CARBON MITIGATION: CLEAN COAL THROUGH CARBON CAPTURE & STORAGE UNDER CLEAN DEVELOPMENT MECHANISM FOR ENERGY AND CLIMATE SECURITY IN BANGLADESH

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INTRODUCTION

The Earth faces the grave threat of climate change (CC). R.K. Pachauri, the chairperson of the Inter Governmental Panel on CC (IPCC) based on scientific studies projects that if nations continue to emit green house gases (GHGs) at current levels, the average global temperature would exceed the tipping point and cause irreversible CC by 2015. The possibilities for adaptation of society and ecosystems will rapidly decline with community disruption through health impacts, water shortages and food insecurity for temperature above 2oc of pre-industrial levels1. Bangladesh will be severely affected causing untold suffering and instability for scarcity of food, shelter, water and large-scale migration.

Energy security is the prime concern of every nation. Source and supply of energy has always remained one of the focuses of nation states. Exploitation of traditional, non traditional energy sources and secured supply ensure energy security.

Coal is the dirtiest of all fossil fuels. Study reveals that coal will meet over 25% of global energy demand in the coming decades. Coal is the major fossil fuel for generating electricity in the industrialized nations and emerging economies. It will continue to do so as long as it is cheap and plentiful. The major challenges for coal are its 'impacts on environment for carbon dioxide (CO_2). CO_2 makes up 80% of anthropogenic GHGs emissions causing global warming (GW). The main anthropogenic sources of GHGs emissions are energy.

The alarming environmental degradation and rise of global temperature have forced the energy experts to make a transition to a new era of greener, cleaner energy development to meet CC. Clean Coal Technology (CCT) seeks to reduce harsh environmental effects by using multiple technologies to clean coal and contain its emissions. Carbon capture and storage (CCS) is perhaps the most promising clean coal technology. Captured CO_2 is stored in geological formation or ocean bed.

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1. Mazo, Jeffrey (2010) " *Climate Conflict-How global warming threatens security and what to do about it",* New Yourk, USA, Routledge, p. 12

Robert Malone, Chairman and President British Petroleum (BP) America said that "Deploying CCS at scale is not as much a question of technology availability but of economic viability. CCS is available today to play a significant role in reducing GHG emissions and addressing CC." The present investment cost of CCS is US$ 40-80/t CO_2 but this cost is reducing to the range of US$ 40 – US$ 60/t.

Bangladesh has very limited energy resources. Gas and coal are the most exploreable energy resources with 12.52 Tcf of gas and 3.3 Giga ton (Gt) of coal reserve. All the gas fields are likely to deplete by the year 2030. Coal is yet to explore to its full capacity. Bangladesh can convert coal into electricity through CCT using CCS under Clean Development Mechanism (CDM). Depleted gas fields and coal bed methane (CBM) seams provide opportunity for carbon sequestration. CCS technology along with improved efficiency can reduce CO_2 emissions to the atmosphere by 80%-90% at coal-fired power stations.

To avoid CC, synergy between energy and climate security is a requirement. Bangladesh can mitigate carbon and contribute positively to CC and the gross domestic product (GDP) through CCT under CDM for energy and climate security. CDM under Kyoto Protocol for emerging economies like Bangladesh is the key to address the challenges of environmental pollution and GW.

There are several Near Zero Emission Coal (NZEC) projects under operation around the globe. Recently China and India also have under taken some NZEC projects. Bangladesh can harness this opportunity for NZEC technology negotiating strongly in conference of parties (COP) and maintaining close liaison with UK, USA, Australia, and through global and regional emissions trading market. The paper attempts to focus on three objectives. These are discussing the CC its impacts and carbon problem; analyze energy scenario in Bangladesh including potential of coal for energy and climate security and explore CCS under CDM options for Bangladesh for CCT.

CC AND CARBON PROBLEM

CC and Its Impact

CC in generaly refers to long-term changes in climate, including average temperature and rainfall.[2] However, the observed changes in the climate system over the 20th century are due to anthropogenic cause. The past decade has seen the hottest summers, the fiercest cyclones and typhoons and alarming rise in sea

2. http://www.climatechange.gov.au/climate-change.aspx.Retrieved on June 30,2010

levels. Cyclone SIDR, Ayla and Nargish that lashed Bangladesh and Myanmar are seen more as disasters triggered by CC[3]. Alarmingly, we may have already passed tipping points that are irreversible within the time span of our current civilization[4].

The expected consequences of climate change include rising sea levels and population displacement, increase severity of typhoons and hurricanes, droughts, floods, disruptions of water resources, extinctions and other ecological disruptions, wild fire, severe disease outbreaks, and declining crop yields and food stocks[5]. CC will cause a large migration of peoples, scarcity of foods and shelters leading to internal and external unrest. The climate conflict will be spreader amongst the countries.

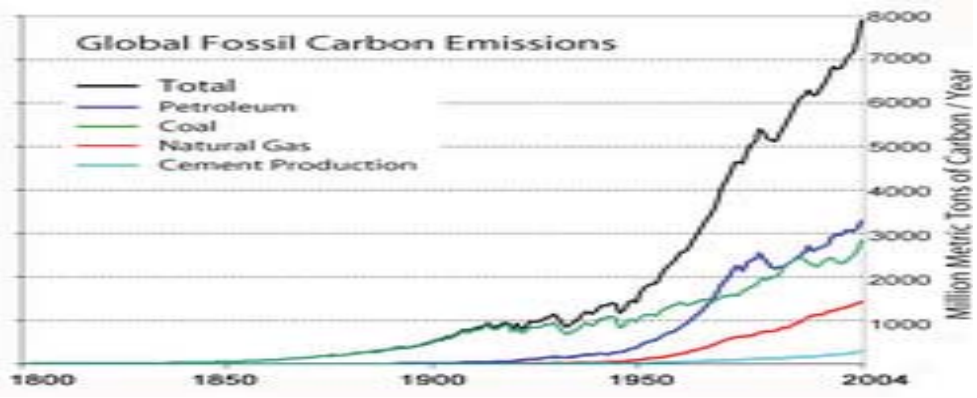
Due to CC, Sea Level Rise (SLR) will be 14 cm, 32 cm and 88 cm by the year 2020, 2050 and 2100 respectively[6]. Major portion of many island states will go under water. It will seriously affect Developing and Least Developed Countries (LDCs). 50 to 100 centimeter (cm) rise of sea levels by 2100 will displace 10% population of the world (more than 600 million peoples)[7]. About 0.5-meter rise in sea level would inundate an area of 22,000 sq.km of Bangladesh, affecting 17 million people[8]. The other impacts would be on Agriculture, Bio-diversity and Forestry, Human Health, Fisheries, Drainage, Fresh water etc.

