I. PREAMBLE

Bangladesh faces formidable challenges in meeting her energy needs and assuring energy security for the near and long-term future. The nation needs to sustain a 7.8% economic growth to eradicate poverty and meet the economic and human development goals. The energy challenge is thus of fundamental importance to the economic growth imperatives of Bangladesh. The total installed capacity of all power plants in 2005-2006 was 5245 MW, while the generation was 23,703 MKWH, out of which the share of gas was 81.5%, hydro 4.3%, furnace oil 5.3%, diesel 4.07% and coal 4.74%.

The nation has a per capita electricity consumption of about 167 kWh per year, probably one of the lowest in the world. The inventory of energy resources is not substantial and natural gas resources are fast depleting, in the absence of any major new discoveries in the recent past. The effects of price volatility, the sky-rocketing oil prices in the international market, the rising aspirations of people and above all the burgeoning population, have been the major drivers of power demand resulting in a yawning supply/demand gap. The critical issues of long-term energy prospects of Bangladesh hinge on security of energy supply, increased access to electricity, efficiency improvement, and updating and refurbishing of energy infrastructure, Recent discoveries of coal resources in northwest of Bangladesh have opened a window of opportunity for meeting the nation's galloping energy demand.

This study has been commissioned by UNDP-Bangladesh to address the energy security concerns in Bangladesh with the outlook for coal as a major alternative source of energy. Additionally, the environmental issues related to open-pit and underground coal mines vis-à-vis groundwater management need to be examined for facilitating coal mine development in the unique hydrogeological setting of coal deposits of Bangladesh. For the purposes of this study, we have sought to present an overview of the energy landscape vis-à-vis sustainable development, examined the geology of the coal deposits of Bangladesh, and the prospects of their optimum utilization, including the related issues of groundwater management. We have finally spelled out an agenda for actions.

II. ENERGY LANDSCAPE OF BANGLADESH

The energy economy of Bangladesh presents a variegated landscape where primary commercial energy resources include natural gas, oil, coal, hydro-electricity and renewable energy. The resource base, however, is limited and the nation has been depending largely on natural gas, whose prospectivity is perceived to be high.

Table-1 portrays the principal indicators of the energy sector up to 2005-2006.

Table-1

Indicators Of The Energy Sector

Items	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
A. Electricity						
Total Installed capacity (MW)	4005	4230	4680	4680	4995	5245
Maximum Demand (MW)	303	3217	3428	3592	3721	3782
Generation (MKWH)	17021	18221	19179	20820	22006	23703
Consumption (MKWH)	11634	12567	13717	15330	16337	20954
Transmission lines in Kilo metre:	3738	3750	3859	3919	6758	6843
Distribution lines in kilo metre (35KV & below) Electrification (No.):	176179	192140	209932	226232	244104	253729
a) Thana	443	443	443	443	443	443
b) Village	3292	3356	3400	3432	3478	3495
c) Deep/Shallow & Low lift pumps	20467	20687	208812	20928	20993	21020
B. Gas						
Production (MKWH)	10573	11087	11926	12821	13783	14921
Consumption (MKWH) of which						
Electricity	4847	5266	5274	5646	5976	6354
Fertilizer	2505	2232	2716	2628	2661	2523
Industrial	1362	1514	1182	1313	1463	1791
Commercial	115	120	128	136	137	147
Tea garden	18	21	21	23	23	21
Brick field	12	15	15	.	0	0
Domestic	902	1041	1269	1396	1486	1607
Captive power	115	115	741	906	1072	1384
C.N.G	0	0	0	55	103	193
Total Consumption	9876	10324	11346	12106	12921	14020
Total Consumption ('000')	1042	1160	1260	1350	1476	0
C. Petroleum ('000' M. Ton)						
Imports:						
(i) Crude Oil	1337	1224	1335	1252	1252	1253
(ii) Refined oil	2069	2072	2220	2236	2262	2381
(iii) Lube base oil	30	15	2	6	7	17
Total	3436	3311	3557	3494	3521	3661
Consumption	3403	3315	3399	3657	3768	3782

Source: PDB, BOGMC, BPC.
Note: BTU-British Thermal Unit. Cons:- Consumption.

The generation of electricity and installed generating capacity of electricity by fuel types are presented in Tables 2 and 3 respectively.

Table-2

Generation of Electricity (Million KWH) By Type Of Fuel

Year	Hydro	Furnace oil	Natural Gas Coal	Diesel	Total Thermal generation	Total system generation (eastern & western zone)
1995-96	739	238	9994	503	10735	11474
1996-97	719	352	10021	466	11139	11858
1997-98	865	296	10896	825	12017	12882
1998-99	833	142	12278	619	13039	13872
1999-00	1027	405	12603	283	13291	14318
2000-01	971	924	14535	223	15682	16653
2001-02	680	820	16561	160	17542	18221
2002-03	837	992	17173	177	18341	19178
2003-04	803	1215	18531	271	20017	20820
2004-05	868	1305	19547	286	21138	22006
2005-06	934	1406	21055	308	21962	23703

Source: Bangladesh Power Development Board

Table-3

Installed Generating Capacity (MW) Of Electricity By Type Of Fuel

Year	Hydro	Steam turbine		Gas Turbine		Combined Cycle		Total Thermal installed capacity	Total installed generating capacity
		Furnace oil	Natural Gas Coal	N.Gas	Diesel	N.Gas	Diesel		
1995-96	230	170	1668	327	282	180	50	2677	2907
1996-97	230	170	1668	327	282	180	50	2677	2907
1997-98	230	170	1858	327	297	180	29	2861	3091
1998-99	230	170	2068	327	297	180	29	3071	3301
1999-00	230	170	2068	584	230	180	249	3481	3711
2000-01	230	170	2058	742	387	180	238	3775	4005
2001-02	230	170	2058	742	252	540	238	4000	4230
2002-03	230	170	2058	742	252	990	238	4450	4680
2003-04	230	170	2058	742	252	990	238	4450	4680
2004-05	230	170	2268	742	357	990	238	4765	4995
2005-06	230	170	2518	742	357	990	238	-	5245

Note: m.w. - megawatt.
Note: Coal is included from the year 2005-06
Source: Bangladesh Power Development Board

The consumption of commercial energy by major sources is given in Table-4

Table-4

Consumption Of Commercial Energy By Major Sources

(Thousand tons of coal equivalent)

Source	Year					
	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Electricity	1406	1441	1557	1699	1899	2024
Gas	11243	12660	13235	14544	15519	16563
Petroleum	11461	12905	13492	14826	15820	16884
Coal (not actual consumption)	50	120	486	175	199	57
Total:	24160	27126	28770	31244	33437	35528

Notes: Includes intermediate consumption of energy
Source: Compiled by BBS

The statistical data reflect the growing mismatch between demand and supply which can be ascribed to energy resource crunch and geriatric problems with power plants (of the 127 power plants, 39 are over 20 years old). The total recoverable reserves of natural gas are presented in Table-5 which demonstrate the urgent need for switching over to alternative fuels and massive investment in gas exploration.

