1. Executive Summary

1.1 Country Profile : Status of Climate Change and Environmental Activities

Bangladesh is a South Asian country located between 20^{O}34$^{/}$ to 26^{O}38$^{/}$ north latitude and 88 ^{O}01$^{/}$ to 92^{O}42$^{/}$ east longitude with an area of 147,570 sq. km. and a population of 119.8 million (BBS, 1996). It is bordered on the west, north and east by India, on the south-east by Myanmar and on the south by the Bay of Bengal.

Bangladesh is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC). It was signed in Rio de Janeiro, Brazil on 9th June 1992 and ratified by the Government of Bangladesh on 15th April 1994.

In December 1994 the UN FCCC received the fiftieth ratification it needed to be put into force and as a result on March 24, 1995 the UN FCCC was put into force. Bangladesh is the 67th Party to ratify the convention as a non-Annex-1 Party.

Since signing the Convention in 1992 Bangladesh has taken several steps, in association with international agencies, to do the following functions: (i) assessing the possible impacts of climate change and sea level rise in different sectors, (ii) assessing Bangladesh's contribution to the global load of GHGs on an annual basis, (iii) identifying possible options to abate national GHG emissions, and (iv) identifying specific steps and projects which would have positive feedback in curbing GHG emissions.

A summary of the major climate change activities in Bangladesh, prior to the ALGAS activities, is presented below;

Name of the activities	***Components***
a) Effect of Climate Change and Sea Level Rise on Bangladesh *By Dr. Fasiuddin Mahtab (1989)*	• assessment of the nature of climate change • assess the physical, economic, environmental and social impacts of the predicted climate change.
b) The Greenhouse Effect and Climate Change: An Assessment of the Effects on Bangladesh *By Bangladesh Unnayan Parishad/CEARS/CRU, 1993*	• the greenhouse effect and climate change • sea level changes in the Bay of Bengal • effects of climate and sea level changes on the natural resources of Bangladesh • socio-economic implications of climate change for Bangladesh • climate change and sea level rise: the case of the Coast • the implications of climate change for Bangladesh: a synthesis
c) ADB, 1994 *By Bangladesh Institute of Development Studies (BIDS), Dhaka*	• socio-economic impacts of climate change • develop and analyse policy options to deal with climate change
d) Vulnerability of Bangladesh to Climate Change and Sea Level Rise *By Bangladesh Centre for Advanced Studies (BCAS) /Resource Analysis (RA) /Approtec Ltd., 1994*	• assessment of sectoral and overall vulnerability of Bangladesh to climate change and sea level rise

e) Climate Change Country Study Bangladesh under U. S. Climate Change Study Programme *By Bangladesh Centre for Advanced Studies (BCAS)/BIDS/BUP, 1996*	• greenhouse gas emission inventory • vulnerability and adaptation • mitigation options and • dissemination
f) Reconnaissance study on the use of Ozone Depleting Substances (ODS) in Bangladesh *By Bangladesh Centre for Advanced Studies (BCAS), 1993*	• assessment of ozone depleting substances according to their sources
g) Update of Ozone Depleting Substances (ODS) in Bangladesh *By Bangladesh Centre for Advanced Studies (BCAS), 1996*	• update to the report on ODS

The government of Bangladesh has set up the Ministry of Environment and Forest (MOEF) in 1989 with two major departments under it, namely the Department of Environment (DOE) and Forest Department (FD) to address the emerging environment related issues. The government has also developed and adopted an Environmental Policy in 1992 and an Environment Protection Act in 1995 as well as a National Environment Management Action Plan (NEMAP) in 1996. Under the Environment Protection Act, 1995, Government also prepared and adopted the Environment Protection Regulation, 1997. It is in the process of implementing the NEMAP which includes action on climate change. The government has instituted an inter-ministerial committee on climate change with the Secretary, MOEF as the chairman and the Director General, DOE as the member secretary. The DOE has been designated as the focal point at the government on climate change related matters and produced a number of reports, publications and media awareness items on the issue.

1.2 1990 National Inventory of GHG Sources and Sinks

a) Energy Sector

Bangladesh has one of the lowest per capita commercial energy consumption rates in the world at 56 Kgoe/yr (1990). Moreover, from the point of view of carbon dioxide emission there are the following redeeming features.

