Mines and Minerals Development (Package # 07) Hydrocarbon Unit

Action Plan and Guidelines for development of CBM, UCG and Hard Rock Projects (Final)

October 30, 2013

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Table of Abbreviations

Abbreviation	Full Form
ADB	Asian Development Bank
AGL	Australian Gas Light Company
ASTM	American Society for Testing and Materials
BAPEX	Bangladesh Petroleum Exploration and Production Company Ltd
BCFPA	Billion Cubic Feet per annum
BCMCL	Barapukuria Coal Mining Company Limited
BERC	Bangladesh Energy Regulatory Commission
BFP-IFT	Below Fracture Pressure Injection Falloff Test
BGFCL	Bangladesh Gas Fields Company Ltd
BGDCL	Bakhrabad Gas Distribution Company Ltd
BMD	Bureau of Mineral Development
BMEDC	Bangladesh Minerals Exploration Development Corporation
BOGC	Bangladesh Oil and Gas Corporation
BOGMC	Bangladesh Oil, Gas and Mineral Corporation
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
BPI	Bangladesh Petroleum Institute
CBM	Coal Bed Methane
CCS	Carbon Capture and Sequestration
CDP	Critical Desorption Pressure
CIL	Coal India Limited
CMC	Chinese National Machinery Import & Export Corporation
CMM	Coal Mine Methane
CSG	Coal Seam Gas
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSM	Coal Seam Methane
DFIT	Diagnostic Fracture Injection Test
DGH	Director General of Hydrocarbon, India
DST	Drill Stem Test
E&P	Exploration and Production

Abbreviation	Full Form
EMRD	Energy and Mineral Resources Division
ELBL	Eastern Lubricants Blenders Ltd.
ERD	Economic Relations Division
ERL	Eastern Refinery Limited
FCFS	First Come First Serve
FDI	Foreign Direct Investment
GAIL	Gas Authority of India Limited
GDP	Gross Domestic Product
GIPCL	Gujarat Industries Power Company Limited
GMDC	Gujarat Mineral Development Corporation
GoB	Government of Bangladesh
GSB	Geological Survey of Bangladesh
GTCL	Gas Transmission Company Ltd
GTDP	Gas Transmission and Development Project
HCU	Hydrocarbon Unit
IED	Industry and Energy Division
IFT	Injection Falloff Test
IGCC	Integrated Gasification Combined Cycle
IMED	Implementation Monitoring and Evaluation Division
IMF	International Monetary Fund
JGTDSL	Jalalabad Gas Transmission and Distribution System Limited
JICA	Japan International Cooperation Agency
JOCL	Jamuna Oil Company Ltd.
JORC	Joint Ore Reserves Committee
KGDCL	Karnaphuli Gas Distribution Company Ltd
LPGL	LP Gas Ltd.
LPI	Logistics Performance Index
M&P Contract	Management Production and Maintenance Service Contract
MGMCL	Maddhapara Granite Mining Company Ltd
MoC	Ministry of Coal, India
MoP&NG	Ministry of Petroleum and Natural Gas, India
MoPEMR	Ministry of Power, Energy and Mineral Resources
MoU	Memorandum of Understanding

Abbreviation	Full Form
MPL	Meghana Petroleum Ltd.
Mtoe	Million tonnes of oil equivalent
NBR	National Board of Revenue
NLC	Neyveli Lignite Corporation Ltd.
OGDC	Oil and Gas Development Corporation
ONGC	Oil and Natural Gas Corporation
PBU	Pressure Build up Test
PGCL	Paschimanchal Gas Company Ltd
POCL	Padma Oil Company Ltd.
PP	Project Plan
PSC	Profit Sharing Contract
RPGCL	Rupantrito Prakritik Gas Company Ltd
SAOCL	Standard Asiatic Oil Company Ltd.
SCCL	Singareni Collieries Company Limited
SCF	Standard Cubic Feet
SGFL	Sylhet Gas Fields Ltd
SGCL	Sundarban gas Company Limited
TCF	Trillion Cubic Feet
TGDTCL	Titas Gas Transmission & Distribution Company Ltd
UCG	Underground Coal Gasification
UDT	Upper Dupi Tila
UNFC	United Nations Framework Classification
USBM	United States Bureau of Mines
USGS	U.S. Geological Survey
VAM	Ventilation Air Methane
VAT	Value Added Tax
VCBM	Virgin Coal Bed Methane
XMC	Xuzhou Coal Mining Group Company Limited

Table of contents

1. Executive summary 10

1.1. Introduction 10
1.2. Understanding CBM and UCG 10
1.3. Action Plan for CBM and UCG 11
1.4. Action Plan for hard rock development 12

2. Introduction 14

2.1. Context 14
2.2. Terms of Reference 14

3. Existing Administrative framework of Bangladesh Mineral Sector 15

3.1. Introduction 15
3.2. Energy and Mineral Resources Division (EMRD) 15
3.3. Hydrocarbon Unit (HCU) 17
3.4. PetroBangla 18
3.5. Geological Survey of Bangladesh (GSB) 19
3.6. Bureau of Mineral Development (BMD) 20
3.7. Department of Explosives 21
3.8. BCMCL 21
3.9. MGMCL 22

4. Coal Bed Methane (CBM) 23

4.1. Overview 23
4.2. Coal Bed Methane Recovery Techniques 24
4.3. Global Resource Base & Potential for Utilization 26
USA 26
Australia 29
India 30
Canada 33
China 33
Russia 34

4.4. CBM in Bangladesh 34
4.5. Technical Studies to establish CBM 35
Studies to be conducted for establishing CBM Resources 35
Estimation of Gas-in-Place 37
Deliverability 41
Well Spacing and Drainage Area 42
Production testing and simulation 42

5. Underground Coal Gasification (UCG) 43
5.1. Overview 43
5.2. UCG resources 43
5.3. UCG Extraction Process 44
5.4. Commercial operations of UCG 45
5.5. Progress of UCG development in key countries 46
India 46
South Africa 46
China 47
5.6. Major players developing UCG Projects 47
5.7. Suitability of a coal deposit for UCG 48
5.8. Studies for establishing UCG 49
6. Hard rock Sector 51
6.1. Overview 51
6.2. Maddhapara Granite Mining Company Limited (MGMCL) 51
6.3. Other hard rock deposits (mainly limestone) 53
Gravel 53
7. Action plan for CBM and UCG development in Bangladesh 54
Stage 1: To establish the feasibility of CBM and UCG 54
7.1. Demarcation of resources 54
7.2. Conducting studies for exploration of CBM and UCG 54
7.3. Financing of studies 54
Stage 2: Development of commercial project 55
7.4. Establishing Priority for exploitation between CBM and Conventional Mining 56
7.5. Establishing Priority for exploitation between CBM and UCG 56
7.6. Exploitation Strategy for CBM and UCG 56
Public Sector Investment 56
Leasing 57
Contracting 57
Infrastructure and Carbon Credits 59
8. Action plan for development of Hard Rock sector in Bangladesh 60
8.1. Classification of Resources 60
8.2. Preparation of Knowledge Repository 60
8.3. Licensing Regime 61
8.4. Granite 61
Environmental Impact 62
8.5. Limestone 63

Environmental Impact 64
8.6. Other Rocks and Minerals 64
8.7. Sourcing from other countries/Development of new indigenous resources 65
9. Guidelines for development of CBM and UCG in Bangladesh 66
9.1. Stage 1: To establish the feasibility of CBM and UCG 66
9.2. Stage 2: Development of commercial project 67
10. Guidelines for development of Hard rock sector in Bangladesh 70
10.1. Adoption of UNFC System of Classification 70
10.2. Preparation of Knowledge Repository 70
10.3. Licensing Regime 70
10.4. Environmental and Safety Aspects 71
Appendix A. - Bibliography 72

1. Executive summary

1.1. Introduction

1.1.1. This report **"Action Plan and Guidelines for development of CBM, UCG and Hard Rock Projects"** is prepared as part of the Mines and Minerals Development Project (Package # 07) of Hydrocarbon Unit, Energy and Mineral Resources Division, Bangladesh

1.1.2. The Terms of Reference of this report is "To recommend Action Plan and Guidelines for the relevant executing agency for development of Coal Bed Methane (CBM), Underground Coal Gasification (UCG) and Hard rock projects".

1.1.3. This report covers:

- An overview of administrative framework of Bangladesh mineral sector
- An overview of the CBM and UCG technologies prevalent globally and status of CBM and UCG development in selected countries
- Discussion on steps for identification and development of CBM and UCG resources
- An overview of hard rock sector in Bangladesh
- Action plan and Guidelines for CBM and UCG development
- Action plan and Guidelines for development of hard rock sector in Bangladesh

1.2. Understanding CBM and UCG

1.2.1. Methane recovered from un-mined coal seams is often referred to as Coal Bed Methane (CBM). This includes recovery of methane from coal seams prior to mining even if coal seam would remain un-mined.

1.2.2. Till 20 years ago, CBM was considered as an unconventional gas play from which most operators stayed away which has now grown into a commercially important, mainstream natural gas source. Currently, CBM projects are commercially operational in several countries.

1.2.3. Underground coal gasification, known as UCG, is an alternative method of capturing energy from coal by decomposing Coal in-situ through controlled burning. This technology provides cleaner source of energy from coal seams which cannot be mined by traditional mining methods due to technical or economic non-viability.

1.2.4. UCG involves conversion of in-situ coal into synthetic gases (syn gas) using earth's crust as a reactor vessel. The process involves injection of steam and air or oxygen into underground coal seam and burning of coal to produce combustible gas which is usable as fuel or chemical feedstock.

1.2.5. However, due to high cost of development and technical difficulties experienced in directional drilling, UCG has not been established as commercially viable alternative to conventional technologies. Other technical challenges faced in successful development of UCG are effective linking in the coal seam, control of gasification front and overall control of multistage gasification process.

1.2.6. Bangladesh has limited resources of coal and natural gas. To expand its energy base, Bangladesh should explore options to exploit alternative potential sources of energy like CBM (prior to coal mining) and

UCG (in unworkable seams). This will help achieve triple objectives of harnessing additional energy resource which would otherwise be wasted, improving mine safety and preventing emission of GHG from coal mines to the atmosphere.

1.2.7. Thus, Coal seams in various coal fields with high gas content may have potential to extract methane trapped prior to coal mining by Coal Bed Methane (CBM) extraction which helps enhance the near-term energy potential of the country.

1.2.8. Further, deep-seated coal deposits of Bangladesh are potential uneconomic for mining by conventional methods though can potentially be exploited by converting into gas through Underground Coal Gasification (UCG).

1.3. Action Plan for CBM and UCG

1.3.1. The Action plan for CBM and UCG development can be divided into two stages; Stage 1: Establishing feasibility and Stage 2: Development of commercial projects.

1.3.2. **Stage 1: To establish the feasibility of CBM and UCG**

- Government of Bangladesh in consultation with various relevant agencies like GSB should demarcate and identify coal fields for exploration and identification of CBM and/or UCG potential and priorities activities.
- The Government of Bangladesh may assign the responsibility of conducting the field work and technical studies to a Government Agency. The Agency may tie up with reputed international players having expertise in this field or institutes engaged in R&D in the area to source expertise and technology.
- Technical studies, R&D and exploration of CBM and UCG may be financed through combinations of Government funding, grants and loans from donor agencies and private sector investment (both domestic as well as international).

1.3.3. **Stage 2: Development of commercial projects**

- First step towards commercial development of project is to establish priority between Conventional Mining, CBM and UCG. Since CBM precedes the coal mining, wherever viable and conditions permit, CBM should be adopted first followed by exploitation of coal resources. Post CBM extraction, conventional coal mining should be preferred over UCG wherever possible unless techno-economic viability establishes otherwise.
- Since, CBM and UCG technologies are capital intensive with number of risks involved it is preferable to examine different models and modalities of financing and risk sharing without sacrificing national interests in the process. Different models which may be adopted for development of these projects are as follows:
  - Provide license to PSU and Government may investment through its companies.
  - Leasing: An asset can be leased to private sector or foreign investors
    - The party establishing feasibility may be given first right of refusal for that particular block (at a Reserve Price). If such party is not interested in developing the asset, then application should be invited from other interested parties. The lease can be granted adopting process similar to process adopted for granting mining license. Alternately, asset can be auctioned through competitive bidding following process similar to one

followed for auction of gas blocks on similar terms and conditions including production sharing.

  - The government may roll out incentives to encourage private sector participation in the form of tax holidays, waiver of local taxes, reduction in import duties on equipment, provisions for preferential sale of gas from such sources etc.

- **Contracting**: Alternate option for developing resources is through contract operations. The contractor should be selected through an international competitive bidding process. The contract may be:

  - Cost Plus contract

  - Levelised Price contract

- Infrastructure and Carbon Credits:

  - If CBM extraction program can be successfully implemented, benefit of carbon credit should be availed.

  - To enable marketing of gas produced through CBM, existing gas grids would be required to be extended till coal mining areas. To feed dry and pure methane gas into grid, suitable gas processing plants would be required.

1.4. Action Plan for hard rock development

1.4.1. **Classification of Resources:**

- It is necessary to classify resources as per common acceptable standard for benefit of all the stakeholders. Hence, adoption of UNFC System for mineral resource classification and reporting should be made mandatory under legislation to classify mineral resources of Bangladesh.

- It is advisable that all the rocks should be classified as per value (by use) which will help prioritize leasing process and select application among several for grating license to ensure higher returns to country.

1.4.2. **Preparation of Knowledge Repository:**

- An inventory of the various minerals should be prepared by carrying out systematic surveys and studies to attract both private as well as foreign investment in the minerals sector.

- Institutional capacity of GSB and/or BMD and other organizations should be strengthened to handle complex commercial contracts, exploration, management, finance, contractor selection, technology and R&D etc.

1.4.3. **Changes in Licensing Regime:**

- The recommendations made regarding mining licensing in report on Review of Existing Acts, Rules and Regulations and Recommendations, should be implemented.

1.4.4. Modifications in operations of Maddhapara hard rock mine is required to increase production. The measures to be taken are discussed in detail in chapter 8.

1.4.5. If the quality of the limestone varies from mine to mine the government may restrict its use by specifying that it be put to the best use (e.g., cement grade limestone be used for making cement) to ensure maximum returns to Country.

1.4.6. Further, Government's thrust should be on mineral processing and production of high value output before sale/export.

1.4.7. GoB should formulate a framework for effective monitoring and control of environmental and safety aspects.

1.4.8. Efforts are required for exploration and exploitation of other construction materials like gravel, sandstone, as well as, other minerals like glass sand, beach sand and white clay etc.

2. Introduction

2.1. Context

2.1.1. Bangladesh is one the world's most densely populated countries. It has posted a consistent economic growth of around 6% for past several years (IMF, 2007-12).

2.1.2. The country faces challenges in energy and infrastructure sector and its economic growth will depend inter alia on its upgrading public infrastructure, in particular, the energy sector, transport, and urban development.

2.1.3. The primary energy consumption in Bangladesh is 24.3 Mtoe (2011) representing 0.2% of global primary energy consumption, against a global population share of about 2.4% (BP statistical review of World Energy, 2012).

2.1.4. A challenge in energy sector is the present over-reliance on natural gas which accounts for about 70% of the country's commercial energy supply even as the resources are depleting. The peak demand for electricity by 2030, as per the Power System Master Plan 2010 (JICA report) considering the Government Policy Scenario is estimated at 33,708 MW. In contrast, sustainable supply of natural gas is uncertain beyond 2030, highlighting the necessity to develop alternative sources of primary energy.

2.1.5. Coal is one of the alternate energy sources available in Bangladesh though some of the identified resources are at high depth and in challenging geological conditions. These deposits can be exploited using alternate technologies to conventional mining. Some of the alternatives are exploitation through Coal Bed Methane (CBM) and Underground Coal Gasification (UCG). Currently, these technologies are in the nascent stage of development and Bangladesh has no prior experience of these technologies.

2.1.6. Currently, the mining and quarrying sector accounts for 1.26% of the GDP (at constant prices) of Bangladesh. Natural gas and petroleum accounts for 58% of this while the rest is from other mineral resources (Bangladesh Economic Review, 2011).

2.1.7. Infrastructure sector face challenges on account of poor availability of local construction materials, in particular Hard rock. Only operating Hard rock mine of Bangladesh at Maddhapara supplies only 1.65 million tonnes rock against annual demand of about 6.5 million tonnes. Balance 75% of demand is met through imports which results in increase in cost as well as impact trade balance of the country.

2.1.8. Thus a cohesive Action Plan is required to ensure exploitation of alternate energy and infrastructure related mineral resources which will provide a roadmap for future activities and developing CBM, UCG and Hard Rock sectors.

2.2. Terms of Reference

2.2.1. The terms of reference of this report is *"To recommend Action Plan and Guidelines for the relevant executing agency for development of Coal Bed Methane (CBM), Underground Coal Gasification (UCG) and Hard rock projects"*.

3. Existing Administrative framework of Bangladesh Mineral Sector

3.1. Introduction

3.1.1. As per the constitution of Government of the People's Republic of Bangladesh, the ownership of its mineral wealth lies with people of country. Thus, on behalf of people of Bangladesh, the mineral and mining sector is controlled and governed by the Ministry of Power, Energy and Mineral Resources (MoPEMR), GoB.

3.1.2. Presently, Prime Minster holds the charge of this ministry and is being assisted by an Adviser and a State Minister.

3.1.3. The MoPEMR has got two major divisions:

a) Power Division

b) Energy and Mineral Resources Division

3.1.4. Energy and Mineral Resources Division and Power Division were created to cater to the need for more specialized intervention in energy (including mineral resources) and power sector. The two divisions are administratively headed by Secretaries.

3.1.5. This chapter brief functioning and responsibilities of key administrative bodies governing the mineral sector of Bangladesh.

3.2. Energy and Mineral Resources Division (EMRD)

3.2.1. EMRD is a division under MoPEMR to administer Energy and Mineral Resources sectors and is responsible for formulation of policies related to Natural Gas, Liquid Petroleum and Mineral Resources. This division also administers and controls the related entities, Hydrocarbon Unit, Petrobangla, Bangladesh Petroleum Corporation (BPC), Geological Survey of Bangladesh (GSB), Bureau of Mineral Development (BMD), Department of Explosives, Bangladesh Petroleum Institute (BPI) and Bangladesh Energy Regulatory Commission (BERC). EMRD through Petrobangla and other entities perform the exploration and development of gas, oil, coal and other minerals.