Table-5

Natural Gas Reserves And Production

Reserve volume as on Nov, 2005)

Sl. No.	Fields	Discovery Year	Reserve Estimate		GIIP	Recoverable	Cumulative Production	Net Remaining Recoverable
			By	Year	PRV+PROB	PRV+PROB	Volume in BCG	Volume in BCF
A. Under Production								
1.	Bakhrabad	1969	IKM	1992	1498.6	1049.0	648.9	400.1
2.	Beanibazar	1981	IKM	1992	243.1	170.2	38.3	131.9
3.	Habiganj	1963	HCU	2001	5139.0	3852.3	1,309.7	2,542.6
4.	Jalalabad	1989	OXY	2000	1195.0	836.5	292.2	544.3
5.	Kailshtila	1962	HCU	2001	2720.1	1903.3	353.9	1,549.4
6.	Meghna	1990	IKM	1992	170.6	119.6	34.8	84.8
7.	Narshingdi	1990	IKM	1992	307.2	215.1	61.5	153.6
8.	Rashidpur	1960	HCU	2001	2002.0	1401.2	371.4	1029.8
9.	Sangu	1996	C/S	1997	1031.0	848.5	351.1	497.4
10.	Saldanadi	1996	Bapex	1996	165.8	116.1	43.7	72.4
11.	Sylhet	1955	PPL	1971	683.9	478.7	179.2	299.5
12.	Titas	1962	HCL	2001	7325.0	5127.5	2468.7	2,658.8
13.	Fenchuganj	1988	PB	1988	404.0	282.8	21.0	261.8
14.	Maulvibazar	1997	Unocal	2000	448.9	359.6	27.1	332.5
15.	Feni	1981	N/B	2000	185.2	129.6	52.3	77.3
Sub Total - A					23519.4	16890.0	6,253.8	10,636.2
B. Non Production								
16.	Begumganj	1977	PB	1984	46.7	32.7	0.0	32.7
17.	Kutubdia	1977	PB	1985	65.0	45.5	0.0	45.5
18.	Semutang	1969	PB	1981	227.0	150.3	0.0	150.3
19.	Shahbazar	1995	Bapex	1996	664.3	465.6	0.0	465.6
20.	Bibiyana	1998	D&M	2000	3144.5	2400.8	0.0	2400.8
	Sub Total-B				4147.5	3094.9	0.0	3094.9
	Sub Total—A+B				27666.9	19984.9	6,253.8	13,731.1
	C. Production Suspended							
21.	Chattak	1959	N/B	2000	677.0	473.9	25.8	448.1
22.	Kamta	1981	N/B	2000	71.8	50.3	21.1	29.2
23.	Sub Total – C				748.8	524.2	46.9	477.3
24.	Grand Total (A+B+C) in BCF				28415.7	20,509.1	6,300.7	14,208.3
25.	Grand Total (A+B+C) in TCF				28.415	20,509	6,558	13.952

C/S = Cairn/Shell N/B=Niko/Bapex

Reserves Based on HCU/NPD

Source: Petrobangla, Ministry of Power, Energy and Mineral resources

The discovery of coalfields in the northwest marks a major milestone in the evolution of sustainable energy development in Bangladesh. Fig-I collates the projections of neat peak load (MW) versus GDP growth rates upto 2025 (Nextant, 2006) and underscores the imperative of augmenting resource base through exploration efforts to find more gas and oil, diversifying with other fuel sources such as coal and by recovering a higher percentage of the in-place reserves.

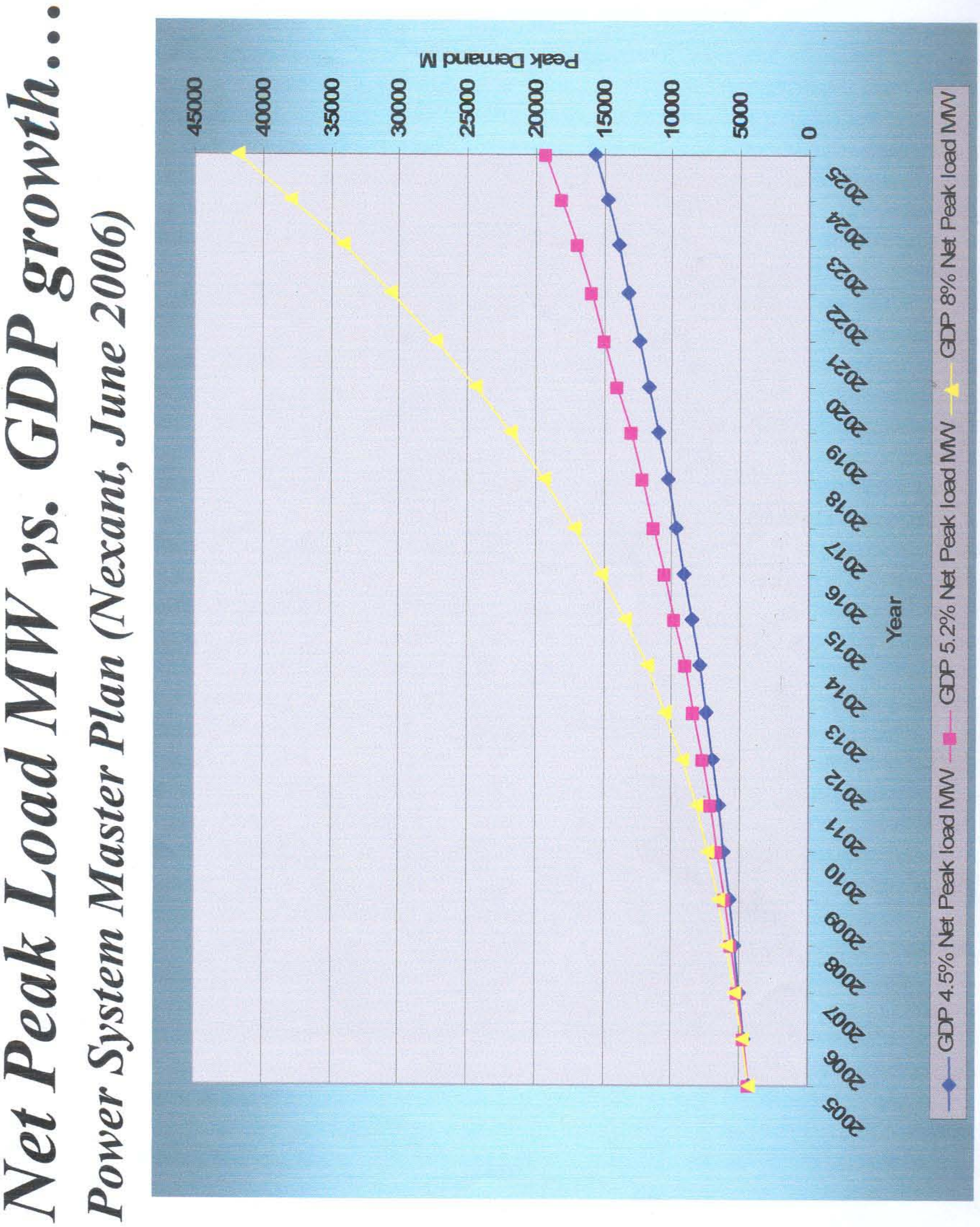
Net Peak Load MW vs. GDP growth…
Power System Master Plan (Nexant, June 2006)
Peak Demand M
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year
GDP 4.5% Net Peak load MW
GDP 5.2% Net Peak load MW
GDP 8% Net Peak load MW