Carbon Problem

Many of the challenges we face, from poverty to armed conflict links to the effects of GW and CC. Fossil fuel burning causes dangerous interference in the climate offering growth of GHGs in the atmosphere. Fossil fuels emit 80% of GHGs and CO_2 only accounts for more than 77% of total emissions. The main anthropogenic source of GHGs emissions is energy. Details of anthropogenic source are given in fig 1&2 below.

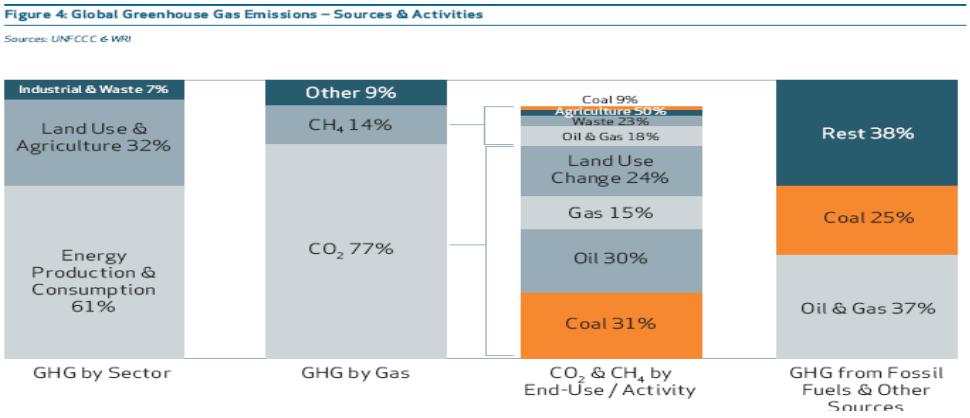
3. Chaudhary, Prashant, 2009,'Enemies of the Earth' India Today, December 21, pp 31-36. Available at http://subscriptions.digitaltoday.in/subscriptions/itoday/regionlInt.html.Retrieved on May 15, 2010.
4. Hossain, Md, Billal, 2009'International and National Response to climate change', *World Environment Day(WED) 5 June 2009*, DoE, MoEF, Peoples Republic of Bangladesh, p.55
5. Mazo, Jeffrey, Op. cit., p.55
6. Hossain, Md, Billal, Op. cit., p.55
7. Danesh Dr.Md Miah 'Change: Carbo*n* Trading and Sustainable Development World Climate', WED 5 June 2009, DoE, MoEF, Peoples; Republic of Bangladesh, Pp, 18.
8. United Nations Environment programme (UNEP) Potential Impact of Climate Change.

Figure 1: Modern global anthropogenic carbon emissions.



Source: (http://en.wikipedia.org/wiki/Greenhouse_gas)

Figure 2: Global Greenhouse Gas Emissions – Sources & Activities



Sources : UNFCCC &WRI

ENERGY AND CLIMATE SECURITY

Energy Scenario

Energy is the main driving force for the economic growth of a country. Bangladesh requires adequate supply of energy to attain desired prosperity within stipulated time. We must explore all available resources to produce electricity to fulfill the development needs**.** Electricity demand projection is given in Table 1 bellow:

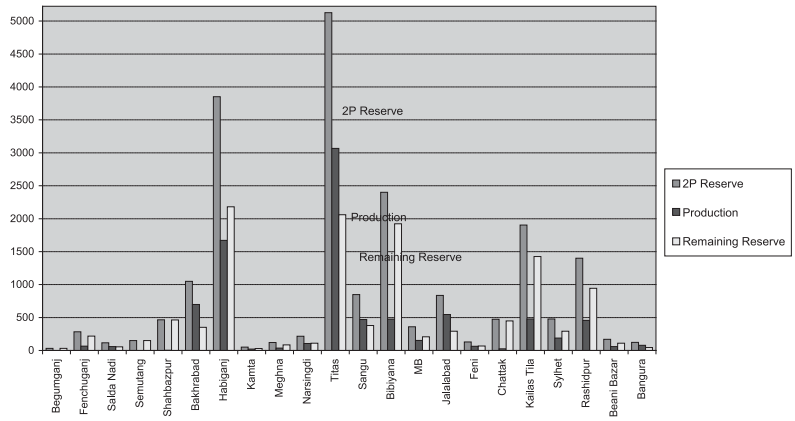
Table 1: Electricity Demand Projection by PSMP-2006			
Year	5.5 %GDP	8 %GDP	Remarks
2008	5569MW	5904MW	* Presently Bangladesh has about 2000 MW electricity shortages.
2009	6066 MW	6567MW	
2010*	6608 MW	7355MW	
2013	8364MW	10473MW	
2015	9786MW	13408MW	
2020	13993MW	24445MW	
2025	19312MW	41899MW	
Source: Petrobangla			

Potentials of Gas Resources in Bangladesh

Gas is the major exploreable and only dependable energy resource in Bangladesh. There is huge deficit between demand and supply of gas. However, there are hopes as well as despair about the potentials of gas in Bangladesh. Proven and probable reserve, exploration, production and depletion state of gas are given in table-2 and figure-3 &4 below:

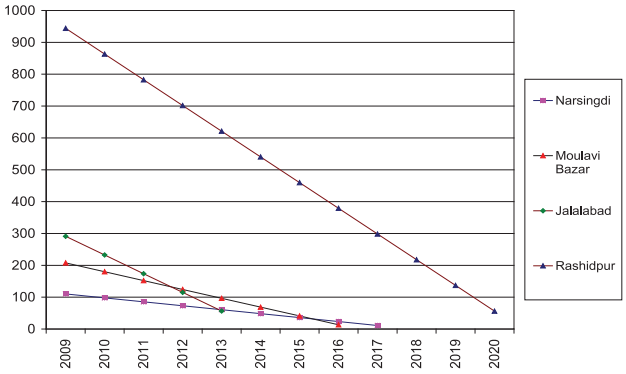
Table 2: Summary of Gas Reserve as of 31st December 2009		
Gas Initially place (Proven + Probable)	28,619.70 Bcf	28.62 Tcf
Recoverable (Proven + Probable)	20,631.50 Bcf	20.63 Tcf
Gas Production in December 2009	58.30 Bcf	0.06 Tcf
Cumulative Production as on 30th December 2009	8106.80 Bcf	8.11 Tcf
Remaining Reserve	12,524.70 Bcf	12.52 Tcf
Source: Hydrocarbon Unit, Energy & Mineral Resources Division		

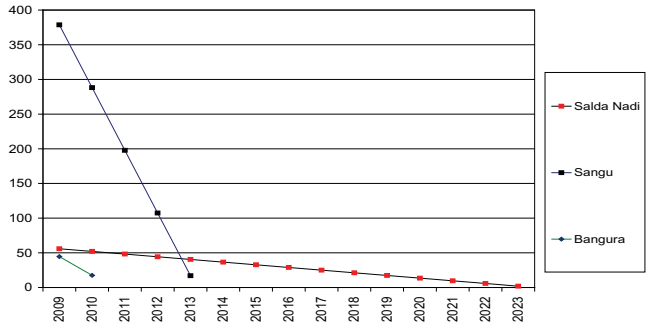
Figure 3: Field Wise Gas Reserve (2P), Cumulative Production and Remaining Reserve (Bscf)

