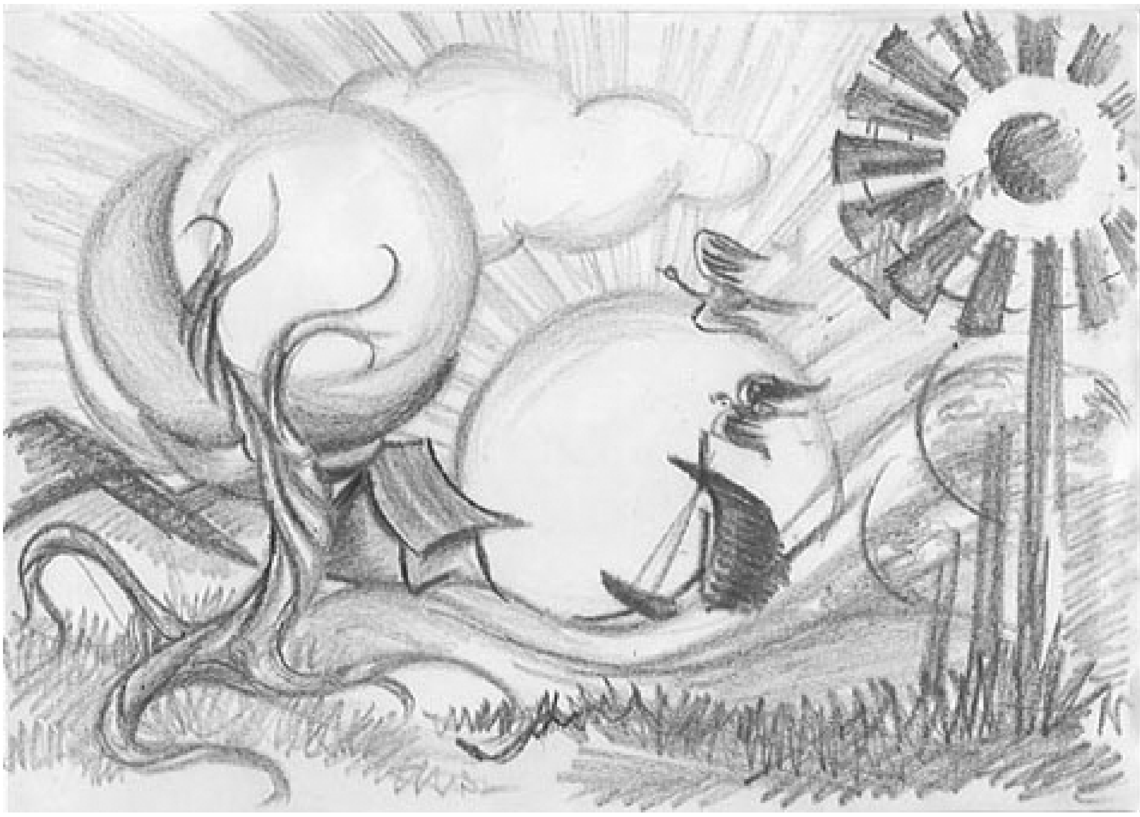
Assessment of Renewable Energy Resources Of Bangladesh

Mazharul Islam



Shakti : Energy Web Site of Bangladesh

"http://shakti.hypermart.net"

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Dedicated to my parents

Nazrul Islam (Late) and Professor Hazera Nazrul

Contents

Preface

This is the first Electronic Book (Ebook) of Shakti, the sole energy related web site of Bangladesh. I have desire to bring out more Ebooks in the future on different energy related topics or issues, which will be available in the Internet.

Renewable energies are highly site specific. For proper estimation of renewable energy sources, micro-climatic data is essential. But in Bangladesh, like most of the developing countries, incomplete national average data from the Meteorological Offices are available for wind and solar energy systems that are inadequate for RET projects formulation. This Ebook will highlight different aspects of renewable energies Resource Assessments in Bangladesh perspective.

In Bangladesh, bandwidth of dial-up internet connection is very low at present. Due to this reason, I wanted to make the volume of the electronic book as small as possible, for which I had to scrap lots of valuable images (which make the size of the file larger). I hope, this attempt will be helpful to the renewable energy enthusiasts of home and abroad. I will expect feedback from the readers, which will encourage me and keep this initiative carry on.

At the end, my sincere gratitude goes to my wife Tazina for constant encouragement and supports, my sons Aninda and Ananta and to my parents for bringing me into this world.

Mazharul Islam
Dhaka
March, 2002

Abbreviations

BAU	*Bangladesh Agricultural University*
BCSIR	*Bangladesh Council of Scientific and Industrial Research*
BFRI	*Bangladesh Forestry Research Institute*
BIT	Bangladesh Institute of Technology
BPDB	*Bangladesh Power Development Board*
BUET	Bangladesh University of Engineering and Technology
EJ	Exa Joule
FMP	Forestry Master Plan
FY	Fiscal Year
GEF	Global Environment Facility
GHG	Greenhouse Gas
GJ	Giga Joule
GS	Grameen Shakti
GW	Giga Watt
IEA	International Energy Agency
IFRD	Institute of Fuel Research & Development
LGED	Local Government Engineering Department
MW	Mega Watt
OTEC	Oceanic Thermal Energy Conversion
PJ	Peta Joule
PV	Photovoltaic
REB	Rural Electrification Board
RERC	Renewable Energy Research Centre
RET	Renewable Energy Technologies
RWEDP	Regional Wood Energy Development Programme
SHP	Small Hydro Power
SRE	Sustainable Rural Energy
SSE	Surface meteorology and Solar Energy Data Set
Tk	Taka, Bangladeshi currency Conversion Rate: 1 US$=57.4 Taka (as of August 19, 2001)
UNEP	United Nations Environment Program
WB	World Bank
WEA	World Energy Assessment
WEC	World Energy Council

Chapter 1

Introduction

Renewable Energy Technologies (RETs) have become multi-billion dollar industry from the realm of laboratories in recent years. At present, most of the large International Oil Companies (IOCs) have started serious business with renewables, like Shell and British Petroleum have individually committed US$500 million for renewable energy investment. Installed capacity of non-hydro RETs is already 60,000 MW [GEF 2001] and at present they are supplying 14 percent of the total global energy demand [WEA 2000]. The World Energy Council (WEC), Shell, the Intergovernmental Panel on Climate Change (IPCC) and several UN bodies expect a significant share of RETs in the future with major contribution from biomass, hydro, wind and solar energy.

Renewable Energy Technologies are mostly in the dissemination and demonstration phase in Bangladesh. About 80% of the total population are still unelectrified. A major portion of the unelectrified population will not be able to get electricity in the foreseeable future due to several constraints, including low consumer density and inaccessibility. It is expected that RETs' can play a significant role in the far-flung remote locations of Bangladesh.

1.1 Global Renewable Energy Utilization Overview

According to Global Environment Facility (GEF), a major financier of RET projects in the developing countries - "A transition to renewable energy is inevitable, not because fossil fuel supplies will run out , large reserves of oil, coal, and gas remain in the world, but because the costs and risks of using these supplies will continue to increase relative to renewable energy. Costs will increase as the environmental impacts of fossil fuel use are increasingly incorporated into the costs of energy and as the cheapest reserves are depleted".

In the developed countries, RETs are promoted by different supporting policy or regulatory-frameworks to combat greenhouse gas emissions. But in the developing countries, renewable projects are mainly donor-driven programs for rural or distant electrification with subsidy or incentives and the market is transforming. It is expected that in the near future some of the RETs will attain commercialization without subsidy or incentives.

For depicting the current status of RETs, global installed capacity of non-hydro RETs presented in the Table 1.1 and technology-wise growth rate, capacity factor, turnkey investment cost, current energy cost per unit and potential energy cost per unit are shown in the Table 1.2.

Table 1.1

Global Installed Capacity Of Non-Hydro RETs [UNEP, 2000]

TECHNOLOGY	INSTALLED CAPACITY (MW)
Biomass	35,000
Geothermal	9,000
Solar Photovoltaic	1,200
Solar Thermal	350
Wind	14,000
Total	59,550

United Nations and other international bodies started advocacy for RETs since the beginning of 1980s. Global Environment Facility (GEF) along with the World Bank, UNDP and UNEP have been the major financiers in the RETs projects in the developing countries. Most of the Aid Agencies (like USAID, CIDA, SIDA, DANIDA, DFID, GTZ etc.) are also funding RETs projects. Apart from these multilateral and bilateral financiers, some of the internationally reputed private banks have also started financing RETs projects.

Table 1.2

Current Status And Potential Future Costs Of Renewable Energy Technologies [WEA 2000]

Technology	Growth Rate (% / year)	Capacity Factor (%)	Turnkey Investment Costs (US$/kW)	Current Energy Cost	Potential Future Energy Cost
Biomass Energy					
Electricity	≈ 3	25-80	900-3000	5-15 ¢/kWh	4-10 ¢/kWh
Heat	≈ 3	25-80	250-750	1-5 ¢/kWh	1-5 ¢/kWh
Ethanol	≈ 3			8-25 ¢/GJ	6-10 ¢/GJ
Wind					
Electricity	≈ 30	20-30	1100-1700	5-13 ¢/kWh	3-10 ¢/kWh
Solar					
Solar PV Electricity	≈ 30	8-20	5000-10000	25-125 ¢/kWh	5 or 6-25 ¢/kWh
Solar Thermal Electricity	≈ 5	20-35	3000-4000	12-18 ¢/kWh	4-10 ¢/kWh
Low-temperature Solar Heat	≈ 8	8-20	500-1700	3-20 ¢/kWh	2 or 3-10 ¢/kWh
Hydroelectricity					
Large	≈ 2	35-60	1000-3500	3-8 ¢/kWh	3-8 ¢/kWh
Small	≈ 3	20-70	1200-3000	5-10 ¢/kWh	4-10 ¢/kWh
Geothermal					
Electricity	≈ 4	45-90	800-3000	2-10 ¢/kWh	1 or 2-8 ¢/kWh
Heat	≈ 6	20-70	200-2000	0.5-5 ¢/kWh	0.5-5 ¢/kWh
Marine Energy					
Tidal	0	20-30	1700-2500	8-15 ¢/kWh	8-15 ¢/kWh
Wave	-	20-35	1500-3000	8-20 ¢/kWh	
Current	-	25-35	2000-3000	8-15 ¢/kWh	5-7 ¢/kWh
OTEC	-	70-80	Not Clear		

1.2 Benefits of RETs : Bangladesh Perspective

Benefits of RETs are numerous. Only the well-established proven benefits are outlined below which are collected from authentic sources and firmly believed by the author.

1.2.1 Socio-Economic Benefits

From the global experience, it has been observed that RETs are economically viable for distant rural electrification program which upgrades the living standard of the rural mass. This fact has also been fully endorsed by Rural Electrification Board (REB), state-own utility devoted on rural electrification in Bangladesh since 1978. A large portion of the remote areas are not likely to be covered by the grid network due to inaccessibility and low consumer density. Renewable Energy Technologies are considered as viable technical options for remote off-grid areas.