- over 60% of the energy presently comes from biomass
- over 60% of the commercial energy comes from natural gas
- the single largest user of energy (other than power generation) is the urea fertiliser industry which utilises natural gas and state-of-the-art technology

The two most significant sub-sectors of commercial energy consumption are Power Generation and Non-energy use. Of the total commercial energy consumed, power generation's share was 30%. In the demand side one single industry (4 urea fertiliser plants) consumed approximately 22% of the total commercial energy. In the traditional fuel category (non-CO_2 emission - CH_4 and N_2O), the significant sub-sectors are residential cooking and industrial process heat (paddy parboiling and brickmaking). The other significant GHG emitting sources are diesel for transport, kerosene for rural lighting, and coal for the manufacture of bricks.

Detailed technology based estimate revealed that 12088 Gg of CO_2 is released from the energy sector of which 4392 Gg was emitted from the energy and transformation sector, 2420 Gg from the industry sector, 1875 Gg from the transport sector and the remaining from small combustion and fugitive emission. In addition 2.2 Gg of N_2O and 169 Gg of CH_4 were also released from the this sector.

B) Forestry Sector

The total land under forest is about 2.56 million ha which include officially classified and unclassified state lands and forest lands accounted for by village forests and tea/rubber gardens. In Bangladesh natural forest areas constitute almost 31% and forest plantation 13% of forest areas. Only 5% of the existing forest land is designated as protected areas. Almost half of the existing forest land is under different types of non-forest land use e.g., shifting agriculture, illegal occupation, unproductive areas, and other areas. In terms of per capita forest land, Bangladesh ranks amongst the lowest in the world which is about 0.02 ha per person.

Forestry is an important sector in Bangladesh's economy, which contributes about 2.6% of the country's gross domestic product (GDP) at constant price in 1989-90. To improve the forestry sector the government commissioned a study to develop a medium to long term plan for the sector with financial assistance from the Asian Development Bank (ADB). The study, the Forestry Master Plan (FMP), looked into the present rate of forest depletion, projected demand and supply potential of forest products and devised development plans for restoration of the existing forests and improve further. It also looked into the economic aspects of forest management for a number of alternative development options. The deforestation rate up to 2013 is according to the forestry master plan and is about 20,880 ha/year which is very close to the deforestation rate estimated based on compression of forestry inventory for the year 1983/84 and 1990/91. Although the Plan did not consider the carbon sequestration potential of the forest species, it gave the basis and database for studying the future emissions from forests (carbon removal) and also the carbon sequestration potential. Forestry sector analysis made full use of the knowledge base of the Forestry Master Plan for its rich data base and information.

The emission inventory for the base year shows that there is a net emission of carbon in the forestry sector in Bangladesh. The existing forests can not uptake more carbon than the rate of removal from the forests. The present net emission from forestry and land use change is 19,738 Gg in CO_2 equivalent.

c) Agriculture Sector

Bangladesh lie in the active delta region of three of the world's major rivers which provide suitable condition for agriculture activities. Most of the land area is being used for agriculture, forest and settlement. Less than one per cent of the land area is being used for industry and other miscellaneous social needs.

Crop agriculture and livestock are the significant sources of methane emission in Bangladesh. Methane emission from the agriculture sector is due to rice cultivation in flooded condition. In addition, non-CO_2 greenhouse gases are emitted when the agriculture residue is burned in the field.

Methane is produced in herbivores as a by-product of the enteric fermentation, a digestive process by which carbohydrates are broken down into simple molecules by micro-organisms for absorption into the bloodstream. The amount of methane produced by an animal depends on its type, age and weight and also on the quality and quantity of the feed given. Greenhouse gas (GHG) emission from the agricultural activities particularly from rice cultivation depends on flooding condition, depth of water and use of fertiliser. Three major types of fertilisers, Urea, TSP and MP are used for rice production.

Over the years, the relative importance of the agriculture sector in terms of its contribution to the national income has declined and at present stands is 21.31% at 1989-90 constant market price, less than a quarter of GDP. Much of agriculture or rather crop agriculture depends on crop cultivation which is mainly due to rice. Much of livestock keeping is also for the need of draught power in crop cultivation. Methane emission in agriculture depends on practiceing rice culture and livestock keeping.

Livestock plays a vital role in the agro-based economy of Bangladesh and in 1989-90, this sector accounted for about 2.8% of the GDP (BBS, 1996). Cattle and buffaloes provide draught power for ploughing and rural transport. This sector provides meat, milk and eggs which are important sources of animal protein for the people. Excreta of cattle are generally used as fuel in the rural areas. Hide and skins are important sources of foreign exchange earning. In Bangladesh an average bull weights about 107.6 Kg, while an average matured cow weights about 91 Kg. On an average a cow produces about 206 Kg milk per annum (as in 1990) which is far too low compared to the average global production of 2129 Kg in 1990.