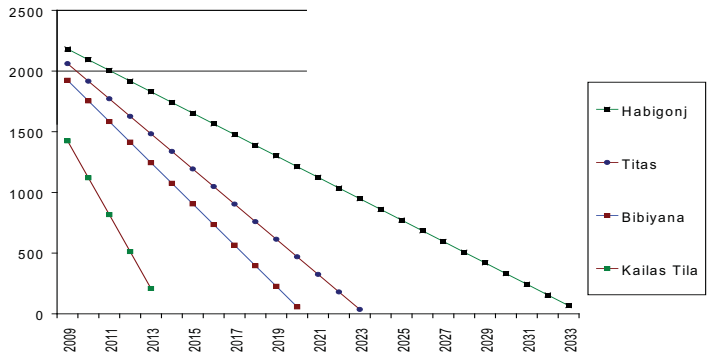


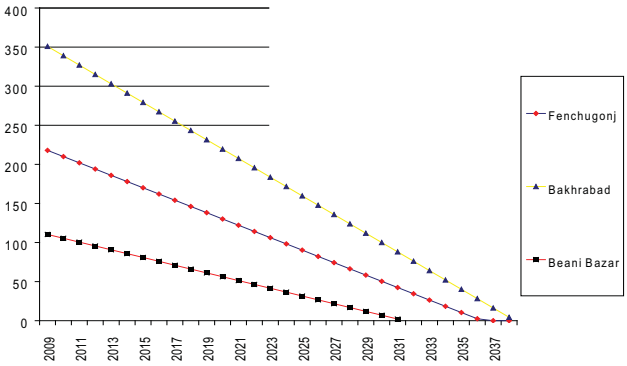
Source: Hydrocarbon Unit, Energy & Mineral Resources Division

Figure 4: Depletion Picture of Gas Field (@ Base Year 2008)









most of these gas fields will deplete by 2030

Coal: A Sustainable Energy

Fossil fuels dominate around 80% of energy needs. Coal will meet over 25% of global energy demand. Coal is abundantly available, affordable, reliable, geographically well distributed and easy and safe to transport. Coal markets are well functioning and responsive to changes in supply and demand[9]. It is the major fossil fuel to generate electricity in the industrialized nations, emerging economies and continue to do so as long as it is cheap and plentiful. The major challenges for coal are its 'impacts on GW for CO_2, which makes up 80% of anthropogenic GHGs emissions.

9. World Coal Institute -Document, 'Coal Meeting the Climate Challenge-Technology to Reduce Green House Gas Emissions', World Coal Institute, London, p.3 available at (http://www.worldcoal.org/carbon-capture-storage/financing-ccs/ accessed on 24 june, 2010).

Clean Coal Technology (CCT)

CCT seeks to reduce harsh environmental effects by using multiple technologies to clean coal and contain its emissions.[10] **CCS** - perhaps the most promising CCT -catches and sequesters CO_2 emissions from stationary sources like power plants. **Fuel- gas separation**- removes CO_2 with a solvent, strips off the CO_2 with steam, and condenses the steam into a concentrated stream. **Oxy- fuel combustion**- burns the fuel in pure or enriched oxygen to create a fuel gas composed primarily of CO_2 and water. **Pre -combustion capture**- removes CO_2 before it burns as a part of a gasification process. CO_2 is stored in either geological formation or ocean bed[11]. CCS technology along with improved efficiency can reduce CO_2 emissions to the atmosphere by 80%-90% at coal-fired power stations[12].

NZEC

NZEC technology enables coal to contribute to zero-carbon energy. To achieve NZEC generation, it is necessary to capture and sequester the carbon emissions. The joint UK-China NZEC initiative addresses the challenge of increasing energy production from coal in China and the need to tackle growing CO_2 emissions[13].

Potentials of Coals in Bangladesh

Coal resources of 3.3 billion ton in coalfields as shown in table -7 have high prospective to meet the energy needs of Bangladesh. Bangladesh has good quality coal. There are also exploration potentials of more coal. Coal import is easy and available from neighboring countries. Clean coal technology is available and environment friendly.

Coal Bed Methane (CBM) is also an important source of energy. Jamalgonj coal deposit has a potentiality of about 500 Bcf CBM. CBM is a form of natural gas, composed mostly of methane and found in coal beds worldwide. Extraction of CBM is technologically feasible and economically viable. CBM extraction can provide immediate relief to the current energy needs. Moreover, extraction of CBM does not exclude coal mining using open-pit or underground mining of the same fields later. Extraction of CBM before mining the coal actually reduces dangers of methane outburst during underground mining[14].

10. HowStuffWorks and the web http://science.howstuffworks.com/environmental/green-science/clean-coal.htm Retrieved on 03-09-2010.
11. ibid.
12. ibid.
13. http://www.nzec.info/en/. Retrieved on 08-09-2010.
14. Islam, Md, Rafiq"Potential for Coal Bed Methane in Bangladesh" Energy Bangla, 2009, available at http ://www.energybangla.com/index.php?mod=article&cat=CoalSector&article=1943. Retrieved on 12-07-2010.

Table 3: Estimated Coal Reserve

Location/ Field	No. of Wells Drilled	Estimated coal resources (Million Tons)	Total in-situ reserves (Million Tons)	Proved in-situ reserves (Million Tons)
Barapukuria, Dinajpur	31 (118-509m)	390	390	303
Khalashpir, Rangpur	14 (257-483m)	685	685	143
Phulbari, Dinajpur	108 (150-240m)	572	572	288
Jamalgonj, Joypurhat	10 (640-1158m)	1053	-	-
Dighipara, Dinajpur	5 (328-407m)	600	600	150
Total		3300	2247	884

Source: Petrobangla

Climate versus Energy Security

Fossil fuels provide 80% of global energy and are responsible for 65% of global GHGs. World large energy reserve is in the unstable region and supply during crisis is very critical. The energy security and climate security thus seems conflicting as well as crucial.

Objective of climate change policies is an effectively zero-carbon-emitting energy sector in the developed world and substantially lower carbon emissions in the developing world. The energy sector will need to change radically in the coming decades to meet both climate and energy security. Increased energy efficiency and greater use of most renewable energies, will enhance climate and energy security. Other energy sources are not so benign and be used with 'do-no-harm' approach.

Bangladesh needs a suitable 'energy mix' for energy security in the form of fossil fuel, nuclear and renewable energy. It also needs optimum utilization of energy through energy efficiency, options for greater quality of supply from

international and regional sources and decreased energy demand through energy efficiency[15].