3.2.2. Governance structure of Bangladesh Mineral Sector is presented in chart below:

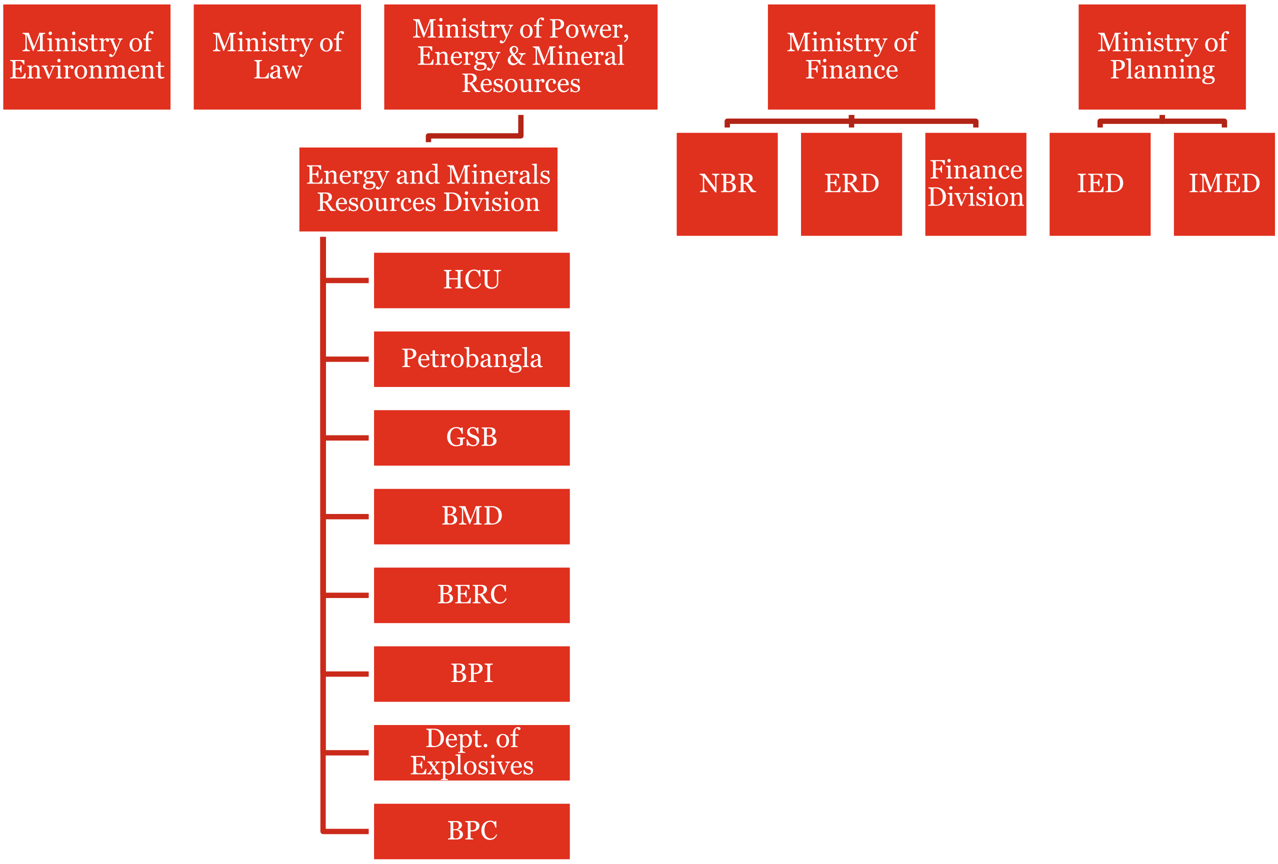

Figure 1: Governance structure of Bangladesh Mineral Sector

3.2.3. EMRD manages the business through two main Corporations:

- Petrobangla for Oil, Gas, Coal and Minerals; and
- Bangladesh Petroleum Corporation (BPC) for petroleum products.

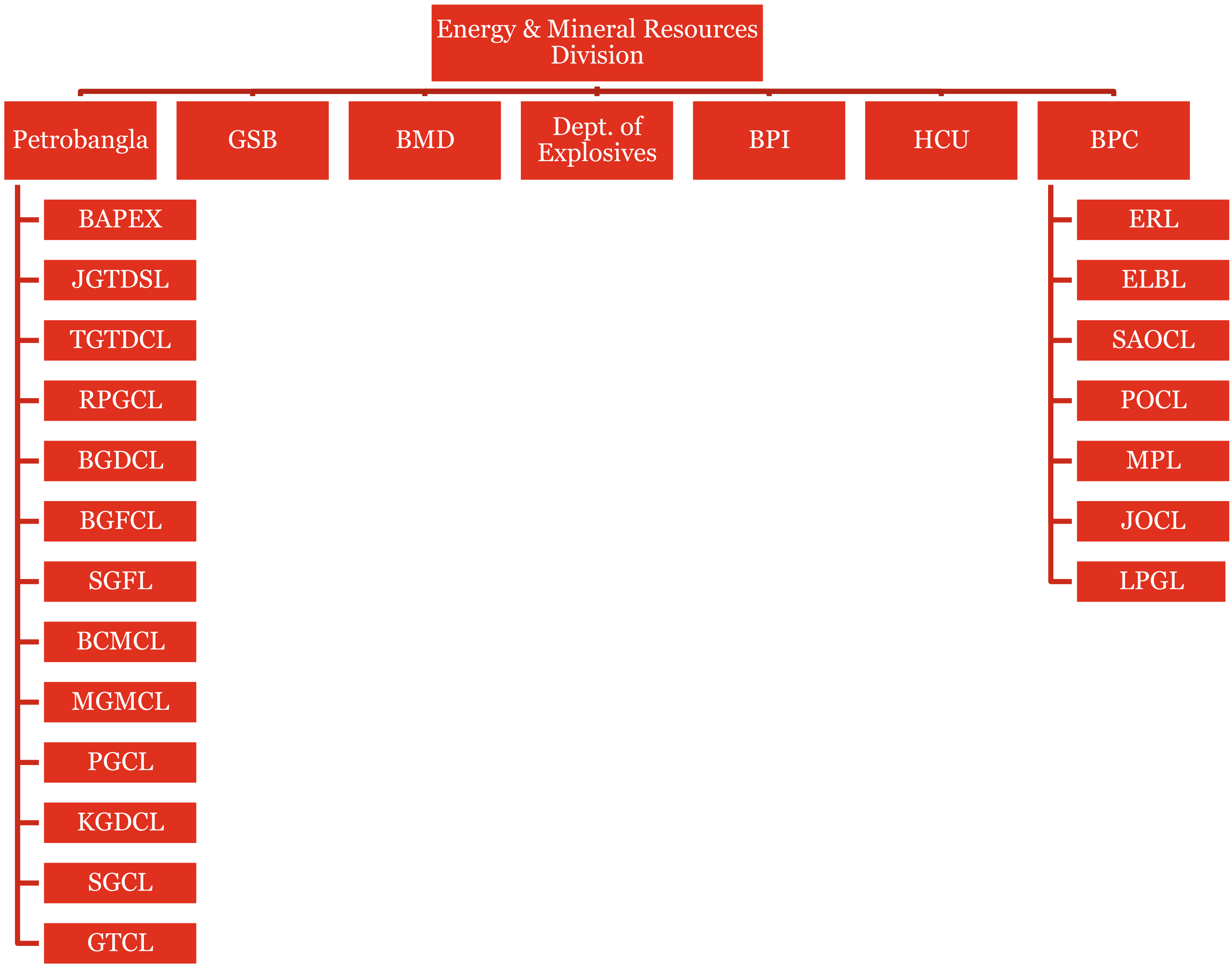

Figure 2: Organisations and Companies under Energy and Mineral Resources Division

3.2.4. Government performs various key functions like survey, exploration, administration and issuance of mining concessions or licenses and mining leases and other regulatory measures through its various agencies like:

- GSB: Survey and exploration;
- BMD: Grant of mining licences and leases, repository of information and other administrative functions;
- Department of Explosives: Administer explosives sector, monitor safety during handling of explosives, gases, petroleum and other flammable liquids, combustible solids etc.

Roles and responsibilities of these agencies have been discussed below.

3.3. Hydrocarbon Unit (HCU)

3.3.1. HCU is technical advisory arm of EMRD for energy sector development. HCU was established as 'Technical Assistance' project under grant financing by the Royal Norwegian Government in July 1999 and continued up to June 2005.

3.3.2. Subsequently, Norwegian Government extended a grant for the project "Strengthening of the Hydrocarbon Unit (Phase-II)", which is being administered by the Asian Development Bank (ADB) under the "Gas Transmission and Development Project (GTDP)". This phase will be continued up to December 2013. On May 28, 2008 HCU was conferred permanent status.

3.3.3. The key responsibility areas of HCU are:

- Assessment of gas reserve, undiscovered gas resources, gas production and consumption at regular intervals.
- Data management for oil and gas sector.
- Overview and observation on PSC activities.
- Internal and regional gas market analysis.
- Formulation of exploration and depletion policy.
- To provide comments towards development of oil, gas and mineral resources of the country in line with the government's strategy and directions.

3.4. PetroBangla

3.4.1. In 1961, Oil and Gas Development Corporation (OGDC) was established as the first public sector national organization. OGDC carried out geological and geophysical survey (including gravity, magnetic and seismic) and drilled wells.

3.4.2. Post independence, part of OGDC operating in Bangladesh was reorganized as Bangladesh Minerals Oil and Gas Corporation (BMOGC). BMOGC was established on March 26, 1972 through the Presidential Order (PO) No. 27. The minerals operation of the corporation was segregated and vested with a new organization, Bangladesh Minerals Exploration and Development Corporation (BMEDC) on September 27, 1972.

3.4.3. In 1974, Bangladesh Oil & Gas Corporation (BOGC) was reconstituted and named as Petrobangla through Ordinance No. 15.

3.4.4. In 1985, BOGC and BMEDC were merged into a single entity and named as Bangladesh Oil, Gas & Minerals Corporation (BOGMC) by the Ordinance No. 21 of GoB.

3.4.5. In 1989, partial modification was made in the Ordinance by the Law 11 and the Corporation was short named as Petrobangla and was given the authority to hold the shares of the companies dealing in Oil, Gas and Minerals exploration and development. The following companies are currently operating under Petrobangla:

- Bangladesh Petroleum Exploration & Production Company Limited (BAPEX)
- Bangladesh Gas Fields Company Ltd. (BGFCL)
- Sundarban Gas Company Limited (SGCL)
- Sylhet Gas Fields Limited (SGFL)
- Titas Gas Transmission & Distribution Co. Ltd. (TGTDCL)
- Bakhrabad Gas Distribution Company Limited (BGDCL)
- Jalalabad Gas Transmission and Distribution System Limited (JGTDSL)

- Gas Transmission Company Ltd.(GTCL)
- Pashchimanchal Gas Company Limited (PGCL)
- Rupantarita Prakritik Gas Company Limited (RPGCL)
- Barapukuria Coal Mining Company Limited (BCMCL)
- Maddhapara Granite Mining Co. Ltd. (MGMCL)
- Karnaphuli Gas Distribution Co. Ltd. (KGDCL)

3.5. Geological Survey of Bangladesh (GSB)

3.5.1. Geological Survey of Bangladesh (GSB) is a government organization established under EMRD and is responsible for geological investigations, exploration, study and research works.

3.5.2. History of GSB can be traced back to Geological Survey of India established in 1851 by then government of British India. Post independence in 1947, part of agency was established as Geological Survey of Pakistan (when Bangladesh was also part of Pakistan). A regional office of Geological Survey of Pakistan was set up in Dhaka in 1957. Soon after Bangladesh's independence, the regional office of Geological Survey of Pakistan in Dhaka was established as Geological Survey of Bangladesh.

3.5.3. GSB started functioning in 1971. On November 20, 1972, Cabinet took decision to entrust responsibility of carrying out exploration of mineral resources on GSB with the exception of oil and gas. GSB was also entrusted with responsibility to venture in the research in different fields of geo-science. In 1980, GSB was declared as a permanent department by the Government of the People's Republic of Bangladesh.

3.5.4. Some of the landmark achievements of GSB include discovery of high quality low sulphur bituminous coal at Barapukuria, Dighipara (in Dinajpur) and Khalashpir (in Rangpur). GSB was also successful in discovering hard rock (granitic) deposit at Maddhapara (in Dinajpur) and Glass Sand, White Clay, Peat and Gravel deposits in various places in the country. The main functions of GSB are as follows:

- To carry out detailed investigation of indicated mineral endowment or the areas identified with favourable accumulation of industrial rocks, minerals, fossil fuel, ground water and other natural resources.
- To conduct extensive mineral exploration by geophysical methods, drilling and geological studies like- geochemical, stratigraphic, petrographic and geochronological analysis, of known and indicated mineral deposits or mineral bearing areas.
- To conduct geological and geotechnical investigations in connection with civil engineering projects and construction, water resources management, land use, environmental studies, etc.
- To conduct marine geological and geophysical investigation and geomorphological studies of river basins and the delta regions.
- To carry out systematic sampling of minerals, fossil fuels and ground water resources and to carry out mineralogical and chemical analyses of the samples.
- To advise the public and private organizations in all matters connected with geology and resources of the earth.
- To conduct research in various fields of geology.

- Delineation of areas affected by Arsenic toxicity and other toxic elements in ground water and to find out the source and origin of toxic elements.

3.6. Bureau of Mineral Development (BMD)

3.6.1. BMD was established in 1962 under Industries and Minerals Division of the then Provincial government which was under Industries and Natural Resources Ministry of the Central government. BMD is responsible for regulating the mineral sector in Bangladesh under provisions of Mines and Minerals Rules, 2012 (earlier Mines and Minerals Rules 1968).

3.6.2. The main functions of BMD are:

- To maintain the records of the mineral bearing area of economic importance.
- To receive the applications for licenses or leases and to examine such applications.
- To grant license or lease to the interested parties for exploration, mining or quarrying purposes.
- To maintain the data and records related to licenses or leases granted.
- To inspect the progress related to licenses or leases and observance of rules and regulations, etc by the parties.
- To initiate appropriate action against a party or parties in case of failure in adherence to rules, regulations and conditions as prescribed by Government.
- To maintain the records of mineral produced, utilized and exported.
- To suggest on framing of laws, rules and regulations related to mineral sector and also on any amendment thereof.
- To fix and regulate the royalty, rent, levies, etc. on minerals.
- To collect royalty and others revenue as per rule from exploration licenses, mining leases and quarry leases of different minerals.

3.6.3. Present status: BMD is now inspecting some areas for granting Mining, exploration and quarry leases.

- Area of granting Mining Leases: Coal & Hard Rock
- Area of granting exploration Licences: Mineral sand, Coal & Metallic Minerals
- Area of granting quarry Leases: White Clay, Silica Sand, Ordinary Stone, Stone mixed with sand.

3.6.4. The flow chart below represents the governance of mineral exploration and mining works in Bangladesh.

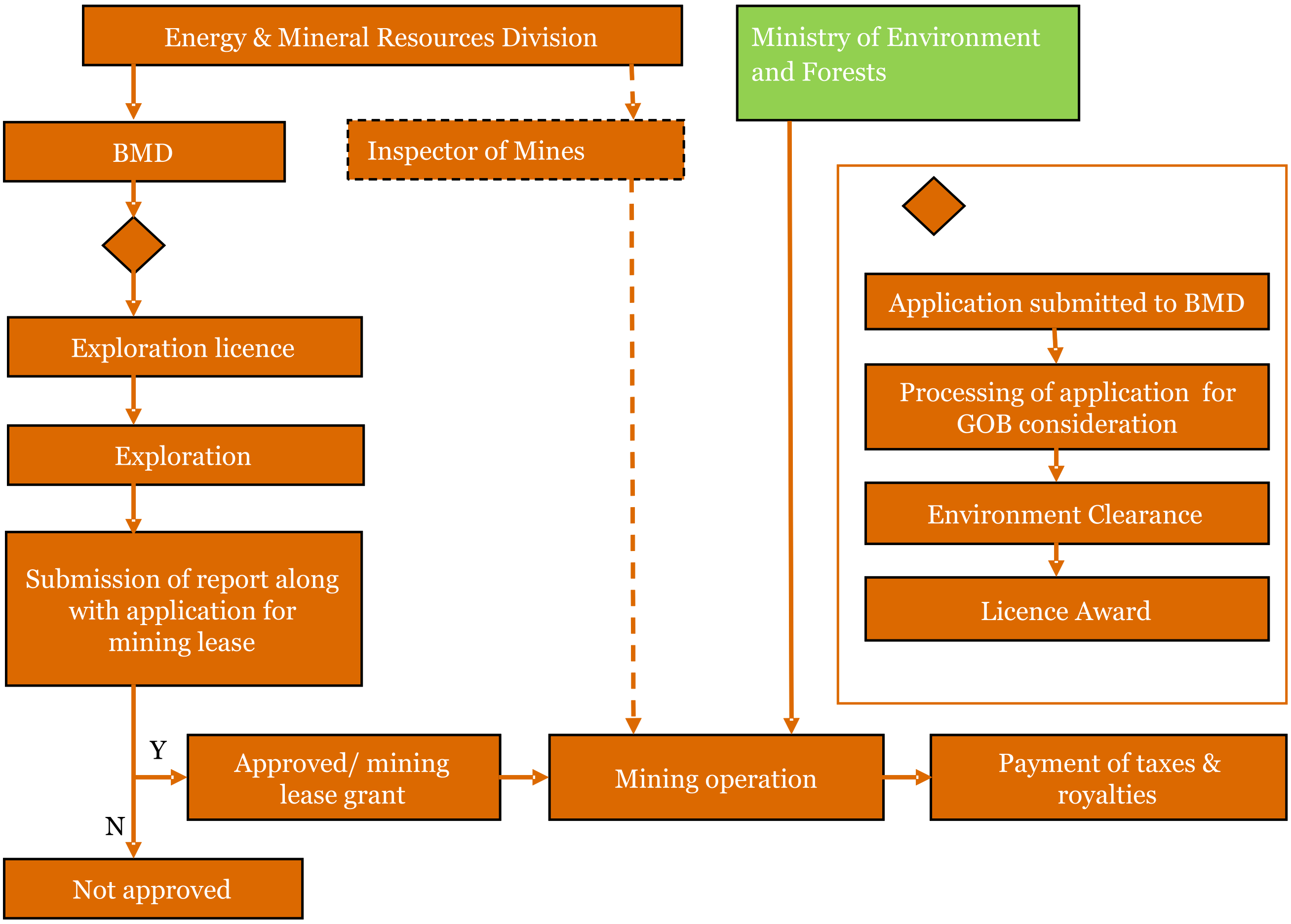

Figure 3: Governance of mineral exploration and mining works in Bangladesh

3.7. Department of Explosives

3.7.1. Department of Explosives is an attached department to MoPEMR. The primary function is to ensure the safety of human life, national property and environment through the administration and enforcement of the Acts and Rules during

- Manufacture/processing/ refining,
- Transport/transmission,
- Import,
- Storage, use and handling etc.

of commercial explosives, compressed gases, natural gases, gas cylinder, gas container and petroleum and other flammable liquids, combustible solids including calcium carbide and oxidizing substances.

3.8. BCMCL

3.8.1. Barapukuria Coal Mining Company Limited (BCMCL) was formed and registered on August 04, 1998 under the Companies Act 1994 of Bangladesh. It operates the first and only coal mine of the country located at Barapukuria in Dinajpur district. It supplies coal to a mine mouth 2×125 MW power plant operated by Bangladesh Power Development Board (BPDB). The remaining coal is primarily supplied for brick making and other consumers.

