Energy Strategy for Bangladesh: A Brief Survey with Recommendations

Prepared by

The Energy Panel of

Bangladesh Environmental Network

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Opinions expressed in this report are personal views of the panel members and are not intended to reflect those of their employers or other organizations they are associated with.

The panel regrets any omissions or errors. Their occurrence was inadvertent.

First release: September 1, 2006. Correction: July 28, 2007

Dedication

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This report is dedicated to the memory of those who made the supreme sacrifice for the independence of Bangladesh.

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Glossary

BAPA:	Bangladesh Paribesh Andolon
BAPEX:	Bangladesh Exploration and Production Company
BEN:	Bangladesh Environmental Network
BCSIR:	Bangladesh Council of Scientific & Industrial Research
BPI:	Bangladesh Petroleum Institute
CO_2:	Carbon dioxide gas
E&P:	Exploration and production
ESMAP:	Energy Sector Management Assistance Program
GBM:	Ganges-Brahmaputra-Meghna
GOB:	Government of Bangladesh
GNP:	Gross National Product
HCU:	Hydrocarbon Unit
IAP:	Indoor air pollution
IFRD:	Institute of Fuel Research and Development
IOC:	International oil company
LNG:	Liquefied natural gas
MW:	Megawatt
NEC:	National Energy Commission
NRB:	Non-resident Bangladeshi
PM-10:	Particulate matter of 10 microns
PSC:	Production sharing contract
PV:	Photovoltaic
REB:	Rural Electrification Board
REDA:	Renewable Energy Development Agency
SAARC:	South Asian Association for Regional Cooperation
SHS:	Solar Home Systems
TCF:	Trillion cubic feet
mmcfd:	Million cubic feet per day

Acknowledgement

BEN Energy Panel thanks BEN for the opportunity and trust placed on them to study and make recommendations on a critical issue for Bangladesh. The BEN Coordinator, Professor Nazrul Islam, is particularly thanked for keeping the panel focused on the task at hand and for periodic feedbacks, which were very valuable. The panel is particularly grateful to Professor Saleh Tanveer of Ohio State University, Professor Sajed Kamal of Brandies University, Boston, Massachusetts, who has been active in solar energy efforts for many years and Dr. Saleemul Huq, Director, Climate Change Programme, International Institute for Environment and Development, London, UK, for their succinct comments on a draft of the report circulated to BEN and friends of BEN for feedback. The final report has been modified to reflect their input. Mr. Abdul Fattah of Vienna, Austria, a retired nuclear safeguards expert turned journalist and a keen observer of the Bangladesh energy scene, is thanked for his insightful comments at early stages of the work.

This effort was a labor of love for the panel members. Each has a fulltime job, a family and social lives to attend to. The panel chairperson thanks the other panel members for their support, candid input and tremendous dedication in completing the task despite these challenges.

Finally, Ms. Aeshna Badruzzaman, a senior at University of California at Berkeley, is thanked for reviewing the Abstract and the Executive Summary for clarity and for keeping her father's long-winded sentences to a minimum.

ABSTRACT

The state of the energy sector in Bangladesh is briefly assessed and a number of recommendations are made to move forward. There appears to be no comprehensive energy strategy for the country. Efforts that are underway are fragmented, policies are often inconsistent and non-transparent, legal/regulatory/institutional frameworks are challenged and the discourse on energy issues is unnecessarily polarized, even among the experts. Energy source options for Bangladesh are limited. Natural gas is the primary indigenous modern energy source and its unutilized proved reserve is insufficient to meet long-term internal needs, let alone consider export or guaranteed supply being proposed by certain quarters. The rural energy sector, which is the single largest component of Bangladesh energy sector, has not received sufficient attention. Proposals for open-pit mining of coal are not well thought out and can lead to severe human dislocations, environmental and ecological disasters. Efforts in utilizing modern renewable energy sources are at an early stage. Despite the extraordinary difficulties noted above, BEN Energy Panel is confident that Bangladesh can make significant strides in the energy sector.

The panel recommends that a comprehensive, holistic energy strategy be developed to address the above short-comings. These policies must be arrived at with a national dialog, free from vested agendas and external interference. While existing institutions and frameworks must be strengthened, new institutions, such as a Center for Energy Excellence, should be set up to coherently arrive at economic, technical and policy options in the energy sector. Policies to support the energy strategy must be based on expert, unbiased economic, geological and engineering assessment, and not on speculation or rhetoric. These policies must utilize international best practices, and promote greater self-reliance in energy exploration, development and utilization. It is recognized that foreign direct investment in the energy sector can infuse needed funds and technology but it must be considered within the context of the comprehensive energy strategy developed. It must support the country's long-term interests, including the goal of greater self-reliance in all aspects of energy sector activities. Partnerships with foreign entities must be based on a win-win proposition and only after a careful, transparent and unbiased consideration of proposals from such entities, as well as a careful assessment of their credentials.

On specific energy source options, the panel recommends increased exploration for gas, a much greater attention to the rural sector including the use of modern cook stoves and a significant increase in research and utilization of modern renewable energy sources. The panel recommends that nuclear energy not be considered at this time but that the country remains abreast of technical developments underway in developed countries to minimize the risks associated with nuclear power. The panel strongly recommends postponement of any decision to exploit coal reserves, especially by open-pit mining, until the associated adverse impacts are clearly understood and appropriate technological, legal and institutional frameworks can be deployed to mitigate them. The panel believes that conservation and environmental safeguards should be cornerstones of policies and practices in the energy sector in Bangladesh, along with an overall emphasis on energy efficiency.

Finally, the panel identifies a number of steps for BEN to inform a wider audience of the recommendations of the panel and help implement them.

I. Introduction

By all measures, energy is a major determinant for socio-economic progress of a country. Bangladesh, with over 140 Million people in 55,000 square mile area and one of the lowest per capita Gross National Product (GNP), would require large amounts of energy in its quest to achieve such progress. Unfortunately, the country faces extraordinary challenges in the energy sector. These challenges include a limited choice of energy sources, a shortage of funds and technical expertise to develop current energy sources while seeking alternate sources for the future and lack of systematic policies needed to develop the energy sector in a responsible manner. These challenges have been compounded by the pressures put on decision makers by various internal and external lobbies for their favored positions, an alleged lack of transparency in the decision-making process, an absence of rational discourse based on input from unbiased experts and a shortage of such experts.

Bangladesh Environmental Network (BEN), a volunteer non-profit organization with world-wide membership, convened a panel of volunteers to assess these issues and make recommendations to address them. This report documents the findings and recommendations. Owing to the limited time-frame mandated in preparing this report, the study will by no means be an exhaustive one. Instead, it will rely on published materials or those communicated to panel members by others to make a broad set of recommendations.

BEN Energy Panel recognizes that there have been a number of studies in the past thirty years on Bangladesh energy issues.[1-8] However, no comprehensive energy strategy appears to have emerged. BEN and the panel feel that in view of growing demands for a better life by the people of Bangladesh and recent world events, such a strategy and its implementation are urgently needed; hence this humble effort.

II. Executive Summary

II-A. State of Energy Sector-A Brief Survey

(i) Strategy and Discussion: Bangladesh appears to lack a clear energy strategy, despite several policy initiatives, reports and drafts. Lack of such a strategy can be crippling even in a country that has abundant energy sources, as has been the experience of many developing countries. Bangladesh faces the additional challenge of limited energy sources. A number of factors illustrate the lack of a clear energy strategy in Bangladesh. These include recurring shortages of fuel previously predicted by various sources, frequent power failures, uncertainty in the gas sector, plans to consider open-pit mining of coal despite well-known and documented devastations it has caused elsewhere in the world, no significant progress in the rural energy sector and occasional clamor for nuclear power. Moreover, much of the discussion in the energy sector appears to be based on incomplete data, inadequate analysis or selective use of the available data to support a pre-disposed position.

(ii) Energy Source Options: We briefly review these next.

Traditional Sources and Rural Energy Sector: Approximately, 65% of the energy consumption in the country is from traditional sources, primarily in rural areas where 80% of the people live. Despite this, no significant attention has been paid to this sector. Use of traditional sources, mainly in the usual open-hearth stoves, remains extremely inefficient and result in serious adverse health effects, mostly on women and children.[9-11] Only about four percent of households in Bangladesh have access to piped natural gas and no more than 20% of households have access to electricity networks.[12] The demand for cleaner modern energy sources, such as natural gas is growing.

Gas & Oil: Natural gas is the major indigenous, modern energy source in Bangladesh. Its resource potential is substantial but proved reserve is still small. With rapid growth in the economy and population, both categories of resources will be strained, especially as demand to replace traditional fuels with natural gas continues to grow. This has resulted in a spirited debate on the wisdom of export of raw gas proposed by some. The debate is fueled by a strong disagreement on reserves estimates and inappropriate use of various categories of reserves and resources to bolster arguments by the two contending camps, for and against export of gas.

Only a very limited oil reserve exists in Bangladesh and thus most oil used in the country is imported and is primarily utilized in the transportation sector.