Bangladesh lacks capacity to exploit resources for energy and climate security. Global carbon policy initiative for carbon sequestration will provide good opportunity for Bangladesh to use its coal for energy and climate security. Bangladesh as a MVC for CC must build the capacity and negotiate in the COP for NZEC technology and fund under CDM from Annex 1 countries.

CARBON CAPTURE AND STORAGE (CCS)

Mitigation of GHGs in Non-annex 1 Countries under CDM

Non-annex countries need support, both financial and technical to mitigate carbon emissions and reconcile economic development. One of the means of achieving this is the Kyoto Protocol's CDM. The World Bank's Prototype Carbon Fund is a public private partnership that operates within the CDM.

In July 2005 the U.S., China, India, Australia, as well as Japan and South Korea, agreed to the Asia-Pacific Partnership for Clean Development and Climate. The pact aims to encourage technological development that may mitigate GW and aid both growth and a cleaner environment simultaneously[16].

Presently emerging economies have undertaken a number of clean development projects under CDM for carbon sequestration. New Carbon Policy Initiative by the developed countries is favorable for global carbon trading for developing and LDCs. Bangladesh should harness this opportunity through strong negotiation.

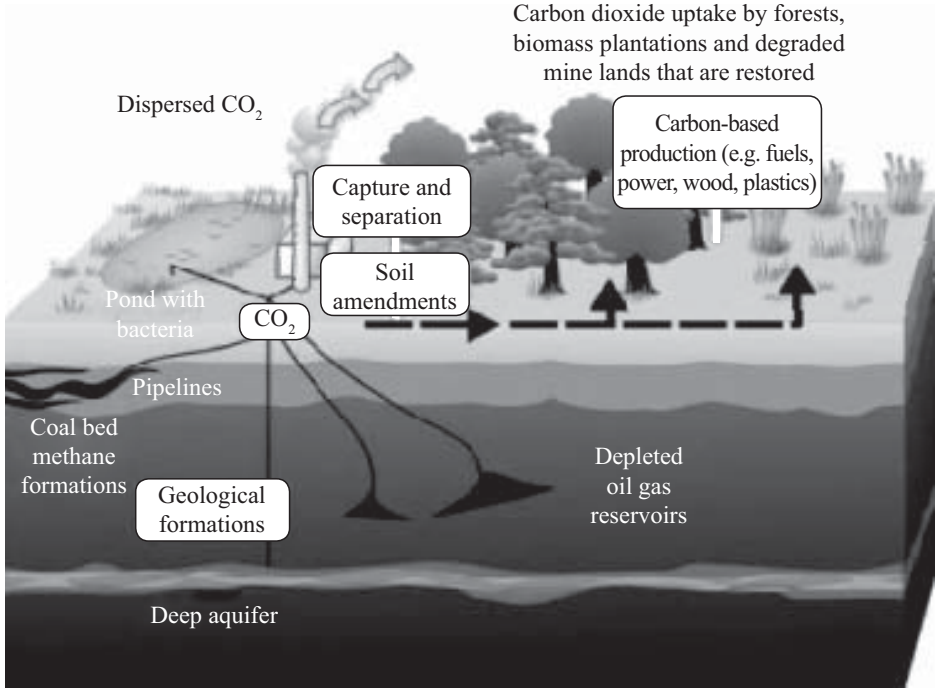
To provide more opportunities for developing countries to adapt clean technologies, UNEP and WTO urged the international community to reduce trade barriers and to conclude the Doha trade round , which includes opening trade in environmental goods and services[17]. Experts suggested that up to the year 2050, an effort to cap GHGs emissions would benefit developing countries significantly when combined with enhanced adaptation.

15. Hossain, Mollah Amzad (2008), "Interview-Bangladesh Needs to Find Right Mix of Energy Resources", Energy & Power, 16 February, Pp. 29-30.
16. Climate Change Mitigation from Wikipedia, the free encyclopedia. Available at http://en.wikipedia.org/wiki/ Climate_change_mitigation#Mitigation_and_developing_countries. Retrieved 14 May 2010.
17. Free trade can help combat global warming, finds UN report, UN News Centre, 26 June 2009. Available at http://www.un.org/apps/news/story.asp?NewsID=31278&Cr=trade&Cr1=environment#.Retrieved 14 May 2010.

CCS to Mitigate CC

CCS is a plan to mitigate CC by capturing CO_2 from large point sources. CCS applied to a modern conventional power plant could reduce CO_2 emissions to the atmosphere by approximately 80%-90% compared to a plant without CCS[18]. CCS technologies enable emissions of CO_2 to strip out of the exhaust stream from coal combustion or gasification and stored in deep saline or geological formations, depleted oil and gas fields, or un-mineable coal seams as shown in figure 5 below:

Figure 5: Terrestrial and Geological Sequestration of CO2 Emissions from a Coal-Fired Plant



Sources (http://wapedia.mobi/en/Climate_change_mitigation?t=1.3. Retrieved 12-07-2010)

Costs of CCS

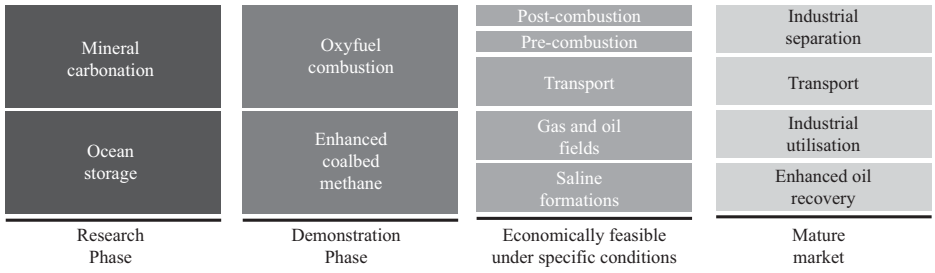
The cost of CCS for power generation from coal is between US$40 and US$90 per ton of CO_2. IEA has found that stabilizing emissions without CCS raises costs by over 70%. Economies of scale and efficiency improvements reduce cost.

18. Main article: Carbon capture and storage Available at http://wapedia.mobi/en/Climate_change_mitigation?t=1.3 . Retrieved on 16 May 2010.

CCS Technology

Different categories of CCS technology (figure 6).

