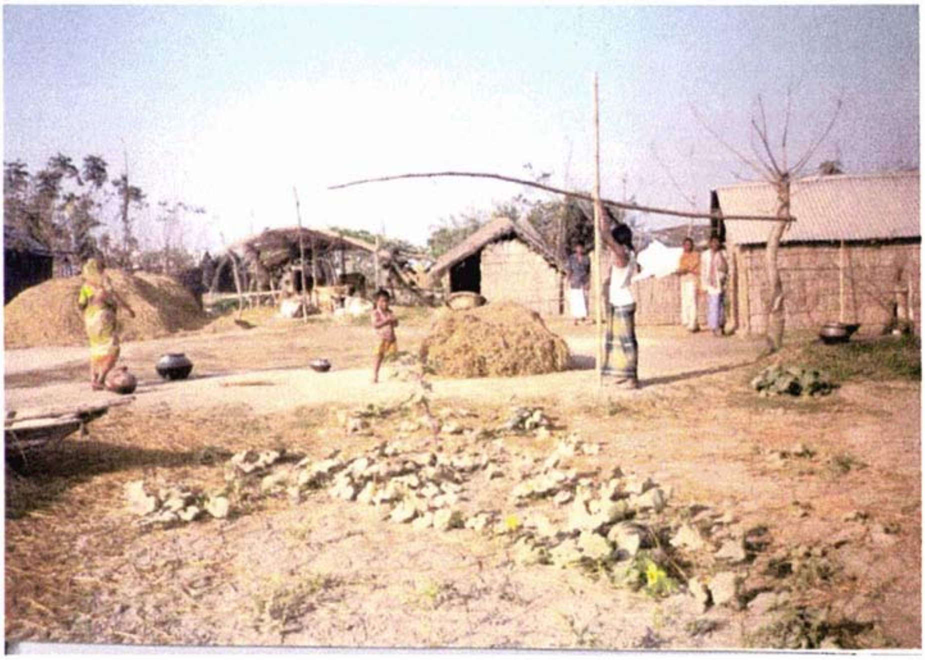
Focus Group Interview:
Male Participants Drawing Map of the Area
to Suitable Location for Windmill at Kutubdia Village



Source: Field Survey

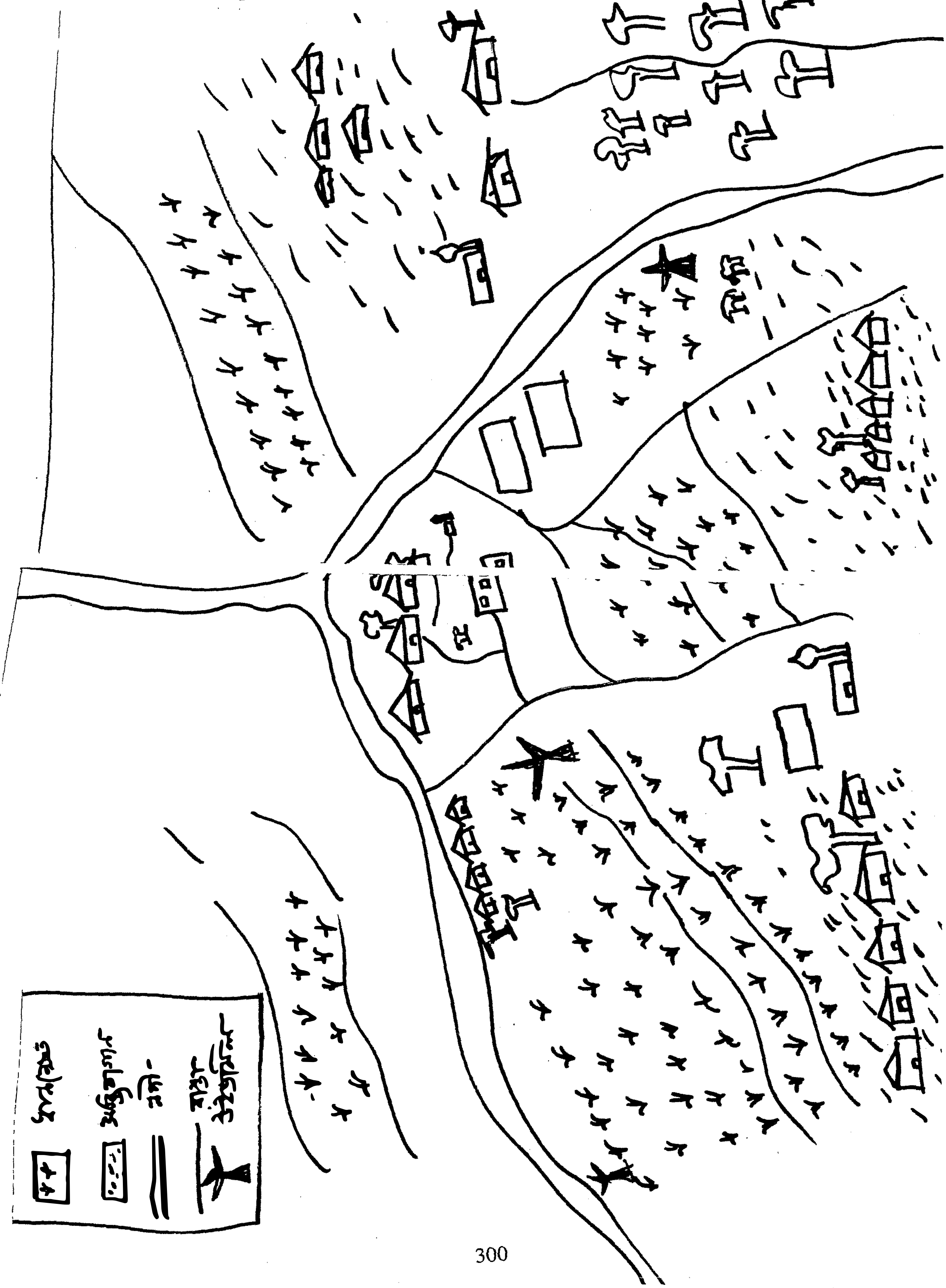
Annex 7

Living Conditions of Focus Group at Kutubdia Village

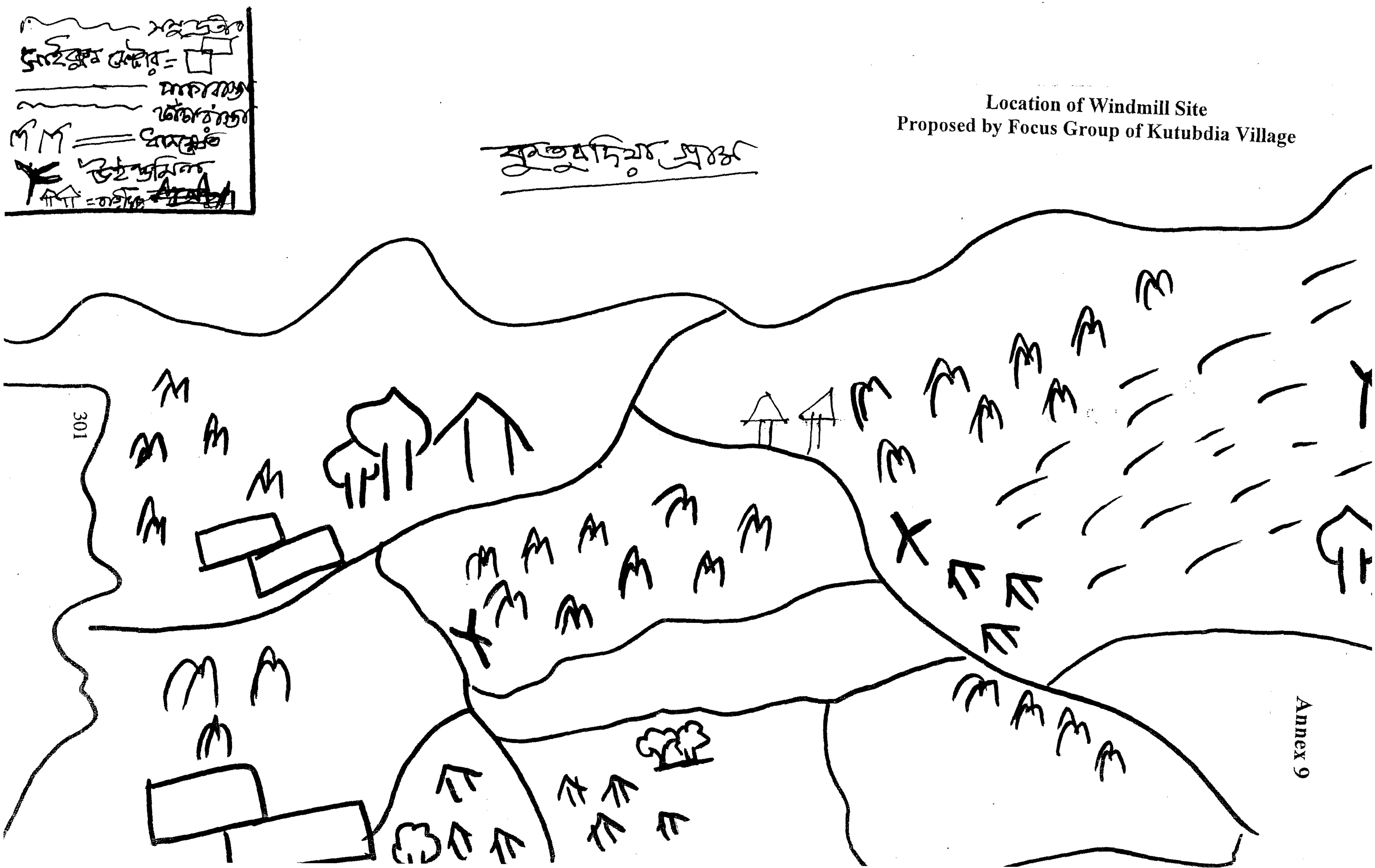


Source: Field Survey

Location of Windmill Site
Proposed by Focus Group of Loxmikola Village



Location of Windmill Site
Proposed by Focus Group of Kutubdia Village



Annex 10

Questionnaire for Household Survey

The User Perception Questionnaire

A Doctoral Research Questionnaire
on
Transfer of Sustainable Energy Technology to Developing Countries as a Means of Reducing Greenhouse Gas Emission: The Case of Bangladesh

Researcher:
Mohammad Ershad Ali
Massey University

Under the supervision of:
Dr. Peter Read
Professor John Overton
Massey University
&
Dr. A.K. Enamul Haque
North South University

QUETIONNAIRE FOR HOUSEHOLDS SURVEY
IN RURAL BANGLADESH

Location code
Khulna Division= 1
Rajshahi Division= 2
Dhaka Division= 3
Chittagong Division= 4

1: RESPONDENT'S PERSONAL INFORMATION

1.1.Name:	1.2 Gender:
1.3. Highest Education:	1.4.Occupation:
1.5. No. of family members	1.6. No. of school going children

1.7.Annual Income: Tk.