Coal: A significant reserve of coal has been identified.[13] However, Bangladesh is not prepared to mitigate the adverse effects that arise from both upstream (extraction) and downstream (burning) activities in utilizing coal.[14] The proposed open-pit mining in Phulbari raises serious water and environmental pollution concerns.[15] It will result in loss of rich agricultural land in an extremely densely populated country and will displace a large number of people from their homes. Consequently, the net economic benefit of coal mining in Phulbari is being hotly contested.[16]

Nuclear Power: This does not appear feasible in Bangladesh at this time but holds some promise as other energy resources become scarce.

Renewable Sources: Some progress has been made in introducing modern renewable sources such as solar, biogas and wind to Bangladesh[1] but much more remains to be done.

(iii) Institutions and Their Functioning: Institutions to support energy exploration, development and utilization in Bangladesh often function under difficult circumstances and with very limited resources. The associated legal, regulatory and enforcement frameworks are weak. It is alleged that decision-making is often non-transparent. In the

[1] S. Kamal, E-mail to BEN-CC on July 8, 2006, in commenting on the draft report of the panel. Without citing data the correspondent notes that more details can be found in a very recent book, Solar Photovoltaic Systems in Bangladesh: Experiences and Opportunities, edited by M. Eusuf and jointly published by Centre for Advanced Studies and The University Press Limited, in 2005. Due the need to get this report out urgently, the Panel did not have an opportunity to obtain the book for review. However, the reader is encouraged to follow-up.

gas sector, these weaknesses may have hindered a satisfactory resolution of the issue of compensation for the 1997 Magurcharra well blowout in greater Sylhet, nearly a decade after the event. Presumably, these weaknesses also resulted in award of exploration or development rights to foreign companies with limited financial and technological means as evidenced by the 2005 blowouts in Tengratila, Sunamganj.

In the coal sector, institutional weaknesses have resulted in severe problems in the Barapukuria mine project in Dinajpur. The project has been beset with delays and cost overruns allegedly due to a lack of attention to the geological structure leading to design flaws, non-compliance with safety rules and poor oversight. Despite this challenging experience, the government is actively considering a proposal by a foreign company for open-pit mining of coal reserve in Phulbari, apparently without a full consideration of well-known, devastating negative impacts of open-pit mining.

While there are several forums in Bangladesh to discuss technology and policy issues in the energy sector, there is no central institution dedicated to studying these issues in-depth.

Certain conflicts of interest within the existing institutions have magnified the challenges Bangladesh faces in the energy sector. For example, Petrobangla and the Atomic Energy Commission each have dual functions in their respective sector, namely, that of being both the proponent of the sector and its monitor.

(iv) Technical Expertise: Bangladesh has a core group of technical experts (geologists, engineers, economists and scientists) in the energy sector, but a much larger group is needed to develop plans to offer independent technical judgment, to monitor the work of foreign companies and ultimately achieve self-reliance. Energy economists are in short supply and until recently, current economists in Bangladesh have not participated in the energy debate in a significant way. This has hampered a meaningful debate based on economic analysis coupled with technological input. In addition, Bangladesh needs legal experts in energy and environmental sectors.

(v) Energy Plans and Draft Policy Documents: As noted previously, there have been several reports on Bangladesh energy issues and over the years the government has developed plans for the energy sector. Energy plans are also documented in the various five-year plans. However, it is not clear how these plans have been implemented. In the gas sector, the national company, Bangladesh Exploration & Production Company (BAPEX), and its predecessors, including from Pakistan-era, had discovered several gas fields.[2] Fearing a short-fall and citing lack of funds and technology, the government has awarded production sharing contracts (PSC's) to several international oil companies (IOC'S) with a 70/30 split of the gas produced in favor of Bangladesh. The country buys the IOC share with hard currency and sells it to the local market at a discounted price. Some have raised questions on the wisdom of the PSC's as a net economic benefit to the country. The Panel cannot address this issue since it does not know the pricing structure over the life of an IOC production project. However, the panel requests the government

[2] While BAPEX and its predecessors have a greater discovery-to-drilled wells ratio, IOC's have discovered significantly larger reserve volumes.

to examine the net benefit of PSC's in a transparent manner. The 1993 Coal Development Policy also envisions production sharing in the coal sector with Bangladesh government getting only 6% in royalty.

Recently, two draft plans have been proposed, one to develop and utilize renewable sources [17] and the other to exploit the coal reserve.[13] These draft plans are detailed and prescriptive, and would require a large human resource base for implementation. For example, reference 17, the draft plan on renewable energies, recommends setting up a renewable energy development agency (REDA). The section titled, "Responsibilities of REDA" recommends 18 major tasks, many of which will require several individuals to implement them. In view of the shortage of trained technical experts on the subject and lack of funds, it is unlikely that these could be readily implemented. In addition, despite being detailed, the draft plans do not contain significant, in-depth benefit-to-cost analysis.

(vi) Foreign Direct Investment (FDI) and Role of Foreign Entities: Fearing a shortage of natural gas, the governments in the 1990's invited foreign companies to invest in Bangladesh gas sector. This resulted in considerable FDI by international oil companies (IOC's) chosen through the two rounds of bidding for gas blocks and also under direct contracts outside the bidding process. In addition, there are proposals on the table to invest in the coal sector, in power plants and auxiliary industries, such as fertilizer plants.

The experience of foreign involvement in Bangladesh energy sector has a checkered history and questions have often been raised on the net benefit of such involvement. There have been well-publicized allegations of lack of transparency in awarding contracts, including those for gas blocks, outright corruption, and foreign companies applying inappropriate pressures for favorable decisions.[3] In this regard one must note the gas well blowout in 1997, in Magurchara, near Srimangal in greater Sylhet, causing damage worth hundreds of millions of dollars and the recent blowouts in Tengratila, Chatak, Sylhet, resulting in significant damage, estimated to be in millions of dollars, and much hardship for people in the area.

The Magurcharra blowout happened under the supervision of an ill-prepared US operator who sold the block to another operator after the accident and left the country. The issue of compensation still remains unresolved. The Tengratila blowouts happened in one of the workover projects noted in Footnote 3. News accounts indicate that investigation by government committees found the Canadian operator responsible[4] but no compensation has been paid and the company is still in business in Bangladesh. A parliamentary committee concluded that there was graft involved in decisions to award the company the contract.[5] Clearly, weak institutional, legal and regulatory frameworks have contributed to the both Magurcharra and Tengratila incidents and their aftermath. While BEN Energy

[3] These allegations span a period of many years and include the KAFCO scandal, award of some prime gas exploration blocks to a small Irish company of limited resources while applying pressures on larger companies to partner with this company, recent award of old fields for workover to a small, apparently ill-qualified Canadian company and pressures by some companies to allow export of gas despite a limited proved reserve.

[4] The New Nation, February 10, 2005, and Voice of America, August 28, 2005.

[5] The Daily Star, July 22, 2005.

Panel has no means or mandate to study these issues in detail, they point out the need for much greater vigilance by the people and accountability by decision makers.

From the above discussion it is clear that Bangladesh faces monumental challenges in the energy sector. Despite the challenges, BEN Energy Panel believes that the country can make huge strides in the energy sector by using a systematic and coherent approach to meet these. We believe that this will require an open, rational and unbiased deliberation of the issues and a comprehensive strategy. Whatever strategy emerges must result in the following:

1. Sustained economic and social growth in the country,

2. Judicious and optimal utilization of available energy sources in the short-term,

3. Access to or development of alternate energy sources for the long-term,

4. Policies, practices and robust institutions to protect the country's environment and ecology from adverse effects that generally accompany any large-scale energy development activity, and

5. Significant progress towards self-reliance in all phases of energy exploration and utilization.

In order to meet the above objectives, we make the recommendations highlighted in the next subsection and further detail these in Section IV.

II.B Recommendations- Highlights

(i) Energy Strategy: Develop a comprehensive strategy containing the following elements:

- A clear identification of energy sources options, short and long term,

- A choice of utilization options for preferred energy sources, based on sound economic analysis and optimized to the country's best interests,

- Assessment of environmental, land-use, social and resource impacts of each source option and incorporation of safeguards against adverse impacts; no energy source is completely devoid of adverse impacts; therefore, it is important to determine in which cases the potential benefits outweigh the externalities with adoption of appropriate measures,

- Steps to increase the local technical expertise base in the energy sector,

- Strengthening or development of institutional, legal, regulatory and enforcement framework to support the strategy,

- A clear, upfront delineation of cost/benefit both in economic and human terms of each component of the strategy,

- A plan to implement the strategy and monitor implementation, and

- Management of upsides and downsides of the strategy.

(ii) Energy Source Options: Consider the following:

- Judiciously exploit the natural gas reserve. In order to accomplish this, resolve the confusion about gas reserves by using sound geological, engineering and economic analysis and not speculation. Use internationally accepted practices to make utilization, supply, field-development and exploration decisions.

- Significantly increase exploration activities in the gas sector to locate additional resources and add to proved reserves. Utilize both domestic funds and investment by international oil companies, latter via **appropriate** partnerships to benefit from the state-of-the-art-technologies and resources these companies would bring.