Figure-1

A slew of measures vis-à-vis energy conservation and energy efficiency is clearly mandated which include inter alia the following

- Efficiency improvement – use of CFLs;
- System load reduction through power factor improvement;
- Refurbishing/rehabilitation of power stations so that nameplate capacities could be restored
- Stimulating co-generation in industries
- Demand side load management

Over this century and beyond, Bangladesh will have to strive strenuously to meet the growing demand for energy services resulting from population growth (projections indicate that the population could grow from 130 million in 2001 to 180 million in 2025) and the hoped-for improvement in the living standards of the people below the poverty line (over 49.8% of population live below the national povertylines whose needs seem so great today and whose children and grandchildren represent a growing percentage. Securing access to energy services that is not vulnerable to short and long-term disruption is one of the key milestones towards sustainable development. A diverse mix of energy sources can provide security to the energy sector of Bangladesh and coal will fit this bill admirably as an alternative fuel source. Sustainable development vis-à-vis non-renewable resource use, however, is an oxymoron and yet it represents a myopic view of resources endowment where a static life-time is often wrongly used. Geological availability could be enlarged through exploration making the fuel resource a stretchable continuum and sustainable. The estimated resources of 2.5 billion tonnes of coal in Bangladesh is equivalent to 65 trillion cft of gas which could assure energy security in the medium and long-term. More extensive exploration in northwest Bangladesh could augment the coal resource base significantly.

III. GEOLOGICAL SETTING OF COAL RESOURCES OF BANGLADESH--AN OVERVIEW

Since 1959, five major coal deposits have been discovered in Bangladesh in the Northwest region (Fig-2). These include Jamalganj, Barapukuria, Khalashpir, Phulbari and Dighipara. Geologically, the entire territory of Bangldesh is occupied by the Bengal Basin, which in terms of plate tectonic theory forms a Rifted Passive Margin Basin. The Bengal Basin is gradually closing due to plate destruction in the subduction zone located beneath the Indo-Burma Ranges in western Burma (Salt et al, 1986). The five subsurface Gendwana basins are formed within the Pre-cambrian basement complex during the Permo-carboniferous time. The Gondwana basins are fault-bounded a symmetri type (half graben) basin formed on the basement complex.

The stratigraphic segmentation of these coal basins are given in Tables-6, 7, 8 & 9 which are more or less analogous.

The Gondwana formations in which the coal deposits occur have significant thicknesses as given in the summarised Table-10, while Table-11 gives the in-situ coal resources of Bangladesh.

In general, the coal deposits of Bangladesh are characterised by very thick coal seams which offer major challenges in underground exploitation vis-à-vis resource recovery. The existence of highly charged aquifers of Upper and Lower Dupi Tila (Fig-3) surfaces intractable problems for coal exploitation and groundwater management.

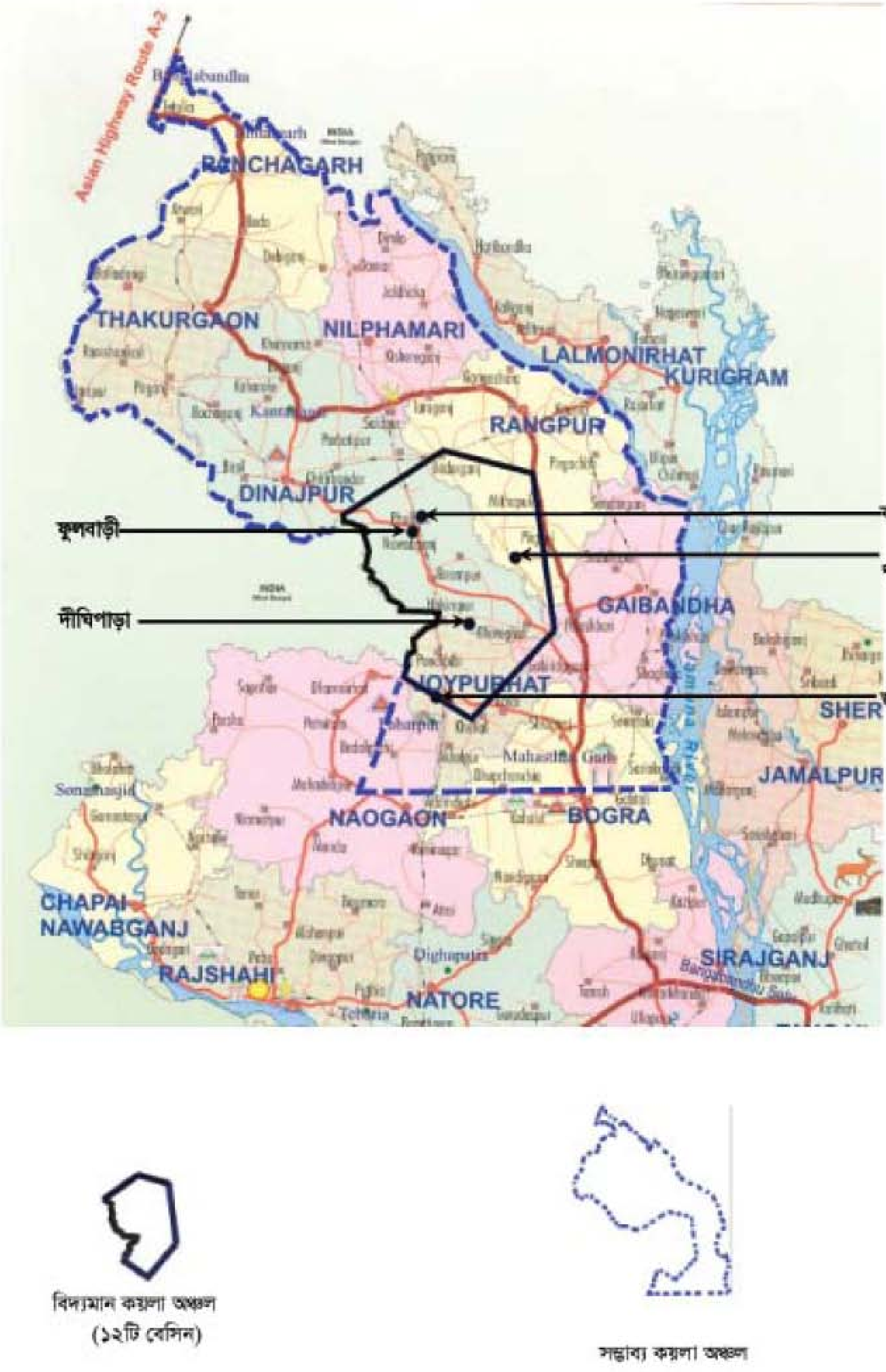
Asian Highway Route A-2
PANCHAGARH
THAKURGAON
NILPHAMARI
LALMONIRHAT
KURIGRAM
RANGPUR
DINAJPUR
বড়পুকুরিয়া
ফুলবাড়ী
খালাসপীর
GAIBANDHA
দীঘিপাড়া
JOYPURHAT
জামালগঞ্জ
SHER
Jamuna River
Mahasthan Garh
JAMALPUR
NAOGAON
BOGRA
CHAPAI NAWABGANJ
RAJSHAHI
SIRAJGANJ
NATORE
বিদ্যমান কয়লা অঞ্চল
(১২টি বেসিন)
সম্ভাব্য কয়লা অঞ্চল