Deploying RETs will not only provide electricity, it will become a stimulant for other development activities, like poverty alleviation, health care, education, women empowerment, family planning etc. This argument is supported by Figure 1.1 which shows how commercial energy usage is inter-related with infant mortality, illiteracy, life expectancy and fertility in the industrialized and developing countries. A recent USAID study's findings and assessments about impact of the rural electrification program in Bangladesh are the following [REB 2001]:

- Ø 93.7% of the electrified households reported decrease in fuel cost.
- Ø 78.2% reported an increase on working hours.
- Ø 62.0 % reported an increase in household income
- Ø 81% reported an increase in reading habits
- Ø 93.7% reported an increase in children's study time.
- Ø 92.0% reported an increase in amusement as well as standard of living.
- Ø 94.7% reported an improvement in security.

In the subsequent sections, different socio-economic benefits are described briefly.

Employment

RETs are up to three times more employment-intensive than fossil fuel or nuclear power options. This benefit can be easily seen from the global wind energy business. According to a survey by Danish wind energy manufacturers, 17 worker-years are created for every megawatt of wind turbine manufactured and five worker-years for every megawatt wind power installed. In the year 2000, the wind energy industry provided more than 85,000 jobs worldwide and could provide up to 1.8 million jobs by 2020 [UNEP, 2000]. Electrification of microenterprises in the off-grid areas can increase income or create new job opportunities for the rural poor which has been observed from the experience of Grameen Shakti which is a leading NGO involved in the RET sector.

Healthcare

At present, a large amount of population are deprived of proper health care due to absence of electricity in remote far-flung areas. RETs can be used by the rural health clinics for lighting and vaccine refrigeration. Understanding this opportunity, South Africa has launched a project to electrify it's rural health clinics by Solar Photovoltaics and gained significant benefit.

Education

Like health clinics, most of the rural off-grid schools don't have electricity. RETs can be used by these rural schools for different amenities. Modern benefits will not only attract more students, but will also retain quality teachers and staffs currently unwilling to be posted in the unelectrified areas. In the evening, the school facilities can be utilized for other social services like adult education, health education or recreational activities.

Family Planning

Electrification helps family planning activities. An exhaustive analysis [Hoque, 1998] to find out the link between electrification and fertility in Bangladesh shows that the fertility rate among girls is 0.67 in electrified households and 1.17 in nonelectrified households.

Development of Rural Women

If chance is given, rural women can be a good entrepreneur which has been noticed by Grameen Bank whose micro-credit program has been acclaimed all over the world. Renewable energy project can be implemented in the rural areas of Bangladesh with women participation. Recently a microenterprise of 33 women in a remote island of Bangladesh has shown a glaring success. This microenterprise is (1) assembling, marketing and selling DC lamps and (2) charging and leasing battery from a Diesel genset. Now it is preparing for Solar Electrification Service. Similar projects can be replicated to other places that will contribute the overall development of rural women.

1.2.2 Energy Security

It is established fact that RETs can promote energy security and price stability by diversifying the energy supply. Currently, In the remote areas, usually diesel gensets are used for few hours in the evening for off-grid electrification. Bangladesh imports diesel with hard-earned foreign currency. It is obvious, that by substituting the diesel gensets with RETs can diversify the energy mix and thereby save foreign currency.

As RETs are modular, energy requirement can be met on-site very quickly and can be scaled up in the course of time with growing demand. Another problem associated with the conventional grid is line interruptions which in the case of RETs are much less and can be avoided if the user is trained properly.

1.2.3 Environmental Benefits

Combating Greenhouse Gas Emissions

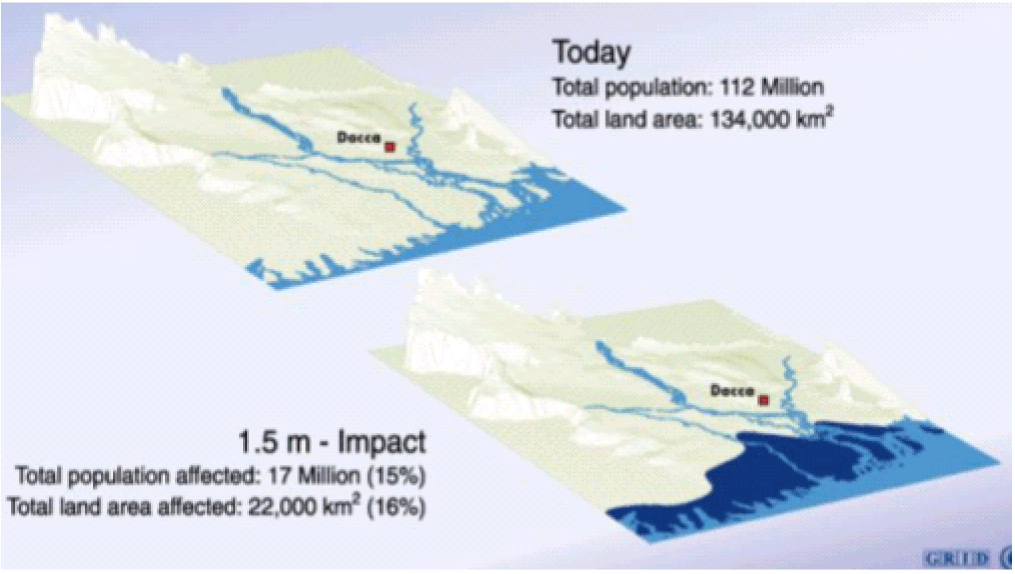
Bangladesh is most vulnerable to sea-level rise. The population is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine to what extent these catastrophes would be with accelerated sea-level rise. In figure 4, Digital terrain Modeling techniques have been used to display the impact of sea level rise in Bangladesh. A three dimensional view of the country has been overlaid with the current coastline and major rivers and potential future sea levels at 1,5 meters. Since this scenario was calculated in 1989, the expected rate of sea level rise has been modified. At present expected rates, this stage can occur in about 150 years from now.

Even a very cautious projection of 10 cm sea level rise, which would most likely happen well before 2030, would inundate 2500 sq. km, about 2% of the total land area. Patuakhali, Khulna and Barisal regions are most at risk from sea level rise. On average, the sea would move in about 10 km, but in the Khulna region, the sea will likely move in further. With the high end estimates, sea level rise in Bangladesh would inundate 18% of the country by 2100.

So, Bangladesh should encourage clean RETs to combat greenhouse gas emissions to avert the potential threats.

Figure 1.1

Potential impact of sea-level rise on Bangladesh [UNEP/ GRID-Arendal, 1989]



Flexibility Mechanisms of Kyoto Protocol

During the Sixth session of the Conference of the Parties (COP) 180 countries have reached agreement on rules for an emissions trading system and other measures that will be used to reach the target, set in Kyoto Protocol in 1997, for a cut of about 5.5 percent between 1990 and 2012 in greenhouse gas (GHG) emissions by industrialized countries. Kyoto Protocol includes 3 flexibility mechanisms namely –

a) Joint Implementation (JI), described in the Article 6, which allows sharing of GHG reduction benefits between developed and developing countries if a developed country enterprise invests in GHG reduction in a developing country

b) Clean Development Mechanism (CDM), defined in the Article 12, which would allow trading of GHG reduction between developed and developing countries. As agreed by the Parties in COP-6, Part 2 that the "Executive Board" will be formed in COP 7 to develop and recommend to COP, at its eighth session, simplified modalities and procedures for the clean development mechanism project activities including Renewable Energy Project activities with a maximum output capacity equivalent of up to 15 megawatts [COP 6, Part 2].

c) Emissions trading, stated in the Article 12, which has been allowed under the Kyoto Protocol between the Annex B (i.e. developed) countries.

It is widely expected that developing countries, including Bangladesh, will receive assistance from developed countries in terms of finance, technology-transfer etc through the above-mentioned flexibility mechanisms.

1.3 Aim of the Book

Renewable energies are highly site specific. For assessment of RETs, availability of micro-climatic data is essential. But in Bangladesh, like most of the developing countries, incomplete (lacking most of the parameters required for RETs projects evaluation or simulation) national average data from the Meteorological Offices are available for wind and solar energy systems that are not suitable for RET projects formulation. Some of the Institutes and Universities have also tried logging of data related to solar energy, wind energy, biomass (biogas, waste etc.) and hydro at different parts of the country which are collected for analysis. Also some of the state-of-the art techniques (satellite remote-sensing, GIS etc.) for renewable resources assessment are used or referred in the subsequent chapters for application in Bangladesh.

Chapter 2

Solar Energy

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Different R&D Organizations, Institutes and Universities are collecting solar insolation at different parts of Bangladesh. Some of them are presented in this chapter.

2.1 Available Solar Insolation Data

At present, solar insolation data can be found from the following sources:

- Ø Renewable Energy Research Centre (RERC), Dhaka University (DU) is the only source which has got long-term measured data of Dhaka city in Bangladesh [UNESCAP 2000]. The published data are average of results of hourly measurements of over three years global (G) and diffuse (D) radiation with Eppley Precision Pyrometer.
- Ø Bangladesh Meteorological Department has 34 sunshine recording stations situated generally in towns and cities.
- Ø Department of Mechanical Engineering, Bangladesh University of Engineering (BUET) and Technology, has also got time series data of Dhaka city.

Apart from the above-mentioned sources, few other organizations or institutes have also measured time series of global radiation, direct or beam radiation, diffuse radiation, sunshine hours and temperatures of different parts of the country. But for meticulous estimation and simulation of different solar energy applications several other parameters are required which are not available at the moment.

Monthly Global Solar Insolation at different cities of Bangladesh and Daily Average Bright Sunshine hour at Dhaka city are presented in Table 2.1 and 2.2 respectively.

Table 2.1

Monthly Global Solar Insolation at Different Cities of Bangladesh (in kWh/m^2/day)

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessor
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source : Dr. Shahida Rafique, Dhaka University, recorded from 1988 to 1998

Table 2.2
Daily Average of Bright Sunshine Hours at Dhaka (Average period: 1961 to 1980)

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Source : Meteorology Department, Government of Bangladesh

2.2 Application of Satellite Remote Sensing for RET Projects

Unfortunately, all the measured data of above-mentioned sources are collected for main cities of the country, which are electrified and not a prospective site for RET application. The surface topology has a major influence on micro-climate resulting in highly variable wind resources and significantly variable solar resources over small areas. Due to this reason, for assessment of RET projects in the far-flung areas of Bangladesh, Satellite Remote Sensing technology can be applied.

Hourly global insolation from satellites with a ground resolution of a few kilometers reproduce data sets with a relative Root Mean Square Error (RMSE) of typically 20-25% [Perez et. al. 1999]. But it has been found out from rigorous analysis that for hourly data, the satellite data become more accurate than a local ground station if the distance from the station exceeds 34 km [Perez et. al. 1997]. At present, many organizations provide remote sensing data, gathered from geo-stationary or polar orbiting satellites, appropriate for RET project appraisal.