- Since current proved natural gas reserve is limited, it should be earmarked for internal economic growth. Export of value-added products should be a priority. The issue of raw gas export can be revisited if future exploration adds significantly to the proved reserve.

- Pay a significantly greater attention to the rural energy sector; it is the largest component of the overall Bangladesh energy consumption. Modernize burning of traditional fuels by such approaches as advanced cook stoves that have benefited other developing countries and install renewable sources as appropriate.

- Postpone any decision to exploit the coal reserve by open-pit mining until the likely severe environmental, land-use and population displacement impacts and resultant economic issues have been clearly understood and only when realistic, proven mitigation plans have been developed. Perform an in-depth cost/benefit analysis of this option. Adverse impact of open-pit mining can last for decades and often cannot be mitigated.

- Address the serious design, compliance and management issues that exist in the Barapukuria coal mining project.

- Do not pursue nuclear power in the near future since issues with technology remain and an adequate framework for its safe implementation in Bangladesh is non-existent. However, do not close out this option permanently. Explore

the experience of China, India and Pakistan in successfully harnessing nuclear energy and remain abreast of developments in the technology.

- Explore increased use of renewable sources such as solar and biogas. Develop a comprehensive research and development program on modern renewable sources. Subsidies may be needed to encourage their growth. However, any mass-scale use will clearly depend on advances in technology and attendant self-sustaining economics.

- Make energy conservation a cornerstone of any energy policy. Reconsider design of energy-guzzling buildings and high rises which are being constructed in the major cities. Include energy-efficiency and renewable energy options as an important component of future infrastructure development.

- In the longer term, consider comprehensive energy source strategies in the context of South Asia and Southeast Asia. The options include, but are not limited to, export of electricity to neighboring countries from gas-fired plants in Bangladesh, gas piped from Myanmar, electricity from coal and nuclear plants in India, hydroelectric development in Nepal, etc. However, given the geopolitical nature of these issues and current state of relationship between various countries in the region, this will be a longer term prospect.

- Beware of untested or unproven, energy source options such as ethanol from corn being touted by some industries and countries as a solution to the energy problem. Recent studies have shown that the analysis in support of this position may be flawed.[18]

(iii) Institutions: Consider the following.

- Set up a non-partisan National Energy Commission (NEC) to arrive at a comprehensive energy strategy for the country. The commission should be drawn from various technological and economic experts, policy planners and decision makers, with a broad but clear mandate.

- Utilize the NEC or a corollary body for the oversight and monitoring of the energy sector, above and beyond the usual government bodies.

- Strengthen the current energy sector institutions, such as PetroBangla and the Atomic Energy Commission. Decouple the proponent and monitor functions of these bodies.

- Strengthen the legal, regulatory and enforcement framework in the energy sector.

- Significantly enhance the internal expertise on environmental, legal and regulatory issues in the energy sector to better support the related institutions and frameworks.

- Set up a Center of Energy Excellence consisting of appropriate expertise to provide a central and permanent location for unbiased discussion, dialog and input to decision makers on energy technology, economics and policy issues.

- Establish a mechanism/platform to actively engage various stake-holders in the discussion and dialog well ahead of making policy choices and decisions.

- If the above recommendations do not appear feasible, the civil society should come together to form a partnership with various segments of the society to discuss the issues rationally and offer options to opinion, policy and decision makers. Such organizations would range from BAPA and BEN to professional groups such as the Society of Petroleum Engineers Bangladesh Section, the Geological Society of Bangladesh and Bangladesh Economics Association.

(iv) FDI and Partnership with Foreign entities: Foreign companies can bring in much needed funds, technology and modern management practices. They can be useful partners in addressing other issues such installing modern drinking water infrastructure and in fighting diseases, as is being done in several parts of the world. On the other hand, some foreign companies have also been alleged to have engaged in less than desirable practices in some parts of the world. However, one must appreciate that they are would-be business partners and are ultimately responsible to their share-holders to make a profit. Also, not all companies are alike. Thus, in order to make the right choices and derive a benefit from partnerships with foreign companies, while avoiding the challenges noted in Item (vi) of Section II-A involving two foreign operators, we recommend the following:

- Internally, examine the need for FDI and partnership with foreign companies using clearly defined criteria in the energy strategy.

- Choice of partners must be based on their documented financial and technological strengths, their record on environmental issues and social commitments, their management practices, their track record of non-interference and respect a country's laws and customs and their willingness to support the goal of self-reliance in the energy sector.

- Consider having companies form consortiums to deal with Bangladesh singly rather than the current fragmented individual deals which are more resource intensive to manage.

- Use clearly identified criteria and a transparent process to make decisions on foreign partners. Make decisions based on expert opinion and stakeholder input. Make decisions in a timely manner.

- Any contracts must include a process for meaningful technology transfer, social support and environmental mitigation.

- Actively monitor the activities of foreign companies to insure compliance with laws and agreements. Here Civil Society has a clear role as should the NEC or a corollary body.

(v) Steps to Self-reliance: In order to facilitate achievement of self-reliance, we recommend the following:

- Encourage and fund local energy entities in exploration and production. Partnerships with foreign companies should be based on the premise of achieving greater self-reliance. Thus, negotiate protocols with foreign energy companies to facilitate a rapid transfer of technology. This should result in the development of in-house expertise at energy related institutions of the country, such as BAPEX and Bangladesh Petroleum Institute (BPI).

- Provide adequate funds to universities in order to encourage the young generation to study subjects impacting the energy sector, such as the sciences, engineering, economics, environmental law and policy, so that they can supply the necessary technical expertise locally.

- Encourage and fund scientists in various government and private academic institutions to carry out innovative research to advance knowledge in all phases of energy generation and conservation appropriate to Bangladesh.

- Draw on non-resident Bangladeshi (NRB) energy experts as resources. Utilize their expertise to expedite technology transfer and help develop in-house expertise, local institutions and educational curriculums.

III. Next Steps for BEN

1. After BEN accepts the report, please forward it to BAPA for review and comments. Consider including in the distribution list Prof. Wahiduddin Mahmud and Prof. Nurul Islam, the Chairs respectively of the two BAPA seminars on January 7, 2006.

2. Consider formation of a joint BEN/BAPA panel to carry forward the recommendations.

3. Alert major national media outlets (electronic and print) to discuss the issues identified in the report, in consultation with the panel chair and members. Seek media support to promote the views expressed in the present document.

4. Initiate the dialog suggested in step (iii) of Section II. Explore the feasibility of holding a National Energy Conference.

5. Initiate a dialog with relevant government and opposition energy sector personalities.

6. Pursue political leaders of all major parties to urge them to include a clear statement on energy policy in their manifestos.

7. Arrange for BEN Energy Panel members to discuss the issues in Bangladesh directly.

8. Have the final document translated into Bangla language for ease of dissemination to a greater audience.

IV. Detailed Report: Energy Source Options for Bangladesh- *Assessment and Recommendations*

IV-A. Traditional Sources:

In Bangladesh, where 80-85% of the people live in rural areas, approximately 65% of the energy consumption is from traditional sources such as wood, twigs, animal dung, jute sticks, etc.[10] Only about four percent of households in Bangladesh have access to piped natural gas and no more than 20% households have access to electricity networks.[12]

Cooking and keeping warm in the winter are the main uses of traditional sources. Open-hearth cook stoves are the norm for cooking. The combustion efficiency of such stoves is low (often less than 10% of the heat produced is utilized). Acute respiratory infection from indoor air pollution (IAP), largely from burning these traditional fuels, causes a significant number of deaths. As in other developing countries,[9] the largest fraction of victims of this in Bangladesh are mostly women and young children.[10] This has led to increasing demands for natural gas, the sole indigenous clean-burning fuel in the country, for cooking and other household activities.

Although Bangladesh has a considerable reserve of natural gas, its amount is limited. An en masse conversion to natural gas for meeting household needs, such as cooking, would cause a severe pressure on this precious industrial/commercial fuel and can retard economic progress. Thus, advanced cook stoves, with far greater combustion efficiency and reduced IAP compared to cook stoves currently used in Bangladesh, appear to be a clear choice to fill the gap till gas reserves increase from exploration and field development activities or other clean-burning energy sources, such as renewables, are introduced on a massive scale.

Improved stove designs have been developed and utilized in many developing countries resulting in a three-fold increase in combustion efficiency (to over 33%).[19] It has been shown that in addition to improved combustion efficiency, such cook stoves can reduce IAP and health risks of traditional fuels. A study on Guatemala showed that improved stoves lowered indoor particulate matter of 10 microns (PM-10), the most damaging constituent of IAP, by 50%.[20]

Advanced cook stoves were designed in Bangladesh and efforts have been made to introduce such stoves in the rural area.[11] The Institute of Fuel Research and Development (IFRD) at Bangladesh Council of Scientific & Industrial Research (BCSIR) has developed examples of improved stoves and implemented projects to promote different models. However, it appears they have not been well accepted. For example, reference 11 reports that a survey of 686 households

[10] Worldwide nearly 3 billion people rely on these sources for cooking and heating homes.

using biofuel found that only nine households had used improved cook stoves; eight were in rural areas. The reasons are not completely understood. Households not using such stoves offered a variety of explanations including a lack of awareness of such stoves and their benefits, unavailability of such stoves locally and their cost. In addition, there may be cultural reasons for the non-acceptance.