Figure-2

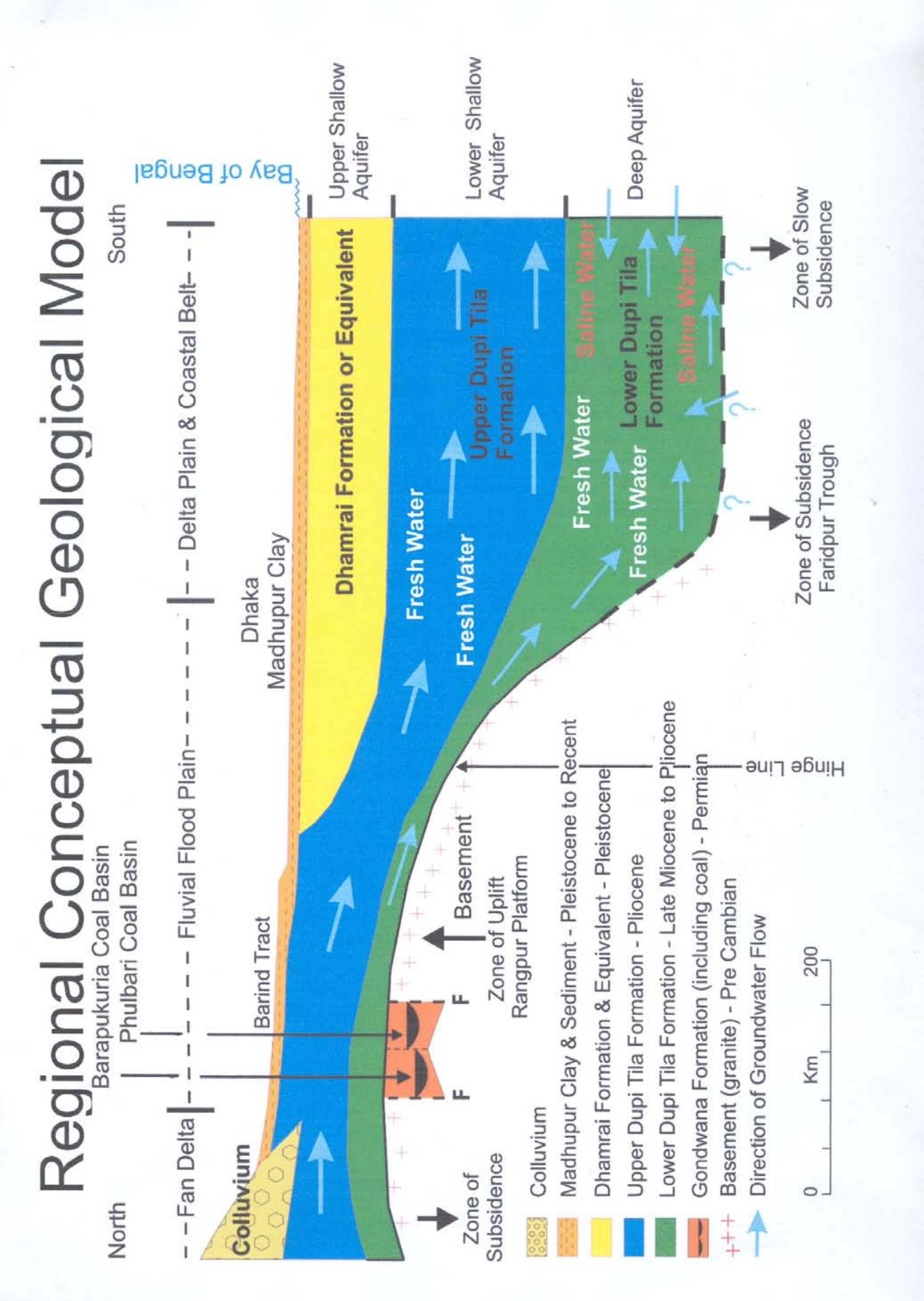
Regional Conceptual Geological Model
North
South
Fan Delta
Fluvial Flood Plain
Delta Plain & Coastal Belt
Barapukuria Coal Basin
Phulbari Coal Basin
Barind Tract
Dhaka
Madhupur Clay
Bay of Bengal
Upper Shallow Aquifer
Lower Shallow Aquifer
Deep Aquifer
Colluvium
Dhamrai Formation or Equivalent
Fresh Water
Fresh Water
Upper Dupi Tila Formation
Fresh Water
Fresh Water
Lower Dupi Tila Formation
Saline Water
Saline Water
F
F
Basement
Hinge Line
Zone of Subsidence
Zone of Uplift Rangpur Platform
Zone of Subsidence Faridpur Trough
Zone of Slow Subsidence
Colluvium
Madhupur Clay & Sediment - Pleistocene to Recent
Dhamrai Formation & Equivalent - Pleistocene
Upper Dupi Tila Formation - Pliocene
Lower Dupi Tila Formation - Late Miocene to Pliocene
Gondwana Formation (including coal) - Permian
Basement (granite) - Pre Cambian
Direction of Groundwater Flow
0
Km
200

Figure-3

Table no.6

Jamalganj coal basin

Period	Formation	Lithology	Hydrogeology
Recent to sub-recent	Alluvium	Clay, silt, coarse, medium and fine sand, coarse, medium and fine gravel	
Pliocene	Dupi-Tila	Coarse to fine gravel and coarse and	Unconfined Aquifer
Upper Oligocene to Miocene	Jamalganj Formation (Surma Group Undiff)	Silt, fine sand, clay, quick sand(i) medium gravel, shaly clay sand-stone, shaly coal	
Eocene	Kopili	Shaly clay and sandstone	
Eocene	Sylhet Limestone Cherra	Limestone shaly clay	
Paleocene to Eocene		Sandstone, shaly clay, silt, shaly coal	
Lower Triassic	Upper Gondwana	Medium to very coarse grained off-white, feld pathic sandstone frequently interbeded with microbracian conglomerates and occasional dark siltstone layers. Matrix is Kaolinitic and it disintegrates in contact with water. Consoli-dation increases with depth.	
Upper or Lower Permian	Lower Gondwana (Raniganj coal measures)	Coal seams in a dominantly sandstone sequence	

Table no.7

Barapukuria coal basin

Period	Formation	Lithology	Hydrogeology
Holocene	Alluvium	Silty clay	
Pleistocene	Barind clay Residum	Clay and sandy clay	
Pliocene	Upper Dupi Tila Lower Dupi Tila	Sand stone, pebbly sandstone and clay / mudstone Sandstone, claystone and mudstone with silica and white clay	Unconfined Aquifer
Permian	Gondwana	Feldspathic sandstone, carbonaccous sandstone and shale, ferruginous sandstone, conglomerates, and coal beds.	
Precambrian	Basement complex	Diorite, granodiorite, quartzdiorite, granite, and diorite gneiss	

Table no.8

Khalashpir coal basin

Period	Formation	Lithology	Hydrogeology
Holocene	Alluvium	Grey sand and silty clay	
Pleistocene	Barind clay Residum	Yellowish grey silt clay	Aquifer
Pliocene	Dupi Tila Formation	Grey to yellowish grey sandstone with uncommon mudstone	Unconfined Aquifer
Miocene	Surma Group	Grey to dark grey mud-stone, sandstone and pebbly sandstone	
Permian	Gondwana Group	Felspathic sand, carbonaceous shale, siltstone, mudstone, coal and conglomerate Basement not seen	