1.8.How much land you own (in decimal):

a. Home   b. Cultivation   c. Forestry   d. Unused/Fallow

1.9.How many animal you own:

a. Cow   b. Buffello   c. Goat/Lamb   d. Others

2: Which of the followings you use as energy source(s) and how do you collect them:

Code: by children=1, by him/herself=2, purchased=3, from own home=4

Sources	Household use	Commercial use	How collected
2.1.Firewood			
2.2.Dung			
2.3.Leaves			
2.4.Biogas			
2.5.Kerocine			
2.6.Natural Gas			
2.7.Cylinder			
2.8.Electricity			
2.9.Diesel			

2.10.Petrol

2.11.Cylinder

2.12 Solar Power

2.13 Wind Power

2.14. Others (specify)

3: For which of the following activities you use energy

Household Activities	Industrial Activities
3.1.Cooking	3.1 Irrigation
3.2 Lighting	3.2 Machine operation
3.3 Washing	3.3 Boiler heating
3.4 Entertainment	3.4 Lighting
3.5 Security	3.5 Security
3.6 Ironing	3.6 Air conditioning
3.7 Fan	3.7 Fan
3.8 Air conditioning	3.8 Entertainment
3.9 Others (specify)_________	3.9 Others (specify)_________

4: From where do you get your energy for household and industrial/commercial actvities?

Code: Own animal=1, Own forest=2, Bought from local retailer=3, Bought from local Agent=4, Bought from wholesaler=5, REB=6, PDB=7, Bought from open market=8, Public=9, Private=10

(a) Type of Energy	For H/H	For Ind/ Comm	(b) Source of collection (Write code from above)
4.1 Dung			
4.2 Wood			
4.3 Leaves			
4.4 Biogas			

4.5 Kerosene

4.6 Natural Gas

4.7 Cylinder

4.8 Electricity

4.9 Diesel

4.10 Petrol

4.11 Cylinder

4.12 Others (specify)

5. Why do you use------------------- as a source of energy?

6. Are you aware about environmental pollution?

Yes No

6a. If yes, what do you know?

7. Do you know that the sources of energy that you use are the major cause of environmental pollution (e.g. climatic change, natural disaster, deforestation etc.)?

Yes No

7a. If yes, what do you know?

8. Do you know there are some other sources of energy that are friendly with environment?

Yes No

8a. If yes, what do you know?

9. Do you know that energy can be produced from wind?

Yes No

9a. If yes, what do you know?

9b. Is there any plant/ unit in this area?

Yes No

10. Do you know that energy can be produced from animal dung, and wastes?

Yes No

10a. If yes, what do you know?

10b. Is there any plant/ unit in this area?

Yes No

11. Do you know that energy can be produced from the Sunlight?

Yes No

11a. If yes, what do you know?

11b. Is there any plant/ unit in this area?

Yes No

12.Do you know that energy can be produced from trees/plants by making carbon?

Yes No

12a. If yes, what do you know?

12b. Is there any plant/ unit in this area?

Yes No

13. Are you familiar with any of the above mentioned technologies?

Yes No

13.a If yes, what do you know?

14. These types of energy sources are friendly with environment, forest, etc., if it is available in this area will you use it?

Yes No

15. Installation of any of these energy technologies involves cost (Money, land, technical knowledge, operational skills, maintenance rules etc.), are you familiar with those?

Yes No

15.a If yes, please give details?

16. If any investor come forward to invest for installing any of these technologies, will you use that?

Yes No

17. For introducing any of these technologies, if your assistance, in terms of land, share of finance, labour, supply of raw materials etc. is needed will you provide that?

Yes No

17.a If yes, what type(s) of assistance you will be able to provide?

18. If energy is produced, and supplied through cooperative basis, will you use that?

Yes No

19. Is there any activity that is being suffered due to shortage of energy?

Yes No

19a. If yes, please specify?

20. What you will do if more energy is available in your home/ premises?

21. Do you think that if the above mentioned energy technologies are available in your area that will contribute to improve your lifestyle?

Yes No

21a. If yes, how?

22. Which of the followings will be directly benefited if more energy is locally produced and supplied?

a. Children education. b. Personal entertainment. c. Change of food habit. d. Grow more industry. e. Grow more business. f. Family planning.
g. Create more jobs. h. Reduce the migration from village to urban.
i. Improve communication. j. Decrease disease. k. Protect environment.

23. Do you have any comment(s) regarding the above mentioned sustainable energy technologies or about this survey?

Annex 11

QUESTIONNAIRE FOR LEADERSHIP OPINION SURVEY IN RURAL BANGLADESH

Location code
Khulna Division= 1
Rajshahi Division= 2
Dhaka Division= 3
Chittagong Division= 4

(The respondents of this questionnaire are such as School Teacher, Union Council Chairman/Member, Political Representative, and local Elite, Old Age People etc.)

1: RESPONDENT'S PERSONAL INFORMATION

1.1.Name:	1.2 Gender:
1.3. Highest Education:	1.4.Occupation:
1.5. No. of family members	1.6. No. of school going children

1.7.Annual Income: Tk.

1.8.How much land you own (in decimal):

a. Home b. Cultivation c. Forestry d. Unused/Fallow

1.9.How many animal you own:

a. Cow b. Buffello c. Goat/Lamb d. Others

1. Are you familiar with Sustainable Energy Technologies?

   Yes No

1a. If yes, what do you know?

2. Followings are some statements about Sustainable Energy Technologies. On a scale from 1 to 5 where 5 indicates strong agreement with the statement. Please tell how much you agree with these statements.

a. The present source of energy (fossil fuel) is the main cause of environmental degradation

1 2 3 4 5 agree strongly

b. It is possible to meet entire energy demand by using local resources as energy source.

1 2 3 4 5 agree strongly

c. It is possible to produce and supply of energy on cooperative basis

1 2 3 4 5 agree strongly

d. Required resources for importing and using the Sustainable Energy Technology are available in this locality

1 2 3 4 5 agree strongly

e. Necessary supports/ cooperation will be available if any initiative is taken to install the sustainable energy sources in this locality

1 2 3 4 5 agree strongly

f. Required finance are available in this regard

1 2 3 4 5 agree strongly

h. Necessary Infractructural facilities will be provided in this regard

1 2 3 4 5 agree strongly

i. The use of these energy sources is essential for sustainable development

1 2 3 4 5 agree strongly

j. If any investor come forward to invest for installing any of these technologies, you will use that

1 2 3 4 5 agree strongly

h. If energy is produced, and supplied through cooperative basis, you will use that

1 2 3 4 5 agree strongly

3. For introducing any of these technologies, if your assistance, in terms of land, share of finance, labour, supply of raw materials etc. is needed will you provide that?

Yes No

3a. If yes, what type(s) of assistance you will be able to provide?

4. Is there any activity that is being suffered due to shortage of energy?

Yes No

4a. If yes, please specify?

5. What you will do if more energy is available in your home/ premises?

6. Do you think that if the Sustainable Energy Technologies are available in your area, that will contribute to improve your lifestyle?

Yes No

6a. If yes, how?

7. Which of the followings will be directly benefited if more energy is locally produced and supplied?

a. Children education b. Personal entertainment c. Change of food habit d. Grow more industry e. Grow more business f. Family planning