We recommend a further assessment of the root causes of non-acceptance of advanced cook stoves with the objective of promoting their use. The experience of utilizing improved stoves in China and India could be helpful in undertaking large-scale projects on such stoves in Bangladesh. It is also very important that the main users of rural energy sources (e.g., women using cook stoves) are well informed of the options and consulted before attempts are made by others to provide them with modern energy sources such as improved cooking stoves.[12] The World Bank is currently conducting a study of feasibility of these stoves in Bangladesh.[21] BEN and BAPA can perhaps partner with the World Bank and others on promoting their use.

IV-B. Natural Gas Sector

Currently, this is the only major indigenous source of commercial/industrial fuel. Nearly 70% of its production is used for electricity generation while almost the rest of it is used to produce fertilizers. Several contentious, interrelated issues have been raised regarding natural gas. These are discussed next.

1. Gas Reserve: There is no consensus on natural gas reserve estimation. Reserves estimates have been at the center of various controversies, namely, the external export vs. internal utilization debate or the internal guaranteed supply vs. other internal utilization options. However, these discussions have often been conducted ignoring basic definitions of various types of reserves and internationally accepted use of these definitions to make supply, field development and exploration decisions. Appendix A provides these definitions and related practices.

   Unfortunately, in discussing Bangladesh gas issues, the definitions and international norms noted in Appendix A are not adhered to. For example, proved and probable reserves are not quoted separately in Bangladesh but are cited together as a composite figure to propose supply decisions such as export. In addition, often 'undiscovered' resource figures generated using probabilistic modeling techniques, are added in to claim a large resource base. Table 1, adopted from reference 5, illustrates this confusing state of affairs.

Table 1

Bangladesh's remaining gas resources as of 2003 cited in ECON-2004

Resource base	Discovered (TCF*)	Undiscovered (TCF)	Total (TCF)
1P or P90%	10.6**	19	29.6
2P or P50%	15.4	42	57.4
3P or P10%	23.1	64	87.1

* TCF: Trillion cubic feet.
** Ref. 5 cites it based on BP annual energy statistics.

In reference 5, the parameters, 1P, 2P and 3P are associated with discovered reserves. These are defined as 1P for proved, 2P for proved and probable, and 3P for proved and probable plus possible. The parameters P90%, P50% and P10% refer to the categories of probabilistic undiscovered resource base.

Reference 5 cites the proved reserve of 10.6 TCF from BP's annual energy statistics.[11] This figure is also cited in the Oil & Gas Journal world reserve estimate for January 1, 2005.[22] Bangladesh government documents do not cite the proved reserve separately.

In contrast with Reference 5, the Hydrocarbon Unit (HCU) of the Ministry of Power, Energy and Mineral Resources, Government of Bangladesh in a recent document cites a proved plus probable reserve of 28.42 TCF.[23] It also cites a recoverable reserve of 20.51 TCF and a cumulative gas production of 6.38 TCF through February 2006. Like other government documents, the HCU document does not cite a proved reserve individually.

Quoting of composite reserves figures and the practice of citing undiscovered resource figures bolster the arguments of those pressing for export. On the other hand, those opposed to export appear to ignore the fact that proved reserves do generally increase with additional field development and exploration. A large reserve addition *can* make export attractive to consider under certain circumstances.

In view of the above confusing and often contradictory data, we will adopt the following using the definitions in Appendix A:

(i) The 10.6 TCF cited by BP and Oil & Gas Journal [22] as the most reliable estimate of proved reserve and 6.38 TCF from the HCU

[11] Generally, 10,000 cubit feet of natural gas is equivalent to one barrel of oil in energy output.

document (reference 23) as the cumulative consumption in addressing the supply issues (internal utilization vs. export and guaranteed supply).

(ii) A proved plus probable reserve ranging from 15.4 TCF in reference 5 to 28.4 TCF in the HCU document for field development.

(iii) The 19 to 87 TCF undiscovered resource figure in reference 5 for exploration.

From the above data, we note that Bangladesh needs to clearly identify her proved, probable and possible reserves using international practices. In addition, following these practices, Bangladesh should only utilize the proved reserve in making supply decisions. We note that in view of the most reliable proved reserve data currently available and the cumulative production noted above, Bangladesh may have as little as 5 TCF of remaining proved reserve, as cited in reference 22 for January 1, 2006. Thus, it is imperative that an aggressive field development effort to increase the proved reserve and exploration effort to discover new reserves be undertaken.

2. Longevity of Bangladesh Gas Reserve: In view of the above confusion about reserves and the attendant export vs. internal consumption debate, the issue of how long the Bangladesh gas reserve will last has been contested hotly for a number of years. Reference 7 studied this issue under two hypothetical scenarios of initial reserve, 13 TCF and 52 TCF at three different rates of increase in production, using 1997 as the base year. Since there is no export, production growth and demand growth are identical. The results reported in reference 7 are cited in Figure 1 of the present report.

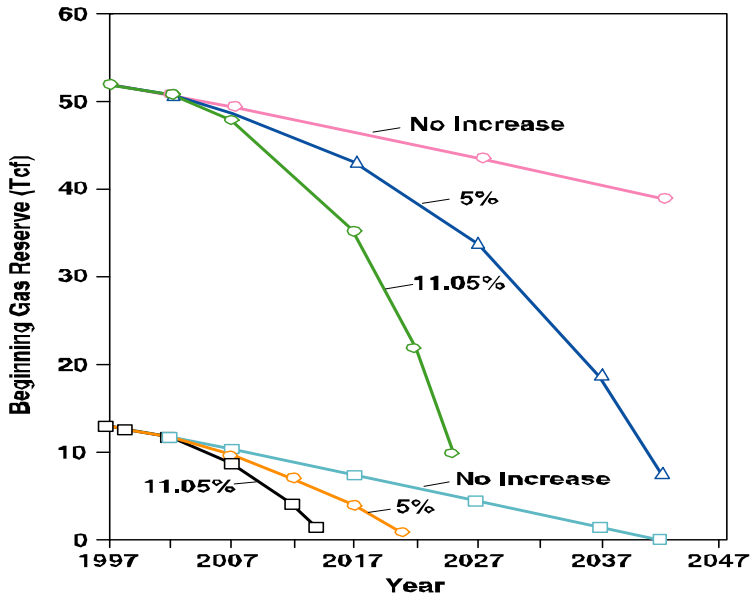

Figure 1. Reserves depletion with two initial reserve assumptions and three production increase scenarios. The historical rate of production increase between 1973 and 1997 was 11.05% annually. (Adapted from Ref. 7)

Using Figure 1, the author of Ref. 7 concluded that, with 1997 as the base year, a 13 TCF reserve would be exhausted around 2014 and a 52 TCF will not last beyond year 2026, if production grew at 11.05 % per year, the compounded rate between 1973 and 1997. Only at a much more moderate growth rate will the reserve last longer. The demand growth rate had declined somewhat between 1997 and 2000 but has picked up recently and is approximately at 10% per year currently. Consequently, unless more reserves are added, Bangladesh gas reserves may be exhausted in less than two decades, perhaps much sooner. Those supporting export were often reluctant to consider this possibility.

However, recent news reports indicate that policy makers in Bangladesh now seem to acknowledge this possibility. In fact, the draft coal policy (reference 13), in arguing for developing alternative sources of fuel such as coal, states that the remaining gas reserve would meet the country's projected energy demand only up to 2015. Even the authors of reference 5, while still insisting that gas export is feasible, have lowered their projected export target from an estimate of 500 million cubic feet per day (mmcfd) in their previous report (reference 4) in 2002 to 100 mmcfd in reference 5.

3. Economics of Gas Utilization Options: There have been several contending views on this with some citing export to India being the most beneficial while others have argued for internal utilization. This issue has not been explored by economists extensively. However, a preliminary analysis by one of the authors (Hossain) cited in reference 8 showed that electricity production will have the highest benefit-to-cost ratio, followed by raw gas export and fertilizer production using current plants. New fertilizer plants were not found to be advantageous by the author. However, the analysis was only a first attempt and did not consider long-term energy security issues exhaustively. Economic parameters have changed since then.

4. Gas Export: Up until recently there was a contentious debate on earmarking a sizeable reserve for export of raw gas to India vs. its internal utilization.[6,7] Gas export was preferred by some quarters, including some international oil companies (IOC's) who are investing in exploration and production in Bangladesh and expect an assured return on what they consider a reasonable time frame.[24] [12] Export would also allow Bangladesh to earn much needed hard currency. However, the issue has not been considered in the context of an overall gas utilization plan that would meet long-term economic objectives, the country's ability to meet its internal needs and an export commitment simultaneously, and ensure the long-term energy security of the nation. The current volume of proved gas reserve and its longevity discussed previously do not appear to support export at this time.