Table no.9

Phulbari coal basin

Period	Formation	Lithology	Hydrogeology
Quaternary	Undifferentiated Madhupur Clay	Alluvial associated with streams Clays, red-brown	Unconfined Aquifer
Tertiary	Upper Dupi Tila Lower Dupi Tila Lower Dupi Tila sands	Interbedded sands and gravels, generally micaceous Mudstone and clays, weathered Intercalated quartz sand and silty clay	Unconfined Aquifer Low permealbility/ aquitard/ confine bed Confined Aquifer
Permian	Gondwana Group	Mudstone and sandstones, weathered Coal seams: Upper, main, lower 1 and lower 2 Mudstones and sandstones, weathered	Low permeabilityu/ Aquitard/ Confined Aquifer (relative to over and underlying materials) Low permeability/ aquitard
Archean		Basement granite/ granodiorite	Not characterized

AVAREGE THICKNESS OF THE COAL SEAMS:

Table no. 10

Coal Basin	Seam-I m	Seam-II m	Seam-III m	Seam-IV m	Seam-V m	Seam-VI m	Seam–VII m	Seam–VIII m
Jamalganj coal Basin	071	2.41	32.16	1.98	1.83	3.10	22.86	-
Barapukuria	4.6	8.2	2.0	18	4.1	36	-	-
Khalashpir	16.95	9.93	1.22	6.96	2.71	2.67	1.66	1.33
Phulbari coal Basin	3.36	10.59	7.31	5.83	4.83	4.66	4.67	11.20
Dighipara	17.00	34.00	7.01	2.00	1.37	-	-	-

Table-11

In-situ Geological Coal Resources of Bangladesh

Location/Field	Year of Discovery	Drilled Well	Depth (Meter)	Proven Reserve (Million Tonnes)	Proven+ Probable (Million Tonnes)
Barapukuria Dinajpur	1985-87	31	118-509	303	390
Khalashpir Rangpur	1989-90	14	257-483	143	685
Phulbari Dinajpur	1997	108	150-240	572	572
Jamalgonj Joypurhat	1962	10	640-1158	1053	1053
Dighipara Dinajpur	1994-95	5	328-407	150	600
Source: BCML, AEC, GSB.					

The coal basins in northwest Bangladesh also can only be exploited in locales with some commonalities of issues: high population density, rich agricultural land, pristine environment and a near-moribund economy. We shall now examine the potential of exploitation of each of the coal basins.

III.1 JAMALGANJ COAL DEPOSIT

Following the discovery of a thick bituminous coal seam at Kuchma near Bogra in 1959, a UN-PAK Mineral Survey Project was initiated in 1961 with the aim to locate coal by deep drilling. Ten holes with a total meterage of 10,000m were drilled preceded by geophysical surveys. The discovery of seven coal seams in the Jamalganj area near the border of Nawgaon and Bogra districts was the outcome of the project. Feasibility study on the exploitation of the deposit was carried out by EPIDC (predecessor of BMEDC) and M/S Fried Krupp of West Germany, M/S Powell Duffryn Services of the UK and Robertson Research International amongst others were appointed as consultants who gave divergent views on the mining method, total resource estimate and cost of exploitation.

The exploitation of Jamalganj coal resources opens up a challenge of many dimensions. Since conventional mining has thus far been ruled out on the grounds of costs, one could explore the possibility of extracting the coal bed methane, if there be any, or the heat content of coal using underground coal gasification (UCG). UCG is a method of converting un-worked coal into a combustible gas. The gas can be processed to remove its CO_2 content, thereby providing a source of clean energy with minimal green house gas emissions. The basic UCG process involves drilling two wells into the coal, one for injection of the oxidants (water/air or water/oxygen mixtures) and another well some distance away to bring the product gas to the surface. The product gas is a combustible syngas containing hydrogen, carbon monoxide, and methane. While the principle is deceptively simple, control of the gasification process has been at the heart of UCG development over many years. High pressure break-up of the coal with water (hydro fracturing), electric linkage etc. have been used with varying degrees of success in both pilot and commercial scale. Currently, two different methods of UCG have evolved and are commercially available. The first is based on technology from the former Soviet Union and uses vertical wells and a method such as reverse combustion, to open up the internal pathways in the coal. The process has been tested recently (1999-2003) in the shallow high-ash coals at Chinchilla, Australia using air and water as the injected gases. The second method, tested in European and American coal seams, is to create dedicated inseam boreholes, using drilling and completion technology adapted from oil and gas production. It has a moveable injection point known as CRIP (controlled retraction injection point) and uses oxygen or enriched air for gasification.

World-wide, UCG activities have stepped up considerably in the recent years. The UK has concluded an extensive review (1999-2004) of the potential of UCG as a method of exploiting its large resources of coal on land and offshore. CSIRO in Australia completed a major study of UCG in 2003 and a joint venture trial has been initiated, in India UCG development is led by the Oil & Natural Gas Company (ONGC) and Gas Authority of India (GAIL). South African utility Eskom has been researching the potential of UCG for its operations in Majuba coal deposit. UCG has synergies with conventional mining by being able to exploit coal reserves that would not be normally mined.

It would be well worthwhile for BCSIR to conduct a pilot/demonstration scale project using UCG at Jamalganj coalfield.

III-2. BARAPUKURIA COAL DEPOSIT

Barapukuria coalfield was discovered by the Geological survey of Bangladesh (GSB) in 1985 in the drill hole GDH-38, which encountered a coal seam at a depth of 159m. The coal reserves estimated in Barapukuria is 303 million tonnes (Wardell Armstrong, 1991). In addition to this about 86 million tonnes is considered as inferred resources. Studies suggested that coal mining is technically as well as economically feasible and underground mining was selected. On the basis of consultant’s opinion, the Government of the Republic of Bangladesh decided to establish an underground coal mine at Barapukuria in 1994, at a production rate of 1 Mt/year. Barapukuria is facing serious problems from the very early stage of development. A water inrush occurred in 1996 during development of the central district. After a long period, with the help of heavy duty pumps, mining development work was resumed, but as a result the central district had to be sealed and abandoned in the area. During trial production in the 1^{st} slice, coal face No 1110, sudden roof fall and heavy gas emission occurred and one coal face had to be sealed. Nevertheless they are producing coal from only one face at the rate of on average 3000 tonnes/day.

Location, extent and accessibility

Barapukuria Coalfield is situated within the Barapukuria village of Hamidpur Union Council under Parbatipur thana, Dinajpur district, at a distance of about 50 km southeast of Dinajpur town. The coalfield has an areal extent of about 5.25 sq. km; an extension of 1 to 1.5 sq. km area to the South face has been suggested (Wardell Armstrong, 1991). The coalfield contains 7 coal-bearing seams with a total thickness of 74.14m. Seam-VI has a thickness varying from 29.4 to 41.00 m and 36.41 m on the average.