NASA has recently launched a renewable energy resource web site called “Surface meteorology and Solar Energy Data Set (SSE)” available in the Internet free-of-charge. Another advantage of user friendly SSE is linked with the Renewable Energy Project Analysis Software (RETScreen) which will be used in this thesis work for analysis of RET Projects in Chapter 6. Application of SSE for solar energy resource assessment is presented in the next topic.

2.3 SSE for Solar Energy Resource Assessment

SSE data set is formulated from NASA satellite- and reanalysis-derived insolation and meteorological data for the 10-year period from July 1983 through June 1993. Results are provided for 1° latitude by 1° longitude grid cells over the globe. The SSE global data set makes it possible to quickly evaluate the potential of renewable energy projects for any region of the world and is considered to be accurate for preliminary feasibility studies of renewable energy projects [Charles H. Whitlock et. al. 2000].

SSE provides:

- over 100 satellite-derived meteorology and solar energy parameters
- monthly averaged from 10 years of data
- data tables for a particular location
- color plots on both global and regional scales
- global solar energy data for 1195 ground sites

Estimated uncertainties of SSE data set for solar energy parameters are found by comparing with (1) World Radiation Data Center (WRDC) ground measurement data (2) RETScreen Ground Monitoring

Stations Weather Database and (3) The RETScreen database available from the RETScreen Website which are shown in Table 2.3.

Table 2.3
Estimated Uncertainty with SSE Data sets [SSE, 2000]

Parameter	Global sites WRDC	Global sites RETScreen	Renewable sites RETScreen
Solar Insolation (kWh/m2/day)	14.2%	13.0%	
Near-Surface Air Temperature (K) (10 meter altitude)		< 243 K = 3.2% > 263 K = 1.1% linear variation between 243 K and 263 K	1.2%
Heating Design Temperature (K)			1.3%
Cooling Design Temperature (K)			1.4%
Summer mean daily design range (K)			0.9%
Heating degree-days below 18° C (degree-days)			14.6%

2.3.1 Example of SSE Application

Thanchi is one of the remotest thana (sub-district) located in the Chittagong Hill Tracts regions of Bangladesh. People of Thanchi suffer from inconvenience due to poor communication system of the area, particularly with the district town. The local river “Shangu” is navigable only for five months in a year. By an engine boat it often takes 15 hours and by road 2 days with a night halt to reach the district town Bandarban. National electricity grid is not present in Thanchi and chances of extending them is also bleak in the near future. So, Thanchi is an ideal place for application of RETs, especially Solar Photovoltaic.

For using the RETScreen Solar Photovoltaic Project Model, site specific solar insolation and temperature data has to be fed. These two parameters can be obtained from SSE web site with respect to the latitudes and longitudes of Thanchi and presented in Table 2.4 and 2.5.

Table 2.4
Average Daily Radiation on Horizontal Surface in Thanchi (in kWh/m^2/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average Daily Insolation	4.88	5.41	6.22	6.14	5.68	3.62	3.43	3.67	4.09	4.51	4.32	4.47

Table 2.5
Average Temperature in Thanchi (in °C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average Temperature	18.4	20.6	23.6	24.5	25.2	26.0	25.8	25.8	25.4	24.4	22.0	19.2	23.4

2.4 Solar and Wind Energy Resource Assessment (SWERA) Project

In most of the developing countries, renewable resource information is absent or inadequate. This is one of the major barriers for wide-spread deployment of RETs in these countries. Understanding this obstacle, UNEP is carrying out a 3-year long “Solar and Wind Energy Resource Assessment (SWERA)” project with GEF fund. The overall goal of this project is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policy making. The project will enable informed decision making and enhance the ability of participating governments to attract increased investor interest in renewable energy.

2.4.1 Components

Five components of SWERA are shown in Table 2.6.

Table 2.6
Components and Activities of SWERA

Components	Activity
Solar Resource Assessment	ü Solar Resource Assessment ü Gather Relevant Meteorological Data from National or other Archives ü Develop Solar Resource Maps ü Generate Time-Series Data ü Relate short -term satellite-derived time series to long-term ground-based time Series ü Conduct Cross-Model Comparisons and Validation Studies
Wind Resource Assessment	ü Review of Existing Wind Surveys and Assessment Methodologies ü Gather Existing Relevant Wind Data ü Process Data Sets and Perform Critical Analysis of Data Quality ü Adjustment of Surface Observations using WAsP methods ü Generate High-Resolution Wind Maps ü Prepare Wind Atlas ü Conduct Cross-Model Comparisons and Validation Studies
Integration with Geographic Information System (GIS)	ü Develop standard GIS datasets ü Develop GIS Toolkit ü Needs assessment for in-country partners ü Establish global archive
National Application of the SWERA tools and information	ü Alternative business development scenarios in energy supply ü Marketing and presentation of the alternative energy development projections to investors
Management and Coordination	ü Coordination of project activities ü Meetings

2.4.2 Solar Resource Assessment of Bangladesh by the SWERA Project

High resolution (approx. 0.05 o to 0.15 o , 1-3 hourly) site/time specific solar resource datasets will be derived from geostationary satellite - INSAT and METEOSAT5. It is expected that since INSAT has higher spatial resolution and METEOSAT has higher time resolution the combination will give the best product. Maps and GIS data sets of monthly and yearly sums of Global Radiation and of Direct Radiation covering the land areas of Bangladesh will be made available with an expected accuracy of better than 10% with respect to the annual sum of solar radiation. The maps will be based on 3 years of time series data with a time resolution of 1 hour. Bangladesh will have:

ü access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information.
ü the capacity to use the data in an effective manner to facilitate solar technology investment.
ü understanding of how the resource data are developed
ü improved ability to undertake measurement programs for further validation data
ü site-specific pre-feasibility studies

Chapter 3

Wind Energy

In Bangladesh, some early studies on wind energy prospects were made by Professor Muhtasham Hussain of Dhaka University and his colleagues [Hussain et. al 1986], as well as some enthusiasts from Bangladesh University of Engineering and Technologies (BUET). The Bangladesh Meteorological department has wind speed measuring stations in towns and cities . Data from earlier measurements and analysis of upper air data by CWET India show that wind energy resource of Bangladesh is not good enough (>7 m/s) for grid connected wind parks [GEF 2001]. Wind data from Bangladesh Meteorological Department and different previous and ongoing wind resource assessment projects are briefly described in the subsequent sections.

3.1 Wind Data From Bangladesh Meteorological Department

Most of the previous wind speed data in Bangladesh is available from the Bangladesh Meteorological Department. Average values calculated from such wind data during 1961 to 1993 are presented in Table 3.1.

Some of the meteorological stations have automatic data logging systems which record wind-speed data onto paper rolls but rest are recorded by office stuff. These are collected and set to the Headquarters in Dhaka where they are entered on computer and made available at an agreed cost to interested parties in addition to their being used for whether forecasting purposes. From experience reported by those interested in wind energy in measurements at low heights and relatively inaccurate instruments.

Bangladesh Centre for Advanced Studies (BCAS) obtained and reviewed Bangladesh Meteorological Department records with a view to establishing the prospects for wind energy and the following information about the wind climate in Bangladesh had been found:

- Wind speeds at most Met Office stations appear to be low, with typical annual mean wind speeds of 2 to 4 knots or 1 to 2 m/s, at heights between 5 to 10 meter above ground level.
- Wind speeds appear to be higher in the east of the country than the west.
- Wind speeds in the coastal areas appear to be higher than inland.
- Wind speed exhibits a strong seasonal cycle, lowest in the winter and higher in the summer.
- Wind speed exhibits a diurnal cycle, generally peaking at noon and weakest at night.

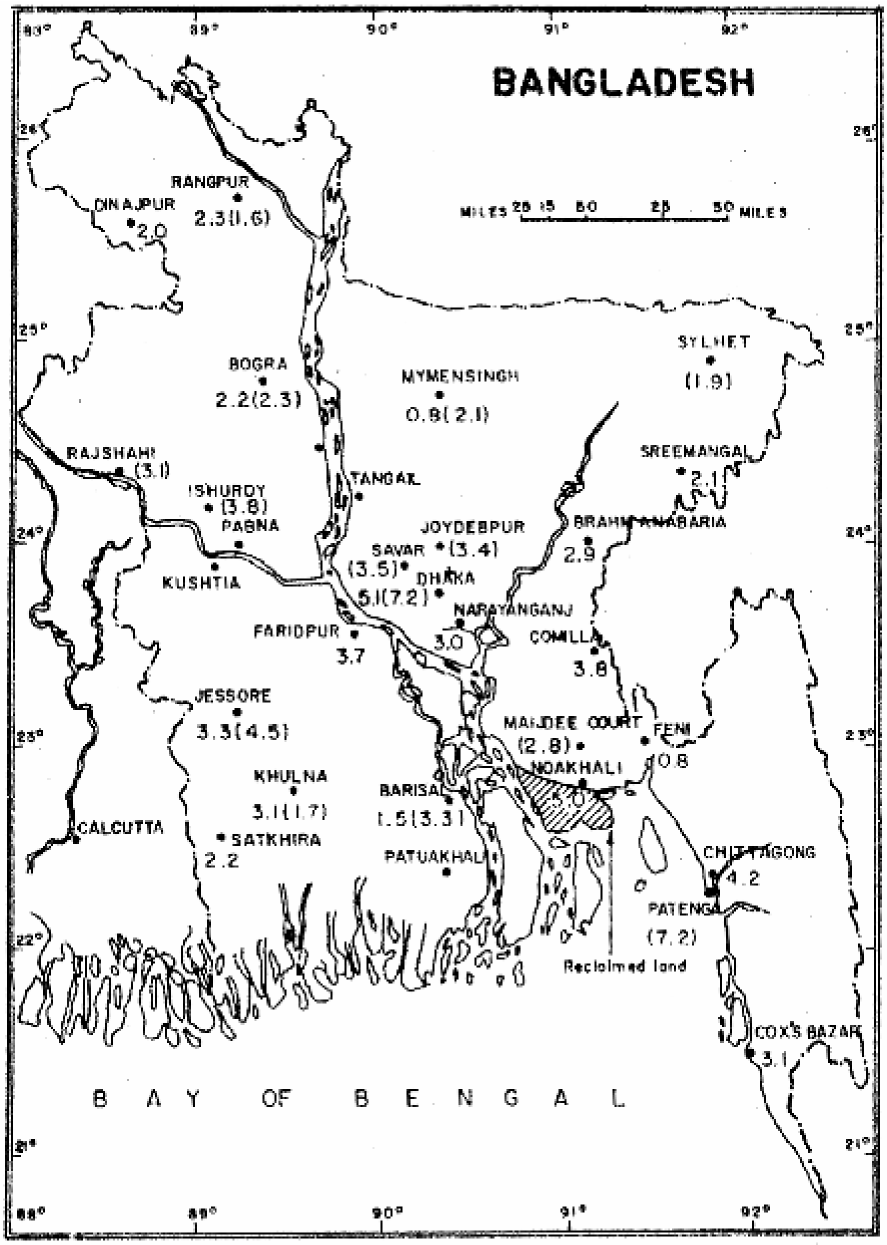
Table 3.1

Annual average wind speed of different sites of Bangladesh during 1961 to 1993 [Bangladesh Meteorological Department]

Site	Reference height (m)	Annual average wind speed (m/s)
Teknaf	5	2.16
Cox's Bazar	10	2.42
Patenga Airport	5	2.45
Kutubdia Island	6	2.09
Sandip Island	5	2.16
Hatia Island	6	2.08
Bhola Island	7	2.44
Khepupara	10	2.36
Comilla Airport	6	2.21

Figure 3.1

Map of Bangladesh showing annual average wind speed in knots. Number in parentheses represent old data and number outside are data collected by Hussain et. al. in 1986



3.2 Wind Energy Study Project (WEST)

The Wind Energy Study (WEST) Project of Bangladesh Centre for Advanced studies (BCAS) was an attempt to collect wind-speed data through technically sound monitoring system, since no such study had previously been done in Bangladesh. The project was approved by Aid Management Office, Dhaka (AMOD) in September,1995. BCAS has been provided with necessary technical assistance and cooperation by Energy Technical Support Unit (ETSU), Harwell, UK in the implementation of the project. Local Government Engineering Department (LGED) helped in installation of the wind monitoring masts, collection and dispatch of data cards from the monitoring sites to BCAS Headquarters at Dhaka on regular basis.