[12] Investments in the hydrocarbon sector may amount to hundreds of millions to over a billion dollars.

5. Guaranteed Supply to Tata: The export debate has now been replaced by a debate on the proposal by Tata of India for a 20-year supply guarantee of gas to industries and plants they are proposing.[25] Reference 25 states, "Tata wants the government to provide it with gas reserve data on daily or regular basis (from the time it starts project implementation). It also asks the government to stop new gas connection in case the gas reserve-production ratio exceeds a certain limit. If there is further problem with gas supply, the government may ration its supply to other consumers and ensure full supply to Tata. And if required, Tata will be supplied gas by closing other entities, its conditions say."[13]

   Tata's investment proposal is complex with many components. It includes an urea plant from gas and a steel plant that could be supplied with gas or coal as power source. Reference 26 discusses Tata's investment and concludes, "economic viability of the fertilizer project may depend largely on subsidized gas supply." The subsidy can be US$ 68 million to US$ 83 million annually, according to reference 26.

6. Production Sharing Contracts (PSC's): In the 1990's, IOC's were invited to invest in Bangladesh gas sector fearing an oncoming gas shortage and citing shortage of funds and technology. However, questions have been raised on advertised benefits of production-sharing and other contracts in the exploration and production (E&P) sector.[8] According to most PSC's, the Government gets 70% and the foreign company gets 30% of the produced gas. With no export allowed, Bangladesh then has to buy company's share in hard currency at the current international market price. The amount has been substantial. For example, in 2002 alone the government paid US$ 161.42 million to purchase the IOC share of the gas.[27] This causes an undue burden on a limited foreign reserve and Bangladesh cannot often pay this amount in a timely manner. Hence, these foreign companies are pressuring Bangladesh to allow them to export gas via pipeline. PSC's allow export of liquefied natural gas (LNG). However, LNG production and export would not be cost-effective in Bangladesh.[8]

   Some allege that IOC investments have resulted in a reduction in the E&P funding by the government of BAPEX, the national E&P company. If true, this likely increases dependence on IOC's for E&P activities, contrary to the preferred objective of self-reliance in the energy sector. In addition, the large amount of hard currency expended per year to pay for the IOC's share of the gas under PSC's raise a serious question, namely, could not these resources be utilized to fund domestic efforts in E&P?

7. Safety, Environmental, Land-use, Pollution and Social Issues: Sufficient attention has ***not*** been paid on these important issues in Bangladesh. The

[13] In addition, news reports indicate that Tata is negotiating to get the gas at a price of one US dollar per 1000 cubic feet. With world market price for natural gas over nine US dollar per 1000 cubic feet in some cases, this is an awfully low price even for a long term contract.

country's gas reservoirs are, in many cases, over-pressured and cause problems for drillers as evidenced by several blowouts that have occurred over the years. Petroleum exploration and production, in general, can cause environmental damage and social problems. Bangladesh is a very densely populated country and many of her gas fields are located near large population centers. In many cases, the gas reserves are on rich agricultural land or in ecologically sensitive areas, such as the Sundarbans. These raise serious land-use, environmental and ecological issues. However, there are technologies which can either mitigate or minimize these problems. These issues are discussed in reference 7 in the Bangladesh context, pointing to potentially serious pitfalls but also to possible technical solutions.

8. Qualification of Some IOC's: Questions have been raised on the financial and technical abilities of some of companies who have been given contracts for drilling, exploration or production. The blowouts in Magurcharra and Tengratila are testimonials to that.

Recommendations on Natural Gas Exploration and Exploitation: We recommend a judicious exploitation of the natural gas reserve. In order to accomplish this, take the following steps:

- Resolve the gas reserve issue utilizing sound geological and engineering analysis and not speculation. This will require a clear delineation of proved probable and possible reserves, individually, as opposed to the present practice of citing proved and probable reserve as a sum and sometimes quoting an entity called 'undiscovered' resource to bolster a reported view that "Bangladesh is floating on gas."

- Use internationally accepted practices to make utilization, field development and exploration decisions. Thus, supply decisions, such as export or guaranteed supply to an internal consumer, should be based solely on proved reserve and field development decisions should be based on a weighted sum of proved, probable and possible reserves. Only exploration decisions should utilize 'undiscovered' resource figures that are derived by probabilistic modeling.

- Since proved unproduced reserve may be no more than 5 TCF, initially utilize the gas internally, and possibly, for power plant development, fertilizer manufacture, or other value-added products, which can also be considered for export. Making a long term commitment, such as export of raw gas or guaranteed long-term supply, do not appear justified at this time in view of the very limited amount of proved un-produced reserve.

- However, revisit the issue of export if proved reserves increase as a result of field development and increased exploration activities.

- Increase field development activities to ascertain the probable and possible reserves and bring them to the category of proved reserve.

- Since the 'undiscovered' resource is estimated to be 19 TCF to 87 TCF, significantly increase the exploration activity to convert it to reserve.

- Re-examine the PSC's whenever they come up for renewal and review new E&P proposals with greater rigor and transparency.

- Explore internal financing options for gas exploration, especially to fund local E&P companies to promote greater self-reliance.

- Do not exclude partnering with appropriate IOC's to explore and produce gas. Seek foreign companies with the sufficient technical and financial resources and a commitment to truly partner with Bangladesh for the long term instead of pushing for a quick return on their investment. Such companies can infuse significant funds and state-of-the-art technology in a timely manner. While some partnerships may have not benefited a given country and allegations abound on damages caused by foreign companies, there have been several win-win partnerships around the world between countries and desirable companies.

- However, agreements with foreign companies must balance their expectation of a reasonable and timely return on their investment with the country's long-term interest. It also must include a significant technology transfer component to promote self-reliance in the gas sector.

IV-C. Coal Sector

1. Present Status: Coal has been discovered in several places in Bangladesh. The known reserve is estimated to be 2.7 billion tonnes with a mineable reserve of 1400 million tonnes.[13] There is one underground mine with a capacity of 1.3 million tonnes per year and a planned 250 MW coal-fired power plant in Barapukuria, Dinajpur. However, the Barapukuria mine project has been plagued with problems. The project was approved in March 1992 and was to be completed in 2001. It was suspended in April 1998 when underground water began rushing in at a depth of 1,100 feet. There were allegations of design flaws and serious, repeated non-compliance with safety regulations by the Chinese contractor.

   However, the project was allowed to continue and trial production began on September 6, 2005.[28] But on October 9 2005, deadly gas flooded the mine forcing its suspension of activities once again.[29] Mine sources put the responsibility for this on the Chinese contractor, CMEC, who allegedly left highly inflammable coal pits exposed to air since May of 2005 in violation of safety rules designed to prevent self-combustion.[29] The mining authority who had taken over the mine three weeks earlier for trial production had

overlooked the situation. A committee chaired by the Barapukuria Mining Company managing director was formed to investigate the incident!

2. Draft Coal Policy Document: Despite the above dreadful experience with coal exploitation in Bangladesh, the draft policy document proposed an ambitious plan to develop the country's coal reserves, primarily by open-pit mining.[13] This is to mitigate the effect of dwindling natural gas reserve, the only major indigenous commercial energy resource currently used for power generation in Bangladesh. The coal policy document claims that the mineable reserve of coal would be equivalent to approximately 37 TCF of natural gas. The document proposes a number of steps for the growth of coal industry in Bangladesh. These include:

   (i) A large-scale development of coal fields in north-west Bangladesh using open-pit mining (labeled, "open-cast" in the document). The target production would be 30 million tonnes per year.
   (ii) Infrastructure development for coal export (up to 66% of the mined amount), in addition to other utilization options.
   (iii) Seeking foreign investments for extraction, since open-pit mining is expensive and public sector funds will not suffice.
   (iv) Foreign investment in coal-fired plants and enhancement of transmission capacity between the western sector and the eastern sectors of the country where the power demand is much greater.
   (v) Significant growth in qualified technical expertise.

   The document does mention that open-pit mining damages large land areas, displace people and causes agricultural losses. However, there is no quantification of these damages and no cost/benefit analysis of the massive coal production it envisions.[14] In order to move forward on its draft recommendations, the government is seriously considering a proposal by Asia Energy Corporation (a United Kingdom company) for open-pit mining in Phulbari. This has become a very contentious issue. In addition to this proposal, Tata of India has proposed an open-pit mining project (reference 25) and asked for a five square km area in Barapukuria of Dinajpur to be awarded to it for the project.