III.2.1 BARAPUKURIA COAL MINE

The first coal mine in Bangladesh, Barapukuria commenced coal production in September 2005. The mine development and construction including shaft sinking by freezing, was executed by CMC of China who, along with Xuzhou Coal Mine Group Corporation (XMC), signed a production, maintenance and management contract in June, 2005 for producing 4.75 million tonnes of coal within a period of 71 months. Despite many trials and tribulations, including sealing of a coal face 1110 with complete equipment due to spontaneous heating, problems of hot water, high temperature, the mine has been producing coal, albeit below capacity, and supplying coal to the 250 MW thermal power plant of Bangladesh Power Development Board (BPDB) at Barapukuria. During 2006-2007, a total of 0.388 Mt of coal was produced. The coal deposit, comprising seven seams, is overlain by Upper and Lower Dupi Tila aquifers. Only seam-VI (average thickness of 36m) is currently being mined by longwall mining in the top slice with a thickness of 2.8 to 3.2m. While multi-slice longwall, with wirenetting between the slices, had been conceptually suggested the mining of subsequent slices could be compounded by severe ground control problems (due to presence of unworked coal blocks/barrier in the upper slice) and overall ground movement leading to massive subsidence on the surface and excessive water inflow from the aquifer above. Even if the mine can exploit with difficulty 2 slices, the resource recovery may be less than 10%.

One could envisage a partial extraction system below the first slice using either room and pillar system or the single entry retract longwall system which was attempted at Selby coalfield, UK in working below the water-bearing Bunter sandstone. In any event, this would nor permit of resource recovery greater than 10-12%.

Under the circumstances, the feasibility of exploitation of the entire deposit by open pit method merits serious consideration, if not review. This would also allow of recovering coal reserves in seams-I, II, III, IV, and V besides uprating the scale of operation.

The Barapukuria Coal Mine management team certainly deserves to be commended for their heroic efforts in maintaining coal production under severe geo-mining conditions by the present method. The overall sizeable loss of coal reserves implicit in this method should however call for a closer look at the earlier reports by Rheinbaun and CMPDI in 1991 who had recommended exploitation by open pit method where risks would be significantly lower, and production could be even 5-10 million tonnes/year. Such a paradigm shift in exploitation method, if implemented, would allow of Barapukuria Mine to add 5 to 10 Mt/year to the national energy balance from the year 2016 – 2018.

III-3. KHALASHPIR COAL DEPOSIT

The Khalashpir Coal Basin is situated at a distance of about 290 km north of Dhaka, 48 km south of Rangpur Town. The main coal basin area (Madankhali Union) has a population of over 20,000 with density of population of 767 per sq. km. In the Khalashpir coal basin, Geological Survey of Bangladesh had drilled four drill holes and Hosaf International Limited drilled fourteen more drill holes, to assess the coal resources, and conducted 2-D and 3-D seismic surveys.

There are two aquifers in the Khalashpir sedimentary basin. One is in the Dupi Tila formation of the Pleistocene age and the other is Gondwana

Group. The Dupi Tila aquifer is composed of coarse to fine sand and pebbly sandstone. Aquifers in the Gondwana sandstone and conglomerates below the coal zones are not prominent.

The Dupi Tila formation is the major aquifer in the Khalashpir area. Top and bottom of this formation is bounded by the less permeable Madhupur clay and Surma Group respectively. Pumping test results of Dupi Tila Formation in Khalashpir Coalfield indicate a filtration coefficient/ permeability as 32.10-42.20m/day, transmissivity at 49-569m^2/day and water inflow rate as 644-846m^3/day/m. For the Surma Group, the results of pumping test show filtration coefficient/permeability as 0.02 m/day, transmissivity as 0.64- 1.63 m^2/day and unit filtration rate as 0.51-0.63 m3/day/m. The pumping test results of Gondwana Group have shown filtration coefficient/permeability of 0.64-0.067 m/day, transmissivity 4.9-5.30 m^2/day and unit filtration rate 0.71-1.53m^3/day/m. Analyses of pumping test data indicate that permeability of Dupi Tila Formation is very high while the permeability of Surma and Gondwana Group is low. The low permeability of the Surma Group will prevent infiltration of Dupi Tila water to the coal-bearing zone. The open fractures/fault planes in the coalfield however may play a critical role for the penetration of Dupi Tila water in the coal bearing zone.

Two-dimensional seismic survey was done in order to find out the boundary of coal deposit, basic structural shape and throw of the faults larger than 20 meters. Three-dimensional seismic survey was carried out in the area to have a clear picture of the faults. In terms of the quality of coal, average analytical results show that it has moisture content of 0.6 - 5%, fixed carbon 32-66%, volatile matter 6-29%, ash 7-50% and sulphur less than 1%. The coal is of bituminous variety with good coking properties. The maceral analyses of the coal show more than 70% vitrinite in 6 samples. Fusinite is rare in the samples and pyrite is present as veinlets or nodular pore fillings. Coal seam I & II has relatively high inertinite content with low volatile matter. The upper 6 meters of coal seam II contains about 100% inertinite which can be mined as a special cut for blending with high vitrinite coal to increase the coke strength.

The total in-situ reserves of coal in 8 seams of the 7.5 square km surveyed area is 451.00 million tonnes. Table-12 shows the average thickness of the seams, in the coal deposit:

Table-12

Average Seam Thickness:

Coal Seam	Seam-I	Seam-II	Seam-III	Seam-IV	Seam-V	Seam-VI	Seam -VII	Seam -VIII
Av. Thickness, m	16.95	9.93	1.22	6.96	2.71	26.7	1.66	1.33

The measured reserves are 277 million tonnes and the Indicated reserves are 174 million tonnes. Of these, reserves in seam I, II and IV are considered to be preferred candidates for mining. The seismic survey shows that there is more coal in the NW side of the surveyed area. The reserves of coal seam I, II and IV could be taken up for mining in the first phase and the reserves in other seams may be accessed later in the life of the mine, if the mining conditions permit. The in situ mineable reserve base of seam, I, II and IV is 277 million tonnes.

Considering the geological setting of the overlying strata above the coal measures and the thickness and depth of the different coal seams, exploitation by shaft is considered as suitable and selected as the mode of entry for the development of Khalashpir coal deposit. Two vertical shafts using freezing method are proposed to be sunk to develop the mine. For control of surface subsidence stowing may be necessary and mine planning has included provision for the use of some hydraulic stowing even though this may be of a limited extent only.

For Khalashpir coal mining project, Environment Management Plan (EMP) embracing Environment Impact Assessment (EIA) of proposed mining activities and control measures are contemplated, and for subsidence-damaged land due to underground mining operations, the calendar of phased reclamation has been drawn up.

Khalashpir coal deposit can be developed into an underground coal mine with an initial production capacity of 2 million tones per annum and ramped up to 4 million tonnes per year in about 5 years with additional investment in shaft, machinery, ventilation and drainage system. Financial analysis of the underground coal mine at Khalashpir has been undertaken and the project is considered as technically feasible and economically viable.