Seven Wind measuring stations were located at –

1. Patenga
2. Cox's Bazar
3. Kutubdia
4. Teknaf
5. Noakhali
6. Kuakata and
7. Char Fassion

3.2.1 Monthly and Annual Average Wind Speed Values

The final report of WEST indicates that the average monthly wind-speed is relatively high during the months of April through August and low during September to March. The average annual wind speed values at 25 meter height for the seven stations vary from 2.96 m/sec to 4.54 m/sec. The highest average annual value (4.54 m/sec) was observed in Kuakata (Table 3.2) and the lowest value (2.96 m/sec) was observed in Teknaf and Noakhali.

Table 3.2 shows the monthly average wind speeds obtained from measuring stations of WEST.

Table 3.2

Monthly average wind speeds from seven WEST stations

Month	Patenga	Cox's Bazaar	Teknaf	Noakhali	Char Fassion	Kuakata	Kutubdia
Jun '96	8.75	-	-	-	-	-	-
Jul '96	5.87	5.42	5.77	-	-	-	-
Aug '96	5.32	5.33	4.90	4.70	4.60 at 10m height 5.20 at 25m height	5.70	-
Sep '96	3.36	3.69	3.46	2.94	2.80 at 10m height 3.34 at 25m height	3.77	3.58
Oct '96	3.20	3.74	3.30	2.83	3.07 at 10m height 3.70 at 25m height	2.18	3.98
Nov '96	2.61	2.93	2.29	1.91	Lost	1.98	3.23
Dec '96	2.97	1.78	1.44	1.35	2.38 at 10m height 3.09 at 25m height	3.35	3.38
Jan '97	3.25	2.33	1.99	1.31	2.19 at 10m height 2.80 at 25m height	3.18	3.67
Feb '97	2.66	1.99	1.90	1.90	2.02 at 10m height 2.69 at 25m height	3.37	3.29
Mar '97	3.13	2.42	2.26	2.38	3.09 at 10m height 3.54 at 25m height	4.84	3.53
Apr '97	2.88	1.84	1.65	2.25	2.28 at 10m height 3.29 at 25m height	4.93	3.11
May '97	4.96	3.97	3.09	3.99	3.71 at 10m height 4.81 at 25m height	6.28	4.89
Jun '97	5.83	4.64	3.26	5.00	4.42 at 10m height 5.76 at 25m height	7.31	5.90
Jul '97	5.67	4.80	4.33	4.92	3.94 at 10m height 5.22 at 25m height	7.34	6.17
Aug '97	5.13	4.31	4.03	3.85	4.01 at 10m height 5.17 at 25m height	-	5.34
Sep '97	-	2.96	1.83	2.77	2.20 at 10m height 3.08 at 25m height	-	3.97
Annual Average	3.95	3.34	2.94	2.96	3.21 at 10m height 4.07 at 25m height	4.52	4.21

Table 3.3

Wind energy potential in Kuakata (Sensor Height : 25m)

Month	Monthly Mean Wind Speed (m/s)	Standard Division of Wind Speed (m/s)	Peak Wind Speed (m/s) (Date/Time)	Lull Period (Hours)	Coefficient of Variation	Prevailing Wind Direction
August' 96	5.88	0.65	19.83 (21/08:40 hr)	9.47	0.13	SW
September' 96	3.77	0.57	21.92 (28/07:00 hr)	140.5	0.2	SW
October' 96	2.18	0.46	23.17 (29/20:50 hr)	426.33	0.23	N/NE
November' 96	1.98	0.48	13.17 (5/06:40 hr)	236.33	0.29	N/NE
December' 96	3.35	0.48	9.42 (7/09:10 hr)	12.33	0.16	N
January' 97	3.18	0.44	10.25 (22/13:00 hr)	36.5	0.15	W/SW
February' 97	3.37	0.42	14.42 (1/09:50 hr)	19.33	0.14	SW
March' 97	4.84	0.5	35.25 (23/04:30 hr)	6.67	0.12	W/SW
April' 97	4.93	0.57	35.67 (7/06:40 hr)	7.67	0.13	W/SW
May' 97	6.28	0.63	21.5 (19/15:40)	6.83	0.11	W/SW
June' 97	7.31	0.68	24 (27/07:30 hr)	20.67	0.1	W/NE
July' 97	7.34	0.65	20.67 (10/05:40 hr)	3.09	0.1	W
Average (Aug' 96-Jul' 97)	4.54	0.54		0.26	0.01	

3.2.2 Frequency

The frequency distribution were constructed for one year data collection period. The shape of the frequency curves is generally found to be skewed due to low frequency for high speed values and high frequency for low speed values. Significant variations were observed in the monthly frequency distribution specially between periods of high and low wind speed months. In the case of Patenga station for example, the frequency above 4m/sec was above 70% in June compared to less than 7% in November. The frequency distribution for entire data collection period showed in the Table 3.4.

3.2.3 Diurnal Variation

The diurnal cycles showed that wind speed reaches its maximum during 12 to 15 hours and minimum during early morning. The available data showed that diurnal variation is high in June to August and low in the winter season (November to January).

3.2.4 Wind Direction

Wind Roses were developed by using one year’s wind direction data for all stations. By analyzing the wind rose, it was found that wind blows mainly from two directions (NE and SE) in all stations except at Kuakata. Wind blows from north-east direction in the winter season and from south-east direction during summer season. But at Kuakata, wind blows from south-west direction during the summer and from north-east direction in the winter.

Table 3.4
Percentage frequency of wind speed above 4m/s

Month	Name of Wind Monitoring Stations						
	Patenga	Cox's Bazar	Kutubdia	Teknaf	Noakhali	Kuakata	Char Fassion
July' 96	76.78	65.09	-	70.81	-	-	-
August' 96	65.77	63.66	-	57.97	60.74	81.14	59.46
September' 96	32.82	34.14	36.89	34.49	25.93	45.14	25.3
October' 96	25.07	36.18	43.64	31	16.53	18.01	25.43
November' 96	6.62	24.54	35.49	18.84	5.35	5.53	LOST
December' 96	12.86	19.76	40.3	16.49	5.22	21.26	28.96
January' 97	22.78	25.96	41.73	24.53	6.85	27.15	23.63
February' 97	17.41	20.81	35	21.9	14.58	29.18	21.75
March' 97	32.86	28.52	40.66	26.39	24.13	55.98	35.78
April' 97	27.94	18.7	31.37	15.23	24.05	56.02	37.22
May' 97	58.42	45.56	61.07	33.4	48.48	78.83	55.76
June' 97	73.84	59.56	79.14	40.49	64.7	87.94	70.53
July' 97	70.45	60.37	79.12	48.9695	63.75	90.46	49.55
August' 97	68.67	53.29	66.5099	50.99	43.73	-	55.49
September' 97	-	30.67	45.05	16.11	27.62	-	32.2
Average	42.31	39.12	48.92	36.26	33.20	66.29	45.39

3.3 TERNA Project

TERNA Project was initiated by Bangladesh Atomic Energy Commission (BAEC) and the Rural Electrification Board (REB). Site selection took place in March 1996. In cooperation with GTZ of Germany, measurement systems were installed and the collected data was analyzed as part of a training course for REB-engineers.

TERNA Project has collected wind data in four selected sites with the help of Rural Electrification Board (REB). The sites were located at - (1) Patenga (2) Anwara (3) Teknaf and (4) Feni. The project concluded that “the mean annual wind velocities are to low” [GTZ, 2001]. The monthly average wind speed at Patenga is shown in Table 3.5.

For comparison, the wind speed values of BCAS and GTZ (whatever available) are shown in Table 3.6. The difference proves the point that wind-speed could vary considerably even at a small distance.

Table 3.5
Monthly average wind speed at Patenga [TERNA 1996]

Month	1995	1996
January	-	-
February	-	-
March	6.7	-
April	7.2	-
May	7.7	8
June	8.1	6.9
July	8	8.4
August	7.4	3.5
September	6.8	3.9
October	6.2	3.2
November	4.4	2.6
December	4.2	2.2

Table 3.6
Comparison of Wind Data of BCAS and GTZ

Month	Patenga			
	(GTZ)		(BCAS)	
	1995	1996	1996	1997
January	-	-		3.25
February	-	-		2.66
March	6.7	-		3.13
April	7.2	-		2.88
May	7.7	8		4.95
June	8.1	6.9	8.75	5.83
July	8	8.4	5.87	5.67
August	7.4	3.5	5.32	5.13
September	6.8	3.9	3.36	-
October	6.2	3.2	3.2	-
November	4.4	2.6	2.61	-
December	4.2	2.2	2.97	-

3.4 WERM Project

Sustainable Rural Energy project, in collaboration with BUET (Bangladesh University of Engineering and Technology) and BIT (Bangladesh Institute of Technology), Chittagong, has taken up a study on titled "Wind Energy Resource Mapping (WERM)" in the year 2000. WERM has identified twenty wide resource measuring sites (including existing seven sites of WEST Project) for wind resource assessment.