3.8.2. In 1985, GSB discovered high quality bituminous coal in Barapukuria in the district of Dinajpur. During 1987-1991, a UK based organization M/s Wardell Armstrong carried out the techno-economic feasibility study on this coal reserve under ODA financial support programme. Based upon the Wardell Armstrong report, Petrobangla undertook Barapukuria Coal Mine Development Project and the Project Plan (PP) was approved by ECNEC on April 21, 1993.

3.8.3. After the approval of the Project, a Construction Contract under supplier's credit was signed on 7th February, 1994 between China National Machinery Import and Export Corporation (CMC) and Petrobangla with a view to develop an underground mine having a capacity of 1.00 Million Metric Tonnes of coal per annum. To ensure proper implementation of the project and smooth functioning of the mine operation, BCMCL was formed under Petrobangla.

3.8.4. After substantial completion of the project, the mine was taken over from the Contractor (CMC) on June 30, 2005 issuing a Conditional Acceptance Certificate. A Management, Production and Maintenances Service Contract (M&P Contract) was initialed between BCMCL and a consortium of CMC and Xuzhou Coal Mining Group Company Limited (XMC) and commercial production of coal was started on September 10, 2005. This M&P Contract had term of 71 months with target production of 4.75 Mt. The contract term was completed on 10.08.2011 and the total production achieved during the term of Contract was 3.65 MT. To maintain the coal production from the mine and for ensuring mine safety, a new M&P Contract has been signed between BCMCL and CMC-XMC Consortium. This contract has commenced from August 11, 2012 and will remain effective for a period of 72 months. A total coal production of 5.5 MT has been envisaged from the mine during the current contract period of 72 months.

3.9. MGMCL

3.9.1. Maddhapara Granite Mining Company Limited, a company under Petrobangla, was formed in 1998 for developing Hard Rock mine in Maddhapara. It operates Maddhapara granite mine located in Parbatipur Upzila of Dinajpur district. Maddhapara mine was executed through a contract between Petrobangla and NAMNAM.

3.9.2. It is an underground hard rock mine with a designed capacity of 1.65 MTPA and produces hard rock as construction material to meet the requirement of flood control, construction of coastal and town protection embankment, construction and maintenance of bridges, roads & highways, river training, railway ballast, high rise buildings and other heavy construction works.

4. Coal Bed Methane (CBM)

4.1. Overview

4.1.1. Methane present in un-mined coal seams is often referred to as Coal Bed Methane (CBM). This includes

1. Recovery of methane prior to mining in the coal seams.
2. Presence of methane in seams where coal remains un-mined. (Virgin Coal Bed Methane – VCBM)

4.1.2. Methane is recovered from un-mined coal seams for two primary reasons:

1. It may be necessary to drain the seam of as much methane as possible before mining takes place. This reduces the risk of explosion improving mine safety and also reduces methane emissions to the atmosphere during coal extraction leading to less environmental impact.
2. The methane may be recovered for its energy production potential, regardless of whether the coal will eventually be extracted.

4.1.3. Till 20 years ago, CBM was considered as an unconventional gas play from which most operators stayed which has now grown into a commercially important, mainstream natural gas source. Currently, CBM projects are commercially operational in several countries.

4.1.4. If methane trapped in the coal seams is not extracted and utilized, it is not only a lost resource but also contributes to global warming. Even though the volume of methane contributing to greenhouse gasses is three times smaller than carbon dioxide, its greenhouse potential is 21 times higher. According to World Coal Association, coal mining is estimated to contribute about 9 per cent of global methane emissions.

4.1.5. Thus extraction of Coal Bed Methane (CBM) has converted this methane as significant source of environment friendly fuel from centuries-old mining hazard. CBM holds the intriguing potential to help supply energy needs for revitalizing industries in environmental friendly manner.

4.1.6. CBM is being produced in U.S.A., Australia and Canada. Pilot projects are underway in China, India and in about 15 other countries. Much potential exists internationally in various countries like Spain, France, Poland, Germany, Zimbabwe, and Russia which have undertaken projects after the initial success in the United States.

4.1.7. The use of CBM has the following advantages:

- Provides a clean-burning fuel.
- Improves safety of coal mines.
- Decreases the methane vented to the atmosphere from coal mines that contributes to global warming.
- Provides mean to exploit energy potential of abundant coal resource with high gassiness that is often too deep to mine.

4.1.8. The potential for future mining operations post CBM extraction is largely dependent on the accessibility of the coal seams. Coal found at extremely deep depths is often not considered feasible for extraction through conventional mining because of practical, safety and economic considerations.

4.1.9. Depending on quality, methane from mines could be sold to gas companies, used to generate electricity, used to run vehicles, used as feedstock for fertilizer or methanol production, used in blast furnace operations at steelworks; sold to other industrial, domestic or commercial enterprises; or used on-site to dry coal.

4.2. Coal Bed Methane Recovery Techniques

4.2.1. Methane gas and coal are formed together during coalification, a process in which biomass is converted by biological and geological processes into coal. Methane is stored within coal seams and also within the rock strata surrounding the seams. Methane is released when pressure within a coal bed is reduced as a result of natural erosion, faulting, or mining. Deep coal seams tend to have higher average methane content than shallow coal seams, because the capacity to store methane increases as pressure increases with depth.

4.2.2. Conventional gas reserves are typically characterised by the accumulation of free gas occupying void spaces within a sedimentary reservoir rock and capped by an impervious rock that traps the gas in place. In contrast, CBM collects in underground coal seams by bonding to coal particles. The gases adhere as a thin layer of molecules to the surface of the coal (i.e. 'adsorption'). As coal is porous, the surface area of coal is much larger than it appears. Some gas occurs in the natural fractures of the coal, and some is dissolved in the waters in the coal seam, but the vast majority of the methane comes from the micro pores.

4.2.3. Methane from un-mined coal seams is recovered through drainage systems constructed by drilling a series of vertical or horizontal wells directly into the seam. Water must first be drawn from the coal seam in order to reduce pressure and release the methane from its adsorbed state on the surface of the coal and the surrounding rock strata. Once dewatering has taken place and the pressure has been reduced, the released methane can escape more easily to the surface via the wells.

4.2.4. The choice of vertical or horizontal wells is dependent on the geology of the coal seam. In the case of seams at Shallow depths, vertical wells have been used traditionally. These vertical systems often use layers of fracture wells, which drain the methane from fractures in the coal seam produced as result of increased pressure created during the dewatering process. At these shallow depths, combination of high permeability and low pressure make the vertical systems ideal as extra methane flow enhancement is not required and the structure of vertical and fracture wells remains stable.

4.2.5. At greater depths, the structure of vertical and fracture wells may not be able to withstand higher pressure levels and extra flow enhancement may be required to produce the methane. This is often true in cases of VCBM recovery due to depths at which the coal is found. In these instances, horizontal drilling techniques may be used for increased accuracy and flexibility. Within these horizontal systems, flow enhancement techniques such as extra hydraulic fracturing - where water is pumped into the seam at high pressure - may be deployed to further facilitate release of methane from coal seams.

4.2.6. Although horizontal systems can recover much higher volumes of methane from coal seams at extreme depths than a vertical system possibly could, recovery efficiency is relatively low and heavily dependent on overall length of the drill through the coal seam. Horizontal systems are still in their infancy and over time there may be increased movement towards their use as the technologies mature and efficiencies are improved. Figure below represents typical coal bed methane recovery process:

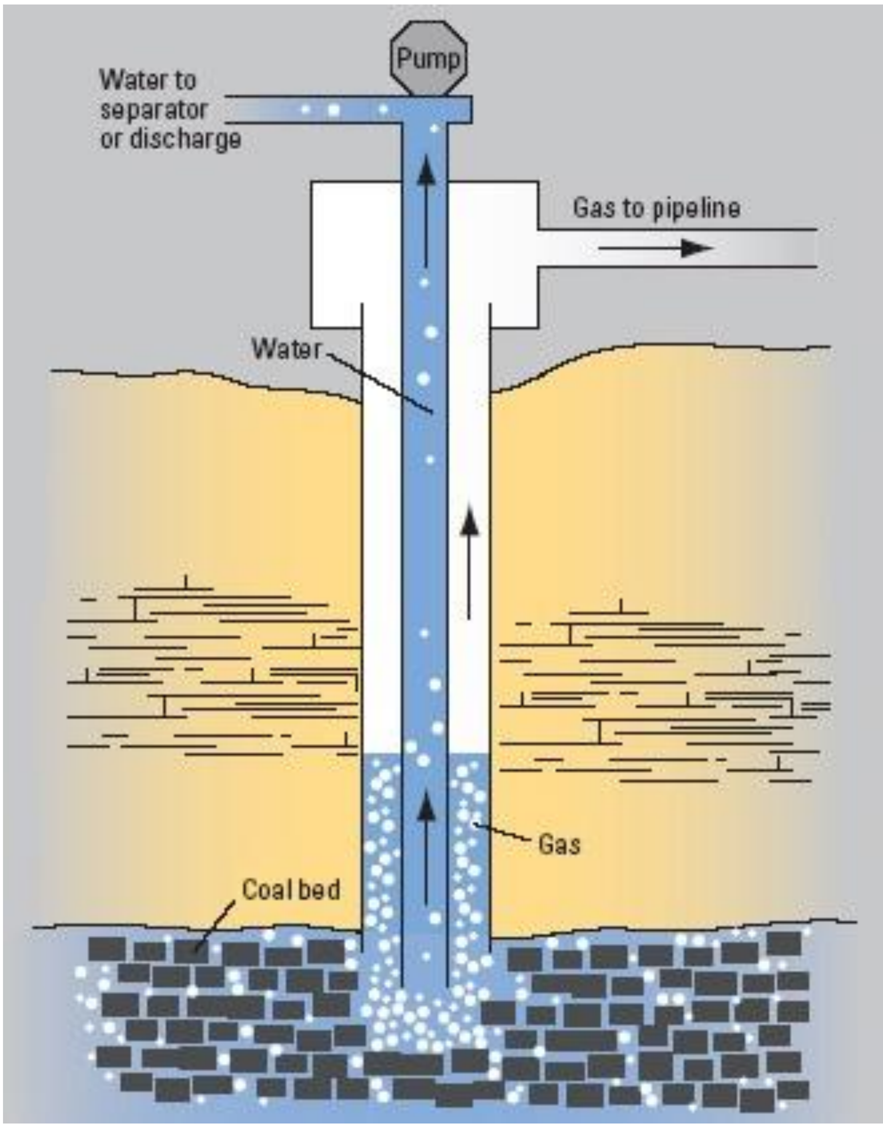

Figure 4: Coal Bed Methane Recovery Process

4.2.7. Methane from coal bed reservoirs can be recovered economically, but disposal is an environmental concern. Most gas in coal is stored on the internal surfaces of organic matter. Because of its large internal surface area, coal stores 6 to 7 times more gas than the equivalent rock volume of a conventional gas reservoir.

4.2.8. Gas content generally increases with increase in coal rank, depth of burial of the coal bed, and with reservoir pressure. Fractures or cleats in coal beds act as methane reservoirs which are usually filled with water. At higher depth, less water is present in coal bed but it is more saline.

4.2.9. By removing water from coal bed, pressure is reduced partially which help releasing gas from coal seam. Thus, large amounts of water, sometimes saline, are produced from coal bed methane wells, especially in the early stages of production.

4.2.10. Disposal of water recovered during methane production in environmental friendly and economically feasible manner is a concern. Water may be discharged on the surface if it is relatively fresh, but often it is injected into rock at a depth where the quality of the injected water is less than that of the host rock. Another alternative, not yet attempted, is to evaporate the water and collect the potentially saleable solid residues.

4.3. *Global Resource Base & Potential for Utilization*

4.3.1. The largest CBM resource bases are identified in the former Soviet Union, Canada, China, Australia and the United States. However, much of the world's CBM recovery potential remains untapped.

4.3.2. Only a few countries - namely Australia, Canada, China, India, Kazakhstan, Russia and the USA currently have operational commercial CBM projects. USA has the longest history and largest volumes of CBM production, with Canada, China and Australia ramping up CBM production significantly over last decade.

4.3.3. Preliminary worldwide CBM resources are estimated to range between 5,800 and 24,215 Trillion Cubic Feet (tcf)[1]. CBM resources in the UK and in Europe are in the process of being estimated. Though proven reserves in Australia have been estimated at nearly 90 tcf by IHS.

4.3.4. In Asia, the estimated size of the CBM resources is about 1,200 tcf in China, and 453tcf in Indonesia[2].

USA

4.3.5. United States has the most established CBM market with history of almost thirty years of commercial production of CBM. In USA, CBM accounts for approximately 10% of domestic gas production.

History

4.3.6. In 1970s, development of CBM started in the Black Warrior Basin of Alabama. By mid-1980s, technology and economics of CBM extraction was established and active drilling program was started.

4.3.7. CBM production from the Black Warrior Basin peaked in 1998 at 113bcfpa and has remained stable at around 109bcfpa since then. The Basin has recovered nearly 2.1tcf till November 2012 from a total of 6,000 wells.

4.3.8. San Juan Basin was next significant CBM project where drilling activities started during mid 1980s. Wells in the San Juan basin proved to be more productive than wells in the Black Warrior basin, with average cumulative recoveries of around 4bcf as opposed to recoveries of 0.4bcf in the Warrior.

4.3.9. Since mid-1980s, the San Juan Basin has become most prolific CBM basin in the world. Production from the basin peaked in 1999 at around 895bcfpa, with cumulative recovery till September 2009 estimated at 15.0037tcf.

4.3.10. CBM development in USA registered rapid growth in late 1990s. Pilot projects were established in coal basins across the country, including the Arkoma, Cherokee, Green River, Forest City, Piceance, Powder River and the Raton basins.

4.3.11. Due to lower rank of coal, some of these regions were considered uneconomic for CBM extraction but shallow depths of wells (typically between 180m – 400m) compensates for lower gas content making these projects viable.

4.3.12. Since 2000, Powder River basin has been one of the most active CBM extraction site the USA. Currently, the Fort Union coals are producing around 465bcfpa from over 11,000 producing wells. The federal government estimates 27,000 CBM wells in the basin ultimately.

[1] Historical Perspective And Future Opportunities Of Coal Bed Methane, Andrew R. Scott, Altuda Energy Corporation, San Antonio, Texas

[2] Worldwide Coalbed Methane Overview, Alex Chakhmakhchev, Information Handling Services (IHS), SPE Hydrocarbon Economics and Evaluation
Symposium, 1-3 April 2007, Dallas, Texas, SPE 106850

4.3.13. History of CBM development in USA can be summarized as below:

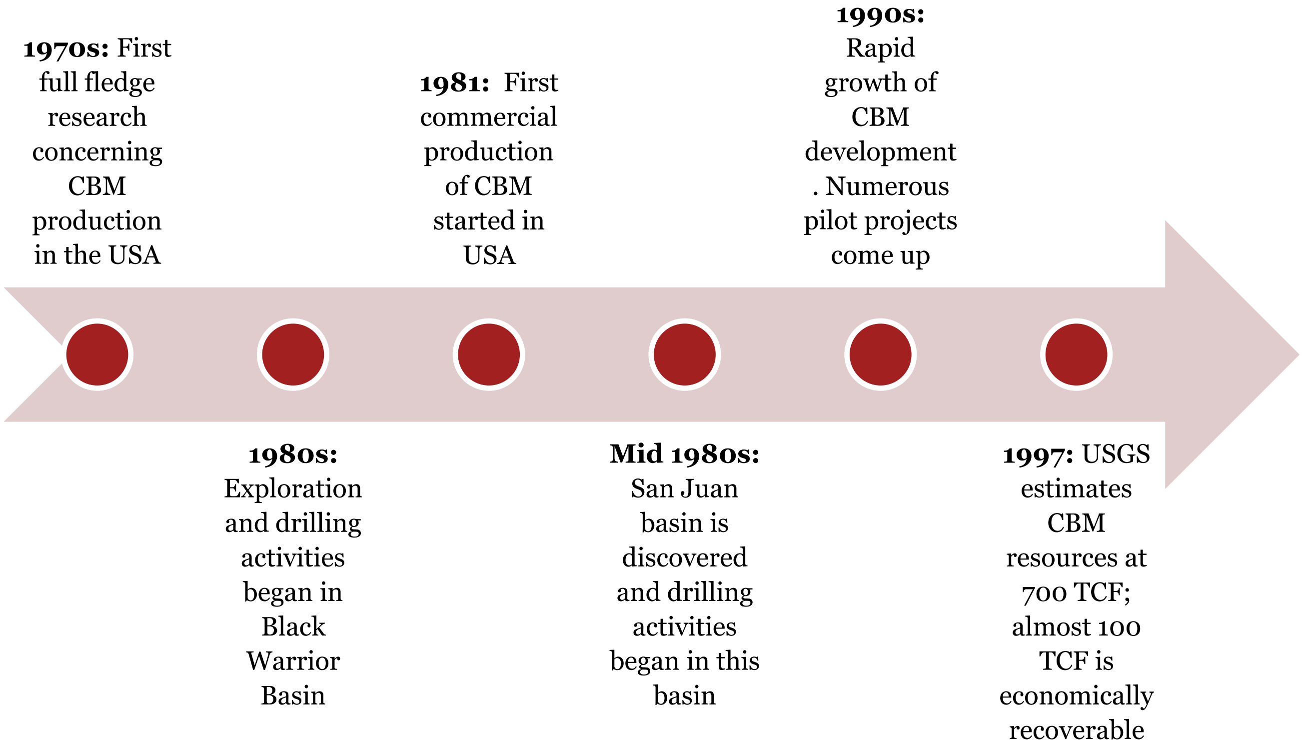

Figure 5: Development of CBM resources in USA

Reserves and Production

4.3.14. In 1997, the U.S. Geological Survey (USGS) estimated in-place coal bed methane resources in the United States at more than 700tcf; of which almost 100tcf is economically recoverable.

4.3.15. Half of the estimated 100tcf of recoverable CBM reserves in the contiguous 48 U.S. states is in the Powder River, Northern Appalachian, San Juan and Black Warrior basins. Almost 75tcf may yet be discovered in the contiguous 48 states. Another 57tcf of CBM reserves is estimated to be recoverable in Alaska.

4.3.16. The proved CBM reserves in U.S.A. have grown from 3.67tcf in 1989 to 21.87tcf in 2007, almost a six fold increase.