   The above approach reveals a general lack of appreciation and understanding of the adverse effects of coal exploitation in general and of open-pit mining in particular. Coal is perhaps the most polluting fossil fuel. "Serious environmental problems exist at practically every part of the coal system," according to reference 14. While technologies and implementation of strict environmental regulations have reduced these effects, hundreds of miners still die every year and damage from open-pit mining continues. Open-pit mining has caused serious devastation in many parts of the world, including in

[14] This lack of a comprehensive cost/benefit analysis is common to most energy sector proposals in Bangladesh.

developed countries, requiring expensive remediation. However, such remediation often does not restore the land and communities affected to an acceptable state many decades after the mines ceases to operate. Appendix B cites three examples, one from Vietnam, one from Meghalaya, India, and the other from Pennsylvania, USA.[30-32]

Some analysts have predicted similar dire outcomes in Bangladesh. These would include: i) dislocation of large numbers of people (in the order of 100,000) from several square kilometers area in a densely populated country with limited land, ii) elimination of use of rich agricultural land, iii) desertification and iv) generation of acid mine drainage and chemical waste streams that destroys ecosystems in surface water and soils, and pollute rivers and fishing grounds irreparably. Some analysts estimate that despite access to the coal as an energy source, open-pit mining in Phulbari could result in a net, large negative economic impact.[16]

In addition to adverse effects of coal mining, burning coal produces many pollutants such as ash, sulfur dioxide, nitrogen oxide, etc., in addition to CO_2. Technologies now exist to reduce many of the pollutants significantly. Any coal-fired plant in Bangladesh must utilize these technologies. Underground coal gasification, in situ, being explored elsewhere in the world can possibly reduce the need for mining to utilize coal in Bangladesh.

Recommendations on Coal Sector: In view of the above, consider the following:

- Bangladesh should postpone any decision to mine coal on a massive scale, especially by the open-pit technique.
- We recommend that the technical, compliance and management issues in the current Barpukuria project be addressed first.
- We strongly recommend that a clearly defined cost/benefit analysis be performed on open-pit mining taking into account environmental, water, land-use, agricultural, population displacement and human cost issues, and the cost of the mitigation that will be required. The proposals by Asia Energy Corp. and Tata for open-pit mining must be examined thoroughly taking into account these issues and the experience in mitigation around the world.
- We further recommend that Bangladesh investigate alternative coal utilization technologies to exploit its coal reserves, instead of pursuing such harmful options as open-pit mining.
- We also strongly recommend that the almost non-existent legal, regulatory and enforcement frameworks in Bangladesh be strengthened with appropriate laws, regulations and institutions to mitigate the adverse impact of *any* coal utilization activity.
- Any coal mining should be only to meet domestic needs and only after the above issues have been addressed.

IV-D. Nuclear Power

From time to time proposals surface to build a nuclear power plant and here too the discussions turn quickly to arguments which appear intractable. The advantage of nuclear power is that only a small amount of nuclear fuel is needed to produce the energy equivalent to much larger amounts of other fuels. Thus, the fuel cost for nuclear is generally much lower than that for oil and gas. For example, even as far back as 1996 when oil and gas prices were considerably lower than currently, the electricity cost from nuclear in the US was 1.96 cents/kWh-hr vs. 4.14 cents/kW-hr for oil, 3.83 cent/kW-hr for gas and 1.83 cent/Kw-hr for coal.[33] Note that the US has a large coal reserve, making coal competitive with nuclear in terms of fuel cost.

Despite its fuel cost advantage, safety concerns over current designs and the issue of radioactive waste disposal have stymied the growth of nuclear power in the West except in a handful of countries, including France, where nearly 80% of the electricity comes from nuclear. Radioactive waste disposal is not an issue for Bangladesh since most suppliers of nuclear fuel would accept the used fuel rods. Modern plants have vastly improved safety designs and research is on-going to design reactors with advanced and inherently safe fuel design features. These aspects, coupled with concerns with the current high oil and gas prices, have regenerated interest in nuclear power among the public and policy makers in the West. Several developing countries such as China, India and Pakistan, with limited fossil fuel resources, have successfully and safely operated nuclear power plants. It should be noted that production of coal kills more people per year than have been killed from the 1986 accident at Chernobyl in Ukraine which released significant amounts of radioactivity in Europe.[15]

Significant funds will have to be marshaled for the high capital cost of nuclear plants, and an extremely stringent institutional and cultural framework for safety and safeguards will be required to introduce nuclear power; such a framework does not *currently* exist in Bangladesh. However, the experiences in India and Pakistan may be helpful in assessing nuclear. In addition, the growing energy shortage, projected exhaustion of gas reserves and the challenges which will arise from using coal, as discussed elsewhere, may necessitate Bangladesh to consider the nuclear option in the future.

IV-E. Modern Renewable Sources

Research shows that even if the recent yearly rate of electrification (200,000 households[16] per year) is doubled, by 2025 only 50 percent of the present

[15] The other major accident was at one of the reactors at Three Mile Island plant in Pennsylvania in 1979. It was caused by an operator error brought on by unclear procedures coupled with the particular heat exchanger design. The highly radioactive reactor core partially melted but the containment building was able to confine it as designed and *no substantial radioactivity was released to the environment*. The Chernobyl plant had no such containment building.

[16] Households are classified as either landless or marginal farmers (occupying areas between 0.02 and 0.39 ha) or small farm households (occupying areas between 0.4 and 0.99 ha), or medium

population of Bangladesh may be provided with access to electricity.[12] Additionally, it may not be economical to supply grid access in many instances.

Potential main sources of renewable energy in Bangladesh include biogas and solar photovoltaic (PV) in the near term, and wind energy and possibly tidal power in the longer term. Among other renewable sources, hydro-electricity, which is seasonal in nature, accounts for only 3 percent of the total electricity consumption in the country. Due to geographical and topological constraints, further hydro-electricity potential in Bangladesh is quite low.

1. Biogas.

   Past attempts to promote biogas plants (including Grameen Shakti) achieved limited success especially because of low social acceptance of cooking with biogas that is produced from a mixture of human and animal excreta and the limitations in the availability of the latter. However, large-scale dissemination of biogas plants has been possible in China and India. Again, in Nepal, 130,000 high-quality biogas plans have been installed as of 2005 and there are 40 companies that are involved in construction, marketing, installment and providing for guarantees for biodigesters. The by-product of biogas plants, *slurry*, has high fertilizer value and can be used for crop and vegetable production and for feeding fish.[12,34] In Bangladesh, biogas plants can possibly be established for safe disposal of available farm wastes from dairy and poultry firms located in rural areas and producing a benign source of modern energy as well as good quality fertilizer and fish feed.

2. Solar PV

   In terms of solar PV, there have been two substantial interventions in Bangladesh. These are the solar PV project by Grameen Shakti and Narsingdi pilot project by the Rural Electrification Board (REB).[17] Both projects attempted to provide basic needs such as electric lighting. Globally, with gains in production experience and improved manufacturing methods, the costs of PV production have come down significantly.[35] More effort should be undertaken to introduce solar power on a larger scale in Bangladesh.[18] It should be noted that the first photovoltaic (solar cell) project in Bangladesh was opened at Sandwip Island in 1989 to provide power for two different applications, namely, the communication link in a hurricane shelter and medicine preservation.[36]

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farm households (occupying areas between 1.0 and 2.98 ha), or large farm households (more than 3.0 ha) (Haque 1993)

[17] Among other players in renewable energy implementation in Bangladesh are, Infrastructure Development Company Limited, Rahimafrooz Solar, BRAC, etc.

[18] Speakers at a seminar organized by BAPA in Dhaka on August 8, 2006, and reported in the Daily Star on August 9, 2006., noted, "some 80,000 solar energy units in the country are generating nearly 3.5 megawatt electricity that is less than 0.1 percent of conventional energy generation of the country."

3. Rural Electricity and Solar PV's

As noted before, even with major rural electrification efforts and significant progress, a vast majority of rural Bangladeshis have a very remote prospect of obtaining an electricity supply within the next decade or more. United Nations/World Bank Energy Sector Management Assistance Program (ESMAP) defines the niche for solar PV's as areas where satisfactory grid supplies are not available and are unlikely to be available within the next five to 10 years.[35] No doubt, the service provided by PV's is more limited than that provided by the grid. Solar PV's are essentially confined to lighting, with a few additional low-load uses such as cassette players or small TVs used for a few hours in the evening. However, the positive influence of this form of energy is evident in those cases where the only other option would be depending on traditional biomass resources which provides little illumination if at all. Moreover, solar PV's can be considered as an in-between measure in other cases where electrification may reach in the medium term.[12]
Solar PV's are also appropriate in case of small loads because they are freestanding. It is considered a good option especially for dispersed consumers and clusters with combined loads too small to justify grid systems for electrification of individual homes. In this arrangement, solar home systems (SHS) can complement grid-supported conventional methods of power generation for providing electrification services to sparsely distributed un-electrified households. These systems can offer basic electricity services of lighting and operation of small appliances such as televisions, radios or fans. The convenience, safety and high quality service provided by SHS make them generally more desirable than traditional rural energy usages such as candles, kerosene and highly charged automotive batteries.

The options of financing Solar PV's in Bangladesh have mainly been fee-for-service or through credit sales. Innovative consumer credit or fee-for-service arrangements have the potential to serve a greater percentage of households that now lack access to electricity.

4. Wind Power

Coastal areas are the potential locations for windmills. Average inland wind speeds are only 3-5 km/h. The speed is relatively high during the monsoon months when solar radiation becomes unpredictable. Therefore, wind generators could possibly be part of a hybrid system with PV's for electricity generation. However, pilot initiatives for setting up wind energy projects are yet to become successful in Bangladesh.