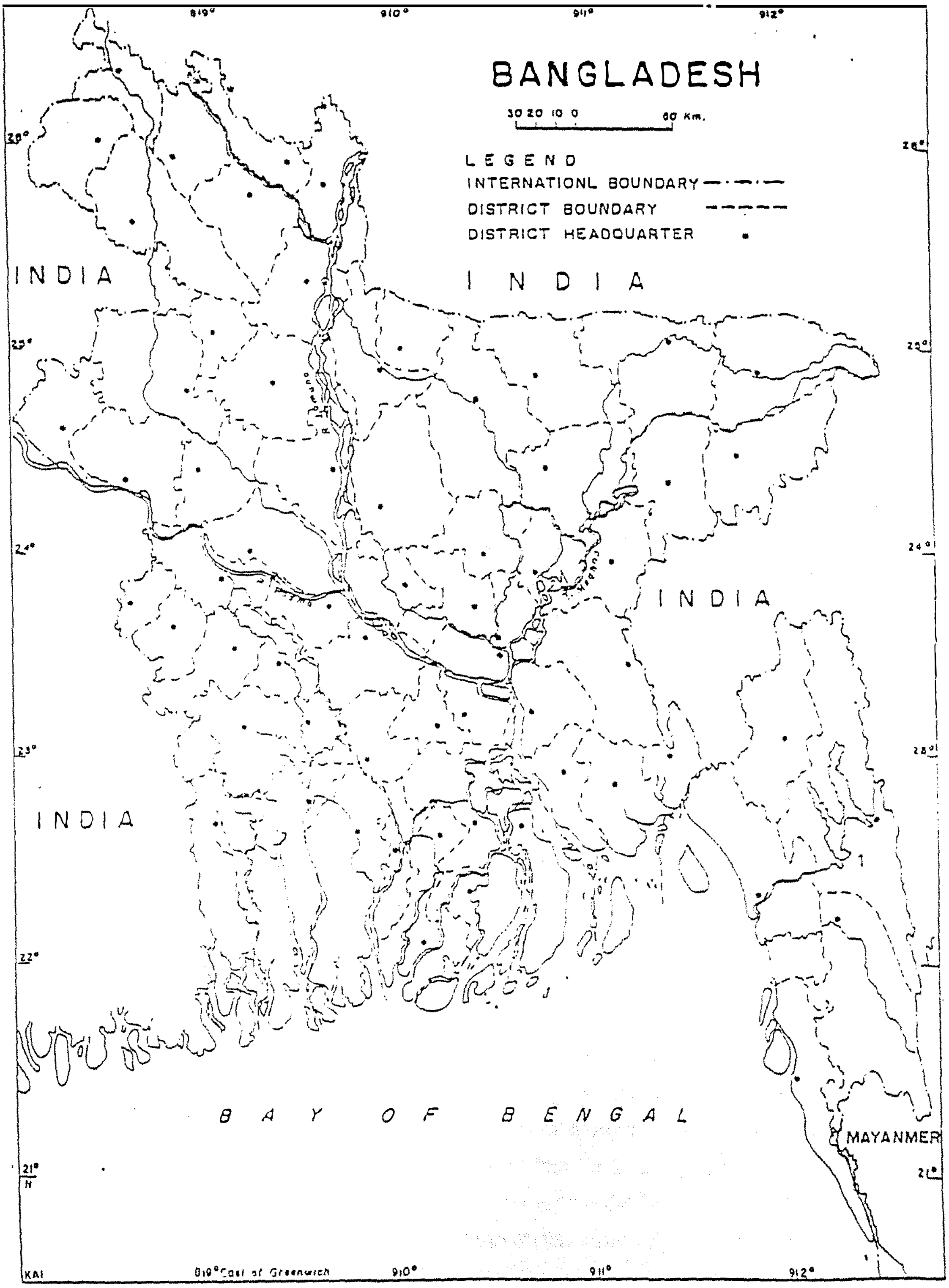
g. Create more jobs h. Reduce the migration from village to urban

i. Improve communication j. Decrease disease k. Protect environment.

8. Do you have any comment(s) regarding the above mentioned sustainable energy technologies or about this survey?

Annex 12

Map of Bangladesh



Source: ADB 1994

Width of Banks of Major Rivers in Bangladesh

River Name (BIWTA)	W (<25m)	W(25m-50m)	W(50m-100m)	W(>100m)	Total Length (km)
AFRA KHAL			21	15	36
AGUNMUKHA				19	19
AMTALI				13	13
ANDHARMANIK				30	30
ARIAL KHAN				182	182
ARPANGASIA	4			91	95
ASHNI	3		5	26	34
ATAI				17	17
ATHORABANK		31		25	56
ATRAI		25	9	191	226
AZIMPUR	10			51	61
BAGRA		21			21
BAL				33	33
BALESWAR	2	24	16	99	140
BALU			22		22
BANAR		169	75		244
BANGALI		42		103	145
BANGRA				43	43
BANNI		27			27
BANSI		52	56		108
BARA MATAMUHURI				27	27
BARA PANGGAS				20	20
BARAK		70	31	18	119
BARAL		23	110	10	144
BARANAL			23		23
BARISAL				38	38
BARNAR			58		58
BATHAIL		63	11		74
BAULAI		3	30	81	114
BAURI		41	31		72
BETNA	11	139	7	19	175
BHADRA				48	48
BHAIRAB		192	155	41	388
BHALRAB		17			17
BHOLA				42	42
BHUGAI			45		45
BIGHAI				20	20
BILSURJIA		14			14
BISHKHALI	3			58	61
BOALKHALI			52	6	58
BRAHMAPUTRA				67	67
BULLAI		77			77
BURA GAURANGA				55	55
BURI		31			31
BURI TISTA		68	20		88
BURIGANGA			12	29	41
BURISWAR	3			44	47
CHANDPAI		4	9	13	26
CHAUI			30		30
CHENGRAL		26	11	6	43
CHIKLI		59	18		77
CHINAI		74		6	80
CHINGRI		16	69		85
CHITRA		85	59	41	185
DAHUKA	3	2	70	44	119
DAKATIA	4	103	26	21	154
DASHANI				32	32
DAUDKHALI	2	16	8	15	40
DAUK			22		22
DHAKIAIDAH				19	19
DHALAI			70	40	111
DHALESWARI	2	12	70	145	229

River Name (BIWTA)	W(<25m)	W(25m-50m)	W(50m-100m)	W(>100m)	Total Length(km)
DHAMALIA			9	27	36
DHANKHALI				15	15
DHANRCHHITA	2			41	43
DHANU	6	23	4	160	192
DHARLA				77	77
DHEPA				61	61
DHUNAGODA				41	41
DHURANG		23	13		36
DUDHKUMAR				56	56
FALKI		60	16		75
FENI		21	12	52	84
FUTJANI			21		21
GAJALA				42	42
GALACHIPA				70	70
GANESHPURA				40	40
GANGES				122	122
GARAI				85	85
GHAGAR		28	26		54
GHAGAT		77	132		209
GHASIAKHALI				52	52
GOHALA				14	14
GOPALDI				24	24
GOPALPURER DARA				26	26
GOPLA LUNGLA		31	36		67
GOYAIN			34	40	74
GUMRI		31	14		45
GUMTI			49	49	98
GUR			14	33	47
GURNAI			9		9
HAJA		32			32
HALDA			15	38	53
HARINBHANGA				64	64
HARINGHATA	2			19	21
HARLHAR	8				8
HARTHAR		55			55
HATIA CHANNEL	2			112	114
HATIN		21	4		25
HATRA				14	14
HUNDA	3	29	4	18	54
HURASAGAR		41		13	54
ICHAMATI		17	110		127
JALLAGANG		16	5		21
JAMUNA		66	166	159	391
JAMUNESWARI		120		39	158
JAYANTI				15	15
JHINAI	9	40	106	26	181
JIRJIRA			27		27
JURI	9	89	10		107
KACHA	3			34	37
KACHUA		17			17
KAIKHAL		19			19
KALIGANGA	16	46	6	118	186
KALNI				71	71
KALUDAHA		23			23
KANGSA		115	62	52	229
KARATOYA		121	42	244	407
KARKHANA				23	23
KARNAFULI				84	84
KASALANG		19	38		56
KATAKHAL	5			62	67
KATAKHALI				17	17
KAZAL				17	17

River Name (BIWTA)	W(<25m)	W(25m-50m)	W(50m-100m)	W(>100m)	Total Length(km)
KHALPETUA				32	32
KHALPSTUA	5	49	3		58
KHARKHARI		116			116
KHOWAIR			19	58	77
KHUKNA			5	18	23
KOBADAK	3	25	48	161	237
KOYRA				21	21
KOYRA KHAL				28	28
KULIK	16	59			75
KULKULIA NADI	2	10		56	68
KUMAR		19	13	19	50
KUNGA				26	26
KUSHIARA				294	294
LAKHYA				108	108
LITTLE FENI		82	15	24	121
LOhajang				35	35
MADHUMATI				166	166
MADHUMATI BILL ROUTE		19		58	77
MAHANANDA				97	97
MAJUL KHAL				6	6
MALANCHA	4			88	91
MALJHI		10			10
MANGLA				21	21
MANU	8		56	40	105
MARISI		67			67
MATAMUHURI				77	77
MEGHNA				125	125
MOBARI		71	7		78
MOGRA	3	103	11	8	126
MOHANANDA				24	24
MUHURI		59	7	11	77
MYANI		31	60		91
NABAGANGA		97	25	74	196
NAF				61	61
NAGAR	4	185		79	268
NALCHITI				22	22
NARIA KHAL			34	19	53
NARSUNDA		68		4	72
NAWA			2	38	40
NAYABHANGA	2			36	37
NEHALGANJ				23	23
NILGANI				14	14
NITAI	2	16	34		52
OLD BRAHMAPUTRA				267	267
OLD DHALESWARI	20			38	58
OLD KUMAR		144	71	18	233
PADMA				107	107
PAGLA		20	30	58	108
PALONG			2	49	51
PANDO				20	20
PASUR	6			117	123
PATHRAI		55			55
PATNAL GANG		7	15	21	43
PHALLA	2	4		10	15
PIYAIN GANG		25	20		45
PIYANI			3	23	26
PUNARBHABA		135	11		146
PUTIMARI				10	10
RABNABAD	2			45	47
RAIMANGAL	2			23	24
RAJGANJ				48	48
RAKTI			11	19	30

River Name (BIWTA)	W(<25m)	W(25m-50m)	W(50m-100m)	W(>100m)	Total Length(km)
RANKHAING		32	23	22	77
RUPSA				31	31
SANDWIP CHANNEL				58	58
SANGU		88	92	67	247
SEAL GANG				53	53
SHAHBAZPUR				155	155
SIB	2	108	22		132
SIBSA	4			131	134
SINGAR			12		12
SOLMARI				8	8
SOMESWARI		76	35	37	148
SONAI			61		61
SSIKARPUR				27	27
SURMA				393	393
SUTANG		41			41
SUTARKALI				30	30
SUTIA	2	16	49		66
SWARUPKATI				34	34
TALMA			36		36
TANGAN		91		65	156
TARKI			33		33
TETULIA	2	3		202	207
THALANG	2	30			33
TISTA				113	113
TITAS		14	31	38	83
TLMAL	7	39			45
TONGI KHAL		16			16
TULSI GANGA	4	109			113
TURAG	3	5	7	67	81
					16886