4.3.17. As of 2010 the proved CBM resources in USA stand at 17.50tcf. The following figure shows the growth of CBM reserves in USA:

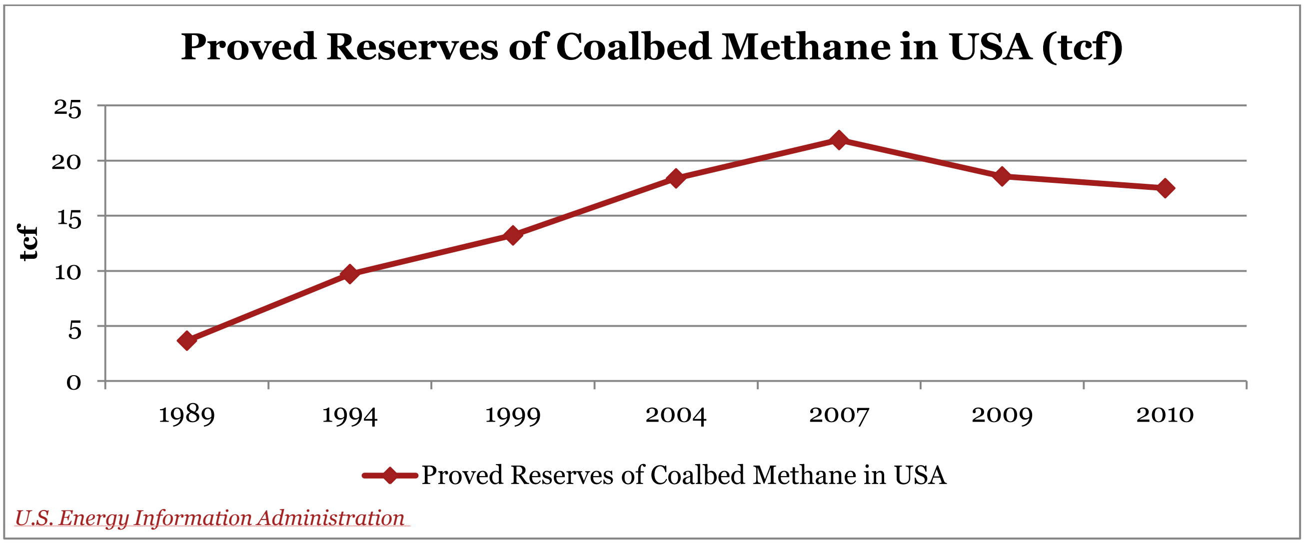

Figure 6: Growth of CBM reserves in USA

4.3.18. The CBM production in U.S.A. has grown significantly from a mere 91bcf in 1989 to a high of 1966 bcf in 2008.

4.3.19. As of 2010 the CBM production in USA stands at 1914 bcf. Trend of CBM production is presented below:

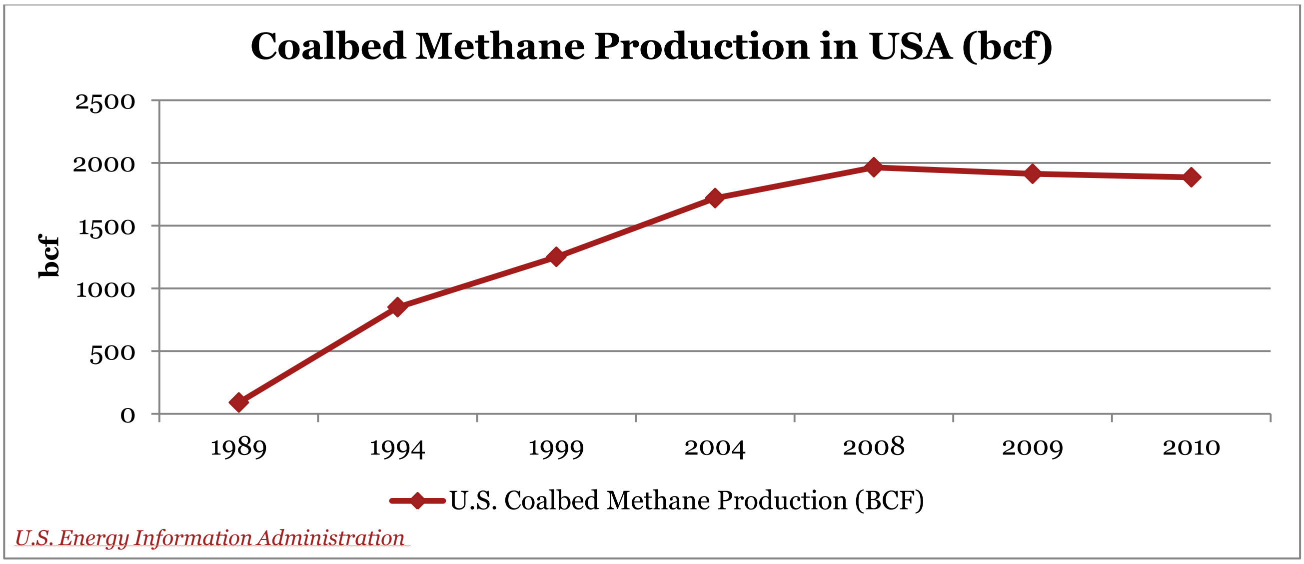

Figure 7: Growth of CBM production in USA

Current Status

4.3.20. The growth in recovered coal bed methane in the USA can be attributed to five primary factors:

- Continued use in natural gas pipelines
- Use for a variety of purposes besides pipeline injection thus availability of market
- Legislation concerning ownership issues has been enacted in most coal bed methane producing states i.e. appropriate regulatory framework is enacted

- Various projects have proven the profit-generating potential of coal mine methane recovery i.e. economic viability is established
- Growing awareness of the climate change impacts of methane emissions i.e. support from government and population

4.3.21. Introduction of tax credits further enhanced viability of CBM projects and maintained competitiveness against conventional projects.

4.3.22. This tax credit allowed producers to reduce their tax liability for all wells drilled between 1980 and 1993. The credit effectively provided the upstream industry with an incentive to actively pursue CBM gas projects, spurred additional drilling activity and further enhanced the economic viability of marginal resources.

4.3.23. Today, there are coal bed methane recovery and use projects at mines States of Alabama, Colorado, Pennsylvania, Virginia, and West Virginia in USA.

4.3.24. As of 2006, at least 23 mines operate drainage systems, with drainage efficiencies in the range of 3% to 88%. Twelve of these mines already sell recovered methane, and two mines consume methane onsite for power generation and to heat mine ventilation air.

Australia

4.3.25. Nomenclature of CBM is Australia is different and is commonly known as coal seam gas (CSG) in Queensland and as coal seam methane (CSM) in New South Wales, South Australia and Western Australia.

4.3.26. The coal bed methane associated with coal mining operations is traditionally called coal mine methane (CMM). The coal mine methane that is emitted to the atmosphere through mine ventilation systems is called ventilation air methane (VAM).

4.3.27. Australia has been producing CBM for over fifteen years now. CBM accounts for 30% of gas supplied in Queensland.

History

4.3.28. The first attempts to develop CBM projects began in the late 1980s and early 1990s. In the first attempt, techniques implemented successful in the United States were adopted. The wells targeted shallow coal seams with moderate to high permeability.

4.3.29. During this period, over USD 130 million were spent in Australia for CBM development but attempts were failed to produce gas at commercial rates in most cases.

4.3.30. Consequently, major companies such as ConocoPhillips withdrew from the industry and CBM was considered to be an expensive alternative to potential gas customers.

4.3.31. Despite these initial set-backs, a number of companies persevered with CBM through 1990s. These companies re-examined the techniques used and the coals targeted and identifies certain changes required to make CBM a success in Australia.

4.3.32. In February 1996 the first commercial CMM operation commenced at the Moura mine in Queensland methane drainage project (then owned by BHP Mitsui Coal Pty Ltd). In the same year at the Appin and Tower underground mines (then owned by BHP Pty Ltd) a CMM operation was used to fuel on-site generator sets (gas fired power stations).

4.3.33. The first stand alone commercial production of CSG in Australia commenced in December 1996 at the Dawson Valley project (then owned by Conoco), adjoining the Moura coal mine. The Moura mine is now called Dawson and is owned by Anglo Coal Australia.

Current Status

4.3.34. CMM is actively produced in Australia, which ranks sixth globally in CMM emissions (18.4million metric tonnes CO2 equivalent). Mining companies such as BHP Billiton and Envirogen use CMM gas for on-site electricity generation.

4.3.35. As on December 2009 the 2P reserves (proven plus probable) of CSG in Australia were 26,132 Petajoules (PJ)[3] or more than 130 years of production life at current rates of extraction of 195 PJ per annum.

4.3.36. Queensland has 23,038 PJ (or 88%) of the 2P reserves with the remaining 3,094 PJ in New South Wales. Queensland's Surat Basin has 65% and the Bowen Basin has 23% of Australia's 2P CSG reserves respectively.

4.3.37. The Australian Greenhouse Office provides funding to CMM projects with an aim of reducing Australia's greenhouse gas emissions. With the exception of the United States, Australia has the most commercially advanced CMM and CBM industry.

4.3.38. The companies involved in the production of coal seam gas in Australia are:

- Westside Corporation
- Santos Ltd
- Origin Energy
- Queensland Gas Company (BG Group)
- Arrow Energy
- Australian Gas Light Company (AGL)

4.3.39. A number of companies including Shell Australia, Arrow Energy, Santos Ltd and Queensland Gas Company are planning to use coal seam gas to operate Liquefied Natural Gas plants at Gladstone in Queensland from about 2013-14.

4.3.40. Coal mines that extract CMM include German Creek and Oaky Creek in Queensland and Appin, Westcliff, Teralba, Tahmoor and Glennies Creek in New South Wales.

India

History of CBM in India

4.3.41. India has large proven coal reserves and holds significant prospects for commercial recovery of CBM.

4.3.42. Prior to 1997, due to absence of proper administrative, fiscal and legal regime, CBM E&P activities were limited to R&D only. It was only after the formulation of the policy for exploration and production of CBM by the Government in July 1997, CBM exploration activity commenced in the country.

[3] 1 Petajoules = 10^{15}Joules = 1 Billion Cubic feet Methane

4.3.43. Ministry of Petroleum & Natural Gas (MOP&NG) was identified as the administrative Ministry and Directorate General of Hydrocarbons (DGH) was designated as the implementing agency for CBM policy. DGH functioning under the aegis of MOP&NG plays a pivotal role in development of CBM resources in India

CBM Resources in India

4.3.44. The total sedimentary area for CBM exploration in India is of the order of 26,000 sq. km. Out of this, exploration has been initiated in only 52% of the area thus a large potential CBM bearing area still remains unexplored.

4.3.45. CBM blocks in India are awarded to prospective developers through competitive bidding system. In total 33 blocks have been allocated to different Indian and foreign operators during previous 4 rounds of CBM bidding. The prognosticated CBM resources are about 50 TCF, out of which only 8.39 TCF has been established.

4.3.46. The exploration carried out by various operators in the state of Jharkhand, West Bengal and Madhya Pradesh reveals that Gondwana coal constitutes excellent CBM potential areas that can be harnessed commercially with the induction of appropriate technology.

CBM Bidding Rounds

4.3.47. As per guidelines of the approved CBM policy, prospective blocks are to be delineated by deliberation between MoC and MoP&NG and are to be allotted by the latter through global bidding for exploitation in line with the practice followed for oil and natural gas resources.

4.3.48. The government of India has already conducted 4 rounds of CBM bidding. The exploration awareness for Coal Bed Methane (CBM) in India shows a dramatic change of scenario from lukewarm response in the first round of bidding (2001) to 'CBM rush' in the third round (2006), within a span of five years. A fourth round of bidding conducted in July 2010 also evolved a decent response with contracts for 7 out of the 10 blocks being signed.

CBM Round – I

4.3.49. DGH in coordination with Ministry of Coal (MOC), carved out several prospective CBM blocks in different coalfields of the country, developed CBM related data and prepared Information Dockets & Data Packages. In May 2001 Government of India offered 7 blocks under 1st round of CBM bidding, out of which 5 blocks were awarded and contracts signed. Contracts for another 3 blocks awarded on nomination basis were also executed.

CBM Round –II

4.3.50. Under 2nd round of CBM bidding 9 blocks were offered through international competitive bidding in May 2003 with bid closing date of 15th October 2003. A total of 14 bids were received for 8 out of 9 blocks offered. Contracts for these 8 awarded blocks were signed in June 2004.

CBM Round –III

4.3.51. International competitive bids were invited by Government of India for 10 CBM blocks under 3rd round of CBM bidding with bid closing date of 30th June 2006. This round received overwhelming response. For the first time major foreign E&P companies participated in the CBM-III bidding round. 70 nos. of data packages valued Rs. 10 crores (approx.) were sold and a total of 54 bids were received for all the 10 blocks, from 26 companies including 8 foreign and 18 Indian companies. All the 10 blocks received multiple bids. The blocks were allotted amongst 4 companies/consortium. Contracts for these 10 awarded blocks were signed in November, 2006.

CBM Round –IV

4.3.52. Given success of previous 3 rounds of Global bidding of CBM blocks, to increase pace of exploration and production of CBM, the Government of India offered ten additional blocks in different coal/lignite fields under CBM Round-IV. 7 CBM Blocks were awarded under the fourth round of CBM bidding and the contracts for these 7 blocks were signed on 29th July 2010.

Current Status of CBM Production in India

4.3.53. Commercial production of CBM has already commenced in Raniganj (South) CBM block in West Bengal which is the only project under commercial operations currently.

4.3.54. Efforts are also being made in Sohagpur blocks in Madhya Pradesh and Jharia block in Jharkhand for commencement of commercial production at the earliest.

4.3.55. CBM production is expected to increase from current level of 0.15 MMSCMD to 7.4 MMSCMD by the 2013 - 14. (DGH – India)

Existing Policies for CBM Development

4.3.56. A New Petroleum Tax Code is pending for approval. It offers CBM projects “infrastructure status”, which allow a 5-year tax holiday from the date of commencement of production, and a 30% concession on income tax payable in the following 5 years. Extension of this period by 2 years is under consideration of Government of India.

4.3.57. This concession reduces corporate income tax from 48% on foreign operating companies to 33.6% during that period. No customs duties would apply. The companies will be subject to a base rate of 10% ad valorem royalty, payable to the respective state government.

4.3.58. An additional production-linked payment would be payable to the central government on a sliding scale based on the production level. This payment schedule has been kept as a biddable item. A nominal commercial bonus of USD300,000 would be paid on declaration of commercial assessment.

4.3.59. To increase participation and make projects more attractive, Government of India is following attractive terms for CBM E&P:

- No participating interest of the Government.
- No upfront payment.
- No signature bonus.
- Exemption from payment of customs duty on imports required for CBM operation.
- Walkout option at the end of Phase-I & II.
- Freedom to sell gas in the domestic market.
- Provision of fiscal stability.
- Seven years tax holiday.

Canada

4.3.60. Western Canada has vast coal resources. First CBM pilot project was started in 2000 at Horseshoe Canyon in central Alberta leading to commercial production in 2003. In-place CBM reserves are estimated at more than 400tcf in Alberta and 15tcf in Saskatchewan.

4.3.61. CBM exploration commenced in 1977 with drilling in the Coleman-Canmore corridor of the Southern Alberta Foothills. There were several sporadic and largely unsuccessful attempts at exploration over the next 20 years by numerous companies.

4.3.62. The Horseshoe Canyon formation in central southern Alberta has seen the largest early development focus and commercial success, largely due to negligible dewatering requirements.

4.3.63. The CBM resource potential of the Mannville Group in southwest Canada is considered to be the most significant with ultimate reserves estimated between 140tcf and 230tcf.

4.3.64. A number of pilot projects have been conducted in Alberta and British Columbia and companies have started to commit significant capital to developments since the end of 2003.

4.3.65. Further CBM potential exists and is being tested for commercial viability in the Elk Valley and on Vancouver Island in southern British Columbia.

4.3.66. The United States has demonstrated a strong drive to utilise its resource base. Exploitation in Canada has been somewhat slower than in the US, but is expected to increase with the development of new exploration and extraction technologies.

4.3.67. CBM industry in Canada is in early stage with large size players in appraisal phase.

China

4.3.68. China is the largest producer and consumer of coal accounting for 46% of global coal production. China's energy needs are primarily met by coal. It is net importer of coal. It is also the largest emitter of coal mine methane.

4.3.69. To meet increasing energy demand, China is resorting to import of coal which increased in recent years. To reduce dependence on coal, China is developing LNG and other gas infrastructure which also help reduce pollution.

4.3.70. China started CBM exploration in 1990s and over 30 areas have been tested so far. Petrochina pursued CBM project for over 11 years but failed to develop it successfully due to poor exploration results and lack of technology.

4.3.71. In view of this, Government of China opened up sector to foreign participation. There are several companies who are now constructing CBM projects in China including Green Dragon, China United and Fortune Oil.

4.3.72. China's first commercial production from the Panhe CBM project located in Shanxi Province has started in November 2005.

4.3.73. Since 2011, China has eliminated tariffs and value-added taxes on equipment and components used to develop coal bed methane refining in mines to quicken the exploration of gas stored in coal beds.

4.3.74. Usually, domestic gas prices are set by the Government, but this is not the case for CBM. As a result, CBM receives preferential treatment over conventional gas supply.

4.3.75. During the 11th Five-year Plan period ending 2010, China extracted 9.5bcm of coal bed methane, which equaled saving of 11.5 million tonnes of coal equivalent and reducing the emission of carbon dioxide by 142.5 million tonnes. (Xinhua)

4.3.76. During the new five-year plan period ending in 2015, China aims to extract 65.8bcm of coal bed methane, which, if comes true, will help save 79.62 million tonnes of coal equivalent and reduce 990 million tonnes of greenhouse gas emission. (Xinhua)

Russia

4.3.77. Russia has the largest coal reserves globally and is one of the large coal producers. The largest and most important coal-producing area is the Kuznetsk Basin. The Kuznetsk Basin is located in the south-central part of the country and has coal reserves estimated to be in the order of 14.5 billion tonnes.

4.3.78. Kuznetsk region account for about one third of coal production of Russia. Country is fourth largest emitter of CMM but these emissions are expected to decrease over time.

4.3.79. CMM emission abatement potential at Russian mines directly depends on the efficiency of degasification systems, and upon mining, geological and reservoir conditions. While Russian mines and mining associations welcome developments leading to the reduction of methane content of mined coal seams, they lack institutional and technical support to initiate CMM abatement projects.

4.3.80. Gazprom has plan to develop CBM in the Kuznetsk Basin. This area has an estimated 460tcf (gas in place) of CBM resource to a depth of 1,800m.

4.3.81. Gazprom has invested more than 2 billion roubles (USD 70 million) in the project between 2008-10 and had planned to invest another 1.5 billion (USD 52 million) in 2011. A Russian government approved program calls for Gazprom to invest more than 80 billion roubles (USD 2.8 billion) in the project by 2020 in order to increase industrial methane production from coal beds in the region.

4.3.82. In February 2011, Russia began producing electricity using methane gas from coal beds. The expansion of this technology has the potential to considerably reduce methane emissions from mines and free up natural gas for export.

4.3.83. Russia's first coal bed methane power plant is located in the Kemerovo Region mining town of Talla. Using two GE-produced Jenbacher gas generators, the plant powers two mine excavators and provides electricity to the village of Zhernovo, which borders the Taldin coal field

4.4. CBM in Bangladesh

4.4.1. The USA and Australia produces Coal Bed Methane (CBM) from coal fields where coal production did not commence i.e. virgin coal seams. In 2001, the USA produced 1.56Tcf CBM which was 8% of the natural gas production of the country. China also started CBM production which is growing. Given the commercial operations of CBM in several countries and significant development towards commercial operations of CBM in many other countries, Bangladesh also wishes to develop CBM as source of energy. Coal resources existing at high depth may have potential CBM resources which provide opportunity to Bangladesh to develop CBM. Conditions in the Jamalganj coal field represent good case for CBM development.