Greenhouse gas emission due to enteric fermentation and manure management of the livestock sector, methane emission from rice cultivation and field burning was estimated by using IPCC methodology. Furthermore, the methodology and coefficients used come from several sources, IPCC, Indian data and Bangladesh data. The bias in the estimates are thus difficult to calculate. Only the use of country specific coefficients and internally consistent data set will help in calculating more definitive and firm emission figures for Bangladesh.

Methane emission from livestock sector

Enteric fermentation

For Bangladesh, total methane emission from livestock sector due to enteric fermentation is estimated at about 519 Gg of which contribution by cattle is about 374 Gg, nearly 72% of the total emission. Within the cattle population, dairy and non-dairy cattle accounted for 73 Gg and 301 Gg, respectively. Contribution of goat population is about 123 Gg (24%) of the total emission. Buffaloes contribute about 3%, and remaining 1% comes from Sheep population.

Manure Management

Manure management in livestock sector is also another source of methane gas emission. It is estimated that 73.07 Gg of methane is emitted from manure management. The contribution of cattle population is nearly 83% of which dairy and non-dairy cattle account for about 31 and 52 per cent respectively. Contribution of poultry population is small (4%).

Methane emission from flooded rice fields

Methane gas emission due to rice cultivation has been estimated at 767 Gg. Much of it is due to non-irrigated rainfed and deep water rice cultivation contributing about 518 Gg (68%) and 120 Gg (17%) of total emission, respectively. The remaining methane gas is emitted from irrigated rice fields.

Table 1.1 Bangladesh National Greenhouse Gas Inventory in 1990 (Gg)

Sources and Sinks	CO2 Emissions	CO2 Removals	Net CO2	CH4	N2O	NOx	CO	CO2 Equivalent (excluding CO2 emission from TBB)	Percent of Total CO2 Equivalent
Total (Net) National Emissions	***39900***	***5809***	***34092***	***1739***	***4.51***	***203***	***4309***	**72000**	**100.00%**
1. All Energy (Fuel Combustion + Fugitive)	**12863**		**12863**	**331**	**4.40**	**200**	**4205**	**21186**	**29.43%**
A. Fuel Combustion									
1. Energy and Transformation Industries	4392		4392			40	5.00	4392	6.10%
2. Industry	2420		2420	24	0.44	16	394	3050	4.24%
3. Transport	1875		1875			1.5		1875	2.60%
4. Commercial-institutional	239		239	1	0.01	0.2	7	259	0.36%
5. Agriculture	680		680					680	0.94%
6. Residential	2082		2082	138	1.75	63	1699	5523	7.67%
7. Others (please specify)	400		400					400	0.56%
8. Traditional Biomass Burned for Energy	62084	62084		162	2.20	79	2100	4084	5.67%
B. Fugitive Fuel Emissions									
1. Oil and Natural Gas Systems				7				149	0.21%
2. Coal Mining (N/A)									
Statistical Difference *	**775**		775						
2. Industrial Processes	**1491**		**1491**				**6.49**	**1491**	**2.07%**
A. Cement Production	153		153					153	0.21%
B. Others									
1. Ammonia production	1130		1130				6.48	1130	1.57%
2. Metal (iron & steel)	208		208			0.01	0.01	208	0.29%
3. Agriculture	**2384**	**2384**		**1363**	**0.11**	**3.84**	**97.30**	**28667**	**39.82%**
A. Enteric Fermentation				519				10892	15.13%
B. Manure Management				73				1534	2.13%
C. Rice Cultivation				767				16107	22.37%
D. Agricultural Soils									
E. Prescribed Burning of Savannas (N/A)									
F. Field Burning of Agricultural Residues	2384	2384		5	0.11	3.84	97	133	0.18%
G. Others (please specify)									
4. Land use Change and Forestry	**23162**	**3425**	**19738**					**19738**	**27.41%**
A. Changes in Forest & Other Woody Biomass Stocks	21391	3326	18066					18066	25.09%
B. Forest and Grassland Conversion (N/A)	1771		1771					1771	2.46%
C. Abandonment of Managed Lands (N/A)		99	-99					-99	-0.14%
D. Others (please specify)									
5. Waste				**44**				**918**	**1.27%**
A. Solid Waste Disposal on Land				44				918	1.27%
B. Wastewater Treatment									
C. Others (please specify)									