Government of the people's Republic of Bangladesh
Bangladesh Meteorological Department
Climate Division
Agargaon, Dhaka-1207

Station name : Chittagong   Lat. 22 Deg 16 mts. N   Long. 91 Deg 49 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	8.6	8.8	7.4	6.9	7.1	4.5	3.1	5.4	5.4	8.3	8.4	6.9	6.7
1998	7.0	109.4	9.1	8.4	6.1	6.0	3.2	3.5	6.5	8.5	8.5	9.6	15.5
1999	9.0	9.6	9.3	9.4	5.0	3.8	4.3	3.3	6.1	6.1	9.9	8.0	7.0
Mean	8.2	42.6	8.6	8.2	6.1	4.8	3.6	4.1	6.0	7.6	9.0	8.2	9.7

Station name : Cox's Bazar   Lat. 21 Deg 26 mts. N   Long. 91 Deg 56 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	9.4	9.6	8.4	8.6	8.0	4.9	2.8	6.5	6.1	8.9	8.7	8.7	7.6
1998	8.4	8.7	9.4	9.7	7.6	6.5	4.0	3.8	7.2	8.8	9.3	10.2	7.8
1999	9.6	9.6	9.2	9.3	5.7	4.8	4.0	3.5	5.5	7.3	10.7	8.7	7.3
Mean	9.1	9.3	9.0	9.2	7.1	5.4	3.6	4.6	6.3	8.3	9.6	9.2	7.6

Station name : Barisal   Lat. 22 Deg 45 mts. N   Long. 90 Deg 20 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.5	8.1	7.6	7.4	7.1	4.6	3.1	4.4	4.1	8.5	7.3	4.2	6.2
1998	5.5	7.2	8.1	8.1	4.7	3.1	1.9	2.8	4.1	6.1	7.5	8.7	5.7
1999	8.2	7.8	5.9	7.6	3.8	3.1	2.9	2.6	3.7	4.9	8.7	8.1	5.6
Mean	7.0	7.7	7.2	7.7	5.2	3.6	2.6	3.3	4.0	6.5	7.8	7.0	5.8

Station name : Khulna Lat. 22 Deg 47 mts. N Long. 89 Deg 32 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.6	8.6	8.1	7.5	7.2	5.4	3.5	4.3	4.1	8.8	7.7	6.9	6.6
1998	5.8	7.3	8.1	8.2	6.7	4.9	3.4	3.8	4.8	5.9	7.1	9.1	6.3
1999	8.7	9.1	8.6	9.3	6.8	4.6	3.9	3.3	4.3	6.1	9.5	8.3	6.9
Mean	7.4	8.3	8.3	8.3	6.9	5.0	3.6	3.8	4.4	6.9	8.1	8.1	6.6

Station name : Dhaka Lat. 23 Deg 46 mts. N Long. 90 Deg 23 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	5.1	7.8	7.7	7.3	7.6	5.6	4.1	4.8	4.5	8.5	6.2	5.6	6.3
1998	4.0	6.1	8.1	7.3	5.8	6.8	2.8	3.6	4.3	5.8	7.4	7.9	5.8
1999	7.2	7.5	8.3	8.4	5.5	5.0	3.9	3.8	3.5	5.2	8.3	7.4	6.2
Mean	5.4	7.1	8.1	7.7	6.3	5.8	3.6	4.1	4.1	6.5	7.3	7.0	6.1

Station name : Faridpur Lat. 23 Deg 36 mts. N Long. 89 Deg 51 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.5	8.3	8.5	7.8	7.9	6.0	4.4	4.6	4.7	9.0	7.0	6.6	6.9
1998	5.0	7.2	7.6	7.7	6.0	6.1	3.5	4.5	4.6	6.5	7.5	9.0	6.3
1999	8.5	8.8	8.7	8.4	6.2	5.2	4.0	3.3	4.1	5.8	8.3	7.9	6.6
Mean	7.0	8.1	8.3	7.9	6.7	5.8	4.0	4.1	4.5	7.1	7.6	7.8	6.6

Station name : M.court   Lat. 22 Deg 52 mts. N   Long. 91 Deg 6 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.9	7.7	7.3	7.1	7.3	5.1	3.6	5.2	5.2	8.4	8.1	6.7	6.6
1998	5.8	7.3	8.5	7.9	34.6	5.7	2.5	2.8	5.1	6.7	8.6	9.1	8.7
1999	8.6	9.3	8.9	9.4	5.7	3.5	3.4	2.9	4.6	5.2	9.5	8.0	6.6
Mean	7.4	8.1	8.2	8.1	15.9	4.8	3.2	3.7	5.0	6.8	8.7	7.9	7.3

Station name : Patuakhali   Lat. 22 Deg 20 mts. N   Long. 90 Deg 20 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	6.7	6.5	6.8	6.7	5.7	3.1	2.1	3.5	3.5	7.7	6.9	5.9	5.4
1998	5.3	6.4	7.5	15.7	5.3	3.2	2.0	2.4	3.9	6.2	6.7	7.2	6.0
1999	7.3	7.8	6.9	7.2	4.4	2.6	3.2	1.9	2.9	4.0	8.1	6.6	5.2
Mean	6.4	6.9	7.1	9.9	5.1	3.0	2.4	2.6	3.4	6.0	7.2	6.6	5.5

Station name : Mymensingh   Lat. 24 Deg 43 mts. N   Long. 90 Deg 26 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	6.5	6.5	8.2	7.3	7.6	4.4	3.5	4.8	4.6	8.5	7.7	4.2	6.2
1998	4.7	7.4	7.5	6.4	5.7	3.9	2.1	2.4	5.0	6.3	7.5	8.6	5.6
1999	7.8	8.7	8.5	7.2	4.9	3.9	3.3	3.8	3.8	4.8	9.0	8.7	6.2
Mean	6.3	7.5	8.1	7.0	6.1	4.1	3.0	3.7	4.5	6.6	8.1	7.2	6.0

Station name : Rangpur   Lat. 25 Deg 44 mts. N   Long. 89 Deg 14 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	6.6	7.8	9.4	7.5	8.6	5.3	4.9	4.9	4.4	9.1	7.8	5.8	6.8
1998	4.9	8.5	8.4	7.8	8.1	4.5	3.0	3.6	5.0	5.9	8.1	8.7	6.4
1999	7.6	8.7	9.1	6.4	6.1	4.3	4.3	4.2	5.5	6.6	9.2	9.1	6.8
Mean	6.3	8.3	9.0	7.2	7.6	4.7	4.1	4.3	5.0	7.2	8.4	7.9	6.7

Station name : Dinajpur   Lat. 25 Deg 39 mts. N   Long. 88 Deg 41 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	6.1	7.1	8.5	7.3	8.5	5.9	4.8	4.7	4.5	8.8	7.7	5.9	6.6
1998	4.0	8.5	8.7	8.2	8.0	4.2	2.9	3.3	5.5	6.1	8.4	8.2	6.3
1999	6.8	8.7	9.1	6.5	6.3	5.0	3.8	3.7	4.6	6.5	8.4	8.1	6.5
Mean	5.6	8.1	8.8	7.3	7.6	5.0	3.8	3.9	4.9	7.1	8.2	7.4	6.5

Station name : Sylhet   Lat. 24 Deg 54 mts. N   Long. 91 Deg 53 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.1	6.7	7.5	6.7	7.0	3.1	3.5	4.3	3.3	8.7	8.4	6.5	6.1
1998	5.7	7.0	7.6	6.3	5.5	3.0	1.8	2.7	5.3	6.8	8.3	9.8	5.8
1999	9.0	8.8	8.0	7.0	4.9	4.1	2.8	3.4	4.0	5.8	9.4	9.5	6.4
Mean	7.2	7.5	7.7	6.7	5.8	3.4	2.7	3.4	4.2	7.1	8.7	8.6	6.1

Station name : Tangail   Lat. 24 Deg 15 mts. N   Long. 89 Deg 55 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	6.8	7.7	7.4	6.8	7.5	4.9	4.0	4.3	4.2	8.9	7.1	4.9	6.2
1998	4.3	6.5	7.4	7.3	6.2	6.1	3.0	3.5	5.5	7.1	7.4	8.2	6.0
1999	.0	9.1	9.1	8.3	5.5	4.7	3.6	3.5	3.4	5.9	9.0	8.1	5.8
Mean	3.7	7.8	7.9	7.4	6.4	5.2	3.6	3.8	4.3	7.3	7.8	7.1	6.0

Station name : Rajshahi   Lat. 24 Deg 22 mts. N   Long. 88 Deg 42 mts.E

Monthly and Annual Average Bright Sun shine hour.