4.4.2. Jamalganj coal field was discovered in 1962 after a series of successful exploratory studies. 10 wells were drilled in this area and the coal seams were encountered in 9 out of the 10 wells. General geology of the coal seams suggest that the seams gently dip to the east and the depth range is 640m to 1,158m from the surface. There are seven coal seams identified which have been named as seam 1 to seam 7 from the upper to lower. The average cumulative coal seam thickness is 64m and the main seams are seams 3 and 7 which are thicker and continuous.

4.4.3. During exploration, Gas content of coal (m^3/ton) was not measured though it was reported that there were gas evolutions in several drill holes. Methane gas percentage was unknown and cementation was carried out because of the kaolinite content.

4.4.4. Barapukuria coal mine which is sole operating mine reported low gas content and gas emission. Low gas content was presumed for reasons like presence of many cleats in the coal seam (high permeability), high permeability rock (sand stone) and many faults. Therefore, much gas has already separated itself from the coal seams and the surrounding rock.

4.4.5. In Jamalganj coal field, the coal seams are sandwiched between Gondwana sandstone (course to medium size) strata and thus effectively impermeable due to high compaction and cementation. This is resulting from presence of kaolinite cement. It is perceived that sandstones form seals above the gas bearing coal seams. Given this, this coal field is considered as potential source for CBM recovery.

4.5. Technical Studies to establish CBM

Studies to be conducted for establishing CBM Resources

4.5.1. Exploitation of Coal Bed Methane (CBM) involves four major phases:

- Exploration
- Pilot assessment
- Development and
- Commercial production.

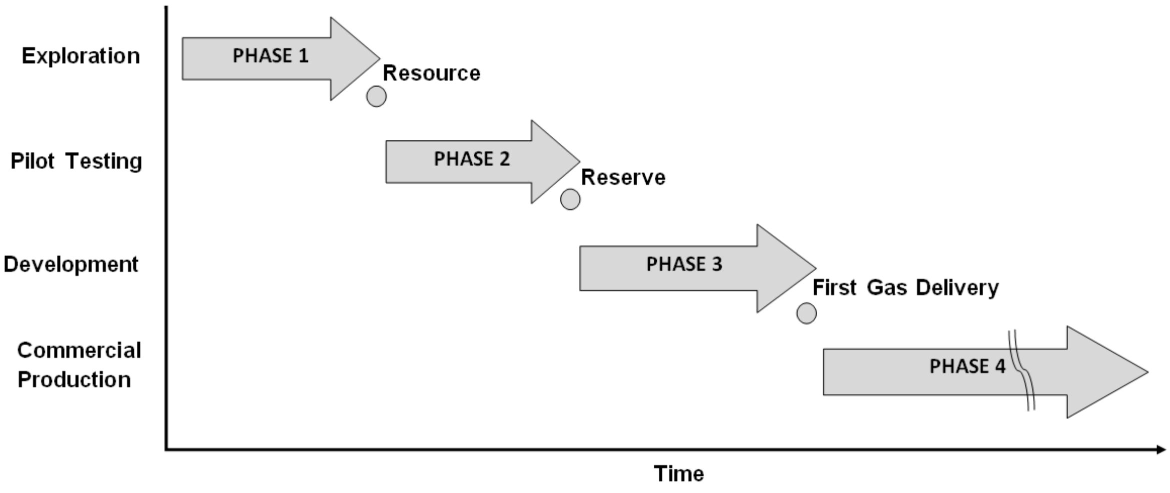

Figure 8: Typical CBM timeline

4.5.2. CBM reservoirs are dual-porosity reservoirs where major portion of gas is stored in low permeability (practically nil) coal matrix by sorption (primary porosity) and a very small amount of gas is contained in the natural fractures, called cleats (secondary porosity).

4.5.3. The flow of the desorbed gas from coal matrix to the well occurs through these cleats due to depressurization of the reservoir mainly affected by drainage of water through the cleats.

4.5.4. The key parameters for evaluation of CBM prospects are:

- Gas resources
- Reserves and
- Deliverability

Gas content and storage capacity govern the gas resources and reserves and; permeability of natural fracture system of coal and relative permeability influence deliverability.

4.5.5. Therefore, evaluation of CBM reservoir is considered to be a complex process involving interplay of several factors like, reservoir characters, CBM resources, hydro-geological regime, structural setting of the reservoir etc.

4.5.6. The approach to evaluation of CBM prospects can be sub divided into the following major stages:

- **Pre-drilling Assessment (green field areas)**
  - Geological evaluation based on available information
  - Remote sensing studies
  - Lineaments, natural fracture studies
- **Drilling of Slimholes (core holes and geophysical logs)**
  - Lay, disposition, depth and distribution/lateral extent of coal seams
  - Structural set up
  - Petrographic analysis (macerals, vitrinite reflectors %)
  - Thickness and lithology
  - Water saturation
  - Permeability
  - Adsorption isotherm
  - Gas-in-place resource assessment
- **Pilot Studies**

  In this phase, pilot production wells are drilled in clusters to achieve the following objectives:
  - Production test
  - Estimate relative permeability
  - Estimate reserve
  - Establish well completion effectiveness of different techniques
- **Reservoir Simulation**
  - Spacing and pattern

- Field/Area production potential
- Field/Area development program

4.5.7. The table below lists the key data that are required for CBM reservoir assessment and their primary sources:

Data items	Primary sources
Storage Capacity	Core Measurement
Gas Content	Core Measurement
Diffusivity	Core Measurement
Pore Volume Compressibility	Core Measurement
Compressive strength	Core test
Gross Thickness	Well Log, Core test
Effective Thickness	Well Log, Core test
In-situ Density	Well Log
Pressure	Well Test
Initial Water Saturation	Well Test
Temperature	Well Test, Well Log
Absolute Permeability	Well Test
Relative Permeability	Simulation
Porosity	Simulation, Well Log
Fluid Properties	Gas and Water analyses
Gas Composition	Desorbed Gas analysis
Well Drainage Area (spacing)	Geologic Study (Data interpretation and integration)

Table 1: Required Data and Their Sources for Analysis of CBM Reservoirs

Estimation of Gas-in-Place

4.5.8. The total initial adsorbed gas in a CBM reservoir is estimated using following expression:

$$G = 1359.7\ A * h * \rho_c * G_c$$

Where:

G = Gas-in-Place, scf

A = Reservoir Area, acres

h = Thickness, feet

ρ_c = Average In-Situ Coal Density, g/cm^3

G_c = Average In-Situ Gas Content, scf/ton

4.5.9. The parameters controlling the gas-in-place estimate are assessed as under:

Gas content

- In-situ gas content is generally determined by the USBM direct method. In this method seam core is collected by wire line core drilling so that retrieval of core is quick and minimum gas is lost in the time between retrieval of core and putting it in the sealed canister.

- The gas content is estimated as the total of lost gas, desorbed gas and residual gas. The cored sample after retrieval is put in a sealed canister allowing the gas to desorb. The desorbed gas is measured as a function of time using volume displacement apparatus. Lost gas during retrieval of core, prior to sealing is estimated by extrapolating the rate of desorption of gas (based on the premise that the cumulative desorbed gas is proportional to the square root of elapsed time from the start of gas desorption). The residual gas still left in the core after allowing sufficient time for desorption in canister is measured from the desorbed coal core in the laboratory after crushing the samples to 60 mesh size.

- The total gas volume is reported at standard temperature and pressure and it reflects the total gas volume in the coal at initial reservoir pressure and temperature. The gas contents of different sections of coal in a seam i.e., coal, shaly coal, carbonaceous shale, sandy shale etc. are different.

- Therefore, for better estimation of gas content, a weighted average figure of gas content has to be arrived at for each coal seam. The measured gas volume is divided by the mass of the sample and converted to get gas content in terms of scf/tonne. This will give gas content of the coal on raw coal basis.

- Gas produced from coal often contains significant amounts of CO_2, N_2, H_2 and heavier hydrocarbons apart from methane. Therefore, the composition of desorbed gas should be analyzed to determine the methane content which has to be used for the calculation of gas content in coal.

Reservoir area

- Geological evaluation of the deposit should provide ideas about coal seam continuity and other pertinent details. However, there may be significant structural and stratigraphic variations within the reservoir which are difficult to decipher in absence of detailed geological exploration of the deposit. The presence of a detailed geological report, 3-dimensional seismic data can be utilized to get an idea of coal bed methane reservoir geometry.

Reservoir thickness

- Gross thickness of coal seams can be determined accurately by wire line density logs in fresh open-holes. The cut off density is usually taken as equal to the coal ash density. Determination of net thickness is more complicated as only such thicknesses within a seam which will actually contribute to CBM production are to be considered.
- Resistivity logs can be used to estimate the net thickness. Also band by band core analysis (proximate analysis) results for each seam can give gross thickness and net thickness.

In-situ density

- The correct in-situ density may be obtained from open-hole density log data. In absence of well log data, in-situ density can be calculated from the following equation:

$$\frac{1}{\rho} = \frac{f_a}{\rho_a} + \frac{1-(f_a+f_w)}{\rho_a} + \frac{f_w}{\rho_w}$$

Where :

ρ = bulk density, g/cm3

ρ_a = ash density, g/cm3

ρ_o = pure coal density, g/cm3

ρ_w = moisture density, g/cm3

f_a = ash content, fraction

f_w = moisture content, fraction

Gas reserves

- The most common model in use for estimation of gas reserves for a CBM reservoir is the Langmuir isotherm which can be described by the following equation:

$$G_S = (1 - f_a - f_m)\frac{V_L P}{P_L + P}$$

Where:

G_S = Gas storage capacity, scf/ton

P = Pressure, psia

V_L= Langmuir volume constant, scf/ton

P_L = Langmuir pressure constant, scf/ton

f_a = Ash content, fraction

f_m = Moisture content, fraction

- The isotherm is determined by grinding the coal (core sample) to a fine mesh and systematically measuring the amount of methane gas that the coal can store under incremental pressures in constant temperature (reservoir temperature). The test results are used to determine Langmuir parameters VL and PL.

- The adsorption experiment should be done at equilibrium moisture condition to get accurate result. The equilibrium moisture content, which is defined by ASTM standards, is assumed to be the same as the in-situ moisture content. The measured isotherm data must be normalized to a dry ash-free basis because it is important to have the sorption isotherm and gas content values on the same basis.

- A typical sorption isotherm is shown in figure below.

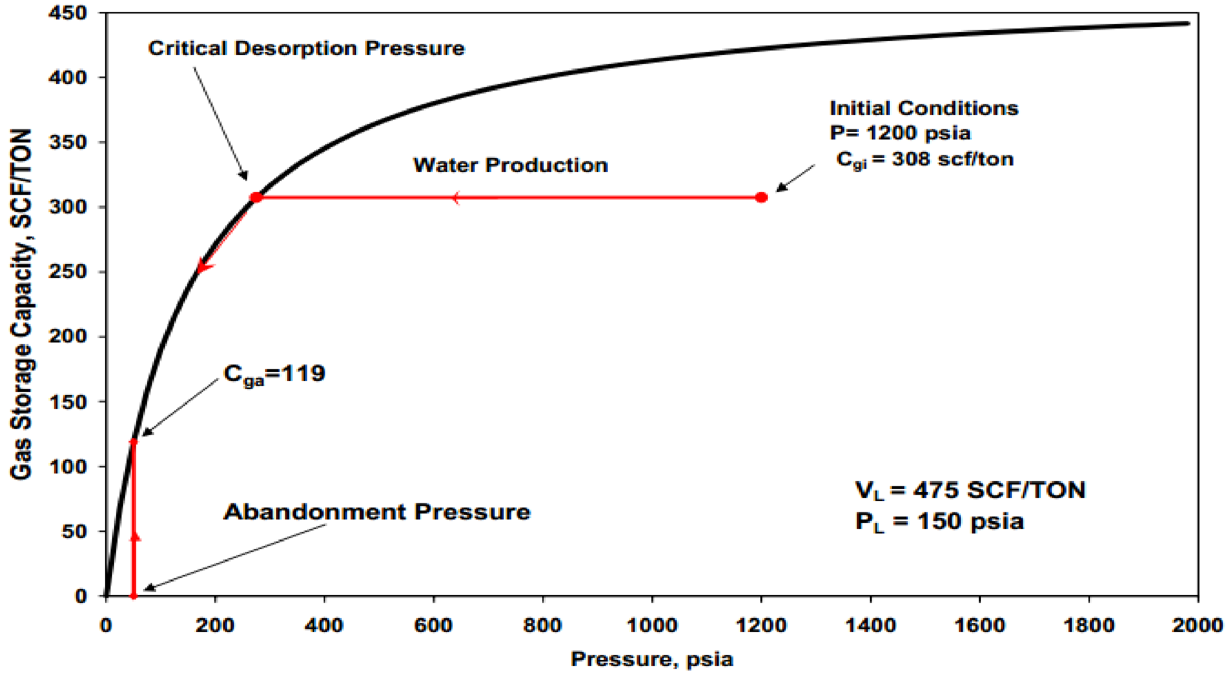

Figure 9: Hypothetical adsorption isotherm

- The initial gas content is also plotted in the same graph. When the initial gas content is below the isotherm, then no free gas will be present and the natural fracture system (cleats) will be filled with water.

- Gas desorption will start once the pressure in the cleat system is lowered to critical desorption pressure (CDP), normally by water production. Below CDP, the gas content will be the maximum value (as per isotherm) down to abandonment pressure.

- If the initial reservoir conditions (pressure and gas content), desorption isotherm and abandonment pressure as available, the recovery factor at the economic limit can be estimated from the following equation:

$$R_f = \frac{C_{gi} - C_{ga}}{C_{gi}}$$

Where :

R_f = Gas recovery at economic limit, fraction

C_{gi} = Initial average gas content, scf/ton (dry ash-free)

C_{ga} = Gas storage capacity at abandonment pressure, scf/ton (dry ash-free)

- Gas reserves can be calculated by multiplying gas-in-place by the estimated recovery factor at the economic limit.

Deliverability

4.5.10. The flow of gas and water to the wellbore in the CBM reservoirs takes place through the natural fracture system (cleats). Hence, properties of the natural fracture system have a great effect on gas and water production rates.

4.5.11. Reliable estimate of deliverability requires accurate estimates of the flow properties of natural fracture system of coal. Absolute permeability and relative permeability are the most important natural fracture system flow properties that effect gas and water production rates.

Permeability, pressure, skin factor etc.

- Accurate measurement of permeability is difficult with core sample test because permeability of coal is a function of stress and the core samples are not likely to be representative. Therefore, values measured in the laboratory cores will not be accurate. The values measured in the laboratory tend to be less than those realized in the field because the small cores may not contain all fractures or joints.
- Hence, it is necessary to determine permeability from one of the following pressure transient tests:
  - Drill stem test (DST)
  - Slug test
  - Injection falloff test (IFT)
    - Tank Test
    - Below fracture pressure injection falloff test (BFP-IFT)
    - Diagnostic fracture injection test (DFIT)
  - Pressure buildup test (PBU)
  - Multi-well interference test
- Well testing is carried out for measurement of reservoir parameters like permeability, pressure, skin around the wellbore, reservoir extent etc. Parameters measured from well testing are used in

predicting future production and determine the optimum flowing condition of the well. It also helps to analyze, improve and forecast the reservoir performances. Injection falloff test (IFT) has been considered to be the best way to carry out testing in CBM wells.

Relative permeability

- Relative permeability is one of the key parameters in determining the deliverability of CBM reservoirs. It is generally accepted that laboratory measurements of core samples do not provide accurate indicator of relative permeability of CBM reservoirs. History matching is the only practical method to obtain realistic relative permeability values. History matching involves using a reservoir simulator to reproduce gas and water production data. Simulators have been developed specifically to account for the complex characteristics of coal. Where production has not been initiated or when production history is limited, a relative permeability has to be assumed.

Well Spacing and Drainage Area

4.5.12. Interference of one well with an adjacent well may increase methane production if dewatering of the seams is facilitated by such interference. It is important to know the impacts of permeability, hydraulic fracturing length and well spacing for field development as these factors will affect the rate and quantity of water removal from a continuous coal seam.

4.5.13. A five spot pilot project is recommended by experts to evaluate field performance where the center well will be most representative of field performance.

4.5.14. An optimum well spacing for development of CBM field can be obtained by simulation where effects of interference from permeability, fracture lengths and permeability anisotropy are considered.

Production testing and simulation

4.5.15. It is usual to carry out production testing before taking up commercial production through pilot test or small-scale demonstration project. These initial production data provide an idea about the actual production characteristics of the reservoir under field conditions. Analyses of the production data require use of coal bed methane simulator to characterize the gas flow from the CBM reservoir. It has been established that reservoir models calibrated with production test data can be utilized for estimating deliverability and reserves of CBM reservoirs. Such calibrated models will also be useful for optimizing completion and production methods as well as for optimizing development well spacing.

5. Underground Coal Gasification (UCG)

5.1. Overview

5.1.1. Underground Coal Gasification (UCG) is a method of converting un-mined coal into a combustible gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or diesel fuel. UCG provides opportunities to exploit resources which are considered uneconomic to be worked by conventional mining methods (due to low grade, thin seams etc.) or are inaccessible due to geology, depth and/or other considerations.

5.1.2. UCG technology allows countries that are endowed with coal to fully utilise their resource from otherwise unrecoverable coal deposits in an environmentally safe way. UCG turns this resource into high value products.

5.1.3. The concept of coal gasification is present for more than 150 years. It was first used in the USA during late 1800 and in India in early 1900. In many cities streetlights were fueled by town gas - the product of early and relatively crude forms of coal gasification. The use of town gas disappeared with the discovery of natural gas resources and transport of gas to consumers through pipelines.

5.1.4. Former Soviet Union started development of UCG technology during the 1930s. Later, the shortage of energy after World War II ignited the interest for developing UCG technology in Western Europe and US. However, the UCG activity declined later with the discovery of the large natural gas resources in 1960s.

5.1.5. In Western Europe the field test works commenced in Britain in 1949 which continued for about 10 years. Later, testing and field trial were done in Belgium (1980s) and Spain (1997) respectively.

5.1.6. In the US, significant R&D funding was done from the mid 1970s to the late 1980s. This converged in the Rocky Mountain test program, conducted for 102 days, during 1987-1988 in Wyoming and gasified over 10,000 tonnes of coal. Later as gas and oil prices dropped in 1990s, US stopped efforts to commercialize UCG.

5.1.7. Over the last decade, as the fuel prices increased, many countries have shown interest and have put efforts for developing the UCG technology. Currently, more than 30 pilot projects are either operating or in the planning stage in more than 25 countries. Various demonstration projects and studies are being conducted in countries like USA, Western and Eastern Europe, Japan, Indonesia, Vietnam, India, Australia and China.