III-4. PHULBARI COAL DEPOSIT

Phulbari coal deposit in Dinajpur basin has resources aggregating to some 572 MT of high quality bituminous coal. Asia Energy Corporation (Bangladesh) has submitted to the Government of Bangladesh, a feasibility study and scheme of development for a 15 MT/year open-pit mine. The project proponents have received approval for environmental impact assessment and environmental clearance from the Government. The project however has encountered significant resistance from the community and interest groups and a lot of heat has been generated on the issue by civil society. The net outcome has been that the project continues to languish. The primary objections raised appear to centre on:

1. Impacts of dewatering on ground water resources in the environs of Phulbari due to drawdown of ground water in the locale affecting the existing hydro- geological regime;

2. Socio-economic impacts on the community, especially the displacement of project-affected people; and

3. Damage to and disruption of valuable agricultural land.

The issues related to management of groundwater have been examined in depth by GHD Pty.Ltd of Australia and later by Dr. Len Drury of SMEC International who has posited that mine dewatering and depressurisation of large open cut mines have been successfully undertaken in many pits around the world for ensuring safe working condition and stability of pit slopes. Computer modelling indicated that some 80 to 100 dewatering tubewells/borewells will be required at any one time to cumulatively pump some 6000 litres/sec, part of which will be needed for recharge of the aquifer. One of the mitigation works planned to control the impact of mine dewatering activities in the Phulbari area is aquifer injection. This will involve injecting water in the Upper Dupi Tila aquifer at around 5km from the pit which will hydrologically isolate the impacts of dewatering within and outside the injection zone. Figure-4 shows the schematics of aquifer re-injection for groundwater management.

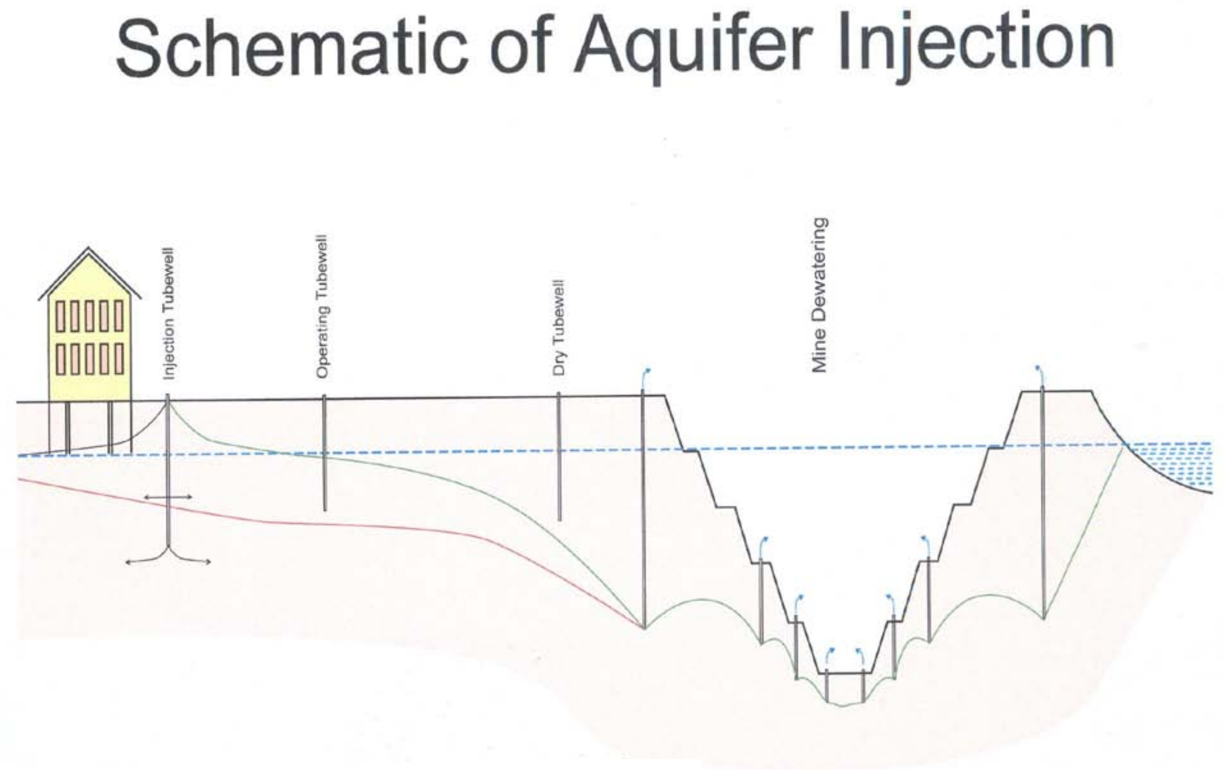

Figure-4

Appendix—A describes the method of groundwater management in Neyveli lignite basin in India. The issue of groundwater drawdown has apparently a high severity affecting as it does groundwater resources available to Phulbari and surrounding village communities . From experiences in Rheinbraun and Neyveli, it should be possible to mitigate the potential impacts as described in the experiences at Neyveli Lignite basin.

The issue of displacement, resettlement and rehabilitation of project affected people has been carefully addressed in Phulbari Project. The success of this, however, will be contingent upon timely land acquisition and managing the sensitivities implicit in all such emotive interfaces, including issues of fair compensation and resettlement entitlements, training and provision of jobs for 'locals' amongst others and will certainly call for enormous support from the Government for facilitating the R&R plan being executed smoothly.

In so far as disturbance to agricultural land is concerned, it needs to be reiterated that coal mining is necessarily a transitory land use. As the open-pit is successively backfilled and reclaimed in a phased manner, the land will be returned, often with higher attributes.

Phulbari project has opened up new vistas of economic development of the region, as the nation's power hub in the northwest. Phulbari coal could provide an alternative, reliable, affordable energy source for powering the wheels of the nation and one could conceive of installation of 2000 MW of power plants in a phased manner and thus assure energy security for Bangladesh. Estimatedly, Phulbari Project could contribute to 1% annual increase in GDP of Bangladesh and on a conservative basis make available US$ 21.00 billion to the GDP over project life, besides some US$7.1 billion to government revenue through corporate tax, royalty and service charges. It would also upgrade significantly the Bangladesh Railway system, Mongla Port and a deep sea entry to Akram Point contributing overall to sustainable development of the nation. The project would yield some valuable co-products like construction material, kaolin, high-grade silica sand and large quantity of potable water of high quality.

III-5. DIGHIPARA COAL DEPSIT

Dighipara coal deposit is situated in Northwestern part Bangladesh at a distance of about 300km north of Dhaka. The village Dighipara is 12 km from Bhaduria Bazar of Nawabjonj thana and 1 km from Dhalaedargah Bazar of Gabindaganj-Phulbari Highway. A railway Station Birampur of Dinajpur District is about 15 km away from Dighipara. The area is mainly plain and mostly cultivated land. The area lies between the latitudes N25^{o} 18' 52.8" and, N25^{o} 20' 01" and longitudes E89^{o}05'05". Geologically, Dighipara is located in Rangpur Saddle (Rangpur Platform) Tectonic zone of Bangladesh.

Dighipara coal field was discovered by the Geological survey of Bangladesh (GSB) in 1995 and the coal was found at a depth of 323m to 408m from the surface. Within the Dighipara coal basin, five bore-holes were drilled by GSB during 1995-2004 with extension in area of 1.25 sq.km of the basin. The maximum drilled depth in Gondwana formation/ basement rock was 526m. The coal deposits were encountered in all the five bore holes. Within the 323m to 408m depth 6 nos. of coal seams were found. The average thickness of 5/6 seams are 61.71 meters. Among them seam No.II is the thickest one, which is about 36 meters thick. It is expected that the proven reserve of coal within the area is about 1000 million tonnes (estimated by GSB) and probable reserve within an area of 5 sq.km is expected about 500 million tonnes.