Year : 1997- 1999

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1997	7.0	8.4	8.7	7.6	9.2	7.2	5.3	4.9	5.3	8.5	7.3	6.2	7.1
1998	5.3	7.3	8.5	8.3	7.3	5.9	4.0	4.3	6.0	6.6	7.9	8.5	6.6
1999	8.2	9.5	9.7	8.4	6.7	5.2	4.2	4.2	5.0	7.0	8.7	7.9	7.1
Mean	6.8	8.4	9.0	8.1	7.7	6.1	4.5	4.5	5.4	7.4	7.9	7.5	6.9

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Climate Division
Agargaon, Dhaka-1207

Station name : Chittagong Lat. 22 Deg 16 mts. N Long. 91 Deg 49 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	4.0	N	5.6	W	10.6	S	6.6	S	10.3	S	10.6	S	11.0	S	10.3	S	7.0	SSE	3.7	NE	4.3	N	4.3	N
1998	4.6	N	3.7	N	6.0	SW	6.4	S	9.5	S	10.0	S	9.7	S	7.5	SSE	9.0	S	7.9	SSE	4.4	N	3.3	NNE
1999	4.4	W	4.7	N	9.2	S	6.9	S	10.0	S	9.9	S	9.1	S	9.2	S	8.1	S	5.7	S	3.7	NNE	3.4	NNE

Station name : Cox's Bazar Lat. 21 Deg 26 mts. N Long. 91 Deg 56 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	6.3	N	7.0	NNW	7.3	SSW	6.4	SSW	8.1	S	7.3	S	6.7	S	6.8	S	6.0	SE	5.7	N	4.7	N	5.5	N
1998	5.7	N	7.1	NNW	6.7	N	6.3	S	8.5	S	7.8	S	9.2	S	8.1	S	8.3	S	8.6	S	6.3	N	6.1	N
1999	5.5	N	7.7	NNW	8.6	S	5.4	SSW	7.9	S	8.1	S	7.3	S	6.0	S	6.8	S	5.2	N	5.8	N	5.9	NNE

Station name : Barisal Lat. 22 Deg 45 mts. N Long. 90 Deg 20 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	5.8	N	4.2	S	5.5	SW	5.5	S	6.5	S	5.9	S	5.9	SE	7.8	SE	5.7	S	5.1	N	4.3	N	5.6	N
1998	5.7	N	5.3	SW	6.9	SW	6.6	S	7.5	S	7.7	S	5.8	S	5.4	S	6.0	SE	6.1	SE	4.9	N	4.3	N
1999	4.6	NNW	6.1	N	5.8	S	6.7	S	7.2	S	6.0	S	5.3	SE	4.7	SE	4.9	SE	4.4	SE	2.8	N	5.3	NW

Station name : Khulna Lat. 22 Deg 47 mts. N Long. 89 Deg 32 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	3.0	NW	3.9	S	3.3	S	3.8	S	5.1	S	4.2	S	3.7	S	3.8	S	2.6	S	1.9	N	2.1	N	2.2	N
1998	2.7	N	2.5	N	2.8	S	3.8	S	4.4	S	4.2	S	2.9	S	3.1	S	2.5	S	2.6	S	2.7	N	2.1	N
1999	2.6	N	2.4	N	3.8	S	5.0	S	4.6	S	3.5	S	3.0	S	2.6	S	2.8	S	2.6	SE	1.8	N	1.7	N

Station name : Dhaka Lat. 23 Deg 46 mts. N Long. 90 Deg 23 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	1.5	W	1.8	W	2.4	W	2.3	S	2.2	S	2.4	S	2.2	SE	2.9	SE	2.0	S	1.4	NW	2.0	N	1.7	N
1998	1.5	NW	1.7	NW	2.7	W	2.5	S	3.1	S	2.8	S	2.0	S	1.9	S	2.1	SE	2.7	SE	3.6	NE	2.0	NW
1999	2.1	NW	2.2	NW	2.2	S	2.5	S	2.5	S	2.5	S	2.6	SE	2.3	SE	1.9	SE	2.4	SE	1.6	N	1.7	N

Station name : Faridpur Lat. 23 Deg 36 mts. N Long. 89 Deg 51 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.2	N	2.3	N	2.9	S	3.7	S	5.1	S	4.7	S	3.3	S	3.3	S	2.8	S	2.7	N	2.7	N	2.8	N
1998	2.7	N	2.7	N	3.8	S	5.8	S	6.3	S	7.2	S	4.8	S	4.6	S	4.5	S	4.2	S	3.2	N	2.6	N
1999	2.8	N	3.0	N	3.8	S	5.6	S	5.7	S	4.6	S	3.7	S	3.8	S	3.7	S	3.0	E	2.5	N	2.3	N

Station name : M.court Lat. 22 Deg 52 mts. N Long. 91 Deg 6 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.3	N	2.4	SE	3.4	S	2.5	S	3.2	S	4.4	S	4.6	SE	4.6	SE	2.9	SE	2.6	N	2.6	N	2.5	N
1998	2.8	N	2.7	N	2.6	N	4.0	S	4.6	S	4.6	SE	4.7	SE	3.1	SE	3.4	SE	3.3	SE	2.3	N	2.4	N
1999	2.7	NW	2.6	NW	3.3	SE	3.3	S	4.2	SE	4.6	SE	3.9	SE	4.6	SE	3.6	SE	3.3	SE	2.4	NW	2.6	N

Station name : Patuakhali Lat. 22 Deg 20 mts. N Long. 90 Deg 20 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	3.1	N	3.3	NE	3.8	S	3.2	S	4.9	S	4.6	S	3.1	S	3.6	S	2.9	S	3.3	N	2.8	N	3.1	N
1998	3.2	N	3.1	S	4.0	W	5.3	S	7.1	S	6.2	S	4.7	S	3.8	S	3.2	E	3.2	SSE	3.2	N	3.0	NNW
1999	3.5	N	4.0	N	3.4	S	5.1	S	5.9	S	4.7	S	4.1	S	3.1	S	2.9	S	3.3	E	2.7	N	2.7	N

Station name : Mymensingh Lat. 24 Deg 43 mts. N Long. 90 Deg 26 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	3.0	NE	4.5	E	3.5	E	4.1	E	5.0	E	5.1	E	5.5	E	4.6	SE	3.6	E	2.6	E	2.3	NE	2.5	NW
1998	2.7	W	2.6	NE	3.1	NW	4.7	E	3.8	E	4.1	E	3.9	SE	3.6	SE	2.6	E	2.5	E	2.4	E	2.4	E
1999	2.6	NW	2.7	NW	3.3	E	4.0	E	3.9	E	4.5	SE	3.6	SE	4.1	SE	3.3	E	3.0	E	2.1	NE	2.2	NE

Station name : Sylhet Lat. 24 Deg 54 mts. N Long. 91 Deg 53 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.9	E	3.6	E	3.7	E	3.9	E	3.5	E	3.1	E	2.6	E	3.0	E	2.9	E	2.6	E	2.8	E	3.0	E
1998	2.7	E	3.2	E	3.5	E	3.8	E	3.5	E	3.3	E	3.0	E	2.5	E	2.6	E	2.5	E	3.0	E	3.0	E
1999	3.0	E	3.3	E	3.1	E	3.0	E	3.2	E	2.9	E	2.5	E	2.7	E	2.4	E	2.6	E	2.6	E	3.1	E

Station name : Tangail Lat. 24 Deg 15 mts. N Long. 89 Deg 55 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.4	NW	2.7	W	3.6	W	2.9	SE	3.6	SE	3.8	SE	2.9	SE	2.7	SE	2.9	SE	2.4	N	2.3	N	2.6	N
1998	2.5	W	2.8	W	3.0	W	3.1	S	3.9	SE	4.8	SE	3.6	SE	3.1	SE	3.5	SE	3.5	SE	2.3	N	2.2	NW
1999	2.6	NW	3.0	NW	3.2	S	4.4	SE	3.6	SE	3.6	SE	3.3	SE	3.1	SE	3.5	SE	2.7	SE	2.2	N	2.7	N

Station name : Rajshahi Lat. 24 Deg 22 mts. N Long. 88 Deg 42 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.0	N	2.4	W	2.3	S	3.3	E	3.5	E	4.5	E	3.5	E	3.8	E	2.2	E	1.5	N	1.3	N	2.2	N
1998	1.7	N	2.3	N	2.1	W	3.4	E	4.0	E	2.8	SE	2.8	S	2.7	S	3.2	E	2.4	E	2.5	N	2.6	N
1999	2.6	N	2.7	N	2.5	W	3.4	S	3.7	E	3.9	E	3.1	E	2.7	E	3.1	E	3.1	E	1.9	N	2.2	N

Station name : Rangpur Lat. 25 Deg 44 mts. N Long. 89 Deg 14 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	3.4	NE	3.8	NE	3.7	SW	3.9	E	3.3	SE	3.7	SE	3.2	SE	3.2	E	2.8	S	2.7	NE	2.8	NE	1.9	NW
1998	2.3	NW	2.8	W	3.1	W	3.5	E	3.3	E	3.1	SE	3.2	SE	2.5	S	2.9	E	2.9	NE	3.8	NE	3.4	NE
1999	2.4	NW	2.7	W	3.2	SW	3.6	E	3.0	SE	3.0	SE	3.2	SE	3.2	SE	3.9	SE	4.0	NE	2.5	NE	3.7	NE

Station name : Dinajpur Lat. 25 Deg 39 mts. N Long. 88 Deg 41 mts.E

Monthly Prevailing Wind speed in knots and direction.

Year : 1997-1999

Year	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir
1997	2.0	W	2.1	W	3.5	W	2.0	E	2.0	E	2.4	E	2.3	SE	2.0	E	1.9	SE	1.6	W	1.8	W	1.6	W
1998	1.8	W	2.1	W	2.6	W	1.9	E	2.0	E	1.9	E	2.2	SE	1.7	SE	1.7	E	1.9	E	1.9	E	2.3	W
1999	2.6	W	2.5	W	3.3	W	2.1	E	2.2	E	2.4	SE	2.0	E	1.9	E	2.3	E	2.3	E	1.9	N	1.9	N

Note :- SPD = wind speed in knots,
DIR = wind direction

Concept/Guideline for Preparing Project Proposal of Capacity Building on Sustainable Energy Technology Transfer

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BACKGROUND

With nearly 120 million people and a per capita annual income of only 277 US dollars (1997) Bangladesh is one of the most densely populated (822 persons per square kilometre 1995) developing countries of the world. The overall growth of urban population is 5% annually and nearly 23% of the total population of Bangladesh live in urban areas (1995 estimate). Growing population in urban centres implies growing demand for basic amenities of life such as food, clothing, shelter, health care, education and entertainment.

Over the period of 1997 to 2002, the economy of Bangladesh is expected to grow at a rate of 7% annually (Fifth Five Year Plan). This means increased production. Since the economy is largely agricultural, the boost in production is expected to come from industrial sectors (expected growth of the industrial sector is 15%). This also means an increased rate of energy use.