3.4.1 Main Objectives of WERM

- To identify the most potential wind energy sites of the country.
- To record systematically 5 years wind speed data with automated logging equipment so that any human influence on wind speed data is avoided. The standard statistical wind energy recording format should be used.
- To develop a reliable wind energy resource mapping data-base with related information of wind energy utilization based on the above objectives.
- To determine the standard Weibull characteristics for those locations to design various Wind Energy Conversion Systems (WECS) suitable for Bangladesh.
- To compare various wind speed characteristics with other sources, as for example, from satellite wind mapping data.
- To select suitable Wind-Driven Systems (either independent Electricity Generating Systems or Wind-Diesel Hybrid Systems) based on the above information.
- To procure, install and performance test of those system

3.5 Feasibility Study on R & D on Renewable Energy by IFRD

Recently a project on " Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the Institute of Fuel Research Development (IFRD), of Bangladesh Council of Scientific and Industrial Research (BCSIR). Under this program, wind speed data have been collected in the following sites:

i) Saint Martin (offshore island)
ii) Teknaf
iii) Meghnaghat, Dhaka

The maximum velocity obtained at St. Martins Island is 20 m/s and yearly average wind speed in 4.9 m/s. The maximum velocity obtained at Tecknaf is 16 m/s and yearly average wind speed in 3.8 m/s.

3.5.1 Wind Speeds in Saint Martin's Island

Available wind speeds in Saint Martin's Island are presented in the Table 3.7 below.

Table 3.7

Monthly average wind speeds in the island [IFRD, 2002]

Month	V_{av} (m/s)	V_{max} (m/s)
January	5.08s	23.32
February	4.71	19.78
March	4.29	18.94
April	3.58	20.03
May	5.75	26.30
June	5.96	29.80
July	5.33	24.20
August	5.96	20.40
September	4.79	17.70
October	4.17	15.90
November	3.79	14.50
December	4.08	15.20

3.6 SSE for Wind Energy Resource Assessment

SSE data set is formulated from NASA satellite- and reanalysis-derived wind energy data for the 10-year period from July 1983 through June 1993. Results are provided for 1° latitude by 1° longitude grid cells over the globe. SSE provides –

- ü satellite-derived wind energy parameters
- ü monthly averaged from 10 years of data
- ü data tables for a particular location
- ü color plots on both global and regional scales
- ü global solar energy data for 1195 ground sites

Estimated uncertainties of SSE data set for wind energy parameters are shown in Table 3.8.

Table 3.8

Estimated uncertainty with SSE Wind Energy Data sets [SSE 2000]

Parameter	Global sites RETScreen	Renewable sites RETScreen
Surface Air Pressure (kPa)	3.6%	2.4%
Wind Speed (m/s) at 10 meter altitude	1.9 m/s	1.4 m/s

For comparing SSE data set for wind energy resource assessment, wind speed map of Bangladesh has been generated from SSE web site and analyzed which is shown in Figure 2.10. It can be seen from the Figure 2.10 that SSE data set gives inland wind speed variation between 1 to 2 m/s and in the coastal regions between 2 to 4 m/s. For a particular location, SSE gives lower values in comparison to the ground measured values, e.g. for Chittagong (Latitude 22.35 and Longitude 91.82) the annual average wind speed measured at 10 meter height by Bangladesh Meteorological Department is 2.45 m/s (32-year average) whereas SSE value is 1.4 m/s (10-year Average).

3.7 Wind Resource Assessment of Bangladesh by the SWERA Project

Wind speed measurement errors are commonly downwardly biased due to mechanical wear and physical obstruction effects. The techniques proposed in SWERA involve the use of upper air data sets from weather balloons and radiosondes that are much less prone to measurement errors. The mapped information proposed in SWERA is high resolution and much more valuable than interpolations of wind speed made between measurement sites. Ridges and valleys are often of interest for wind energy whereas, they are poor sites for airports with meteorological stations. The SWERA products will, therefore, be much more reliable, cover a wider area in detail, and give have a much higher value than the existing meteorological statistics.

High-resolution (1-km) annual average wind resource maps and GIS data sets for Bangladesh will be mad available. Accuracy of the resource values is expected to be approximately 10% in wind speed and 20% in wind power at more than 80% of locations. The output data will be based on NREL's Wind Resource Assessment and Mapping System (WRAMS) which uses, as input, analyses of existing surface and upper-air meteorological data sets covering many years of record. Other outputs will include elevation maps at the same spatial resolution (1-km) and scale of the wind resource maps, and maps showing the locations where measurement data were available for analysis.

Risø will carry out a 4 day extended WAsP course for RERC staffs. The course will include training in the theory behind resource modeling and in the program itself. A case study will be carried out and the last day will be used in training the participants in doing the evaluation task. Output: "WAsP Experts" capable of carrying out the validation of the NREL maps using in-country meteorological data.

It is expected that at the end of the project Bangladesh will have:

- access to high-resolution wind resource maps and databases that will support planning for the deployment of a large range of wind technologies, from large utility-scale to small off- grid applications, water pumping, etc.
- the capacity to use the wind data in an effective manner to facilitate wind technology investment.
- an understanding how the mapped resource data was developed

Chapter 4

Hydro Power

Bangladesh is a riverine country with three main rivers (1) Ganges (2) Brahmaputra and (3) Jamuna. About 1.4 trillion cubic meter (m^3) of water flows through the country in an average water year.

Numerous rivers flow across the country which are mostly tributaries of these main rivers which are shown in Figure 2.8. Out of these, 57 rivers are transboundary which originate from India and Myanmar. Apart from the south-eastern region, other parts of the country are mostly flat in nature. Major rivers of the country have high flow rate for about 5 to 6 months during monsoon season, which is substantially reduced during winter. More than 90% of Bangladesh's rivers originates outside the country, due to which proper planning of water resource is difficult without neighboring countries' cooperation. Downstream water sharing with India is a highly contentious issue in Bangladesh.

4.1 Rainfall Pattern

In Bangladesh, the annual average rainfall is about 2,300 mm, which varies from 1,200 mm in the north-west to 5,800 mm in the north-east. Most of the rainfall (80 %) occurs during the months of May/June to September/October.

4.2 Types of Rivers

In Bangladesh, there are three types of rivers –

1. Major and medium size perennial rivers with most of the catchment area outside the national border
2. Medium and small size seasonal internal rivers mainly tributaries and distributaries of the main rivers and
3. Small and medium both perennial and seasonal border rivers

4.3 Medium and Large Hydro Potential

At present only 230 MW of hydro power is utilized in Karnafuli Hydro Station, which the only hydro-electric power plant operated by Bangladesh Power Development Board (BPDB). BPDB is considering extension of Karnafuli Hydro Station to add another 100 MW capacity which will add energy marginally, but will be effective to operate it as a peaking power plant. The additional energy will be generated during the rainy season when most of the year water is spilled. Apart from Kaptai, two other prospective sites for hydro power generation at Sangu and Matamuhuri river are identified by BPDB. But no pre-feasibility study has been made so far. A brief description of these two sites is given below.

4.3.1 Sangu Project

This would be a new Project with an annual energy of about 300 GWh per year. For an installed capacity of 140 MW, the annual plant factor is 23%, and it is estimated that the plant would operate in peaking mode. However, this project needs a detailed environmental, social and economic study in the present day context.

4.3.2 Matamuhuri Project

The Matamuhuri development would be a new project of capacity 75 MW and an approximate average annual energy 200 GWh per year.

4.4 Small Hydro Potential

Several attempts have been made in the past to find out the potential of small-hydro power generation which is believed to be more environment or ecology friendly in comparison to large hydro with dams. Some of the previous studies at different parts of the country are described in the following headings.

4.4.1 BPDB/BWDB Joint Study in the early eighties

To explore the possibility of hydropower from small hilly rivers/streams in the country, a working committee was constituted on February 1981 with officers both from Water and Power Development Board (BWDB) and BPDB. The committee explored 19 prospective sites for possible installation of small hydro power plant. The finding of the committee is summarized in Table 4.1. Later in the month of April 1984 a group of Chinese experts visited Bangladesh and identified 12 prospective sites in the hilly areas of Bangladesh. Out of those 12 sites, Mahamaya Chara, near Mirersharai, close to Dhaka-Chittagong highway was identified as best site for development of small hydro. Accordingly Bangladesh Water Development Board (BWDB) is considering to develop a multipurpose project at Mahamaya Chara. It has been found out from the feasibility study that generation of electricity is possible throughout the year except in the month of April and May (see Table 4.2) and a small Hydro Power plant shall be installed at the down stream foot of the proposed dam for the generation of electricity.

Table 4.1

Potential Small Hydro Sites Identified by BPDB and BWDB Engineers [BPDB]

Sl. No.	District	River/Chara/ Stream	Potentiality of Electrical energy (kW)
1	Chittagong	Faiz Lake	4
2	Chittagong	Chota Kumira	15
3	Chittagong	Hinguli Chara	12
4	Chittagong Hill Tracks	Sealock	81
5	Chittagong	Lungichara	10
6	Chittagong	Budichara	10
7	Sylhet	Nikhan Chara	26
8	Sylhet	MadhabChara	78
9	Sylhet	Banga Pani Gung	616
10	Jamalpur	Bhugai-Kangsa	60 kW for 10 months 48 kW for 2 months
11	Jamalpur	Marisi	35 kW for 10 months 20 kW for 2 months
12	Dinajpur	Badul	24
13	Dinajpur	Chawai	32
14	Dinajpur	Talma	24
15	Dinajpur	Pathraj	32
16	Dinajpur	Tangon	48
17	Dinajpur	Punarhaba	11
18	Rangpur	Bari Khora	32
19	Rangpur	Fullkumar	48

Table 4.2
Average monthly flow and head at Mahamaya Chara [BWDB, 1999]

Month	Flow (meter)	Head (meter)
Jan.	5.8	11.4
Feb.	4.9	9.9
March	5.4	8.1
Apr.	5.1	5.3
May	2.2	4.3
June	2.0	7.8
July	2.0	10.8
Aug	2.0	13.3
Sep	2.0	14.0
Oct.	2.1	14.0
Nov.	2.6	13.7
Dec.	3.8	13.0

4.4.2 Flood Action Plan (FAP)

In 1992 under the Flood Action Plan, Northeast Regional Water Management Project (FAP-6) a preliminary assessment of selected rivers in the Northeast Region has been carried out. The finding for the most promising rivers and sites shows that they suitable for development of run-off-river low head schemes. However, to obtain the required head for generating power a weir or barrage need to be constructed across the river channel. The identified site, along with the flow data, are listed in Table 4.3. Based on mean monthly discharges and an assumed 5m head the hydro potential of the 10 major and medium perennial rivers of the Northeast Region is estimated at about 161MW of continuous power, with an annual energy production of about 1410 GWh. These are perennial rivers with sufficient flow for power generation throughout the year [Werszko 1999].