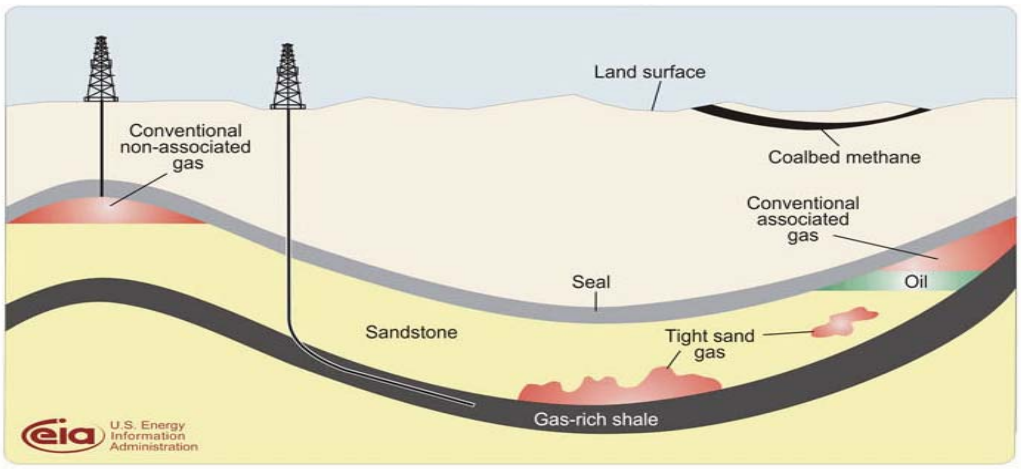
Figure 6: Maturity of CCS Technology



Source: IPCC 2005

Geology of Natural Gas Resources

Figure 7: Schematic Geology of Natural Gas Resources



Source; U.S. Energy Information Administration

Conventional gas accumulations occur when gas migrates from gas rich shale into an overlying sandstone formation, and then becomes trapped by an overlying impermeable formation, called the seal. Associated gas accumulates in conjunction with oil, while non-associated gas does not accumulate with oil[19]. CBM does not migrate from shale. It is generated during the transformation of organic material to coal.

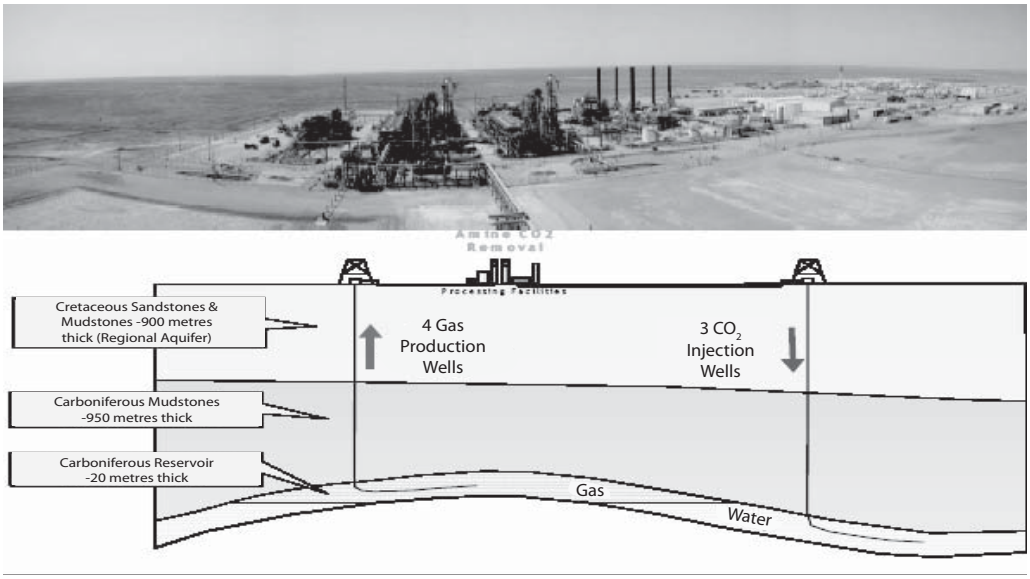
19. U.S. Energy Information Administration (eia) available at http://www.eia.gov/oil_gas/natural _gas/ special/ ngresources/ngresources.html. Retrieved 14-07-2010.

Geological formations currently are the most secured and promising storage capacity of CO_2[20]. IPCC 2005 Special Report on CCS found that the risk of leakage from geological storage more likely to be less than 1% over 100 years and likely to be less than 1% over 1000 years.

Case Study -1: Geological Storage of CO2

In Algeria at Salah Desert, industrial scale demonstration projects for conventional CCS of CO_2were undertaken by BP group technology for CO_2 storage at an incremental cost of US $ 6/t CO_2 without commercial benefits for test bed for CO_2 monitoring technology. Salah project addressed various aspects of the CCS benefits, challenges and technology options for stabilization. It was a CCS for coal plants in Salah depleted gas field (figure 8).

Figure 8: CO_2 Storage Operation in Salah Gas Field.



Source:http://unfccc.int/files/meetings/sb24/in-session/application/pdf/sbsta_may_20th_in _salah_wright.pdf

The result of the project provided with (1) excellent analogue for other countries; China, Europe, North America (2) already stored I mmt CO_2 (3) Incremental cost was US$ 6/t CO_2 and no commercial benefit earned. (4) Research project cost was US $30 million.

20. Main article: Carbon capture and storage Available at http://wapedia.mobi/en/ Climate_change_mitigation?t=1.3 . Retrieved on 12 May 2010.

Case study-2: Coal Mine Methane (CMM)

CMM is a significant source of energy in Australia and the USA and is of growing importance in a number of other countries, including China, Germany, Kazakhstan, Poland, Russia, Ukraine and UK. Xstrata oaky Creek power station in Queensland, Australia was commissioned in 2006 and is expected to save 341,000t $CO_{2\text{-}4}$ per annum. The gas-fired station uses methane extracted from the coalmine to generate electricity for supply to the national grid.

CCS under CDM

Under the Kyoto Protocol's 'Flexibility Mechanisms' – the CDM, Joint Implementation (JI) and Emissions Trading – are adapted for large-scale CO_2 mitigation projects, such as CCS. An important step has been the recent approval by the CDM Executive Board (CDM EB) of a "Consolidated Methodology for New Grid Connected Fossil Fuel-Fired Power Plants Using a Less GHGs Intensive Technology". The new methodology allows Certified Emissions Reduction (CERs) credits to issue for the CO_2 emissions[21].

IETA's Views on CCS

- CCS is an important part of a portfolio of options available for CC mitigation.
- CCS is urgently needed to meet near-term emission reduction targets and longer-term stabilization of atmospheric CO_2 concentrations.
- CCS is a proven technology. The oil and gas industry has gained considerable experience over several decades relating to the capture, transport and storage of CO_2 and the monitoring of CO_2 injected in geological formations.
- CCS can contribute towards sustainable development to coal-based developing countries for GHGs mitigation.
- CCS needs incentives for deployment due to the additional costs of capture, transport and storage. Certain "early opportunities" for CCS deployment could be incentivized via CDM for wider deployment in the medium-term.
- Project-based mechanisms provide a valid potential incentive for CCS deployment in non-Annex I countries for "early opportunities.
- Early deployment of CCS projects in developing countries will come with good expertise and capacity building efforts from developed countries.

21. WCI Climate Policy Paper 5 – Investing in CCS accessed to http://www.worldcoal.org/carbon-capture-storage/financing-ccs/.Retrieved 02-07-2010.