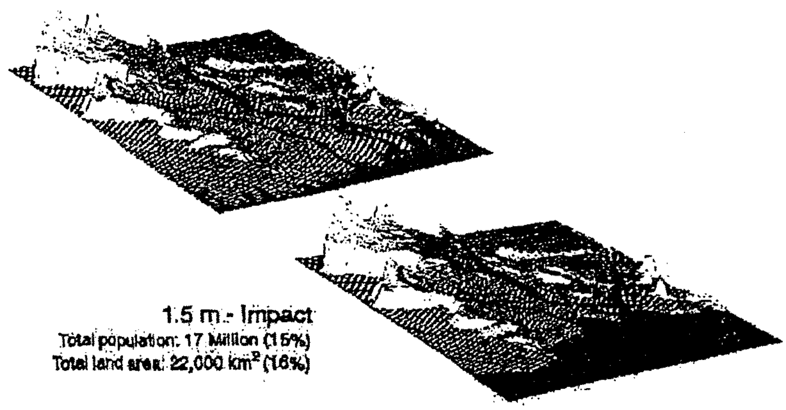
However, both non-renewable and renewable resources are being used up in a way that many now conceive to be unsustainable in the long run. Ambient environmental qualities have deteriorated and ill-effects from this are felt on the biotic system in particular and on the ecosystem in general.

The environment is thus under threat in Bangladesh. This is recognised as one of its national priorities. Major environmental concerns in Bangladesh are: increased GHG emissions (Bangladesh emits 12 to 15 million tons of CO_2, and 3.2 to 6 million tons of CH_4 each year), deforestation (rate of deforestation is 80 km^2 per year), air pollution (mostly from vehicular emissions), water pollution (due to industrial discharges), and river bank erosion. These call for the immediate attention of policy planners and decision-makers.

Bangladesh is also going to be a major victim of climate change and the consequent sea-level-rise. Figure 1 shows the estimated impact of a sea level rise of 1.5 meter on Bangladesh. This estimate shows that nearly 15% of the total population and 22,000 km^2 of the area of Bangladesh will go under water because of this type of greenhouse effect.

FIGURE 1

Potential impact of sea-level rise on Bangladesh



Source: UNEP/GRID Geneva; University of Dacca; JRO Munich; The World Bank; World Resources Institute, Washington D.C.

FRAMEWORK CONVENTION ON CLIMATE CHANGE AND KYOTO PROTOCOL

We are changing the way energy from the sun interacts with and escapes from our planet's atmosphere and by doing that, we risk altering the global climate. Among the expected consequences are an increase in the average temperature of the earth's surface and shifts in world-wide weather patterns. Other -- unforeseen – effects cannot be ruled out. Combating the impact of global climate change is a major challenge.

The 1992 United Nations Framework Convention on Climate Change is one of a series of agreements through which countries around the world are banding together to meet this challenge. Bangladesh is party to the United Nations Framework Convention on Climate Change. It signed this multilateral treaty on

9 June 1992, and ratified the Convention on 15 April 1994.

UNFCCC establishes a framework and a process for agreeing to specific actions in this area. The Convention encourages scientific research on climate change. Studies of global climate change put the lion's share of the responsibility for battling climate change -- and the lion's share of the bill -- on the rich countries. The Convention tries to make sure that any sacrifices made in protecting our shared atmosphere will be distributed fairly among countries -- in accordance with their "common but differentiated responsibilities and respective capabilities and their social and economic conditions". It notes that the largest share of historical and current emissions originates in developed countries.

At the same time, as more energy is being used both in the North and in the South, it puts pressure on our atmosphere. The convention, therefore, calls for developing and sharing environmentally sound technologies and know-how. Technology will play a major role in dealing with climate change. If we can find practical ways to use cleaner sources of energy, such as solar power, we can reduce the consumption of coal and oil. Such technology must also be made available to all countries and it must be shared by richer and more scientifically advanced countries with poorer countries that have great need of it.

To this end, there are several problems. First, people in developing countries are not fully aware of the consequences of climate change and so changing human behavior, in terms of more use of clean technology, is very difficult. Second, the cost of clean energy technologies is often higher and sometimes much higher than conventional low-cost high-emissions based energy technologies. Third, developed countries themselves are also not 'ready' to switch to cleaner technologies. So, in 1997, Kyoto Protocol was adopted. The Kyoto Protocol sets binding targets for GHG reductions for the developed countries. However, realizing the difficulty in implementation of a binding emission target in some developed countries, the protocol provides for emission trading between developed countries. Additionally this Protocol provides for project-based actions to enable emissions reducing projects in another (host) country to count towards achieving the emissions reduction commitment of the developed (donor) country that funds the additional cost of projects relative to conventional technologies. Where the host country is a developed country the Portocol provides for Joint Implementation (JI). Where the host country is a developing country, the Protocol provides the Clean Development Mechanism (CDM) to facilitate collaboration between developed and developing nations in projects that both meet the sustainable development policies of the host country and result in emissions reductions.

Joint action is already provided for under the Rio Convention and has been trialed in a pilot phase of activities implemented jointly (AIJ). Under AIJ two countries agree to jointly carry out a GHG reduction project , although no carbon crediting was permitted. Under AIJ, countries like Costa Rica, India, Argentina, Brazil, some Caribbean Islands, Egypt, Jordan, Malaysia and few others have hosted projects funded by developed countries. Costa Rica and USA have already started carbon trading which is still not sanctioned by the COP although it might be done after the pilot phase ends in 2002.

CDM is a mechanism which was created at Kyoto to allow some form of carbon trading to take place internationally under UNFCCC auspices which would be certified and approved by UNFCCC and would also allow some of the funds created through the CDM to be allocated for particularly vulnerable countries (such as Bangladesh) and for adaptation measures. While this remains one of the most promising and interesting avenues opened up for carbon trading it still remains bogged down in procedural difficulties about how it would work, who would make it work, who will monitor it and who will allocate the proceeds. Nevertheless it's likely (but by no means certain given the reactionary position taken by the US Senate, which is the ratifying institution under the constitution of the USA) that these problems may be largely sorted out and some form of

CDM may begin within a year or two.[1]

Considering the problems regarding implementation of the recommendation of Kyoto Protocol it has been suggested by many that, developing countries need to develop capacity both to implement projects under the JI provisions of the UNFCCC or the CDM provisions of the Kyoto Protocol. Developing countries also need to build capacity to design their own 'country-driven projects that would fit into the strict conditions under which financial claims can be made by them on GHG emissions. This has been emphasised on many occasions, for example, in decision 2/CP.4, 1(g) of the fourth Conference of Parties to the UNFCCC, meeting in Buenos Aries in 1998 (COP4).

This paper is an attempt to conceptualise the issue of capacity building to ensure transfer of sustainable energy technologies from the developed nations.

THE PROBLEM

Acceptance of the dual environmental and developmental objectives at the Rio UNCED reflects the reality that unless developed country Parties enable other Parties to develop using sustainable energy technology, the growth of fossil fuel emissions from developing countries will swamp any conceivable reduction of developed country emissions. These priorities provide the basis for developing countries to receive direct foreign investment (DFI) in greenhouse gas mitigation as an offset against greenhouse gas emissions in developed countries. Pressure for early action may lead to a surge of interest in securing low cost greenhouse gas mitigation opportunities in developing countries.

There is concern that, unless a start is made to building the human capacity to respond effectively to such interest, the flow of DFI will falter. This could be either from disillusion by donor country firms over host country [[now previously defined in text]] unpreparedness, or from adverse host country community reaction to projects poorly related to their development priorities and local concerns. Unless host countries are well prepared to ensure that projects are

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[1] Saleemul Huq, The Daily Star, Dhaka. *(Internet Edition)*

country-driven, they will reflect the emissions reduction priorities of donor firms, with only lip-service paid to host country development priorities.

Being prepared entails human capacity-building at various levels: (a) creating a receptive community through the training and awareness programs; (b) creating a corps of qualified professional specialists for project design and implementation; and (c) developing research capacity to expand the frontiers of knowledge of sustainable development.

To ensure that the host countries are adequately prepared, and also to facilitate foreign investments in carbon trading or similar activities, pilot schemes for such capacity building are needed. Such pilot schemes must include all three components in order to provide experience of all aspects of the problems of capacity building as quickly as possible. There are many stakeholders in such capacity building schemes: local people and non-governmental organisations as well as government agencies, host country entrepreneurs, donor country firms transferring technology, and the common interest in greenhouse gas mitigation expressed through the UNFCCC agencies. Where land use change for carbon sequestration is involved, landowners (government, individual or institutions) become stakeholders and arrangements should also include careful examination of end-use of the forest products.[2] These types of multi-stakeholder, multi-sectoral and inter-generational arrangements are not present in most of the developing countries. So pilot experiences would require that understanding is developed of the legal, institutional and social networks needed to successfully implement such projects.

CAPACITY BUILDING IN SUSTAINABLE ENERGY TECHNOLOGYTRANSFER

The following description briefly explains the context of a Pilot Scheme to enable capacity building for country-driven projects in terms of the need for, and prospective large scale of, such capacity building, together with an outline of a long term response. It details a Pilot Scheme for Bangladesh involving collaboration between Massey University of New Zealand, North South

University and Dhaka University of Bangladesh.

The pilot scheme emphasized that such enablement is globally novel and would require a span of time to be implemented effectively. Since the idea of project based carbon credits is, despite the AIJ experience, still to some extent academic, there will be an evolution through learning from experience, both within this Pilot Scheme and from other Pilot Schemes. For this several Pilot Schemes need to be developed and funded through international agencies in developing countries. Through these schemes, links could be established between project designers and project financiers in developing and developed countries. In terms of the funding organisations, Global Environmental Facilities (GEF) is a possible candidate that can fund the pilot schemes. GEF can do this under a new Operational Program within the GEF's Operational Strategy in line with decision 2/CP.4, para 1(g) noted previously.