Table 4.3
Values of Monthly Discharges at representative sites in Major and Medium Size Rivers in Northeast Region of Bangladesh [Werszko 1999]

Name of River and Site	Average Year		
	Min	Mean	Max
Meghalaya Group			
Kangsha at Jariajanjail	16.7	274.3	738.5
Sari-gowain at Sarighat	6.4	128.2	381.9
Barak Group			
Surma at Kanairghat	6.4	524.4	1429.3
Surma at Sylhet	7.8	545.0	1470.1
Kushiyara at Sheola	80.8	660.0	1610.0
Sonai-Bardal at Jaldhup	7.2	138.8	331.6
Tripura Group			
Manu at Manu River Barage	10.4	83.7	182.2
Brahmaputra Group			
Old Brahmaputra at Mymensingh	19.4	704.9	2055.5
Lakhya at Demra	38.8	692.3	1750.9
Old Brahmaputra at Bhairab Bazar	4.3	123.3	452.5

There are also rivers which carry high discharges during the monsoon season and very small during the dry season. They have relatively high longitudinal slope across alluvial fans close to the Indian border. Most of the rivers have little flow in the winter months , and in dry years sometimes they dry out. The suitable scheme would include diversion structure across the river channel, diversion channel along the ridge and the powerhouse at a suitable location that offers sufficient head. 9 rivers are identified here. The mean monthly power distribution from these rivers is given in Table 4.4. The potential annual power output of these rivers is estimated at 35MW and the annual energy production at 307 GWh. The above mentioned power potential analysis is based on mean monthly flows and the results may be on an optimistic side. More dependable flow data (90% or 95% daily flows commonly used) would produce lower figures. However , taking into account the purpose of the hydropower generation in Bangladesh these criteria would need to be studied in detail [Werszko 1999].

Table 4.4

Hydropower Potential in Meghalaya Rivers of Northeast Region (MW)

River	Site	Catchment Area	Estimated Annual Output	
		(km2)	MW	GWH
Someswari	Dugapur	2134	5	43
Jadukata	Saktiakhola	2513	13	115
Jhalukhali	Dalura	448	5	45
Sarigoyain	Lalakhal TG	802	3	30
Lubha	Mugulgul	724	3	27
Dhalai	Khalasadaq	342	2	15
Umium	Chalelhnapur	518	2	20
Bhugai	Hatipagar	453	1	6
Darang	Ghosegaon	381	1	6
		Total	35	307

4.4.4 Bamer Chara Irrigation Project

LGED has implemented Bamer Chara Irrigation Project in Banskhali Thana under Chittagong district with an intention to provide irrigation facilities to 355 hectares of land. A large reservoir has been built in this project for dry season irrigation. Water enters the project area through a gated spill way and flow is controlled at the downstream by a conventional regulator. Currently LGED is examining the flow rate in the spillway and exploring the scope for installing a Micro-hydro power plant at the site [SRE 2001].

4.4.5 Tista Barrage Project

Tista Barrage located in the North-Western part of the country. It is the largest irrigation project of the country. There are at least nineteen potential sites of hydropower generation in the Teesta Barrage Project having 10 sites with more than 2 meter head. The construction of these regulating structures have been completed and most of them are in operation. Still these sites can be investigated for development of small hydro projects. The prospective sites at Tista Barrage is shown in Table 4.5.

Table 4.5

Prospective potential sites in the Teesta Barrage for small hydro power generation [BWDB, 2002]

Serial No	Regulating Structure (number)	Discharge (m^3/sec)	Water Level		Head (meter)
			Upstream (meter)	Downstream (meter)	
A.	Teesta Canal				
1	R3T	154.6	47.9	45.8	2.1
B.	Rangpur Canal				
1	R2R	73.1	43.1	40.9	2.2
2	R4R	53.5	38.9	36.8	2.1
3	R5R	45.2	36.2	34.1	2.1
C.	Bogra Canal				
1	S1B (L)	1.4	43.3	40.5	2.7
2	R1S2B	0.7	41.9	39.3	2.6
3	R1S3B	4.0	41.6	38.6	3.0
4	R1S4B	1.0	41.5	38.3	3.3
5	R1S5B	2.1	41.5	37.5	4.1
6	R3B	73.6	41.3	38.7	2.6

4.4.6 Feasibility Study on R & D on Renewable Energy by IFRD, BCSRI

Recently a project on " Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the Institute of Fuel Research Development (IFRD) of Bangladesh Council of Scientific and Industrial Research (BCSIR).

BCSIR is conducting pre-feasibility study for installing micro or mini hydro project at some of the small water fall sites in the hilly regions of Bangladesh. Flow meters and necessary equipment has already been installed to measure the water flow and head at –

(a) Sailo propat, Bandarban and
(b) Madab Kunda, Sylhet.

Summary of different measurements and calculations for small hydro power generation are shown in Table 4.6

Table 4.6

Summary on Micro Hydro Power Generation in Hilly Districts [IFRD, 2002]

Name of Water Falls	Average Discharge	Approximate Duration of Flow	Probable Fall for Hydro Power Generation	Electrical Power	Annual Energy Production
	(Litre/sec)	(months)	(meter)	(KW)	(kWh)
Sailopropat, Banderban	100	12	6	5	43,800
Madhobkundu, Moulvibazar	150	12	10	15	131,400

Chapter 5

Biomass

Biomass in the most significant energy source in Bangladesh which accounts for 70% of the total final energy consumption in Bangladesh [Islam 2000]. The main sources of biomass fuels are –

1. Trees (woodfuels, twigs, leaves, plant residues)
2. Agricultural Residues (paddy husk, bran, bagasse, jute stick etc.) and
3. Livestock (animal dung).

Land use pattern and different biomass fuels of Bangladesh are described below in separate subsections.

5.1 Land Use Pattern

Approximate land use pattern of the country is

- Agricultural land : 64 %
- Forests : 18 %
- Human Settlement : 8 %
- Water and other : 10 %

Different types of land pattern and forests with approximate percentage are shown in Table 5.1 and remote sensing image map of Bangladesh showing the land use patterns can be found at Figure 5.1.

Table 5.1
Land Use Pattern of Bangladesh, Base 1996 [FRA, 2000]

Total area ('000 ha)					
Land area					Inland water
Forest		Other wooded land		Other land	
Closed	Plantation	Shrubs/Trees	Forest fallow		
720 (5%)	232 (1.6%)	105 (0.7%)	17 (0.1%)	11,943 (82.9%)	1,383 (9.6%)

5.2 Woodfuel

Total wood fuel consumption of the country is 8 million m^3 where domestic cooking accounts for estimated 5.1 million m^3 (63%) annually and the industrial and commercial sectors 2.9 million m^3 annually(37%). Overall, tree and fuels provide 48%, agriculture residues 36%, dung 13% and Peat 3% [FMP, 1992]. Though it is commonly thought that reserve forests are the main source of wood fuel in the country, but from statistics it has been found that village forests are supplying 84% of total consumption which has been shown is Figure 5.2 along with other sources.

At present there is acute shortages of wood fuel in Bangladesh, due to which poor people opt for other inferior type (not compact, difficult to handle) of biomasses like agricultural residues or animal dung. The future projection of demand and supply of wood fuel by Forestry Master Plan (FMP) 1993 is bleak which is shown in Table 5.2.

Figure 5.1

Land Use Pattern of Bangladesh [FAO Forestry web site]

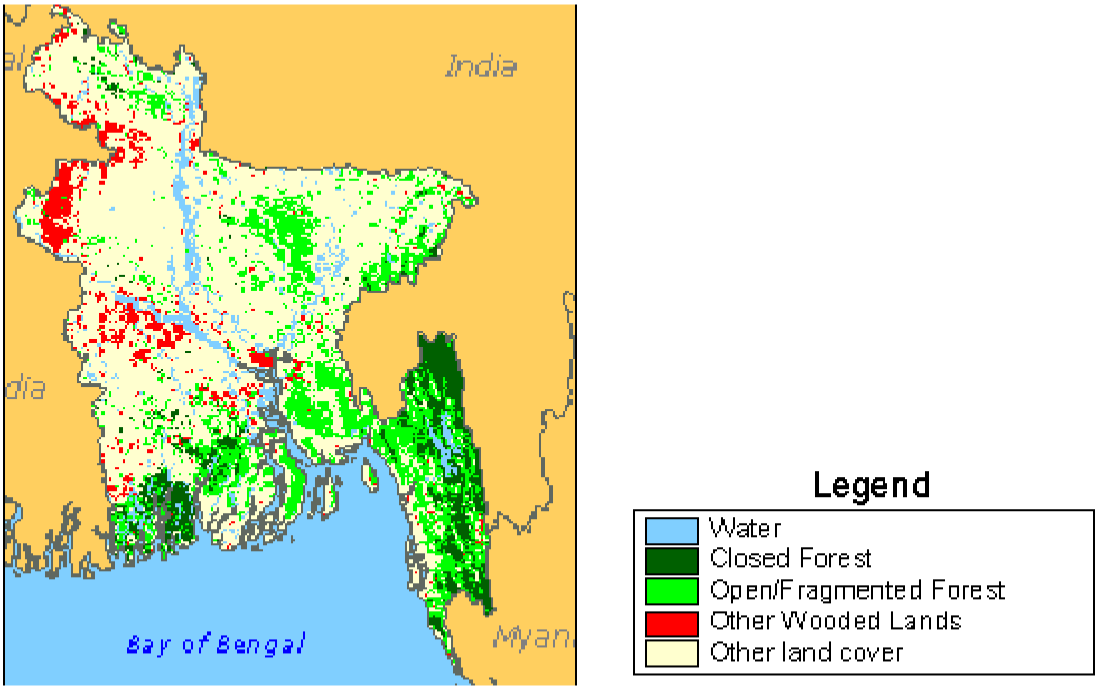


Table 5.2

Woodfuel demand-supply projections up to 2013 (in 1000 m^3 per annum)

Year	1993	1998	2003	2008	2013
Estimated demand	8272	9045	9847	10682	11553
Estimated supply	6135	6450	6787	7212	7742
Balance	-2137	-2595	-3060	-3470	-3811

Table 5.3

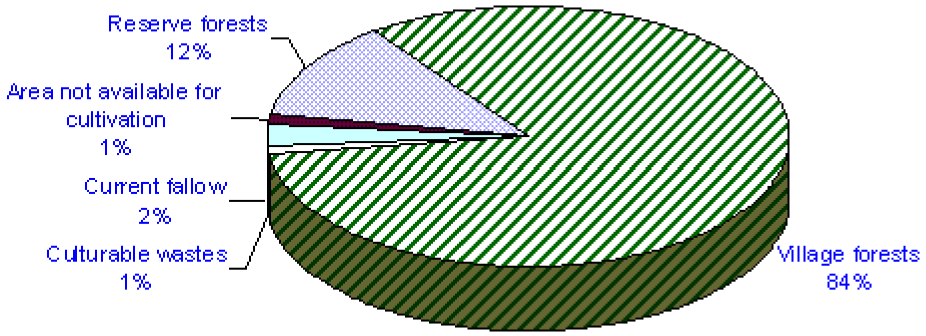
Projection of Woodfuel Supply in 1000 m^3 [Farid et. al, 2000]

Year	1993	1998	2003	2008	2013
Forest lands:	2040(33.2)	1957(30.3)	1857(27.4)	1765(24.5)	1704(22.0)
Natural forests	193(3.14)	196(3.03)	200(2.94)	206(2.85)	211(2.72)
Plantation forests	22(0.36)	36(0.55)	32(0.47)	34(0.47)	68(0.88)
Unclassified state forests	1825(29.7)	1725(26.7)	1625(23.9)	1525(21.1)	1425(18.4)
Non-forest lands:	4095(66.8)	4493(69.7)	4930(72.6)	5447(75.5)	6038(78.0)
Homestead lands	3971(64.7)	4370(67.7)	4806(70.8)	5288(73.3)	5817(75.1)
Strip lands	52(0.84)	51(0.8)	52(0.76)	83(1.15)	85(1.09)
Agroforestry	12(0.19)	12(0.18)	12(0.17)	16(0.22)	16(0.2)
Woodlot	60(0.98)	60(0.93)	60(0.88)	60(0.83)	120(1.55)
Total	6135(100)	6450(100)	6787(100)	7212(100)	7742(100)

figures in parentheses indicate percent of total supply, calculated from FMP 1993

Figure 5.2

Woodfuel Supply By Sources



5.2.1 Forest

Broadly Bangladesh's forests can be divided into three types. (1) Mangrove forests in the coastal delta, (2) hill forests in the interior, and (3) a smaller area of inland sal (Shorea robusta) forest. Significant areas of both hill forest plantations and mangrove plantations have been established. A number of protected areas are under the jurisdiction of the Forestry Department, though most of these have been degraded by illegal logging and forest clearing.