Global Carbon Policy Analysis

This new report "Global Carbon Policy Analysis: Policy Initiatives Driving the Growth of Carbon Sequestration Market" provides an in-depth analysis on the policy initiatives by the EU, US, Canada, Australia and other developed and developing economies. The report suggests investment decisions in CCS projects by providing trends and information on global carbon trading policies. It provides an opportunity on the current investments in CCS projects globally[22].

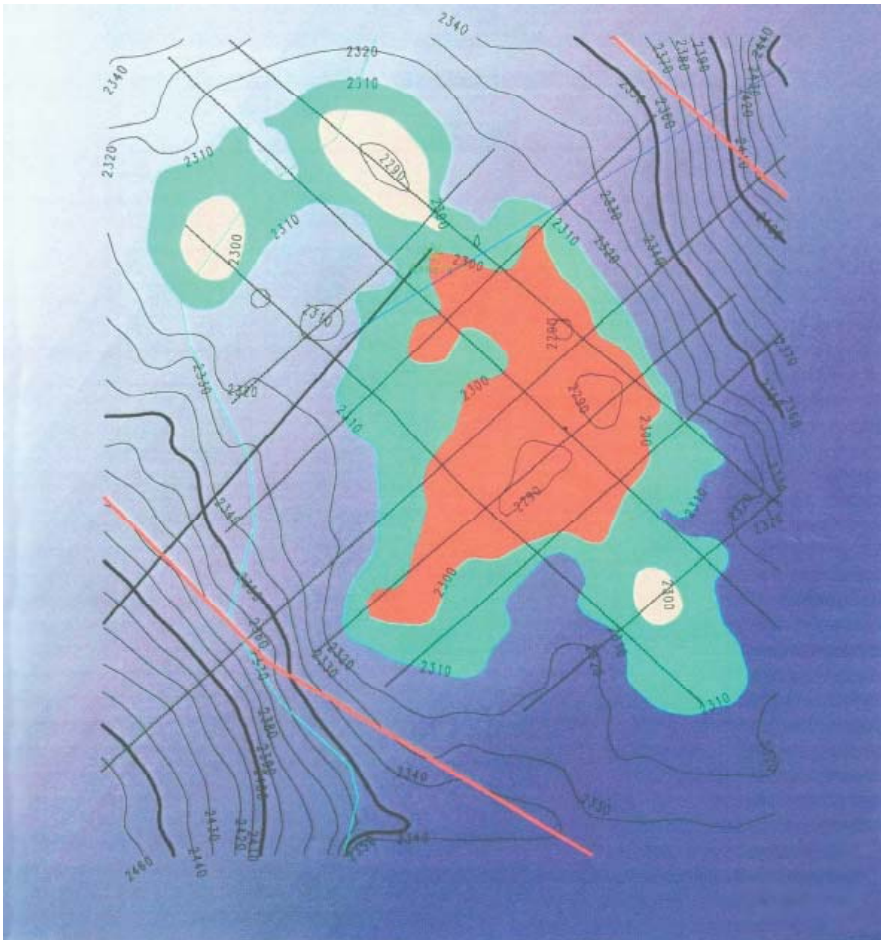
The EC's commitment towards reducing GHGs has accelerated the deployment of CCS projects globally. EU has promoted these projects by incentivizing power plants that are planning to modernize with integrated CCS facilities. EU has fixed the cap on distribution of excess carbon emission allowances to achieve emissions reduction ahead of 2020. EU member states can partner with emerging nations to develop net zero emission plants and these investments can be traded with the emissions reduction.

UK and China are in the implementation of China's first NZEC power plant China-EU (COACH) project, which is expected to be operational by 2015. China is also working closely in conjunction with the UK and receiving financial and technological support for many CCS projects. It is vital to achieve global carbon trading schemes and meet the wider environmental challenge. CDM is a key to engage emerging economies. Bangladesh can negotiate strongly as MVC of CC for CERs from CDM Executive Board (CDMEB) for CCT power plant. Government can promote CCS as a public good under PPP for initial research project.

22. http://www.pr-inside.com/global-carbon-policy-analysis-policy-initiatives-r1452861.htm. Retrieved 02-07-2010.

Geological Sequestration in Bangladesh Gas Fields

Figure 9: Kamta gas field



Source: Hydrocarbon Unit, Energy & Mineral Resources Division

Kamta Well #1figure 9 was drilled in 1981 to a depth of 3618m. BAPEX's technical consultant BGR (Fedaral Institute for Geo-science & Mineral Resources, Germany) selected Kamta gas field for lean period gas storage. Later no detail study or action was carried out for feasibility.

Depleted Gas Fields and Coal Seams.

Experts opine that almost all of present 24 Gas Fields of Bangladesh will deplete by 2020-2030 (figures 4). These depleted gas fields of Bangladesh is a large geological formation for carbon storage and could be a huge source of income for carbon trading through CCS. Jamalganj and Jaypurhat CBM coal seams is also good for exploration and carbon sequestration.

Benefits of CCS

Technological Benefit

Now the mature CCS technology is available in the developed world. The annex 1 countries are committed under Kyoto Protocol to transfer technology to developing countries and emerging economies. It will yield benefit from the skilled jobs and advanced technologies.

Economic Benefits

Carbon trading is presently operating in EU markets. Experts opine that it will be functional in US market also. The market price for per ton of CO_2 currently is 20 US$. It will increase with opening of US market. Bangladesh gas fields are well impermeable as it contained gas under high pressure for thousands of years. Approximately 419.22 $X10^{-3}$ Giga tons of CO_2 (equivalent to 20.63 tcf of gas) can be stored; whose cost would about be US$ 8385 Million dollars.

Table 4: Cost Benefits for CCS in Bangladesh Gas Fields.

Storage Type	Volume				CO2	Cost in Million Dollors
	Tcf	Bcf	B.Cu.m (Bcfx0.02834)	G.t (B.Cum x 0.717kg)	G.t	(@US$20 per ton CO2
Gas Fields	20.63	20,631.50	584.70	419.22 X10-3	419.22 X10-3	8384.55
Oil Fields			Not calculated			
CBM Seams			Not calculated			

Source: Reference for estimation " CDM and its Opportunities in Bangladesh", Waste Concern, November, 2004, p. 8

Social Aspect

Bangladesh is a land scarce country. Gas fields are either on private/ government land or near to the population. Most of the people are illiterate and lack adequate knowledge on CCS. People will be suspicious and skeptic about the bad effect of CO_2 storage and its leakage. Our divisive political culture may take an opposite view with the ruling regime. This may create social chaos and unrest, which may turn to a movement. Social awareness and political consensus is a precondition for such huge projects of global nature.

RECOMMENDATIONS

Strong Negotiation at COP. As a victim of CC and a leader of MVCs and LDCs, Bangladesh will have to negotiate strongly in the coming COP for climate agreements for GHGs emissions reductions for second and more terms including fund for CC.