5.2. UCG resources

5.2.1. In 2007, World Energy Council estimated world's potential gas reserves from UCG (as natural gas) to be 145.6 trillion m^3. The largest potential reserves are estimated in the USA (28%) and the Russian Federation (18%).

5.2.2. The table below provides the distribution of estimated potential reserves in the world[4]:

[4] As per WEC "*The quantifications of reserves and resources presented in the tables that follow incorporate, as far as possible, data reported by WEC Member Committees.*"

Country	Estimated available coal reserves for UCG (billion tonnes)	Potential gas reserves from UCG (as Natural Gas) (trillion m3)
USA	138.1	41.4
Europe	130.1	21.8
Russian Federation	87.9	26.3
China	64.1	19.2
India	51.8	15.5
South Africa	48.7	8.2
Australia	44.0	13.2
Total	**564.7**	**145.6**

Source: 2007 Survey of Energy Resources, World Energy Council

Table 2: Distribution of estimated potential reserves in the world

5.3. UCG Extraction Process

5.3.1. UCG uses a process similar to surface gasification of coal. The main difference between both gasification processes is that in UCG, the cavity itself becomes the reactor so that the gasification of coal takes place underground instead at the surface.

5.3.2. The basic UCG process involves drilling two wells into the coal seam, one for injection of the oxidants (water/air or water/oxygen mixtures) and another well, at a specified and pre-determined distance, to bring the product gas to the surface. Coal at the base of first well is heated to temperatures that would normally cause coal to burn. However, through careful regulation of the oxidant flow, coal does not burn but separates into the syngas. The syngas is then drawn out of the second well.

5.3.3. Two different methods of UCG have evolved and are commercially available:

- Vertical wells combined with methods for opening the pathway between the wells.
- Inseam boreholes using technology adapted from oil and gas production that can move injection point during the process

5.3.4. The process is expanded through addition and linkage of further injection and production wells. The gas produced is a mixture of hydrogen, carbon monoxide, methane, carbon dioxide and higher hydrocarbons, along with nitrogen if air is used as the oxidant.

5.3.5. In late 1990s, tests were conducted in Europe which demonstrated the possibility of:

- greater control of deep drilling
- creating larger cavities in the coal seam
- providing more efficient combustion.

5.3.6. In Former Soviet Union, UCG technology with simple vertical wells, inclined wells, and long directional wells was used. This technology was further developed by Ergo Exergy Technologies of Canada and tested at Linc's Chinchilla site (1999–2003); in Majuba UCG plant (2007–present); in Cougar Energy's UCG plant in Australia (2010). Various developers in New Zealand, Canada, USA, India and other countries are attempting to apply the same technology.

5.3.7. The advantages of UCG over conventional coal mining and utilization techniques can be summarized as below:

- Lesser capital and operating expenditure
- No surface disposal of ash and coal tailings from coal washing plants
- No scope for Land degradation due to OB dumps; landscape changes; R&R issues; mine accidents; dust & noise pollution
- Smaller footprints for surface installation
- Reduced NOx and SOx production as compared to surface coal processes
- Utilization of deep and thin coal seams, which are not accessible for mining and could provide an efficient carbon capture and sequestration (CCS) possibility
- Increased worker safety

5.3.8. While the UCG technology provides many advantages, it is not a foolproof technology for coal exploitation. The disadvantages of UCG can be summarized as below:

- Migration of VOCs (Volatile Organic Compound) in vapor phase into potable groundwater
- Organic compounds derived from coal and solubilized metals from minerals contaminating coal seam groundwater
- Upward migration of contaminated groundwater to potable aquifers due to:
  - Thermally driven flow away from burn chamber
  - Buoyancy effects from fluid density gradients resulting from changes in dissolved solids and temperature
  - Changes in permeability of the reservoir rock due to UCG

5.4. Commercial operations of UCG

5.4.1. Currently, Yerostigaz, located in Angren, Uzbekistan, is the only commercial UCG operation in the world. It is in operation since 1961 and produces UCG synthesis gas which is used for power generation. Yerostigaz produces one million m^3 of synthesis gas per day that is supplied to the nearby Angren Power Station.

5.5. Progress of UCG development in key countries

India

5.5.1. In India, coal accounts for more than half of the total energy produced. Looking at current and future energy demands and potential depletion of the coal reserves in foreseeable future, alongside focus on the environmental impacts of coal utilization, UCG is one of the most favorable options to mine the reserves which are unmineable with conventional technology. India has more than 35% of coal resources locked at depth higher than 300m which are potentially exploitable by UCG.

5.5.2. In 1981, a protocol for UCG development was signed between the Government of India and the Government of erstwhile Soviet Union. In 1984, Government of India constituted a National Committee on UCG.

5.5.3. ONGC drilled two pilot wells near Mehsana city, in North Gujarat during 1984-86. However, the Pilot Scale Test could not be taken up due to apprehension of contamination of ground water, on which the local population is dependent.

5.5.4. Government of India has already notified UCG as one of the permissible end uses under captive mining policy to facilitate allotment of coal blocks to potential entrepreneurs.

5.5.5. Further, Ministry of Coal, Government of India, has awarded an S&T study project to Neyveli Lignite Corporation. ONGC has signed an Agreement for Collaboration with Skochinsky Institute of Mining, Russia in November 2004. ONGC has also signed MoUs with NLC, GMDC, GIPCL, CIL and SCCL. Vastan Lignite block of GIPCL has been identified suitable for UCG.

5.5.6. GAIL signed Memorandum of Cooperation with Ergo Exergy, Canada and Memorandum of Understanding with Government of Rajasthan. Land has been earmarked for GAIL. Thus we observe that while the initiatives have been taken for developing UCG, commercial operations are yet to develop.

South Africa

5.5.7. In South Africa, Sasol and Eskom have UCG pilot facilities that have been operating for some time.

Eskom

5.5.8. Eskom commenced trial UCG operations in Majuba coalfield in January 2007 for power generation. The coal seam is 3.5 m thick and is at a depth of 300 m. The figure below depicts the timeline for development of UCG operation at the site.

Source: http://www.eskom.co.za/c/article/86/ucg-technology/

Figure 10: Histogram of development of UCG operation at Majuba coalfield

5.5.9. The production from pilot plant is increased to 15,000 Nm^3/h gas flow (equivalent to 6 MW electricity). Eskom is planning to scale up the operations to meet the requirements of 350 MW IGCC power generation plant.

Sasol:

5.5.10. Sasol initiated a new UCG trial project at Secunda as a potential feedstock for CTL Plant.

China

5.5.11. Since 1980s, China is working on developing the technology using abandoned tunnels in conventional mines and currently has a large developing UCG programme.

5.5.12. China has about 30 projects in different phases of preparation.

5.6. Major players developing UCG Projects

5.6.1. **Linc Energy:**

- Linc Energy has controlling interest of 91.6% in Yerostigaz Project, Uzbekistan – the world's only commercial UCG operation.
- Linc has conducted pilot projects in Australia with the technology provided by Ergo Exergy. It has constructed UCG demonstration facility near Chinchilla in Queensland. The facility has a series of UCG gasifiers to produce syngas. The facility also contains Gas to Liquids facility. In 1999, the UCG first started at the facility and Linc Energy ignited its fifth UCG gasifier in October 2011.

5.6.2. **Cougar Energy:**

- Cougar Energy Limited is a publicly listed Australian company with a focus on the development of commercial projects using UCG technology.
- Cougar owns 47.8% in its subsidiary company, Cougar Energy (UK) Limited established to develop similar UCG based opportunities in India, Pakistan, the UK and Europe.
- Cougar Energy is currently working to develop a 400 MW power station based on UCG gas with coupled UCG project at a site near Kingaroy in Queensland (JORC resource of 73 MT), Australia.
- Its other interests are:
    - Wandoan, Queensland - Target coal resource of 800 million tonnes
    - Latrobe Valley, Victoria - Target brown coal resource of 1 billion tonnes
    - Thar Coal Field, Pakistan - Target resource on proposed lease of 1 billion tonnes
    - India - MoU with Essar Oil and Exploration

5.6.3. **Carbon Energy:**

- Carbon Energy, a JV between Metex Resources Ltd. and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), was formed in 2006 to develop and commercialize UCG.

- The company's pilot-scale 5 MW power station (Phase I) is located at Bloodwood Creek and is the company's first trial into commercialising its proprietary UCG technology "keyseam".
- In August 2011, Carbon Energy achieved key milestone by generating electricity from this syngas power station. Later, in February 2012, Carbon Energy started commercial power production from this power station and exported electricity to Ergon Energy's (Queensland Government-owned) local electricity grid.
- In Phase 2 of power generation company is planning an additional 25 MW Power Station co-located with the 5MW Power Station at Bloodwood Creek. Further, in phase 3, company is planning to develop commercial scale 300 MW Power Station to be fuelled by UCG syngas the Bloodwood Creek site.
- Carbon Energy has acquired UCG mining rights in Mulpun, Chile; Wyoming and Montana / North Dakota border region of the USA and Amasra in Turkey.
- In July 2012, Carbon Energy announced confirmation of 1.2 billion tonnes of conventional coal in its wholly-owned Surat Basin tenements, in south east Queensland.

5.7. Suitability of a coal deposit for UCG

5.7.1. Technical factors affecting UCG are coal rank, site access, seam thickness, depth of occurrence of seam, angle of inclination of coal seam, ash content of coal, porosity and permeability of coal, presence of subsurface water, temperature, roof rock characteristics, water table etc. (S. K. Ray, D. C. Panigrahi and A. K. Ghosh; "Underground coal gasification: conditions of operation" in the Proceedings of International Conference on Advanced Technology in Exploration and Exploitation of Minerals, Mining Engineers' Association of India, 2009, Jodhpur, 14-16 February, pp. 125-130).

Factors	**Impact on UCG process**
Coal rank	Better for lower rank coals such as lignite. Lower rank coal shrink upon heating, enhancing permeability and connectivity between injection and production wells
Seam thickness	More thickness is better as lesser number of wells are required
Depth of occurrence of seam	Deeper seams require high costs but process is more efficient and air emissions will be correspondingly less. Less prospects of watercourse contamination, subsidence and gas escape.
Ash content of coal	Coal seams with ash > 50% by weight decrease the calorific value of the gas and hinder the process control (Europe investigations). In case of moderate ash quantities the oxides of some metals act as catalyst in gasification reaction and increase calorific value of the product gas.
Porosity and permeability	More permeability makes reactant transport easier and hence increases the rate of gasification. However, higher porosity and permeability also increase the influx of water and product losses.
Roof rock	Strong and dry roof rock reduce heat losses and escape of gas to the overburden
Water table	Site should be located below water table to prevent any contamination of drinking water.

Source: S. K. Ray, D. C. Panigrahi and A. K. Ghosh. Underground coal gasification: conditions of operation" in the Proceedings of International Conference on Advanced Technology in Exploration and Exploitation of Minerals, Mining Engineers' Association of India, 2009, Jodhpur, 14-16 February, pp. 125-130.

Table 3: Factors which impact UCG process

5.7.2. Apart from the technical factors, economic factors e.g. size of resource, marketability, cost of production etc. also need to be taken into consideration for establishing suitability of resource for UCG.

5.7.3. Presently, Bangladesh has not made any progress in UCG. It needs to conduct various studies and tests to establish the potential resource for UCG. The required studies and tests are provided in section below.

5.8. Studies for establishing UCG

5.8.1. Since the UCG process involves complex physical and chemical phenomena, such as mass and heat transfer, chemical reactions, and geo-mechanical behavior, the following studies are required for establishing commercial viability of UCG operation in Bangladesh:

- Study of the geological structures including coal and layers interspersed between coal seams.
- Study of coal seam characteristics, viz. seam thickness, depth of occurrence and other geological features etc.
- Study of the coal characteristics, viz. coal rank, porosity and permeability variation, ash content, Volatile Matter content, fixed carbon content and moisture content etc.
- Study of gas emission characteristics of the coal seam.
- Study of engineering properties of overlying strata, viz. shear strength, compressive strength and compaction test etc under normal condition and observing the change in these properties after subjecting it to the gasification temperature.
- Analyzing the stability of gasification chamber face during gasification.
- Study of thermal conductivity of the coal and different strata lying above the coal seam
- Establishing the thermal profile of seam layers and different strata up to the surface.
- Conducting geo-mechanical studies, such as shrinkage behavior of coal bed and its effect on the surface due to underground coal gasification.
- Prediction of surface subsidence due to UCG.
- Conducting computer modeling and simulation studies for prediction of the UCG process in the field scale.
- Conducting pilot-scale studies.
- Market study to establish market for UCG Gas and price for the same (in and around the potential UCG production site).

5.8.2. However, the following problems may create hindrance in the successful implementation of the UCG in Bangladesh:

- The presence of water bearing aquifer (UDT) above the coal seams may result in uncontrolled water influx and create the risk of quenching the reactor. Thus appropriate studies need to be conducted.

- The combustion products of UCG will pass through the aquifers and may contaminate the ground water.

6. Hard rock Sector

6.1. Overview

6.1.1. Hard rock is a term used loosely for igneous and metamorphic rocks, as distinguished from sedimentary rocks. However, in context of Bangladesh, this term is used for construction materials like limestone, sandstone, granite, etc. These are needed for a variety of uses in infrastructure development like construction of buildings, bridges, roads, and flyovers etc.

6.1.2. Most of the Bangladesh land mass consists of alluvial soil brought in by the two mighty rivers, the Padma (Ganga or Ganges) and the Jamuna (Brahmaputra), and their tributaries over millions of years. Hence, there are no rocks for several hundred feet below the ground, particularly in southern Bangladesh.

6.1.3. The infrastructure of Bangladesh is not well developed. This is one of the primary deterrents to economic growth in Bangladesh. Long years of under-investment has taken a toll and resulted in poor access to basic infrastructure for a large part of Bangladesh's population.

6.1.4. Bangladesh ranks 79th in the International Logistics Performance Index (LPI) with the LPI of 2.74 (on the scale of 5) and infrastructure index of 2.49 (on the scale of 5) (World Bank).

6.1.5. According to the CIA World Factbook, Bangladesh is served by a network of 2,39,226 km of primary and secondary roads, but less than 10 percent of them i.e. about 22,726 km are paved. It has a railway system of about 2,622 km of which only 946 km is a broad gauge and the remaining 1,676 km is narrow gauge (1.000 metre gauge), according to CIA estimates for 2010.

6.1.6. Regular flooding during the monsoon season makes it difficult and expensive to build modern transportation and communication networks. Poor and inefficient infrastructure in past has undermined the economic development in the country, and only recently the government has been able to address the problem systematically and channel investments towards expanding its highways, railroads, seaports, and airports. Currently, Bangladesh is putting considerable effort into developing its aviation industry to serve growing tourism and business needs.

6.1.7. One of the reasons of poor infrastructure development in Bangladesh is the poor availability of indigenous construction materials. The annual demand of hard rock in Bangladesh is about 6-6.5 million tonnes. The only hard rock mine of the country, Maddhapara is capable of producing only 1.65 million tonnes of stones per annum. The huge gap in the demand and supply of hard rock makes it necessary to optimally utilize the resources of hard rock in the country.

6.2. Maddhapara Granite Mining Company Limited (MGMCL)

6.2.1. Bangladesh has some granite/granodiorite deposits in the north-west part of the country but these deposits are located at great depth. At present, there is only one hard rock mine, namely, Maddhapara Hard Rock Mine which is located at Maddhapara village, under Parbatipur Thana of Dinajpur district in the Rajshahi division. The mining area is well connected with capital Dhaka and other parts of the country by rail and road.

6.2.2. It is an underground hard rock mine and produces hard rock for use as construction material. This hard rock is mainly massive intrusive igneous rock and occurs as basement complex of Palaeoproterozoic age which is covered by a Quaternary and Tertiary sedimentary rock.

6.2.3. The hard rock is extracted from depths ranging from 240 m to 300 m below the surface.

6.2.4. The classification of resources as per UNFC System of Classification of Maddhapara Hard Rock is given in the table below:

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1) (Mt)	General Exploration (2) (Mt)	Prospecting (3) (Mt)	Reconnai-ssance Study (4) (Mt)
Economic (1)	Feasibility study (1)	*125.15			
	Pre-feasibility study (2)	**792.65			
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)		1521.90		
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)			1201.50	

*125.15 Mt - Mineable reserve upto 270m

** 792.65 Mt– Extractable reserve between 160m and 350m depths.

Source: Report on Mineral Resource Assessment prepared by PwC as part of Mines and Minerals Development Project (Package#07)

Table 4: Classification of resources as per UNFC System of Classification of Maddhapara Hard Rock

6.2.5. In present scenario, the MGMCL is engaged in mining granite to produce construction materials which are of low value. Even this is sold at a loss as the cost of mining is USD 29/tonne (2009-10) and the selling price ranges between USD 5 and USD 23 per tonne depending on the size. The main reason for the high cost of mining is, presumably, the depth at which the deposit is located (240 to 300 metres). However, basis discussions and inputs provided by MGMCL, we understand that MGMCL is in the process of engaging Mine Management Contractor with fixed target of production from the mine and MGMCL expects the cost of production will reduce significantly after engagement of contractor.

6.2.6. **Selling price:** Rock pricing is regulated by Board of Directors of MGMCL and set considering market conditions etc. While as stated above, current rock prices are set below production cost, MGMCL may increase or decrease the prices based on the market demand. The table below shows the selling price of rocks of various sizes prevailing during 2011:

Category	**Size**	**Price**
Boulder	250 mm & above	USD 16/tonne + (VAT USD 0.90/tonne)
Crushed Stone	60 – 80 mm	USD 20/tonne + (VAT USD 0.90/ton)
	40 – 60 mm	
	20 – 40 mm	
	05 – 20 mm	USD 23/tonne + (VAT USD 0.90/tonne)

Stone dust	00 – 05 mm	USD 5/tonne + (VAT USD 0.90/tonne)

Source: Data received from MGMCL for the purpose of Mineral Resource Assessment of Hard rock deposit, Mines and Minerals Development Project (Package #07), Hydrocarbon Unit

Table 5: Selling price of rocks of various sizes (MGMCL)

6.3. Other hard rock deposits (mainly limestone)

6.3.1. Limestone is a sedimentary rock consisting of mainly calcium carbonate, primarily in the form of the mineral calcite, with or without magnesium carbonate. Common minor constituents include silica, feldspar, clays, pyrite and siderite.

6.3.2. Much of the limestone is highly fossiliferous and clearly represents ancient shell banks or coral reefs. It is the chief raw material for cement and is also used in the preparation of paper, steel, sugar, glass and lime.

6.3.3. In Bangladesh there are surface and sub-surface deposits of limestone. The surface to near surface deposits occur at St. Martin's island of Cox's Bazar district and Bhangerghat-Lalghat-Takerghat of Sunamganj district. The subsurface deposit is present at Joypurhat of Joypurhat district.