Table-13

STRATIGRAPHIC SUCESSION OF THE AREA

Age	Formation/Group	Av. Thickness (m)	Remarks
Recent	Alluvium	2	
Pleistocene	Madhupur Clay	28	
Plio-Pleistocene	Dupitila	1072	
Permian	Gondwana	545	
Permian	Basement Complex	135	

Table-14

AVERAGE SEAM THICKNESS OF COAL SEAM AT DIGHIPARA

Coal Seam	Seam-I (m)	Seam-II (m)	Seam-III (m)	Seam-IV (m)	Seam-V (m)	Seam-VI (m)
Average thickness (m)	17	34	7	2	1.37	-

From the chemical analysis of coal sample, it is revealed that the coal is of High volatile Bituminous type with low ash and sulfur content. This coal is suitable for almost all types of thermal conversion including generation of electricity, brick burning and other domestic fuel, which will release prevailing pressure on forest resources. A portion of the coal might be suitable for the steel industries.

Chemical composition of coal from representative samples

1)	Sp. Gravity	-	1.18 - 1.44
2)	Moisture content%	-	2.87 - 4.32
3)	Ash content %	-	2.53 - 20.05
4)	Volatile matter %	-	25.29 - 37.59
5)	Fixed carbon %	-	43.10 - 65.63
6)	Sulfur %	-	0.49 - 1.29
7)	Heating Value (Btu/lb)	-	10,200 - 14,775

Dighipara coal deposit is amenable to exploitation by open-pit method, but this would call for more detailed drilling for understanding the geotechnical setting and establishing reserves.

IV. AGENDA FOR ACTIONS

In the backdrop of the imperatives of energy security for Bangladesh, diversification will remain the fundamental starting principle with coal emerging as an alternative, reliable and affordable energy resource. Given what we can reasonably expect about the pace of change in the years to 2025, energy policy cannot be settled on a "once for all basis"; rather it must be flexible and responsive to changing circumstances. The roadmap for sustainable energy development has to give a purposive thrust on coal development and the priorities in the agenda for actions should include:

- Approval of National Coal Policy and sizable investment for exploration for coal in the northwest Bangladesh, to augment the resource base. Drilling should be supplemented by state of the art geophysical surveys and 3-D modeling.

- Approval for "go ahead" at Phulbari project removing all the stops. The Government has to initiate steps for speedy acquisition of land, launch advertisement advocacy for assuaging the sentiments of project affected people so that the development and execution of the project could be facilitated. Phulbari is the crown jewel in coal inventory of Bangladesh and its development would help transform the economy of the nation.

- Review and reconsideration of the mining strategy at Barapukuria coal mine where underground mining by multiple slice longwall from roof downwards is destined to lead to huge losses of coal reserves. The feasibility of change-over to open-out mining also needs to be studied in depth.

- Promote the development of coal deposits at Khalashpir and Dighipara, either in the private or joint sector.

- Appraisal of coal bed methane resources, at Jamalganj needs to be conducted on a priority basis. If CBM resources are not promising, a pilot plant trial / demonstration of underground coal gasification (UCG) at Jamalganj needs to be undertaken.

- Re-assessment of resources at all the coal deposits based on UNFC classification.

- Approval for a mining degree programme at BUET or RUET to bridge the critical gap in manpower for coal development. Simultaneously, an Industrial Training Institute (ITI) for meeting the need for supervisory manpower in coal mines may be set up in the northwest. Capacity building for sustainable coal development deserves high priority.

An appropriate time-frame for the actions as above has to be fixed so that accelerated coal development in Bangladesh could be translated into a reality. Energy from coal is fundamental to the aspirational goals of higher quality of life and to the economic prospects and performance of the nation.

V. CLOSURE

Unless Bangladesh strikes some rich gas deposits in the near future, sustainable energy development and economic growth could be in serious jeopardy. Coal discoveries in northwestern region offers a window of opportunity, if only these deposits can be developed in an accelerated manner and stave off the looming energy crisis. The way forward, however, is strewn with several road blocks of which the hydro-geological regime of the deposits (an endowment of nature!) and resistance from civil society figure prominently. The all-pervasive syndromes of NIMBY (Not in My Back Yard) and BANANA (Build Absolutely Nothing Anywhere Near Anyone) have to be dispelled and overcome, before sustainable coal development becomes possible. With access to world best practices in environmental technology for reducing the ecological footprint and supported by political will, the road blocks should not be insurmountable and coal could provide the much-needed energy security for the nation. Where coal cannot be physically extracted, the recovery of coal bed methane and underground coal gasification deserve to be considered as energy options. The agenda for actions outlined herein should be viewed as suggestions and not as policy prescriptions.

This report does not contain any specific proposals for nuclear energy development. We cannot rule out the possibility that at some point in the future, nuclear energy will have to play a role in the nation’s energy mix. Likewise, renewables are likely to have a niche role too.

Bangladesh needs a soundly based, enduring national energy policy where coal will have an undeniable role to play.

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REFERENCES

Bakr, M.A., et al, 1996, Geology and Coal Deposit of Barapukuria Basin, Dinajpur Districts, Bangladesh. Records of Geological Survey of Bangladesh, vol.8, part-1, p-36.

China National Machinery Import and Export Corporation (CMC), 1994. A supplementary Hydogeological Feasibility Study of Barapukuria Coal Basin, Dinajpur Bangladesh (Unpubl).

Imam, B., 2005. Energy Resources of Bangladesh. University Grants Commission of Bangladesh, Dhaka, Bangladesh.

Islam, M.S. 1993, Anatomy and Environment of deposition of the abnormally thick coal seam VI in the Barapukuria basin, Dinajpur, Bangladesh, Bangladesh Journal of Geology, vol.12, p.27-38 (Published in 1996).

Matin Mondol, A. A proposal of open pit coal mine at Barapukuria coalfield, Dinajpur, Bangladesh, M.Sc. Thesis, University of Rajshahi, p.92 (Un published).

Uddin, M.N. and Islam, M.S. 1992. Gondwana Basins and their Coal Resources in Bangladesh. Geology in South Asia-1, Proc. First south Asian Geological Congress Pakistan, p.224-230.

Wardell Armstrong Ltd, 1991. Techno-economic Feasibility Study, 4Barapukuria Coal Project, Dinajpur, Bangladesh. Volume-I, Chapter-I. Report submitted to Ministry of Energy and Mineral Resources, Government of People’s Republic of Bangladesh (Unpublished).

Ghose, A. K., 1998, Sustainable Energy Development in India into the next millennium - Challenges for Geoscientists, Indian Journal of Geology, vol. 70, No.4, p-291-298.

Ghose, A.K., 2001, Are Renewable Energies realistic alternatives to Fossil Fuel and Nuclear Power Generation for Asia? Proceedings. World Congress on Safety of Modern Technical Systems, Saarbrucken, TUV Saarland Foundation, p.235-245.

Ghose, A.K., 2006, Energy Security for India - The Emerging Role for Coal, Proceedings. National Conference on Coal and Alternative Energy Resources, p.37-41.

Mondal, Debasis 2007. Selection of Mining Method in the Khalashpir Coal Field, Rangpur, Bangladesh, M.Sc. Dissertation, Department of Geology & Mining, University of Rajshahi, p.130.

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