It is additionally envisaged that this and other Pilot Schemes could, in the event that the Kyoto Protocol is ratified provide field experience input into the development and possible eventual implementation of the Plan for Facilitating Capacity Building under decision 7/CP.4 para 4, (which deals with a work programme in preparation for such ratification). However, it is to be noted that this additional benefit does not turn Pilot Schemes (or an eventual Main Programme of capacity building) into an outcome of CoP3 since decision 2/CP.4 is based in CoP2 decisions and relates to the FCCC and is thus not related to the Kyoto Protocol. Experience of the pilot schemes could lead to large scale programme funding for similar schemes globally. Eventually global emission reductions through the trading of credits arising from an increasing volume of projects generated by the professionals trained under such a programme may emerge as a sustainable strategy.

THE COST BENEFIT OF COUNTRY DRIVEN PROJECTS ON CAPACITY BUILDING

It is expected that projects that would facilitate project based trading would involve nearly two or three billion tons of carbon abatement. Total investments

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[2] Without this, reduction of carbon will be only a temporary phenomenon.

on these projects will involve transfer of funds (in terms of investment in carbon emission abatement technologies) from developed to developing nations that will exceed many billions of dollars annually. These investments will be needed to secure least cost achievement of FCCC objectives for sustainable development and greenhouse gas mitigation.

It is further expected that the number of such projects would spread to over 100 host countries and exceed several thousand in large host countries. This would require that each project must be planned and implemented in accordance with host country sustainable development priorities and measured and monitored in accordance with agreed FCCC practice. With a possibility of 'banking' of credits against future commitments, the prospect is of a rapid build up of demand for projects as Parties to the FCCC come to commit themselves to emissions reductions consistent with IPCC scenario studies.

Symbiosis exists between the twin objectives of the FCCC: sustainable development and greenhouse gas mitigation. Thus, emissions reducing sustainable energy and sustainable land use technology transfer yields both

- the emissions savings needed by donor country firms seeking offsets against emissions policy burdens imposed in the donor country and
- a boost to the sustainable development of the host country.

With regards to the latter, the macroeconomics are simple: host countries will get an injection of new investments (in renewable energy) that will generate multiplier effects with balance of payments constraints relaxed. Since such investments are long-term investments, the host countries will continue to receive foreign currencies for a longer period. At the same time, since investments in sustainable energy technologies will mean a reduction of imports of fossil fuel in most of these countries, sustainable energy technology projects will be a great import-saving mechanism for many developing countries. In the longer run, export led growth of such host countries leads to expanding markets for developed country products and to mutually beneficial gains from trade.

Prejudicing these prospects is the lack of appropriate human capital in prospective host countries. Unless host countries are well prepared to ensure that projects are country-driven, such projects will reflect only the emissions reduction priorities of donor firms, with mere lip service paid to host country sustainable development priorities. The concern is that, unless a start is made to building human capacity to respond effectively to rising demand for country-driven projects, the process will falter. This could be either from disillusion by donor country firms over host country un-preparedness or from adverse host country community reaction to projects that are poorly related to sustainable development priorities and local needs. Effective preparedness entails human capacity-building at all levels. These include: creating a receptive bureaucracy and business community through short course provision of in-career training , building a committed local community that would cooperate with foreign investors, entrepreneurs, etc. through networking with NGO groups, etc, and creating a group of professionals who would develop projects for implementation. This can also be enhanced by expanding research capacity to explore the frontiers of sustainable development.

Globalized Human Capacity Building

It is perceived that to implement such a huge number of projects across over 100 developing countries, a corps of trained professionals will be needed. Expected number of such professionals will exceed tens of thousands world-wide. These 'project implementation officers' (PIO's) will be the ultimate champions, that is, acting as the problem-solving focus of individual commitment that makes projects happen.

The role of PIO's (or 'Project Champions') would vary over the life of a project. Initially, project championing involves:

a) conceiving emissions reducing projects in line with host country sustainable development policies and priorities;
b) seeking out appropriate specialist technological advice, including prospective technology transfer from overseas firms;

c) gathering a prospective stakeholder conjunction of interests in the range of benefits associated with reducing emissions (e.g. employment, reduced local pollution, health, bio-diversity, flood control, etc), including:
   - community commitment at the project location,
   - entrepreneurial commitment to project management,
   - capital finance both risk bearing and aid-programme related where relevant,
   - involvement of overseas C-credit seeking firms,
   - and bureaucratic commitment to facilitation of the project

d) developing project proposals, including greenhouse gas emissions reductions estimates to do scoping study for presentation to stakeholders;

e) recruiting project management acceptable to both the foreign investor and local stakeholders and transferring operational responsibility for the project.

In later years, their role would shift to:

a) monitoring scheme progress for delivery of
   - carbon credits and reporting requirements under the FCCC, and
   - sustainable development objectives of the host country government

b) providing extension services to the community to ensure on-going delivery of community benefits needed to ensure the continued acceptability of the project;

c) securing high level support and research services in relation to non-routine project evolution.

Each PIO would champion a portfolio of a few to many projects, depending on size and complexity.

Building up of needed human capacity in each of these over 100 countries will be a massive job and will require time. At the same time, it is also understood that this manpower should be supplied fast. Without this, our effort to reduce carbon emissions and to minimize the impact of global warming world-wide may be defeated.

However, to conduct this *comprehensive capacity-building* on the scale envisaged above would require commitments and collaboration of a substantial number of institutions of higher education in developed and developing nations. These institutes should collaborate with the following three purposes in mind.

a) Rapid development of trained manpower
b) Ensuring that the training mechanism itself is transferred from developed to developing nations and
c) Development of collaborative projects in host countries and implementing them under UNFCCC requirements.

It is further envisaged that this process will involve co-operation agreements between appropriately grouped institutions. Institutions in developed and developing countries seldom have any formal relationship for co-operation. So, an initial thrust is needed to generate such collaborations. This could be done under the aegis of host-country government sponsorship of capacity-building schemes (say GEF funds through UNDP and UNITAR).

THE PILOT SCHEME: COLLABORATION BETWEEN BANGLADESH AND NEW ZEALAND

To investigate the new concept of sustainable energy technology transfer, the following Pilot Scheme activities are suggested to build capacity in Bangladesh to enable country-driven projects in the field of sustainable energy technology transfer.

The basis for this process will be collaborative agreements already in being or well advanced between Massey University in New Zealand, North South University, a private university in Bangladesh and the University of Dhaka a public university in Bangladesh. Under these agreements, specialised knowledge available in Massey University will be transferred to Bangladesh at several levels in order to create the necessary social setting for enablement to be effective.

The objective of such collaborative agreements should be:

1. To ensure that the training scheme could be self-sustaining in the host country after a specific period of time.
2. To train professional project champions to develop projects to scoping study stage and to facilitate a flow of funds from developed and developing countries in sustainable energy production.
3. To guarantee a monitoring scheme that is essential to meet the requirements of FCCC.

The levels at which human capacity-building is required are:

1. At the tertiary education level, to enable the capacity building activity to be transferred back to Bangladesh over a span of six years, after which Massey University's involvement in the training function will terminate.
2. At the research level, where a continuing collaboration is envisaged, with research effort applied to problem solving in relation to specific technological or socio-economic obstacles to the rapid diffusion of sustainable energy technology in Bangladesh
3. At the public service bureaucracy level, both centrally and in district administration, where a pro-active culture is required towards sustainable energy project proposals requiring official permissions, licenses or other bureaucratic consents facilitation
4. At the entrepreneurial level, ensuring an awareness of the profit opportunities to be gained through exploiting overseas demand for the carbon credits that will be generated through sustainable energy projects

5. At the community level, through NGO networking, to ensure receptiveness to projects that will enhance the quality of life, generating employment opportunities and social and educational attainment through the wider availability and utilization of modern energy carriers, including electricity.
6. The capacity for creating Project Champions as outlined above.

The first five of these levels of transfer will provide the supportive social setting within which sustainable energy technology projects can be nurtured and grown. They facilitate technology transfers to the field projects (that will be implemented by the project champions) that will be necessary if climate change threats are to be mitigated and adapted to. However, the fiundamental constraint on realizing the synergy bewteen the twin objectives of the FCCC is perceived to bethe lack of the project champions in the host countries who can become the driving force for country driven projects.

Massey University has proposed that a novel Masterate in Business Management (Sustainable Energy Technology Transfer Enablement specialism). This will be administered initially through Massey University, NZ with close participation by the faculty members from North South University and the University of Dhaka in Bangladesh. These groups of associates from Dhaka will eventually form the core to transfer such courses to Bangladesh.

Besides, there will be a Certificate in Sustainable Energy Technology Transfer that will be designed for policy makers and other in-career personnel from of Bangladesh and it will be delivered in-concert with presentations to the Masterate class. It is envisaged that the typical Certificate student will be middle to senior member from the public service, from industry, and from NGO's, and that the Certificate Courses will involve assignment preparation but be without final examination. It is envisaged that significant benefit will flow from in-concert presentation, with across-generation fertilization of ideas and the initiation of networks that will prove useful when the Masterate students reach the scoping study phase of their projects. This segment of the scheme will also be transferred to Dhaka.

The design of the MBM in SETTE is such that participants (potential Project Champions) will return to Bangladesh after two semesters of academic work and will work individually in separate locations and communities to develop project ideas. This project ideas will be carried forward and completed in the next semester through a scoping study. Evaluation of the student will be based on a combination of formal examination and the eventual project success. Project success will be in terms of actual or potential take up of the scoping study project by local communities (for sustainable development) and by overseas firms (for carbon credit).

The idea of environment friendly projects may not be unknown to most of the informed people and NGOs in Bangladesh but most are not aware of the nature of Sustainable Energy Technologies (SETs) that are available for developing countries. At the same time, it is also not clear to many how the objectives of the FCCC to mitigate GHG emission and sustainable development are linked with SET projects.