Studies using the latest remote sensing techniques have revealed the present land cover types and their variations over the years. As per these data, the evergreen forest cover in Bangladesh reduced from 7.4% to 3.2% between 1985/86 and 1992/93 [RWEDP 1997]. According to FAO Forestry Web Site (http://www.fao.org/forestry)- the deforestation rate of Bangladesh is about 1.3% i.e. 16,503 hector/year [FAO 2000].

5.3 Agricultural Residues

Agricultural residues contribute significantly to the biomass sector of Bangladesh. Crop production generates considerable amounts of residues that can be used as energy source. Crop residues can be distinguished into field residues and process residues. Field residues are residues that are left in the field after harvesting. They are scattered over a wide area, and are generally used as fertilizer. Process residues are generated during crop processing, e.g. milling. They are available at a central location. Besides being as energy source, crop residues are used for several other purposes, such as fodder, raw manufacturing material. In some cases they are just burned as waste [RWEDP 2001]. In Table 5.4, processed agricultural residues production from different principal corps in the year 1998 are shown.

Table 5.4

Processed Agricultural Residues Production in 1998 [RWEDP]

Crop	Cultivated Area	Total Crop Production	Residue	Residue-to-Product-Ratios	Processed Residue Production	Moisture Content
	(hectares)	(metric tons)		(RPR)	(metric tons)	(%)
Rice	10262707	28292940	Husks	0.27	7,639,094	12
Maize	2548	2660	Cob	0.27	718	7 to 8
Maize	2548	2660	Husks	0.2	532	11
Coconut	32092	89320	Shells	0.12	10,718	8 to 9
Coconut	32092	89320	Husks	0.42	37,514	10
Groundnut	34715	39538	Husks	0.48	18,978	8
Sugar cane	175152	7378710	Bagasse	0.29	2,139,826	49
Jute	577390	1086910	Stalks	2	2,173,820	15
Total	11119244	36982058			12,021,201	

5.4 Animal Dung

Total live animals of Bangladesh in 2000 is estimated as 59.55 million heads (Table 5.5). Of the working cattle 92% was used for cultivation and 0.19% was for transportation [Islam 2000]. In Table 5.6, animal residues or manure are given in annual dry matter production in tons. Dry matter of animal manure is the matter left after the removal of moisture.

Table 5.5

Live Animals in 2000 [FAOSTAT, 2001]

Animals	Head
Cattle	23,652,000
Goats	33,800,000
Sheep	1,121,000
Buffaloes	828,000

Table 5.6

Animal Residues in 1999 [RWEDP, 2001]

Animal	Output (tons)
Buffaloes	757,000
Cattle	24,427,000
Chickens	2,018,000
Total	27,202,000

5.5 Municipal and Industrial Solid Wastes

The main cities of Bangladesh are already over burdened with solid wastes from different sources. According to the World Banks study, the rural population generates only 0.15 kg per capita per day, while their urban counterparts generate 0.4 to 0.5 kg per capita per day [World Bank, 1998]. All city corporations, responsible for waste management, are unable to handle the solid waste properly. But attempts have been made to establish private community-based waste management systems through NGOs.

In the capital city of the country – Dhaka, one of the most populated city in the world with about 10 million inhabitants and area of only 360 km2, waste disposal system has become one of the major civic project. It has been estimated by different sources that each day about 3000 to 5000 tons of solid waste materials are generated in the city. Recently, Waste Concern, NGO involved with waste management, has entered into a Memorandum of Understanding (MOU) with the Dhaka City Corporation under which eight new community-based composting plants are being established throughout the city. Waste Concern have demonstrated how creative ventures, in which non-government and private sector organizations support the work of waste disposal authorities, can tackle the serious problems of waste management and generate revenue for all those involved. Their innovative approach has been recognized internationally and they are requested to provide technical support in India and Palestine [Waste Concern 2001].

At present two projects are under active consideration of Ministry of Environment. Two foreign companies (US & Canadian) have submitted their proposal to convert waste into energy in Dhaka using "Plasma Technology". According to Waste Concern, a leading NGO involved in waste management in the country, conversion of waste to energy may not be financially viable as our waste has low calorific value and high moisture content. Moreover, our waste has 70-75% organic matter [Iftekhar Enayetullah & Maqsood Sinha 2001].

5.5.1 Study by CGEA-ONYX of France

A study was done by CGEA-ONYX of France in October 1997 to find out the possibility to install a waste-to-energy plant at Dhaka. Average calorific value and density of the solid waste were found to be 750 to 950 kcal/kg and 0.35 ton/m3 respectively.

The estimated daily volume, physical composition and major composition parts of solid waste in the city is presented in Table 5.6, 5.7 and 5.8 individually.

Table 5.7

Daily Volume of Solid Waste at Dhaka [CGEA-ONYX, 1997]

Source	Tons
Household	1400
Commercial	600
Industrial	800
Medical	200

Table 5.8

Physical Composition of Solid Waste at Dhaka [CGEA-ONYX, 1997]

Material	% by Weight
Paper	10.0
Glass	1.4
Metal	0.5
Plastic	2.6
Textile	2.5
Wood/Grass	22.0
Ash/Soil	40.0
Food Waste	18.0
Others	3.0
Total	100

Table 5.9

Major Composition [CGEA-ONYX, 1997]

Major Parts	% by Weight
Moisture	45.0
Combustible	20.0
Incombustible	34.7

5.5.2 Feasibility Study by Enviromondial of Canada

Recently, Enviromondial Inc, a Canadian Company, has taken initiatives to conduct a “Feasibility Study” with it’s own costs. Enviromondial expects to sell one power plant upon acceptance of Feasibility Study. They may enter into a possible commercial contract with the appropriate agency under MEMR for the sale of power plant. It is expected, more information regarding the potential of waste-to-energy will be obtained after the successful completion of the study.

Chapter 6

Geothermal

Geothermal energy is the natural heat of the Earth. It is a renewable source of energy if the exploration process don't hamper the ecosystem or emit greenhouse gases.

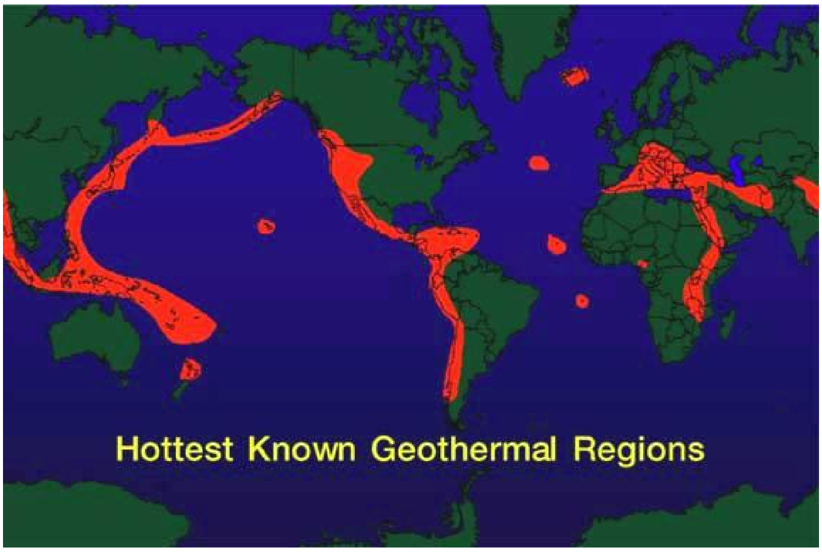
6.1 For Electricity and Direct Use

Geothermal reservoirs that are close enough to the surface to be reached by drilling can occur in places where geologic processes have allowed magma to rise up through the crust, near to the surface, or where it flows out as lava. The crust of the Earth is made up of huge plates, which are in constant but very slow motion relative to one another. Magma can reach near the surface in three main geologic areas:

1. Where Earth's large oceanic and crustal plates collide and one slides beneath another, called a subduction zone The best example of these hot regions around plate margins is the Ring of Fire ñ the areas bordering the Pacific Ocean: the South American Andes, Central America, Mexico, the Cascade Range of the U.S. and Canada, the Aleutian Range of Alaska, the Kamchatka Peninsula of Russia, Japan, the Philippines, Indonesia and New Zealand.
2. Spreading centers, where these plates are sliding apart, (such as Iceland, the rift valleys of Africa, the mid-Atlantic Ridge and the Basin and Range Province in the U.S.) and
3. Places called hot spots-- fixed points in the mantle that continually produce magma to the surface. Because the plate is continually moving across the hot spot, strings of volcanoes are formed, such as the chain of Hawaiian Islands.

There is a known hot salt water spring, known as Labanakhya, in Bangladesh at 5 kilometer to the north of Sitakunda (40 kilometer from Chittagong). Possibility of extracting energy from this site or any other unknown sites can be investigated by Satellite Remote Sensing or Physical Surveys.

Figure 6.1
Hottest Known Geothermal Regions [GEO 2000]



6.2 Heat Pumps

Geothermal heat pumps (ground-source heat pumps) can be installed almost anywhere in the world without a geothermal reservoir. The Earth's temperature a few feet below the ground surface is relatively constant everywhere in the world (about 7 to 15 °C), while the air temperature can change from summer to winter extremes. Unlike other kinds of geothermal heat, shallow ground temperatures are not dependent upon tectonic plate activity or other unique geologic processes. Thus geothermal heat pumps can be used to help heat and cool homes anywhere [Johansson et. al.].