6.3.4. In 1960s, GSB discovered limestone deposit in Joypurhat with a total mineable reserve of 100 million tonnes. The underground temperature of the mine area was found to be higher than the general depth gradient temperature of the area, as estimated by Cementation Mining Ltd. They opined that the freezing cost of the mineshaft will be higher and as a result the mine will not be economically feasible. Based on their opinion the project for extraction of limestone from Joypurhat area was abandoned.

6.3.5. In the mid 1990s, GSB discovered another limestone deposit at Jahanpur and Paranagar of Naogaon. GSB has recently discovered a huge extractable reserve of Sylhet Limestone (a type of limestone) in Panchbibi area of Joypurhat at a depth of 1,498 feet beneath the surface. The area of the basin, where the limestone was found, is 96 square kilometers and the initial studies suggest that the thickness of the reserve could be as high as 100 feet. Various news reports suggest that the reserve is substantial but the exact reserve base is yet to be ascertained.

Gravel

6.3.6. Gravel Deposits are unconsolidated, natural accumulations of rounded rock fragments resulting from erosion, consisting predominantly of particles larger than sand (diameter greater than 2 mm) such as boulders, cobbles, pebbles, granules, or any combination of these fragments. It is the unconsolidated equivalent of conglomerate.

6.3.7. They may be used as a construction material, either directly as fill or as aggregate in concrete. The bigger size material (boulders) may require some sort of crushing to required size.

6.3.8. Deposits of gravel are found along the piedmont areas of the Himalayas on the northern boundaries of Bangladesh. These river-borne gravels come from the upstream during the rainy season. Vast areas of northern and northeastern parts of Bangladesh are covered with gravel beds.

6.3.9. Apart from above, numerous hill streams also deposit gravels on the streambeds of the hill ranges and in the plains close to these ranges. These hill ranges are mostly located in the Sylhet, Chittagong and Chittagong Hill Tracts regions.

7. Action plan for CBM and UCG development in Bangladesh

Stage 1: To establish the feasibility of CBM and UCG

7.1. Demarcation of resources

7.1.1. The Mineral Resource Assessment Report prepared by Consulting Team under Mines and Minerals Development Project (Package #07) suggests that majority of the coal resources are concentrated in the north western part of Bangladesh and other potential coal bearing areas are also expected to be in vicinity of existing coal bearing area.

7.1.2. It was also suggested that identified coal fields in Bangladesh needs further exploration to establish geologically proved coal reserves. Further, currently no tests have been conducted to establish gas content of the coal and for using technologies other than conventional mining. Current studies are not even sufficient to establish the technical viability of all the coal basins by conventional mining. Thus, further studies are required for establishing characteristics of the coal fields.

7.1.3. The Coal fields and potential Coal Basins in northwestern Bangladesh need to be demarcated for conducting scoping studies/feasibility studies to initiate the exploration activities for CBM and UCG.

7.1.4. The Government of Bangladesh, in consultation with GSB, may demarcate the Coal fields and potential coal basins into blocks by surveys/studies, which may be explored for identifying the potential of CBM and/or UCG.

7.1.5. In case of CBM, exploration programme (by slim hole coring and well logging) should be carried out on priority basis to estimate gas content, permeability, and gas-in-place resources for Khalashpir, Jamalganj and Dighipara coal deposits. Adsorption isotherms for coals of each seam of these deposits are also to be developed. Phulbari deposit may also be included if the proposal for opencast mining of the deposit is abandoned.

7.2. Conducting studies for exploration of CBM and UCG

7.2.1. The Government of Bangladesh may assign the responsibility of conducting the field work and technical studies to a Government Agency.

7.2.2. Such appointed Agency shall carry out the work either on its own or may outsource work (partially or fully) to a third party. The studies required to be conducted to identify the CBM and UCG potential has been discussed in Section 4 and Section 5 respectively.

7.2.3. The CBM and UCG industry is at a very nascent stage in Bangladesh. Considering this, it may be possible that the appointed agency may not have the required capabilities to carry out studies on its own. Thus, it may be prudent for the Agency to tie up with reputed international players having expertise in this field or institutes engaged in R&D in the area.

7.3. Financing of studies

7.3.1. The financing of studies for exploration of CBM and UCG may be done in the following manner:

- **Government funding:** The GoB may take up the responsibility of financing the studies for exploration of CBM and UCG by allocating funds to the agency through the Ministry of Finance. This makes a case as at such early stage, private or corporate funding in the sector is not likely.

- **Donor Agencies**: Given that CBM and UCG are cleaner technologies to exploit the energy resources which otherwise might be lost, the possibilities of getting financial assistance from multilateral funding agencies like the Asian Development Bank and/or the World Bank could also be explored. It may be noted that such assistance is usually routed through the Government or its agencies.

- **Private Sector Investment (Domestic as well as Foreign):**

  - It is likely to be an uphill task to mobilize the required resources from private sector for financing of technical studies for early stage resource identification, given the associated technical and economic risks as well as the lack of reliable information in the case of CBM and UCG. In the existing circumstances, it may take a long time and considerable cost to first create a database to attract private or corporate investment and then invite bids.

  - A convenient approach may be to invite bids and it is up to the successful bidder to carry out techno-economic surveys. The risks associated with taking a block would be entirely that of the bidder.

  - In case there are no bidders for any of the block, then the license for exploring the CBM/UCG potential of the blocks may be given to interested parties on First Come First Serve (FCFS) basis.

  - If the outcome is favorable, the party which conducted the studies may be given right of first refusal for extracting CBM/UCG. Such party shall be given the right to exploit the resources at a Reserve Price determined by GoB. In case, the successful bidder does not want to be further involved in extraction, the blocks may be given on lease to other players as discussed in later sections of this report.

  - In case GSB would like to participate (this would help GSB to learn and gain expertise) in the surveys, it could do so with two options, viz., only manpower but no cash contribution or both manpower and material contribution by way of equipment available with the GSB and laboratory facilities (which the successful bidder may upgrade at his cost). If the Government so desires, some cash contribution may also be included. However this should be noted that GSB Participation should be from the perspective of capacity building of GSB while the operations of agency undertaking various studies should not be hampered otherwise this may not provide the required results.

Stage 2: Development of commercial project

- In case the feasibility of CBM and/or UCG project is established in any of the blocks there are primarily four scenarios which may emerge:

  1. The block is feasible for extraction of CBM only.

  2. The block is feasible for extraction of CBM and conventional mining

  3. The block is feasible for extraction of CBM and UCG only.

  4. The block is feasible only for UCG.

7.4. Establishing Priority for exploitation between CBM and Conventional Mining

7.4.1. For energy deficit Bangladesh, every viable source of energy is important. Hence, it is advisable that surveys be carried out to assess the potential of each coal deposit. It may be noted that Bangladesh is keen to go in for a major thrust to mine coal for generating power not only to increase power supply but also to reduce its dependence on natural gas.

7.4.2. To get the maximum out of the mineable coal deposits it is desirable to first extract the methane trapped in the coal and then start mining. While this has the advantage of de-gassing the mine and thus make mining safer, mining the much needed coal has to wait until the methane has been extracted up to the point where it is economically viable to do so.

7.4.3. Thus a careful survey and assessment is needed to decide whether a particular deposit can be kept waiting till the methane has been extracted or to forego the methane and go straight to mining.

7.4.4. In case of deep deposits or deposits not suitable for mining (at least for the present) and yet suitable and viable for extracting methane, the government could invite bids after dividing the area into blocks. The size of a block would depend on the data available regarding the depth of the deposit and seam thickness. It may be kept in mind that even coal deposits with relatively low CBM potential may be economical if the investment required and the operational costs are lower than, say, deep deposits or deposits in difficult geological conditions.

7.5. Establishing Priority for exploitation between CBM and UCG

7.5.1. As discussed in earlier sections, it is understood that the UCG technology would be adopted only if conventional mining is not feasible.

7.5.2. However, in case feasibility is established for CBM and UCG both in any particular block, then a judicious decision need to be taken to establish priority, keeping in mind the timeframes for exploitation and the national interests.

7.5.3. As in case of conventional mining, CBM can only be extracted prior to UCG. In the present scenario where the technology for UCG is yet to be proven commercially on a large scale, it would be rational to go for CBM extraction first.

7.6. Exploitation Strategy for CBM and UCG

7.6.1. CBM and UCG technologies are capital intensive with number of uncertainties involved. Therefore, it is preferable to undertake a separate and exclusive study to examine different models and modalities of financing, so that the best option could be chosen by the Government to proceed with the development of CBM and UCG without sacrificing national interests in the process.

Public Sector Investment

7.6.2. One of the options for GoB is to exploit the CBM and UCG resources on its own through a public sector company. Since, there is no past experience of Bangladesh in these areas it may be necessary for GoB to encourage the option of leasing and/or contracting (as in the case of Barapukuria Coal Mine) so that players with proven technology can be invited.

Leasing

7.6.3. As discussed earlier, the party establishing the feasibility of implementing CBM/UCG technology in any block will be given first preference for that particular block. Such party will be given the lease at a Reserve Price determined by GoB.

7.6.4. If such party is not interested to continue further, then the lease to other parties may be granted on the lines of a mining lease and/or the experience gained from the natural gas sector could be adapted to CBM/UCG to determine the terms and conditions including production sharing.

Profit Sharing Contract (PSC)

- A profit sharing contract (PSC) is a modality through which CBM and/or UCG exploration and development could be implemented keeping the interests of contractor and the country in view.
- In the process, the investor/contractor will be given due return on his investment for exploration and production of the CBM/UCG, during operation and the profit coming out of gas production shall be shared between the partners as is done in case of Natural Gas production sharing contract in Bangladesh.
- Successful negotiation of such options between the host country and the contractor could open a new horizon in the exploration and development of the CBM/UCG blocks, both locally and internationally.
- Direct FDI in Bangladesh for development of CBM/UCG is likely to be limited as the production of gas will be for domestic needs only. Under such a scenario, the scope for Direct FDI in its usual form of investment and taking the profits out of the country in the sector could be limited. Thus FDI, in the form of PSC, could be the best possible option for the country.

7.6.5. In order to encourage private sector participation (domestic as well as international) for exploitation, the government may need to roll out incentives for the private sector in the form of tax holidays, waiver of local taxes, reduction in import duties on equipment, provisions for preferential sale of gas from such sources etc.

7.6.6. Coal mining and CBM extraction authorities should be under the administrative control of the same company as there are only five coal deposits in Bangladesh from where optimal exploitation of CBM has to be aimed at, without jeopardizing coal output of the country. For this, proper operational control on both - coal mining and CBM extraction need to be exercised.

7.6.7. It may be worthwhile to look at the Indian experience. In India the matter was handled by the Ministry of Petroleum and Natural Gas (MOP&NG) in close cooperation with the Ministry of Coal. Government of Bangladesh should appoint/nominate an administrative agency/department/ministry for overseeing the development of CBM/UCG resources in Bangladesh.

Contracting

7.6.8. In case, GoB desires to retain ownership of resources (unlike in the case of PSC), it may explore the option of contracting or joint development with experienced developers wherein the provisions are attractive for both parties (Bangladesh government and contractor/operator).

7.6.9. Adequate returns on investment to contractor/operator need to be ensured to invite more participants which in turn may provide better technological access as well as result in more competitive cost of production. Thus, while selecting an investor for development and operation, the terms of agreement should be such that the investor gets an adequate return on his investments while owner of resources (Bangladesh Government or its agency) gets its due share without compromising any benefit that it may reasonably lay claim to as the sole owner of the resource. It needs to be a win-win situation for both (Bangladesh and Contractor).

Types of Contracts for development and operations

Cost-Plus contract

7.6.10. In cost-plus contract, the contractor is responsible for development and operations of the block. The owner would allow a fixed profit based on percent of operating cost or amount per m^3 or percent of capital cost etc.

7.6.11. The profit to the contractor is assured while owner actively oversees the operations to ensure that the determinants of cost are tightly controlled.

7.6.12. In this type of contracts, the gas is obtained by owner on the cost of mining and not linked with the market price and thus value of the gas lies with owner which can be unlocked by selling in the market.

Levelised price contract

7.6.13. In such contracts, the contractor is fully responsible for development and operations of the block and price at which the gas is delivered is lump sum on per unit quantity delivered subject to escalation based on some pre-agreed formula (to accommodate increase in cost due to inflationary pressure).

7.6.14. In such condition, irrespective of the actual cost of production, the owner pays a fixed fee to the contractor and the owner is insulated against any adverse impact on cost. Further, the owner may not need to monitor the cost of operations. However, the owner should oversee the operations to check compliance with applicable rules and regulations.

7.6.15. In these contracts, on one hand the contractor has an incentive of reducing the cost, which will increase its profit margin, but on the other hand he has to bear all the unforeseen risks (which may result in increased cost). Considering these risks, many international contractors may be less interested as currently enough data is not available for the coal fields of Bangladesh to establish a detailed techno-economic viability.

Procedure for selecting contractor

7.6.16. The contractor selection may be done by conducting international competitive bidding process wherein international and domestic companies can participate individually or by forming consortiums. Some of the key benefits of conducting the bid process are as follows:

- A competitive bid process can be a risk mitigation or a price discovery mechanism.
- Encourages use of new technology, scale, and modern mining methods.
- Unbundling of competitively bid rates and earn-out mechanism.

7.6.17. **Qualifying requirements in bidding process:** Some of the key issues from our past experience in contractor selection are mentioned below:

- Stricter technical capability requirement limits competition. This gives rise to need to plan in pre-sales effort to ensure more credible specialist bidders. The country/asset specific issues are required to be given due consideration before conducting any bid process.

- More permissive technical qualifying criteria will attract new operators that are more competitive but with lesser technical capabilities. This will demand stricter risk assignment and bidder familiarization.
- Allowing consortium provides opportunity to combine strengths and meet qualifying requirements. But this demands specific contract provisions to tie-in parties for the needed duration.

Infrastructure and Carbon Credits

7.6.18. If CBM extraction program can be successfully implemented, benefit of carbon credit should be availed.

7.6.19. For marketing of CBM, existing gas grids have to be extended to coal mining areas. Appropriate gas processing plants are also to be established for supplying dry and pure methane to the grid.

8. Action plan for development of Hard Rock sector in Bangladesh

8.1. Classification of Resources

8.1.1. The sustainable development of mineral resources requires classification and reporting of mineral resources and types as per an internationally acceptable system. This will help increase confidence of investors in the sector and attract global investments.

8.1.2. As a part of the Mines and Minerals Development Project (Package #07), a report titled 'Report on Mineral Resource Classification Systems - Suitability and Selection' has been submitted which suggest suitable classification system.

8.1.3. The suitable classification system was selected after conducting a 'Workshop on Mineral Classification Systems' held in Dhaka on October 5, 2011, where consultations were held with various stakeholders of Bangladesh mineral sector and based on the consultations in the workshop it was unanimously decided to adopt the UNFC system of classification for mineral resources of Bangladesh.

8.1.4. Adoption of UNFC System for mineral resource classification and reporting should be made mandatory under legislation to classify mineral resources of Bangladesh.

8.1.5. Further, all the future exploration work should be planned as per requirements of UNFC system.

8.1.6. It is also suggested that all the rocks should be classified in different categories as per value (by use) to be used to prioritize the leasing process and to reserve minerals only for higher value end use which ensures that more returns are generated for the country.

8.2. Preparation of Knowledge Repository

8.2.1. An inventory of the various minerals should be prepared by carrying out systematic surveys and studies to attract both private as well as foreign investment in the minerals sector.

8.2.2. Bangladesh lacks a central data repository for mineral resource information and in turn "mineral accounting". Also, this shall not be limited to cadastral and geological information rather shall be able to provide all such baseline information which is needed to develop a mineral endowment, e.g. environmental and socio economic information, geological information, exploration data and licenses granted, production, quality etc.

8.2.3. As per the rules, BMD shall maintain a central data repository of all the information pertaining to the mineral resources of the country. However, it has been found that the mineral resource data and information which are collected and analyzed by different agencies are lying with respective agencies. The same should have been deposited with BMD.

8.2.4. GSB shall be responsible for maintaining a Data Repository of all Geological Data for all the minerals including coal, hard rock etc. However, BMD shall be owner and custodian of all data and reports pertaining to mining and minerals sector including but not limited to geology data and information, quality and chemical analysis data, land records of mineral bearing area, leasing and licensing related information, regulatory filings etc. in respect of the mineral inventory of Bangladesh. Thus, BMD shall maintain a central data repository of mineral sector.

8.2.5. This indicates the need for institutional capacity development of BMD, GSB and other relevant organisations.

8.3. Licensing Regime

8.3.1. Licensing and Permitting is the process through which Government exercises higher degree of control in determining the right to mine and extract the economic benefits from mineral resources and impacts the development of mineral sector to a great extent.

8.3.2. To achieve sustainable development goals, it is imperative that government provides a transparent legal process in line with the sustainable development needs; and the mining entities have clear understanding of the process and comply with the conditions laid therein. Thus, recommendations made regarding mining licensing in report on "Review of Existing Acts, Rules and Regulations and Recommendations" should be implemented.

8.4. Granite

8.4.1. As mentioned above, using granite as construction material is a low value use. Further, MGMCL is incurring losses as the cost of production cannot be recovered at current selling prices.

8.4.2. **Modifications in operations of Maddhapara hard rock mine:**

- Though the area containing hard rock has been extensively explored through boreholes, some more boreholes may be drilled in the peripheral areas of the deposit to prove the depth of occurrence of hard rock. This would help in taking a decision regarding extension of the workings further in the present working horizons, because depth-wise there is a limitation in the extension of the workings due to increasing rock pressure (with depth) which will necessitate substantial reduction in the percentage extraction as large size pillars and smaller rooms would be the requirement for continuation of the mining operation. This is mainly because of two overlying active aquifers which would not permit any disturbance to the overlying strata due to mining operation.

- In order to meet increasing demand of hard rock in the country, attempt should first be made to increase the indigenous production. Since the skip shaft hoisting capacity is limited to 1.986 million tons, production at Maddhapara mine can be increased marginally from 1.65 Mtpa to, say, 1.75 Mtpa. Therefore, efforts should be made to utilize the spare capacity of about 0.10 million tons by increasing the number of working stopes.

- The cage shaft hoisting capacity which is 0.112 million tons, should also be marginally increased by making more broken rock available belowground from the new stopes, and by modifying the hoisting schedule.

- The aggregate processing plant capacity on surface needs to be enhanced to cater the increased quantity of rock to be processed due to increased production.

- A trial Room and Pillar stope may be started in the present working horizon(s) for production of hard rock slabs for use in building construction. The slabs could be transported and hoisted through the cage shaft in specially designed/constructed carriages. Reduction in the production of hard rock through cage shaft could be made up by increasing the production through skip shaft. Introduction of hard rock/granodiorite slabs production from the mine shall improve the economy of operation, as well as, meet partly the national requirement of the construction industry.

We understand that some of these suggestions are considered by MGMCL during the process of engagement of Mine Management Contractor and thus may suitably be incorporated in the Contract.

8.4.3. The techniques of mining may also be changed to enable extraction of large blocks (say, big enough to produce 50 to 60 centimeter square tiles of 20-25 mm thickness) to be cut into "slices" to make tiles for flooring and other uses in buildings. This is proposed assuming that the quality of granite is suitable for the purpose.