5. Tidal Power

Generation of electricity using tidal power is very similar to hydroelectric power. Tidal channels are dammed off and tidal water is forced to pass through a narrow gate to which a turbine is connected. The direction of the turbine can be changed to allow both incoming flood tide and outgoing ebb tide to work on the turbine. However, development of tidal power causes

problems to navigation. Siltation behind dams also limits the life of operation. Average life span of hydroelectric station is less than 50 years. Since most tidal channels are used for navigation in Bangladesh, generation of electricity using tidal power will have to be limited to isolated channels inside the Sundarbans area.

Overall, in Bangladesh context, the renewable energy technologies that seem to hold most potential are solar PV and biogas technologies. The potential for wind energy and tidal power will have to be location specific and in some cases, season specific.[37]

6. Environmental Aspects of Renewable Sources

In rural areas, a major portion of biomass fuels is used to meet subsistence needs (for example household cooking), while a small portion is used for productive purposes (for example industries). Since fuel wood is increasingly scarce, a large proportion of agricultural residue and animal dung are used as fuel as well. Fieldwork shows that consumption of biomass fuel beyond regenerative limits has been contributing to environmental degradation.[38] SHS that use solar PV produce no emissions and conserve local resources. Such devices, in contrast to kupis or lanterns, also do not produce smoke or noxious combustion fumes. Such beneficial consequences of SHSs can be categorized as health benefits.

The production of electricity in this off-grid system is silent and there is no emission of harmful gases during the production process. The basic photovoltaic material is silicon, which is considered environmentally benign.

There are, however, some potential environmental hazards associated with the production of more exotic thin-film technologies such as *cadmium telluride* and *copper indium diselenide*. In the case of Bangladesh, manufacturing of PV modules has not taken place yet; however, when this eventually happens, protocols for safe handling of such compounds have to be ensured. Batteries in the solar home systems need to be handled with care.

Another environmental concern related to SHS usage is the safe disposal of used batteries. Specifically, lead-acid type batteries can pose potential health and safety risks as lead persists in the environment and in organic tissue itself. In addition to usage in solar PV's, lead-acid batteries are widely used in Bangladesh in the transportation sector as car batteries and an environmentally safe disposal system has not yet been developed in this sector. Increased usage of SHS, however, will call for safety regulations to ensure safe disposal of all types of batteries including those used in SHS.[12]

7. Renewable Energy Policy Issues

The Government of Bangladesh's (GOB) Renewable Energy Policy was first drafted in 1997 and is yet to be finalized. The latest draft is dated October 2002.[17] Through the formalization of this policy, the GOB can play a more proactive role, especially in terms of solar energy systems expansion

alongside traditional grid extension administered by the Rural Electricity Board. While organizations that provide PV technology depend mostly on international donor grants and soft loans for their capital, local sources of funds are needed for sustainable programs. If commercial sources are not available, the government should provide incentives to private and non-governmental organizations to come forward with innovative ideas for PV program expansion in rural areas. A holistic financial plan is needed to bring the solar photovoltaic technology within the affordable range of low-income households. Public sector programs with targeted subsidies for low-income groups in the rural areas will be needed to cover the cost of the services.

It should be noted, in the context of access to modern energy sources, the discussion on renewable energy issues cannot be complete without the consideration of several key issues that are becoming central to local, regional and global energy policy arena.

For example, while the commercial emission of greenhouse gases such as carbon dioxide is negligible in Bangladesh, from a global perspective, if the trend of widespread usage of solar home systems can be extended in all developing countries including Bangladesh, the emergent global environmental benefit of mitigating greenhouse gases could be quite significant. If such efforts do become reality, this will result in: i) avoidance of fossil fuel use for providing electricity in rural areas; and ii) lowering of solar photovoltaics costs in the global market, stimulating applications in both developed and developing countries that would otherwise have been delayed.[12]

Additionally, incomplete combustion of biomass fuels from indoor cooking stoves, resulting in indoor air pollution is a direct local environmental externality. While improved cooking stoves are yet to become widely accepted in Bangladesh, research shows that the exposure to solar home systems seem to have acted as a sort of catalyst to the women of solar home system households.[38] Therefore, considerations of climate change and gender mainstreaming (as discussed below) are an integral part of energy strategy discussions.

IV-F. A Few Additional Considerations

1. Vulnerability to Climate Change

   Bangladesh is known for its high sensitivity to natural calamities. Additionally, low levels of literacy, poor health delivery systems, low per capita income and high unemployment, already burden the highly populated country.[39] Political instability is a major obstacle to the country's overall macroeconomic growth and stability. Possibilities of climate induced changes, including increases in frequency, duration and intensity of extreme events such as cyclones, droughts and floods, and their expected adverse impacts on the resource base and human activities, would bring the country into an even more difficult position. Targeted social and economic development could possibly contribute to making the country less vulnerable

to these impacts. A comprehensive energy strategy of Bangladesh should recognize these issues.

2. Engendering the Energy Agenda

   Taking a gendered approach means exploring and analyzing an issue from the assumption that women, men and boys have different roles, activities and responsibilities in society.[40] Various surveys conducted in Bangladesh point out that within prevailing gender constraints, access to modern energy sources results in a clear improvement in socio-economic condition for women.[12] The presence of lights and power in the household accelerates the process of learning and exposure to new ideas and information and in a few instances, contributed to an increase in income, especially for women. The positive effect on education and awareness is more apparent in a number of cases, as young girls and boys have time to study and do their homework. This would certainly not have been possible during the day because of the need to work, collect fuel wood/water and take care of younger siblings.

   As discussed elsewhere in this report, the adverse health effects of cooking with traditional (biomass) energy sources fall much more on women and children. High indoor air pollution, as a result of incomplete combustion of biomass fuels is linked to acute respiratory infection, particularly pneumonia and even still-births in women. It should be noted that like most other developing countries, the burden of providing biomass energy sources for domestic use is the responsibility of Bangladeshi women, but they are not well represented in shaping rural energy policies and strategies.[12] These issues should be kept in mind while developing our energy strategy.

3. Technology Transfer in Energy Sector and Role of NRB's

   Many of the technologies utilized in exploring and exploiting modern energy sources discussed in this report are either readily accessible or transferable to a developing country, if a core scientific and technological education infrastructure exists in that country.[41] Despite many challenges to her education system, Bangladesh has managed to maintain, and in some cases grow, such an educational infrastructure. This is evidenced by the significant numbers of graduates from her universities who are employed in technical and academic positions around the world. Thus, in addition to foreign companies, Bangladeshi institutions themselves, properly nurtured as part of the energy strategy being proposed here, can play a significant role in the transfer of energy-sector technologies, thereby promoting the goal of self-reliance in the energy sector. In addition, NRB scientists, technologists and academics can and will be, perhaps, eager to participate in this endeavor and to help develop local expertise and improved educational curriculums in Bangladesh.

4. Hydroelectric Energy through Multinational Approach

   There exists a tremendous potential to generate electricity in upper reaches of various transboundary rivers in Nepal, Bhutan, India, and China. The northeastern states of India are considered to be the "Power House" of India.

There are already 16 large dams in operation in the northeastern states of India and the government of India is planning to unilaterally construct over 100 large dams in this region. Total potential for these planned dams exceeds 90,000 MW of electricity. By comparison, the current production of electricity in Bangladesh is only 4,000 MW. Nepal, Bhutan, and China also share common rivers with Bangladesh, which can be harnessed through a basin-scale integrated water resources planning involving all co-riparian nations. Mini-hydroelectric projects that are acceptable by all stakeholders and are not destructive to ecosystems in the basin could be planned to meet the growing needs of energy in the entire Ganges-Brahmaputra-Meghna (GBM) basin. The GOB should work towards achieving a regional grid for electricity in the GBM basin within the framework of South Asian Association for Regional Cooperation (SAARC). However, given the geopolitical reality of the SAARC region, this will be hard to accomplish.

V. Closing Comments

The present report discusses the challenges in the energy sector of Bangladesh and makes a number of recommendations to overcome them. However, the challenges are more than non-transparency in decision making, alleged interference by vested interests, scarcity of energy resources, and a lack of funds, technology, processes and institutions, enumerated here. The overriding question is: will Bangladesh use the opportunity these challenges accord and take her destiny in her own hands, for it is naive to think others will look out for her? The various groups in the energy sector, currently engaged in an unnecessarily contentious discussion, must come together, not influenced by personal or vested interests but with only the country's interest at heart. They must proceed responsibly to find common ground in order to move forward in a world of ever-accelerating change. BEN Energy Panel very much hopes its report fosters such an outcome.

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Appendix A

Various Reserves Terms and Their Applications

A-1. Reserves and Resources

Proved, Probable and Possible Reserves

Estimates of hydrocarbon amounts with 90%, 50%, and, 10% confidence, respectively, are termed P1 (Proved), P2 (Probable), and P3 (Possible) and together these constitute the "reserve."