Carbon Mitigation. Though Bangladesh emits very less GHGs, even then Bangladesh should follow low carbon path in its economic growth and secure considerable climate fund and technology.

Energy Security. Bangladesh will have to ensure its energy security through energy mix exploiting all local resources and exploring regional & international resources and opportunities.

Energy and Climate Synergy. Bangladesh will have to maintain synergy between energy and climate security through renewable energy, energy efficiency, clean coal and CCS.

CCT. GOB will have to explore its huge coal resources without delay and use it as NZEC for electricity production under CDM for CC.

CBM. GOB needs to extract CBM at Jamalganj, Joypurhut for CO_2 sequestration in un-minable coal seams, while producing methane.

CCS in Depleted Gas Fields. GOB will have to exploit the opportunity of carbon sequestration in depleted gas fields of Bangladesh in near future under CDM.

International Oil and Gas Industry in CCS. GOB will have to take the advantage of the International Oil and Gas Industry in Bangladesh for CCS as they have gained considerable experience over several decades relating to the capture, transportation and storage of CO_2 and the monitoring of CO_2 injected in geological formations.

CCS in Coal-based Developing Countries. GOB will have to take advantage of CCS's contributions towards sustainable development to coal-based developing / non-Annex I countries for GHGs mitigation through use of CCS under CDM from the developed countries. She should also pursue for CCS early deployment as incentives and project-based mechanisms via CDM for expertise and capacity building.

Economic and Technological Benefits for CCS. GOB should take the advantage of billions dollars economic benefits and technological benefits of skilled jobs and advanced technologies under CDM for CCS for CC.

Social Aspect. GOB should not ignore the social aspect, the skepticism about the bad effect of CO_2 storage and its leakage. Social awareness and political consensus should be built for such huge projects.

CONCLUSION

The impact of CC will be the SLR, a large migration of people, increase typhoons, cyclones and floods, disruptions of water resources, extinctions and other ecological disruption, severe disease outbreaks, scarcity of foods and shelters leading to internal and external unrest. The climate conflict will spread amongst the countries.

About 0.5-meter rise in sea level would inundate an area of 22,000 sq.km of Bangladesh, affecting 17 million people. The other impacts would be on Agriculture, Bio-diversity and Forestry, Human Health, Fisheries, Drainage, Fresh water etc. Many of the challenges we face, from poverty to armed conflict, are linked to the effects of GW and CC. Fossil fuel burning is causing dangerous interference in the climate offering growth of GHGs.

Bangladesh has huge shortage of gas production for the generation of electricity. It has 3.3 Gt of coal reserve including CBM. Coal is very cheap, affordable and coal market is well functioning around the globe. Fossil fuels provide 80 per cent of global energy and responsible for 65% of global GHGs. The energy and climate security thus seems conflicting. There are a number of ways to reduce emissions from the energy sector like renewable; switching to near-zero-emission sources; and CCS of fossil fuels etc.

Bangladesh lacks capacity to exploit resources for energy and climate security. Global carbon sequestration provides good opportunity for Bangladesh to use its coal for energy and climate security. Bangladesh can build the capacity and negotiate in the COP for NZEC technology and fund under CDM from Annex 1 countries. She can get huge investment and financial support to ensure environment friendly production processes in the clean coal energy sector through negotiations as a leader of LDC and MVC of the world CC movement.

CCS technology is the only currently available technology that allows very deep cuts 80%-90% in CO_2 emissions to atmosphere from fossil fuels. CCS technologies enable emissions of CO_2 to strip out of the exhaust stream from coal

combustion or gasification and stored in depleted oil and gas fields or unmineable coal seams. Geological formations, depleted gas fields are currently considered the most promising storage of CO_2. Gas has been there with very high pressure for thousands of years and leakage percentage for storage of CO_2 is near to zero or likely to less than 1% in 1000 years. The success of the Salah and Xstrata oaky projects provided with excellent analogy for other countries for CCS.

The cost of CCS for power generation from coal is estimated between US$40 and US$90 per ton of CO_2. Storage at sites, capture and compression costs dominate the overall cost. IEA has found that stabilizing emissions without CCS raises costs by over 70%. Power plants with CCS reduces CO_2 emissions by 80%-90%.

Experts opine that Geological Formations of Bangladesh Gas Fields could be good for CO_2 storage. The depth is adequate, other features and permeability are also considered feasible for carbon sequestration. CCS can benefit Bangladesh technologically and financially. Under Kyoto Protocol developed countries have binding responsibility to transfer technologies to developing countries for emissions reduction. Bangladesh can achieve CCS and CCT for NZEC under CDM to convert its huge coal resource to clean electricity.

Carbon trading is presently operational in EU, markets. The market price for per ton of CO_2 currently is US $20. Present gas fields of Bangladesh possibly will deplete by 2020-2030. Bangladesh can earn billion dollars for carbon sequestration only from developed countries for CC.

LIST OF ABBREVIATIONS

Annex I Countries.	OECD Countries and Economies in Transient Countries
BP	British Petroleum
BAPEX	Bangladesh Petroleum Exploration & Production Co. Ltd
CBM	Coal Bed Methane
CC	Climate Change
CCT	Clean Coal Technology
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CDM EB	CDM Executive Board

CERs	Certified Emissions Reductions
CMM	Coal Mine Methane
COACH	COoperation Action within CCS CHina-EU
CO_2	Carbon Dioxide
COP	Conference of the Parties
EU	European Union
GHGs	Green House Gases
GoB	Government of Bangladesh
GW	Global Warming
Gt	Giga Ton
GDP	Gross Domestic Product
IETA	International Emissions Trading Association
IPCC	Inter Governmental Panel on Climate Change
JI	Joint Implementation
LDCs	Least Developed Countries
MVC	Most Vulnerable Country
MW	Mega Watt
Non-Annex I Countries	Mostly Developing Countries Including LDCs
NZEC	Near Zero Emission Coal
OECD	Organization of Economic Cooperation and Development
PSMP	Power Sector Master Plan
SLR	Sea Level Rise
UNEP	United Nation Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
WTO	World Trade Organization
2P	Proven + Probable