Chapter 7

Marine RETs

Bangladesh has got 710 km long coastal belt along the Bay of Bengal. If the marine RETs become viable option in the future, then the country may harness energy from marine RETs. The main marine RETs are –

1. Tidal
2. Wave and
3. Oceanic Thermal Energy Conversion

7.1 Tidal

Tidal power utilizes the twice daily variation in sea level caused primarily by the gravitational effect of the Moon and, to a lesser extent the Sun on the world's oceans. The Earth's rotation is also a factor in the production of tides.

The normal tidal head rise and fall in the coastal region of Bangladeshi is between 2 and 8 meters as shown in Table 7.1. This tidal range can easily be converted to pollution free clean renewable energy by using the simple low-cost technology of a “tidal wheel” in the sluice gates. The real benefits of this technology however are that it can be applied in a way that simultaneously enables the development of local infrastructure and various resource producing activities such as agriculture and aquaculture along with improved living conditions for the local people [Salequzzaman et. al. 2001]. A demonstration tidal power project is being planned in Sandwip, one of the coastal island of Bangladesh, by ISTP of Murdoch University, Australia. ISTP has developed a feasibility plan for rebuilding a recently damaged sluice gate with a trial paddle wheel [REFOCUS March 2001]. If become successful, the tidal project of Sandwip can be replicated in the other coastal areas and which will usher new light in the region.

Table 7.1

Tidal levels in Coastal Bangladesh [BIWTA, 1999]

STATION	LAT	MLWS	MLWN	ML	MHWN	MHWS	HAT	TD(AT)
Hiron Points	-0.256	0.225	0.905	1.700	2.495	3.175	3.656	3.912
Sundarikota	-0.553	0.036	0.636	1.829	3.022	3.694	4.211	4.764
Mongla	-0.261	0.325	1.194	2.310	3.427	4.296	4.882	5.143
Khal no. 10	-0.444	0.261	1.231	2.664	4.097	5.067	5.772	6.216
Sadarghat	-0.423	0.239	1.100	2.481	3.861	4.722	5.385	5.808
Cox’s Bazar	-0.339	0.205	1.023	1.995	2.967	3.785	4.329	4.668
S. Island	-0.348	0.191	1.045	1.874	2.703	3.557	4.096	4.444
Sandwip	-0.583	0.238	1.634	3.243	4.851	6.248	7.070	7.653
Char Changa	-0.375	0.256	1.060	2.037	3.014	3.818	4.449	4.824
Khepupara	-0.323	0.195	1.025	2.060	3.096	3.925	4.445	4.768
C.Ramdaspur	-0.261	0.189	0.763	2.036	3.309	3.883	4.333	4.594
Barisal	+0.134	0.434	0.692	1.539	2.386	2.644	2.944	2.810
Chandpur	+0.019	0.256	0.493	2.172	3.852	4.088	4.326	4.307
Nalmuri	+0.078	0.370	0.722	2.195	3.669	4.021	4.313	4.235
Narayanganj	+0.458	0.585	0.697	2.770	4.844	4.956	5.083	4.625
Galachipa	-0.159	0.283	0.937	1.764	2.592	3.245	3.689	3.848
Patuakhali	-0.143	0.242	0.740	1.575	2.409	2.907	3.293	3.436

Explanation:
MLWS = Mean Low Water Spring, MHWS = Mean High Water Spring, MHWN = Mean High Water Neap, MLWN = Mean Low Water Neap, ML = Mean Level, AT = Astronomical Tide, LAT = Lowest Astronomical Tide, HAT = Highest Astronomical Tide, TR = Difference between lowest and highest tidal height in “m”.

Figure 7.1
One of many sluice gates in Sandwip that could be utilized for tidal power plant [Refocus 2001]

Tidal Electric Inc. (TE) is one of the major global players in the field of tidal power projects around the world. TE is active in the two neighboring countries of Bangladesh – India and Myanmar in the Bay of Bengal. TE is carrying out feasibility study of a 1000 megawatt tidal power plant in Gujarat, India and target site in Myanmar.

7.2 Wave

Ocean waves represent a considerable renewable energy resource. Waves are generated by the wind as it blows across the ocean surface. They travel great distances without significant losses and so act as an efficient energy transport mechanism across thousands of kilometers.

Energy can be taken from waves almost everywhere but if the waves are to small expenses will be to high. Wave energy is stronger around the poles and around the equator the water contains lesser potential.

Any site in the world with an average wave power level of over 15kW per meter has the potential to generate wave energy at competitive prices [OPD Ltd 2001]. From the atlas shown in Figure 7.2, it can be seen that for Bay of Bengal the value is 8 kW per meter of crest width. So, at present Wave power is not a viable option for Bangladesh.

7.3 Oceanic Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) utilizes the temperature difference between the warm surface sea water and cold deep ocean water to generate electricity. For OTEC to produce a net output of energy, the temperature difference between the surface water and water at a depth of 1000m needs to be about 20°C [Australian RE Website]. From the atlas shown in Figure 7.3, it can be seen that for Bay of Bengal the temperature difference between surface and sub surface (1000m) sea water is between 20 to 22°C. So, OTEC project is expected to be feasible in the Bay of Bengal in the future when the technology will be mature and cost of the system will go down.

Figure 7.2
Annual average wave power in kilowatts per meter of crest width for various sites around the world [OPD Ltd]

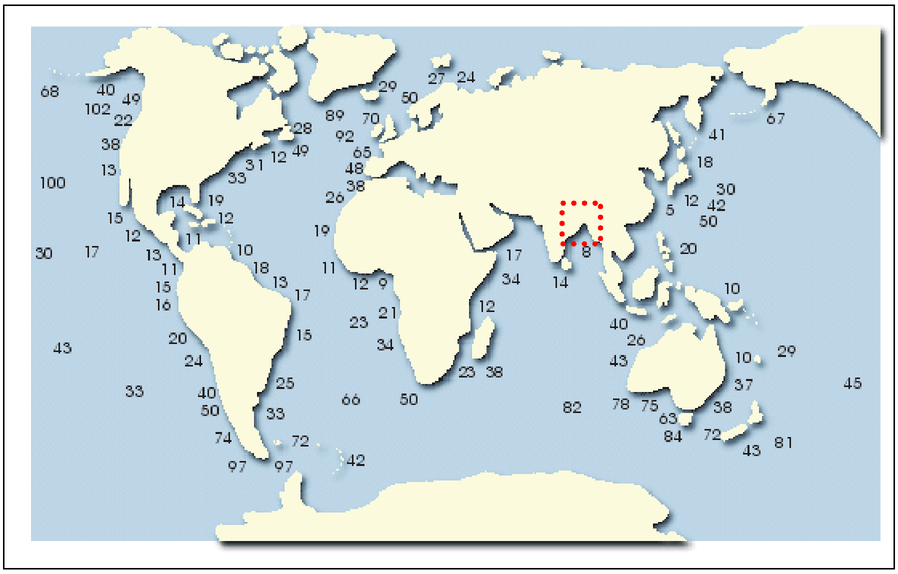
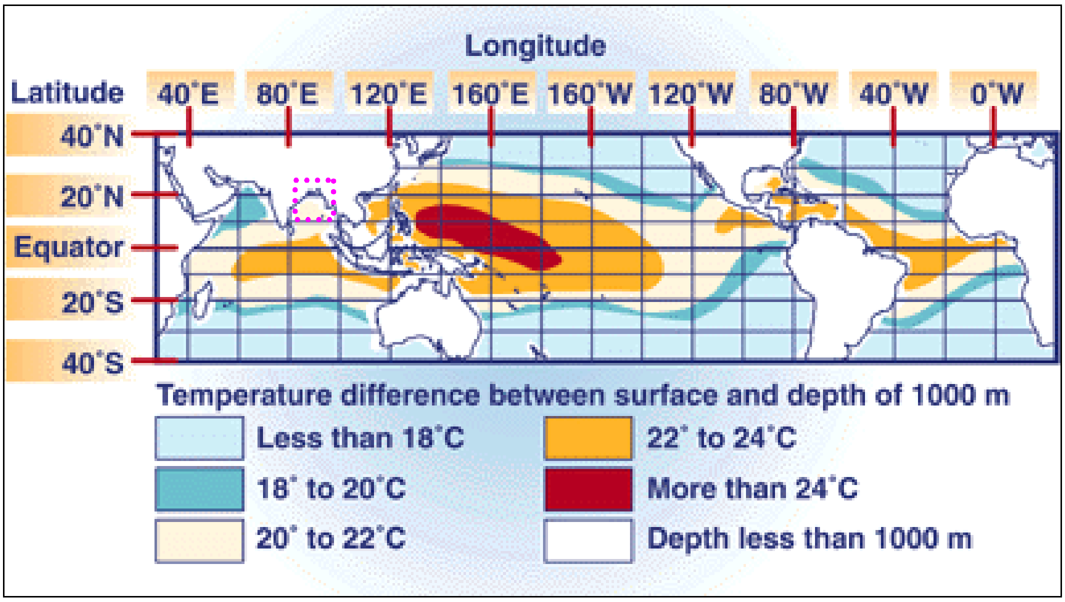


Figure 7.3
Global temperature difference between surface and sub surface (1000m) sea water [NREL]



Chapter 8

Lessons Learned

An attempt has been made in this book to make resource assessment of different renewable energies which is essential for RETs projects. The lessons learnt from the previous chapters are listed below:

- Bangladesh has got ample solar insolation throughout the country. Daily average solar radiation varies between 4 to 6.5 kWh/m^2. Maximum amount of radiation is available on the month of March-April and minimum on December-January. There is bright prospect for applications of solar thermal and photovoltaic systems in the country.

- From the previous studies, it can be inferred that the small wind turbines can be installed in the coastal regions of the country. LGED's ongoing WERM project under "Sustainable Rural Energy (SRE)" program is expected to provide more valuable information regarding Wind Energy potential of Bangladesh for larger projects.

- There is limited potential of small hydro power plants in the hilly regions and existing irrigation project locations. BPDB and Bangladesh Water Development Board (BWDB) should work together to implement a pilot project at any of the prospective regulating structures of Tista Canal system.

- A comprehensive study should be carried out to assess the biomass potential of the country for modern applications like gasifiers. Waste-to-energy project should be given serious contemplation which will not only provide electricity, but also reduce the unpleasant waste disposal problems of metropolitan cities of the country.

- Recently, an initiative has been taken to explore the scope of integrated tidal power plants in the island of Sandwip. If the pilot project becomes successful, similar projects can be replicated to other coastal islands of the country.

- Most wanted UNEP´s Solar and Wind Energy Resource Assessment (SWERA) project will be finished by the year 2004. It is expected that from the middle of the year 2004, energy planners or private entrepreneurs will have clear understanding regarding the solar and wind energy potentials at different parts of the country.

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Being an energy enthusiast, Mr. Mazhar launched "Shakti (http://shakti.hypermart.net)" in 1997 which is an energy related web site of Bangladesh. The whole web site is solely designed, compiled, written and maintained by the author.

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