In the US, energy companies are required to report accurate reserve estimates to the government. The Securities and Exchange Commission (SEC) defines "proved" reserve as the estimated quantity of hydrocarbons (oil and gas) which geologic and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

Based on economic and cost/benefit analysis, technology is utilized to reduce the uncertainty in probable and possible reserves and move them to the proved category. Energy companies are held strictly to accuracy of their reserves estimates by the SEC since various critical decisions depend on their accuracy. These are noted in Section A-2.

Contingent Resources

Contingent resources are those that have been discovered, but commerciality is contingent on changes in product prices, operating conditions, government approval, available technology, and a resolution of number of other factors such as market, delivery system, partner consent, etc. These resources are also similarly categorized using three confidence levels, low, medium and high. Similar to probable and possible reserves, the confidence level of various can be changed by removing bottlenecks. Exploration activities are used to move resources to reserves category.

Undiscovered Resource

In addition there is a parameter called 'undiscovered resource' that is cited by many. It is arrived at by various probabilistic geological modeling techniques to locate prospects for exploration.

A-2. Application of Reserves and Resource Information

Supply decisions are made based on proved reserve. Field development projects are approved using a weighted sum of proved, probable and possible reserves. Decisions by energy companies to bring a given contingent resources on line by exploration and development initiatives, depend on reducing economic and political uncertainty, and cost/benefit analysis relative to other such resources. As noted above, undiscovered resources are used to locate prospects for exploration activities.

Appendix B

Some Experiences with Open-pit coal Mining

B-1. Qang Ninh, Vietnam [30]

Reference 30 noted the following:

"Coal mining activities, whether licensed or not, are polluting air, water and land resources in Quang Ninh through discharging waste water, dust and overburden into the natural environment. Air pollution is caused primarily by coal dust, which results from blasting in the mines and transporting the coal from mines to coal processing plants to the port. Water pollution, in the form of acidified surface waters (pH 2-4) and river and stream sedimentation, is caused by runoff from overburden disposal sites. Polluted water has also affected Bai Chay Beach, a major tourist area. A number of water sources can no longer be used due to coal mining activities and there is currently a water shortage."

The report goes on to sate: "Open-pit and underground mining are also the main cause of deforestation and land degradation in Quang Ninh. In recent years, lake water levels have fallen while barren hill areas have expanded. During the rainy season, overburden is washed away thereby destroying about 200 ha of agricultural land per year. As a result, hundreds of families have had to move to other areas. Additionally, roads have been destroyed and the hydrology of many small streams and rivers has been altered."

The report cites some of the causes as, a) lack of clear regulations, at least as claimed by mining companies, b) compliance, c) lack of environmental impact assessment, d) mitigation and e) lack of enforcement of regulations. The experience is unlikely to be different in most developing countries, including Bangladesh.

B-2. Meghalaya, India[31]

The State of Meghalaya in India is bestowed with large reserves of mineral resources, including coal, and pristine ecosystems. Most of the coal mining is small and isolated. It is estimated that about 560 million tons of coal exists in 20 major and minor deposits in the state, of which about 40 million tons are present in Jaintia Hills District. During the last few decades there has been an increase in coal mining by local miners using open pit and subsurface “rat hole” mining methods. A study showed that coal mining in Jaintia Hills has resulted in tremendous detrustion to the ecosystems. Mining of coal has caused damage to the landscape and biological communities in enormous ways. A considerable forest area has been converted to open non-forested areas. The study concluded that the coal mining in Jaintia Hills is detrimental to vegetation and general environment of the district.

B-3. Pennsylvania, USA [32]

Pennsylvania is the fourth largest coal producer in the United States. Coal mining, most of which is done using open pit method, started in the 18th century and fueled the industrial revolution in the United States. The environmental legacy of hundreds of years of coal mining in Pennsylvania is over 2,400 miles of Pennsylvania's 54,000 miles of streams polluted by acid mine drainage from old mining operations. Acid mine drainage is by far the single largest source of water pollution in the state.

Even after spending millions of dollars each year for the last several decades, degradation to surface water, groundwater, soil and ecosystems in the mined areas remains a major concern in Pennsylvania, and other states where coal was mined in the past. Modern laws and regulations require that present day mining cannot begin if it might result in harm to the environment. In addition, each mining company is required to deposit sufficient funds to the government to mitigate environmental damage should the company decide to walk away from the mining operation before properly ending all aspects of land reclamation as proposed in the original mining plan.

BEN Energy Panel Members

Dr. Ahmed Badruzzaman, Chair. Dr. Badruzzaman specializes in advanced nuclear techniques and related computational methods used to probe the subsurface, with nearly 30 years experience. He developed several of these techniques and has published numerous papers and given many invited talks worldwide on his research. He currently leads the research and development (R&D) effort on the technology at a major oil company R&D center to support the company's exploration and production operations worldwide. He also coordinates an industry technical interest group on the topic. He has previously led R&D projects at several US energy organizations including a US national laboratory. He has also been associated with major universities in adjunct capacities. He currently teaches a graduate course and supervises Ph. D dissertation at the University of California at Berkeley and serves on the Board of Visitors of the School of Mathematics at Claremont Graduate University, Claremont, CA. In 1994-1997, he was an Adjunct Professor at Texas A&M University, College Station, TX. Dr. Badruzzaman is a Fellow of American Nuclear Society, a Distinguished Lecturer of the Society of Petroleum Engineers (SPE) for 2006-2007 and was a Distinguished Speaker of the Society of Petrophysicists and Well Log Analysts (SPWLA). An advocate of technology transfer, he organized a group of overseas Bangladesh-origin petroleum professionals in 1999-2000 to help set up the SPE Bangladesh Section in Dhaka. He has written and spoken on Bangladesh energy issues on numerous occasions and has organized special sessions on the topic at conferences. A Physics (Honours) graduate of Dhaka University, he earned a Ph.D in Nuclear Science & Engineering from RPI, Troy, New York, in 1979.

Dr. Sarwat Chowdhury works for an international donor agency in New York. She also serves as the *energy & environment* focal point for the Asia and Pacific region of this agency. Previously, she worked for another donor agency in Washington DC and Bangladesh respectively and was the task manger of two environment/energy related projects. She earned a Ph D from U of Maryland in 2003. Her thesis focused on renewable energy policy options with fieldwork on solar home systems in Bangladesh. She has represented Bangladesh in different international forums, including as an invited speaker at the Sixth Workshop of European Network of Bangladesh Studies, May 14-16, 2000 at University of Oslo, Norway and at the Inaugural Session of South Asian Network for Development & Environmental Economics, Nepal 1999. Dr. Chowdhury has authored or co-authored several papers and reports on policy issues in the areas of climate change adaptation, disaster management, natural resource management and mitigation of arsenic in Bangladesh groundwater. Her development career started with working for NGOs like Greenpeace International, Grameen Bank and Bread for the World.

Dr. Selim Hannan has been working in the petroleum industry (Canada, US and internationally) for nearly twenty years. He lived in Canada for 24 years and recently moved to USA. He is currently employed by a major oil company. After receiving his high school and college training at Momenshahi Cadet College and briefly attending Bangladesh University of Engineering & Technology (BUET), he left Bangladesh in 1975 to receive further education abroad. He was then educated in the former Soviet Union (Baku and Moscow), Canada and Scotland and received his doctoral degree from the University of Toronto, Canada. His degrees are in petroleum engineering and geosciences, and he holds an MBA degree. Additionally, his professional interests are in environmental science & engineering, history and finance. In past years he worked for oil companies, well service companies, consulting companies, government and its agencies (federal and provincial; national and foreign) and had been involved in teaching and training of petroleum industry professionals through university and professional organizations. Dr. Hannan's background is well diversified. He worked in different sectors of the oil and gas industry and in far flanged areas of the world such as Siberia and Sahara desert, finally returning to work in the R&D sector for the development of a new energy source to meet future energy demand. He has been engaged in other volunteer activities related to the development of educational sector of Bangladesh.

Mr. Golam Kabir holds a Masters degree in Petro-Chemical Engineering from Baku, former USSR. He had worked in Gas sector of Bangladesh from January 1985 to the end of 1991 when he came to the US. Since then he has been working for major petroleum inspection and testing companies. During his tenure in Bangladesh, Mr. Kabir worked in Bangladesh Gas Fields Company Limited an enterprise of Petrobangla. He has worked as production engineer for major gas fields like Titas, Habiganj and Bakrabad. He also

worked as manager for Kamta Gas Field and planning engineer for Bangladesh Gas Fields Company Limited.

Dr. Mohamed Khalequzzaman holds a Masters degree in Mining Engineering from Baku, former USSR, another MS and a Ph.D. in Geology from University of Delaware, USA. He is an Associate Professor of Geology and the Chair of the Department of Geology & Physics at Lock Haven University, USA. His areas of expertise and research include water-related environmental problems in Bangladesh, water quality and watershed management in central Pennsylvania, USA GIS, and coastal oceanography. He has numerous publications on water and energy-related issues in Bangladesh. Prof. Khalequzzaman is a recipient of several national and international awards. He is involved in community-based environmental research in both Bangladesh and in the USA.