BIBLIOGRAPHY

Books and Publications

1. Ali, S. I. and Saleemul Huq (1990) International Sea Level Rise: National Assessment of Effects and Possible Responses for Bangladesh (Dhaka: Bangladesh Centre for Advanced Studies (BCAS).
2. Asaduzzaman, M. (2008) Policy Response of Bangladesh to Climate Change; Presentation made at the International Symposium on Climate Change and Food Security in South Asia (Dhaka, August 25-29)
3. Bangladesh Centre for Advanced Studies (BCAS) (1996) Bangladesh Least Cost Greenhouse Gas Abatement Strategy (Dhaka: Bangladesh Centre for Advanced Studies (BCAS) with BUET, BIDS and BUP).
4. Brammer, Hugh (1989) "Monitoring the Evidence of the Greenhouse Effect and its Impact on Bangladesh", in: H. J. Moudud, H. E. Rashid, A. A. Rahman, and M. Hossain (eds.) The Greenhouse Effect and Coastal Area of Bangladesh (Dhaka: Bangladesh Centre for Advanced Studies).
5. Bruce G. Miller (2010), "Clean Coal Engineering Technology". - Elsevier Science & Technology ,New York, USA .
6. Professor Philip M. Parker, PhD (2009), "Technology: Webster's Timeline History, 1985 – 2007" (on line), Icon Group International, California, USA.
7. "21st Century Essential Guide to Carbon Sequestration: Greenhouse Gas and Carbon Dioxide Capture and Pollution Control to Prevent Global Warming, Coal Power Plant Research" by U.S. Government, Amazon.com.
8. "21st Century Essential Guide to Clean Coal Technology: Future Gen Power Plant, Pollution Control, Gasification, Hydrogen Production, Carbon Dioxide and Greenhouse Gas Reduction by U.S. Government", Amazon.com.
9. Heinz, Termuehlen, "Clean and Efficient Coal-fired Power Plants: Development toward Advanced Technologies", Werner Emsperger - ASME Press (2003)
10. "The Clean Use of Coal: A Technology Book" by International Energy Agency - OECD "(1985)
11. Paul W. Spaite (1986), "Emerging Clean Coal Technologies, Engineering and Economics Research", Inc, Hagler, Bailly & Company, PEI Associates - Noyes Data Corp.
13. Robert C. Porter (1999), "Clean Coal Technology: Advanced Technologies for the Control of Sulfur Dioxide Emissions from Coal-Fired Boilers" - Diane Pub Co, USA.

14. Clean Coal Technology Demonstration Program: Program Update 1996-97 by Barry Leonard in Books - DIANE Publishing Company (1998), USA.
15. Dagmar, Budikova (ed) 2009, " Carbon Capture And Storage" , Boston University, USA.
16. David Adam (2010), " How Will Carbon Capture And Storage Work?" The Guardian, 29 December.
17. Steve Rackley (2010), "Carbon Capture and Storage" Elsevier Science & Technology , New York, USA .
18. Elizabeth Wilson, David Gerard(eds) (2007), "Carbon Capture and Sequestration in Context: Technology, Regulation and Social Acceptance", Black Well Publishing, Iowa, USA.
19. Ronald E. Hester and Roy M. Harrison (eds) (2010), "Carbon Capture and Storage (Issues in Environmental Science and Technology)", The Royal society of chemistry, UK.

Web/Internet

20. United Nations Framework Convention on Climate Change (UNFCCC) http://unfccc.int/
21. Federal Ministry for Economic Cooperation and Development (BMZ)—Energy and Climate Protection http://www.bmz.de/en/issues/energie/index.html
22. International Institute for Sustainable Development (IISD): Climate Change and Energy http://www.iisd.org/climate/
23. World Business Council for Sustainable Development—Energy & Climate http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MenuId=NjY&doOpen=1&Clic menu=Left Menu
24. BEN — Bangladesh Environmental Newsletter http://www.bcas.net/Publication/Pub_Index.html
25. http://unfccc.int/files/meetings/sb24/in-session/application/pdf/sbsta_may_20th in salah wright.pdf
26. http://en.wikipedia.org/wiki/Carbon_capture_and_storage
27. http://www.worldcoal.org/carbon-capture-storage/financing-ccs/
28. http://en.wikipedia.org/wiki/Global_warming
29. http://www.worldcoalinstitute.org/
30. http://www.europarl.europa.eu/climatechange/doc/EU_Legislation_on climate_change.pdf
31. http://www.fuelcellmarkets.com/content/images/articles/CMI(1).pdf
32. http://www.moef.gov.bd/climate_change_strategy2009.pdf
33. http://web.princeton.edu/sites/pei/pdf/9-25cmiannouncement.pd

Interviews/Discussion/Meeting

34. Assistant Professor, Zia Wadud, PhD, DIC, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), April 20, 2010.
35. Professor Mojibur Rahaman,PhD, Head of the Department, Bangladesh University of Engineering and Technology (BUET), April 20, 2010.
36. Mr. Monowar Islam, ndc, Additional Secretary, Director General, Department of Environment, Ministry of Environment & Forest Government of Bangladesh, May 10, 2010.
37. Mr. Fazle Rabbi Sadeque Ahmed, PhD, Director (Technical), Department of Environment (DoE), Ministry of Environment & Forest Govt. of the people's Republic of Bangladesh, June 5, 2010.
38. Professor Dr. Ijaz Hossain, Chemical Engineering Department, Bangladesh University of Engineering & Technology (BUET), June 10, 2010.
39. Professor Md. Tamim, BUET and Former Adviser, Energy & Mineral Resources

Division, Ministry of Power Energy & Mineral Resources June 20, 2010.

40. Mr. M. Moinul Huq, Strategic policy Expert [Regional Geologist], Hydrocarbon Unit,Energy & Mineral Resources Division, Ministry of Power Energy & Mineral Resources June 25, 2010.
41. AHM (Shams) Shamsuddin, ph.d, Chief Exploration Geologist, Chevron Bangladesh, July 20, 2010.
42. Mr. sefaul Alam, Director (Joint Secretary) Hydrocarbon Unit, Energy & Mineral Resources Division, Government of the People's Republic of Bangladesh, July 20, 2010.

Reports

43. Anders Berglund , Rolf Deling , Ulrika Snellman , Ole Stenback ,Jack J. Fritz and Karin Oskarsson (ed) (1990), "Planner's Guide for Selecting Clean-Coal Technologies for Power Plants" (World Bank Technical Paper), Amazon.com.
44. Industry Attitudes to Combined Cycle Clean Coal Technologies: Survey of Status by IEA Coal Industry Advisory Board, Organization for Economic Co-operation and Development - OECD/IEA (1994)
45. 2009 ICO2N Carbon Capture and Storage Report, available at http://www.ico2n.com/ , retrieved on 12-11-2010.
46. World Bank (2000) Bangladesh: Climate Change and Sustainable

Development. Report No. 21104 BD (Dhaka: World Bank, South Asia Rural Development Team, and October.

47. Government of the People's Republic of Bangladesh (GoB), Ministry of Environment and Forest (MoEF) (2002) Initial National Communication under the United Nations Framework Convention on Climate Change (Dhaka: GoB, MoEF, October).
48. Government of the People's Republic of Bangladesh (GoB), Ministry of Environment and Forest (MoEF) (2005) National Adaptation Programme of Action (NAPA), (Dhaka: GoB, MoEF; and United Nations Development Programme (UNDP), November).
49. Government of the People's Republic of Bangladesh (GoB), Ministry of Environment and Forests (MoEF) (2008) Bangladesh Climate Change Strategy and Action Plan 2008 (Dhaka: GoB, MoEF, September).

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