The awareness programs will be built to ensure the following objectives:

- informing the participants on SET projects
- requirements of the FCCC to mitigate GHG emissions
- community level participation and education on wider availability and utilization of modern energy carriers including electricity.
- informing entrepreneurs on profit opportunities by exploiting C-credit programs
- updating the participants on facilitating projects involving C-credit programs.

CONCLUSION

It has been argued that effective achievement of the objectives of the FCCC requires collaboration between developing and developed countries, with the burden carried by the latter in accordance with their shared responsibility and differentiated needs. Many of the lowest income countries are also the most vulnerable to the effects of climate change leading to rising sea levels and accelerated desertification. These have a strong interest in such collaboration to secure adaptation strategies that realize the benefits of the synergy between greenhouse gas mitigation and sustainable development that can be secured through sustainable energy technology transfer.

The primary barrier to such technology transfer, a constantly recurring theme of various scientific assessments coordinated by the IPCC[3], is the lack, in prospective host countries, of human and institutional capacity to absorb an increasing volume of sustainable energy technology transfer projects. The vast benefits to be gained from breaking down this barrier have been documented, with investment in such capacity building showing a return of over a hundred-fold measured only in terms of the value of carbon credits created, without regard to collateral sustainable development benefits[4].

Furthermore, the fourth meeting of the Conference of Parties to the UNFCCC specifically decided that the GEF should fund capacity building for country driven projects (Decision 2/CP.4, 1(g)) and application was made in 1999 for funding to support a pilot scheme, on the lines discussed above, in Bangladesh. However this application was declined on grounds that it anticipated ratification of the CDM and that there is no GEF operational programme to fund such projects. The first of these grounds is irrelevant since Decision 2/CP.4 has nothing to do with the Kyoto Protocol and the application was carefully framed in terms of capacity building for the purposes of the Convention, as discussed above. There must be some doubt as to whether the application was carefully

[3] See for instance the IPCC special reports on technology transfer and on land use, land use change, and forestry.

[4] See Read, P. 2000 "Capacity-building for country-driven sustainable energy projects: an inter-institutional approach" presented to International Conference on the Environment in Bangladesh, East West University, January

read.

As regards the second, while a relevant GEF operational programme may indeed be absent, this is not a defect of the scheme application or of the work of the Conference of Parties to the FCCC. Rather does it seem extraordinary that the GEF can continue for a year in default of a decision of the Conference of Parties to which (inter alia) it is responsible. This lack of accountability on the part of the GEF, in failing to do what it was decided by COP4 that it should do, is cause for disquiet. The main conclusion to be drawn from this experience is that the GEF Council should direct the GEF Secretariat to respond appropriately, and without further delay, to the decisions reached at COP4.

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tatistics Tutorial

iis is one in a series of brief descriptions of statistical analysis procedures provided by TexaSoft. Examples use the INKS Statistical Data Analysis program. For more information, goto the TexaSoft homepage. For an index to ese tutorials click here.

Mann-Whitney Test

(Non-parametric independent two-group comparisons)

efinition: A non-parametric test (distribution-free) used to compare two independent groups of sampled data.

ssumptions: Unlike the parametric t-test, this non-parametric makes no assumptions about the distribution of the ita (e.g., nonnality).

haracteristics: This test is an alternative to the independent group t-test, when the assumption of normality or juality of variance is not met. This, like many non-parametric tests, uses the ranks of the data rather than their raw ilues to calculate the statistic. Since this test does not make adistribution assumption, it is not as powerful as the t-st.

est: The hypotheses for the comparison of two independent groups are:

H_o: The two samples come from identical populations

H_a: The two samples come from different populations

otice that the hypothesis makes no assumptions about the distribution of the populations. These hypotheses are so sometimes written as testing the equality of the central tendency of the populations.

he test statistic for the Mann-Whitney test is U. This value is compared to a table of critical values for U based on e sample size of each group. If Uexceeds the critical value for U at some significance level (usually 0.05) it means at there is evidence to reject the null hypothesis in favor of the alternative hypothesis. (See the Zar reference for etails.)

ote: Actually, there are two versions of the U statistic calculated, where $U' = n_1 n_2 - U$ where n_1 and n_2 are the mple sizes of the two groups. The largest of U or U' is compared to the critical value for the purpose of the test.

ote: For sample sizes greater than 8, a z-value can be used to approximate the significance level for the test. In is case, the calculated z is compared to the standard normal significance levels.

ote: The U test is usually perform as a two-tailed test, however some text will have tabled one-tailed significance vels for this purpose. If the sample size if large, the z-test can be used for a one-sided test.

raphical comparison: The graphical comparison allows you to visually see the distribution of the two groups. If
ɜ p-value is low, chances arethere will be little overlap between the two distributions. If the p-value is not low,
ɜre will be a fair amount of overlap between the two groups. There are a number of options available in the
mparison graph to allow you to examine the two groups. These include box plots, means, medians, and error bars.

ɔcation in KWIKSTAT and WINKS: The Mann-Whitney U test (independent group comparison test) is
ɔated in the Analyze/Non-parametric comparisons menu. When there are more than two groups in this
mparison, the test becomes a Kruskal-Wallis test.

ɘe Also: The independent group t-test.

ĸample: The Mann-Whitney U test

ıe FERTILIZ.DBF database contains information on the heights of plants that were grown using two different
rtilizers. The Mann-Whitney test can be used to determine if there is evidence that one fertilizer that causes the
ants to grow taller than the other. The results of running an analysis on this data is as follows:

```
-------------------------------------------------------------------------------
Non-Parametric Independent Group Comparison          C:\WDATA\FERTILIZ.DBF
-------------------------------------------------------------------------------

ɘsults of Non- Parametric analysis:

roup variable = GROUP Observation variable = OBS

ann- Whitney U' = 24. U = 18.

ank sum group 1 = 46. N = 7 Mean Rank = 6.57

ank sum group 2 = 45. N = 6 Mean Rank = 7.5

ignificance estimated using the z statistic.

 = .357 p = 0.721

Note: This Z calculation uses a correction for continuity.)
```

he program reports the p-value based on the z approximation. Since the sample sizes for both groups are less than
, you should can look up the critical value for n_1= 6 and n_2= 7 in the table contained in the KWIKSTAT or
/INKS manual (or in a textbook) to see if the critical value is 34for a test at the 0.05 level. Thus, if U' were 34 or
reater, you could claim statistical significance at the 0.05 level. In this case, the conclusion is that there is no
ifference in the two groups. Note how this result agrees with the t-test for this same data set.

xercise: Mann-Whitney U test

rofessor Testum wondered if students tended to make better scores on his test depending if the test were taken in
ıe morning or afternoon. From a group of 19 similarly talented students, he randomly selected some to take a test
ı themorning and some to take it in the afternoon. The scores by groups were:

orning	Afternoon
9.8	87.3
0.2	87.6
8.1	87.3
1.2	91.8
8.9	86.4
0.3	86.4
9.2	93.1
4.0	89.2
8.7	90.1
3.9	

. Perform a Mann-Whitney U test on this data. Remember that the program expect two fields, a Group field and n Observation field.

. What was the result?

. From this evidence, does it appear that time of day makes a difference in performance on a test?

. Change the value 83.9 in the second group to 11 and rerun the test. Does this change the statistic calculated or he conclusion? Also perform anindependent group t-test on the original and changed data. Does it effect this tatistic? Why?

. Display a graphical comparison of the original and changed data.

Table 7.4.1a Regression Output

Model Summary

Model	*R*	*R Square*	*Adjusted R Square*	*Standard Error of the Estimate*
1	.432	.187	.176	.4218

A. Predictors (constant): knowledge about energy technologies, annual income, education code, total land in decimals

B. Source: Compiled from survey data

ANOVA

Model		*Sum of Squares*	*Df*	**Mean Square**	*F*	*Sig.*
	Regression	12.185	4	3.046	17.119	.000
	Residual	53.029	299	.178		
	Total	65.215	303			

A. Predictors (constant): knowledge about energy technologies, annual income, education code, total land in decimals

B. Dependent Variable: Respondents' awareness of environmental pollution

C. Source: Compiled from survey data

Coefficients

Model	*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*
1	B	**Standard Error**	Beta		
(Constant)	.324	.052		6.200	.000
Education Code	.119	.019	.348	6.221	.000
Annual income	4.139E-07	.000	.090	1.598	.111
Total land in decimals	1.835E-05	.000	.014	.243	.808
Knowledge about energy technologies	.135	.057	.136	2.384	.018
Knowledge about energy technologies	.135	.057	.136	2.384	.018

A. Dependent Variable: awareness of environmental pollution

B. Source: Compiled from survey data

Table 7.4.1b: Regression Output

Model Summary

Model	*R*	*R Square*	*Adjusted R Square*	*Standard Error of the Estimate*
1	.466	.217	.204	.4147

A. Predictors (constant): knowledge about energy technologies, annual income, awareness of environmental pollution, total land in decimals, education code

ANOVA

Model		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
1	Regression	14.141	5	2.828	16.446	.000
	Residual	51.074	297	.172		
	Total	65.215	302			

A. Predictors (constant): knowledge about energy technologies, annual income, awareness of environmental pollution, total land in decimals, education code

B Dependent Variable: Respondents' willingness to participate in SET

Coefficients

Model		*Unstandardized Coefficients* B	Standard error	*Standardized Coefficients* Beta	*t*	*Sig.*
1	(Constant)	.275	.055		5.033	.000
	Education code	8.519E-02	.020	.249	4.250	.000
	Annual income	-1.236E-07	.000	-.027	-.483	.629
	Total land in decimals	-7.066E-05	.000	-.054	-.951	.342
	Awareness of environmental pollution	.125	.057	.125	2.202	.028
	Awareness of environmental pollution	.125	.057	.125	2.202	.028
	Knowledge about SET	.238	.056	.239	4.242	.000

A. Dependent Variable: Respondents' willingness to participate in SET