8.4.4. It would also be necessary to set up machinery for cutting and polishing the extracted granite. If the quality of granite is good and sufficient quantities can be produced it may fetch higher prices in the market. The aggregates produced in the process could also be sold in the market as a byproduct.

8.4.5. Thus, while formulating policy for hard rocks, preference may be given to those applicants who propose to bring in technology to enable extraction of large chunks which could then be converted to tiles, both polished and unpolished. The polishing or finishing units could be set up independently.

8.4.6. Given the nascent stage for this industry in Bangladesh, some tax incentives may be rolled in the form of reduction of local taxes, import duties on equipment etc. Being labor intensive, this would generate considerable employment.

8.4.7. However, the overall viability would depend on the quality and quantity of the mineable reserves. A detailed survey to arrive at dependable figures is needed. This may be left to the future investor or may be carried out by the GSB. A decision in this regard needs to be taken by GoB

8.4.8. Though technology may be imported, it is felt that this sector may not attract foreign investment and therefore, local private enterprises may be encouraged to take it up. This is due to the reasons that hard rock sector is not a very high value activity.

Environmental Impact

8.4.9. With shafts for underground mining going down to 300m they would interfere with the aquifers and groundwater table in the vicinity of the mines. The problem would have to be dealt with in the same manner as for underground coal mining except that the mineral (granite) is not likely to contaminate groundwater.

8.4.10. At the end of mining operations, due to the underground cavity left by the mined out mineral, could cause subsidence. The affected area would depend on the areas under which mining has been done.

8.4.11. There are two possible solutions to the problem.

- To convert the depression formed by subsidence to a water body to be used for aquaculture
- To fill it up with silt if there are streams or a river near enough to make it economical.

If the area is large, the solution could be a combination of the two. By filling up the depression the land could be restored to its owner, thus saving on the compensation costs.

8.4.12. In Maddhapara, the mine water is discharged to the surrounding paddy fields and watercourses without being treated. As communicated by MGMCL, MGMCL has been doing tests of water discharged from the mine on periodical basis. All the tests are carried out from reputed institutions of Bangladesh. The results are mostly within the permissible range. While the current tests does not suggest contamination, discharge of water without treatment poses a threat to the environment as the mine water may be acidic and generally contains lot of sediments which ultimately contaminate the surface water and soil.

8.4.13. The polluted mine water may contain pyrite and other sulphide minerals which form sulphuric acid. Also mine water may contain a lot of dissolved metals like iron, manganese, suspended solids, some oil and often ammonia resulting from the use of ammonium nitrate based explosives. High concentration of mine pollutants can create considerable ecological problems, as plant life is very much sensitive to sulphur dioxide even at a low concentration.

8.4.14. As far as the Bangladesh Environmental Quality control is concerned, standard pH content of surface water should not cross the limit of 6.5-8.5 to keep the water usable for drinking, irrigation, fisheries, industrial and recreational purposes. Therefore, baseline data need to be collected from the locality to define the tolerance level of ambient water bodies surrounding the mines before indiscriminate discharge of mine water in the surroundings.

8.4.15. Significant quantities of explosives are being used in Maddhapara mines for roadway headings/ underground development and stoping initiating significant vibration in the mine and to the adjacent areas. Thus suitable studies may be conducted to reduce blast induced vibrations.

8.4.16. Maddhapara mine requires to conduct Environmental Impact Studies as the Environmental Conservation Rules 1997 stipulates that all mining projects belong to 'Red Category' industries. Therefore, the mining authorities need to prepare the Environmental Impact Assessment Report, Environmental Management Plan and Plan for Waste Disposal along with other documents for obtaining environmental clearance from the Department of Environment, Government of Bangladesh. At the same time the mining authority needs to establish regular control for water, air, soil quality for the areas.

8.5. Limestone

8.5.1. Limestone has been used for manufacturing cement for over five decades. It is a vital input for building infrastructure like roads, bridges, residential and commercial buildings, dams, weirs, etc. Limestone should be used as aggregates for making concrete.

8.5.2. In the past, limestone was imported from the state of Meghalaya (India) for a cement plant in Chhatak, presently owned by Lafarge of France. But India’s Supreme Court had put some restrictions on limestone mining in state of Meghalaya. However, it has recently (July, 2011) permitted the resumption of limestone mining in the state of Meghalaya.

8.5.3. Given the limited reserves of limestone, it is important that they are managed well. Further exploration in the vicinity of the earlier discovered/worked out shallow depth deposits at St. Martin’s Island of Cox's Bazar district and Bhangerghat-Lalghat-Takerghat of Sunamganj district, should be taken up on modern lines. This may yield very positive results.

8.5.4. For cement plants with captive mines, it is important that the mines provide assured supplies, depending on their production capacities, for at least 25-30 years so as to keep the plant viable and operational. For economic reasons the plants should be located within reasonable distances from the mines.

8.5.5. Further, since cement is a very important component in the infra-structure development, effort should be made to acquire limestone deposits in other countries for supplying the lime-stone/cement to Bangladesh for its infrastructural development.

8.5.6. While granting a mining lease for limestone, other than for cement plants, the area to be leased must be commensurate with the anticipated demand from that mine but it must be ensured that the current demand and future increase in demand can be met from the leased area for about 20-30 years to attract investors. All this requires a detailed assessment of the mineable reserves and adoption of zero waste mining techniques.

Environmental Impact

8.5.7. The main environmental impact of mining limestone is disturbance of the top soil due to removal of the overburden. The extent of this depends on the depth and extent of the deposit. On one hand, the top soil is disturbed and the scarce productive land is lost for at least 20-30 years, if not forever. On the other hand, land has to be found for dumping.

8.5.8. With large quantities of limestone mined over the life of a mine, it cannot be reasonably expected that the land would be fully restored at the time of mine closure. The best that can be done is that the overburden, or at least some of it, is used to give some shape to the mined out area so that it can be put to some use like creating a water body to take up pisciculture.

8.5.9. One of the important considerations at the time of mine closure and also during the progress of mining is to ensure that the mined out areas are safe for the local population. Innumerable cases of fatal accidents in mined out area are reported from time to time. This is particularly true for Bangladesh where due to heavy rainfall deep pools of water are created within a short span of time. The mine owner or "occupier" must also be made responsible for any accident due to negligence. This should hold true even for small leases and quarries.

8.5.10. Ground water is an important source of potable water for the local population which use open dug wells and shallow tube-wells to get their daily needs for domestic use. It is also a source for irrigation. Mining inevitably disturbs this source of water.

8.5.11. Measures are needed for draining the water pumped out during mining operations and also to ensure uninterrupted supply to households and farmers. A well planned and designed system could establish synergy between the mining operations and water needed for irrigation. If there is a likelihood of water leaching back to the mine, thus increasing the volume to be pumped, methods such as drip or sprinkler irrigation may be used subject to financial viability.

8.6. Other Rocks and Minerals

8.6.1. Apart from relatively large deposits of limestone and granite, Bangladesh has deposits of sandstone, siltstone, clay (shale), beach sand, glass sand, white clay, etc. The end uses and the technologies required to convert them to value added products vary widely.

8.6.2. For example, white clay is suitable for making ceramics. Thus, if reliable and sufficient information is readily available it may act a catalyst for expansion of ceramic industries. These industries are usually labor intensive which would generate employment and contribute to the economy.

8.6.3. In case of glass sand, the sub-surface deposits at the Rangpur platform area may be extracted if there is any programme to mine the coal or hard rock by opencast mining method.

8.6.4. Seeing the urgent need for the construction material in Bangladesh, and abundant availability of gravel/boulders in the country, it is suggested that detailed exploration may be carried out, reserves are established and a systematic exploitation carried out to fulfill the needs of the construction industry. This would also provide employment to the local population. The systematic extraction of the gravel/boulders shall also result in desilting of the river beds thereby reducing the chances of flood occurrence.

8.6.5. With mining being in relatively smaller quantities, the environmental effects are not likely to be severe but care must be taken to ensure that the availability of groundwater both for domestic use and agriculture is not affected. Treatment of overburden and subsidence should be similar to those for other mining activities.

8.7. Sourcing from other countries/Development of new indigenous resources

8.7.1. Efforts should be taken to develop the indigenous limestone first. Exploration and development of limestone should be given due importance and priority by the GoB. While GSB should be encouraged to look for more lime stone deposits in the country, the erstwhile Joypurhat Lime stone Mining Project should be revived under the changed scenario and the new discovery of lime stone by GSB (2012) should be brought under further investigation for techno- economic feasibility study.

8.7.2. Bangladesh can acquire hard rock mines in other countries and supply the material to Bangladesh. This may be a good option at the present moment. However, development of hard rock quarries in Chittagong hills, if found suitable, should not be overlooked. This area can be a major supplier of not only hard rock for construction purposes but also of other minerals. This will, however, need thorough exploration and research to be carried out to find the hard rock availability and its suitability for use.

9. Guidelines for development of CBM and UCG in Bangladesh

9.1. Stage 1: To establish the feasibility of CBM and UCG

9.1.1. The GoB in consultation with GSB, shall demarcate the Coal fields and potential coal basins into blocks, which shall be explored for identifying the potential of CBM and/or UCG.

9.1.2. The priority order of these blocks shall be established for conducting the scoping/feasibility studies taking into consideration the coal sector development requirements and immediate need of the country.

9.1.3. The Government of Bangladesh shall assign the responsibility of conducting the field work and technical studies to a Government Agency.

9.1.4. The GoB shall enter into MoUs or understanding with Government of countries where CBM and UCG are developed/under advance stage of development to source technology and help set up sector in Bangladesh.

9.1.5. A data inventory of the various coal fields/basins shall be prepared by carrying out systematic surveys and studies to increase investor confidence and attract both private as well as foreign investment. The institutional capacity of BMD and GSB shall be strengthened to address following:

- Timely collation of accurate information from different agencies to the BMD's central data repository
- Maintenance and management of database by BMD
- Dissemination of data as and when requested from government or users or by private sector at cost.
- Exploration and detailed geological studies by GSB and maintaining geological data repository.

9.1.6. **Creation of Coal Fund**

- As proposed in JICA report, a Coal Fund shall be created with an immediate contribution of Taka 100 million, as a grant for carrying out the immediate Development Works. The fund shall be maintained in a separate bank account for administering the payments from it, as per the decisions of the Coal Sector Development Committee/Government Committee on Coal Sector.
- The fund shall be utilized by the concerned public sector organizations for the purposes such like Institutional capacity building, Manpower development, Reconnaissance survey by GSB, Higher training for concerned officials of GSB and BMD, Coal Sector Master Plan, Coal Zone Study, Peat and CBM exploration and reserve establishment studies, Coal gasification and other scientific studies for coal sector.
- Coal Bangla (as proposed in Report prepared by PwC on Coal Sector Development Strategy) or BMD shall be responsible for management of the above fund for overall development.

9.1.7. **Attracting private sector investment**

- The GoB shall invite bids for carrying out techno-economic studies/surveys (except those already done by GSB/Govt. agencies) for establishing feasibility of CBM and/or UCG in the demarcated areas.
- Separate bid document for CBM/UCG exploration and CBM/UCG extraction shall be prepared.
- For conducting the bid process the GoB shall delegate the authority to an existing government agency or create a new government agency for this purpose.
- In case there are no bidders for any of the block, then the license for exploring the CBM/UCG potential of the blocks shall be given to interested parties on First Come First Serve (FCFS) basis.
- In case the outcome is favorable, the party which conducted the studies in a particular block shall be given right of first refusal for exploiting CBM/UCG from that block. The right to exploit CBM/UCG from that block shall be given to such party at a Reserve Price determined by GoB.
- In case, the successful bidder does not want to be further involved in extraction, the block shall be returned to GoB without any obligations to GoB to pay to explorating agency and/or lessee. After relinquishment of block, the GoB shall have right to award the block to any other interested party based on prevailing allocation policies.
- There shall be no free participating interest of the Government, no upfront payment for lease allocation or upon establishing project viability and no signature bonus. The returns to Government will be in terms of profits sharing thorough PSC. This is with aim to invite more private interest and provide incentives for investment in CBM and UCG sector.
- During the exploration phase, any equipment, machinery, supplies, spares, and consumables etc. imported by the Licensee shall be exempt from customs duties and VAT. Further, upon successful exploration and establishing commercial viability, exploration expenses shall be allowed to be capitalized and be depreciated during commercial production period.

9.2. Stage 2: Development of commercial project

9.2.1. Government of Bangladesh shall appoint/nominate an administrative agency/department/ministry for allotment of lease for CBM and UCG development on auction basis. This agency shall develop the bidding mechanism, qualification requirements, bid framework, model contract to be entered between GoB and allocattee, conduct bid process and evaluate to select the preferred bidder.

9.2.2. This agency shall agree upon the time bound exploration schedule and minimum committed investments. Further, at the beginning itself, this agency shall agree upon the tentative development schedule and facilitation from government. Based on this schedule and contract signed, the agency shall oversee the development of CBM/UCG resources in Bangladesh and reviews the progress of work.

9.2.3. In order to get the maximum out of the mineable coal deposits the methane trapped in the coal shall be extracted first, followed by mining/UCG.

9.2.4. GoB shall take a decision, on the basis of a detailed survey and assessment, whether a particular deposit shall be kept waiting till the methane has been extracted or forego the methane and directly commence mining activity. The decision shall be taken prior to commencement of bidding and a technical committee on Energy shall recommend to Government.

9.2.5. The UCG technology shall be adopted only if conventional mining is not feasible. In case any coal block is suitable for both CBM and UCG, priority shall be given to CBM extraction.

9.2.6. The GoB shall take a decision on the mode of extraction of CBM and UCG, either through leasing or through contracting wherein ownership of resources is retained with the government.

9.2.7. **Jamalganj coal deposit:**

Coal mining program of deep seated (600m -1100m approximately) Jamalganj deposit may be phased later and this deposit may be selected for CBM extraction at present, provided the deposit turns out to be economic after exploration and pilot scale studies. If necessary, enhanced CBM recovery technique by CO_2/N_2 injection may also be tried in this deposit to improve recovery, as recovery may be low due to possible low permeability of coal occurring at high depth.

However, it should be noted that with advanced technology of controlling the underground temperature or ventilation, which was major issue for considering Jamalganj coal field not suitable for conventional mining, Jamalganj coal may also prove to be techno-economically feasible project if examined afresh. Thus, Jamalganj coal field should not be considered negatively for the conventional mining and techno-economic feasibility study of mining should be taken up afresh. Considering this, in case CBM project is taken up, planning should be done in a way that it does not interfere with the prospects of conventional mining.

Further, in case all CBM resources are extracted out and conventional mining is not feasible even in future, then the feasibility analysis of UCG technology should be carried out.

Leasing

9.2.8. The party establishing the feasibility of implementing CBM/UCG technology in any block shall be given first preference for that particular block. Such party shall be given the lease at a Reserve Price determined by GoB.

9.2.9. The route of granting lease to other parties shall be decided by GoB from either of the following:

- Conducting international competitive bidding
- Allocation on First Come First Serve basis

The experience gained from the natural gas sector shall be adapted to CBM/UCG to determine the terms and conditions including production sharing.

9.2.10. Prospective bidders for CBM/UCG exploitation have to procure the existing exploration reports before bidding from the relevant authority.

Contracting

9.2.11. The GoB shall decide the type of contract to be adopted, either PSC, Cost-Plus or Levelised price contract. The coal blocks for which CBM/UCG viability is established by government shall preferably be given on Cost-Plus or Levelised Price contracts and all the gas produced shall be given to Government on agreed cost of production. The coal blocks for which viability is established by private investor shall be given right to mine on PSC basis.

9.2.12. The blocks which are found unviable by government agencies may be given to private developers through competitive bidding on PSC basis without any recourse to Government in case the block is found unviable.

9.2.13. The contractor selection shall be done by conducting international competitive bidding process wherein international and domestic companies are allowed to participate individually or by forming consortiums.

9.2.14. The Qualifying requirements shall be decided upon based on the parameters pertaining to a particular asset taking into account technical experience required, estimated capital investment, experience of similar operations etc.

9.2.15. There shall be a tax holiday on investments for a period to be determined by GoB. For other matters such as corporate tax, income tax & VAT etc, the investors shall receive the benefits as applicable under the present regulations in Bangladesh at the time of contract signing. Government may consider providing fiscal stability to developers once PSC is signed.

10. Guidelines for development of Hard rock sector in Bangladesh

10.1. Adoption of UNFC System of Classification

10.1.1. Adoption of UNFC System for mineral resource classification and reporting should be made mandatory under legislation to classify mineral resources of Bangladesh.

10.1.2. Government through GSB and BMD shall identify the value proposition of various hard rocks viz granite, limestone etc. based on potential usage and classify them in different categories for the purpose of resource allocation. This shall help in prioritizing the end use of each type rock and ensure that the resources are allocated for higher value use to maximize benefits to government and country.

10.2. Preparation of Knowledge Repository

10.2.1. A data inventory of the various minerals shall be prepared by carrying out systematic surveys and studies to increase investor confidence and attract both private as well as foreign investment.

10.2.2. The institutional capacity of BMD shall be strengthened to address the following :

- Timely collation of accurate information from different agencies to the BMD's central data repository
- Maintenance and management of database by BMD
- Dissemination of data as and when requested by the government or users or by private sector at a price.

10.3. Licensing Regime

10.3.1. Reliable estimates of the quantity and quality of the mineral deposits shall be generated through surveys and studies by

- The GSB or,
- By inviting applications for prospecting licenses which would be converted to mining leases if the deposits prove to be viable.

10.3.2. In case of granite, if applications are invited for prospecting/mining lease, preference shall be given to applicants who propose to go in for mining of large blocks to be processed into tiles for buildings, etc. and/or other value added products.

10.3.3. Leases for mining limestone shall be given keeping in mind the needs of the lessee over such period of time and covering such quantity of mineable reserves that it attracts investment for the appropriate kind of use (manufacture of cement or lime, for building aggregates, road construction, etc.).

10.3.4. If the quality of the limestone varies from mine to mine the government shall restrict its use by specifying that it be put to the best use (e.g., cement grade limestone be used for making cement). However, it shall depend on the mineable quantity in a particular deposit and its location.

10.3.5. The mining plans approved for each mining lease shall give due consideration to the local conditions of each mine. There shall be a provision to make a mid-course modification in the approved mine plan if a reassessment of the local situation so warrants.

10.4. Environmental and Safety Aspects

10.4.1. GoB shall formulate a framework in legislation through which progressive mine closure, final mine closure and post mine closure can be effectively monitored and controlled.

10.4.2. The mining entities shall submit environmental management programmes and updates for approval, during the permitting process and whenever there are significant process/operational changes during the operating life of the mine.

10.4.3. The water resources shall be managed by having appropriate standards in place for the use of surface and ground water. The standards shall be strictly monitored, and have appropriate penal measures should they be compromised.

10.4.4. The legislation related to occupational health and safety shall ensure that each mining entity within its jurisdiction accepts corporate responsibility for occupational health and safety and maintains high standards.

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