Note:
CO2 emissions from traditional biomass burning are not included in subtotals and the national total.
CO2-equivalents are based on GWPs of 21 for CH4 and 310 for N2O. NOx and CO are not included since GWPs have not been developed for these gases.
Bunker fuel emissions have already been accounted for in energy sector as per IPCC guideline.
* Difference between reference approach and detailed approach equal to (12863-12088) = 775

Emission from Field Burning of Crop Residues

Since the major crop in Bangladesh is rice, estimation for emission of non-CO_2 gases was done in terms of field burning of paddy-straw only. The amount of CO_2 released was not estimated assuming that it would be balanced by growing plants during the next cropping season. The estimated amounts of CO, CH_4, N_2O and NOx released due to field burning of bio-mass reveal that about 695.4 Gg carbon and about 9.7 Gg nitrogen are being released annually from field burning of bio-mass sources in the form of 4.63 Gg of CH_4, 97.33 Gg of CO, 0.11 Gg of N_2O and 3.87 Gg of NOx.

Much of the CH_4 emission (82%) in Bangladesh comes from rice cultivation and livestock management. Of this 43% is due to enteric fermentation and manure management of livestock keeping and the rest comes from the rice field. Emission of GHGs from the fisheries sub-sector is negligible.

1.3 Baseline Projection of National GHG Inventories to 2020

a) Energy Sector

LEAP, an accounting type energy planning model, has been used for the baseline emissions projection for the energy sector.

Assumptions

The factors (NEP, 1996) which will affect the future GHG emissions most significantly are (i) Economic growth rate (ii) Population growth rate (iii) Natural gas reserves (iv) Growth rate of the fertiliser industry and (v) Power generation and transmission and distribution losses. By South-east Asian standards the economic growth rates used are moderate. If higher growth rates are experienced then emissions will correspondingly go up. The same argument applies for population. If natural gas reserves are depleted and coal and/or oil are used for power generation and industrial use then the growth in emissions will be much greater. The fertiliser industry is the single largest user of commercial energy (22% of the 1990 total) on the demand side. If this industry grows at the same rate as other industries, i.e. as the industrial GDP, then emissions will increase significantly. The power generation efficiency and transmission and distribution losses will also significantly affect emissions. Great uncertainties are associated with these parameters.

GHG Inventory Projection to 2020

As can be seen from GHG emissions projection figure, there will be a seven times increase in the energy sector emissions up to the year 2020. The reason behind this large increase are the expanding industrial and electricity generation sectors. It is worth pointing out that the 1990 per capita GHG emission of Bangladesh is one-fifth that of India and one-tenth that of China. Even with a seven times increase in energy sector emission, the per capita emission of Bangladesh will be only twice the 1990 value of India and half the 1990 value of China.

The emissions from the different energy consuming sub-sectors in the year 2020 reveal the following noteworthy features

- Emission from Biomass has become an insignificant category in relative terms
- Energy and Transformation Industries is the single largest category
- Industry sector has become the largest category among the demand sub-sectors
- Residential sector has dramatically shrunk in size
- Transport sector has gained in importance

In the year 2020 it is projected that emission will be 122 Tg of CO_2 equivalent, of which 54.3 will come from the energy and transformation industries, 63.3 Tg will come from the demand sectors, 6.6 Tg from traditional biomass burned for energy and the remaining from fugitive fuel emission.

b) Forestry Sector

Future projection of greenhouse gas emission from the forestry and land use change sector was restricted to 2013 due to the availability of forest area projection given in the FMP. For the base year (1990) total forested area of the country is about 1890 thousand ha. including plantation, unclassified state forest and village forest. It is also assumed that the rate of deforestation is 20880 ha/year. Considering the deforestation rate forested area for the year 2013 will be 1696 thousand ha including additional plantation and unclassified state forest land. Assumptions that have been used to calculate the forested area for the year 2013 are as follows;

- The base year forested area is considered
- New plantation under the status quo is added to the 1990's plantation assuming that the long rotation will remain up to 2013. For the short rotation plantation, area will be replanted after the end of the rotation.
- Total deforestation area (417.6 thousand ha.) was taken from the Forestry Master Plan and the figure was distributed proportionately among the forest categories including plantaion.

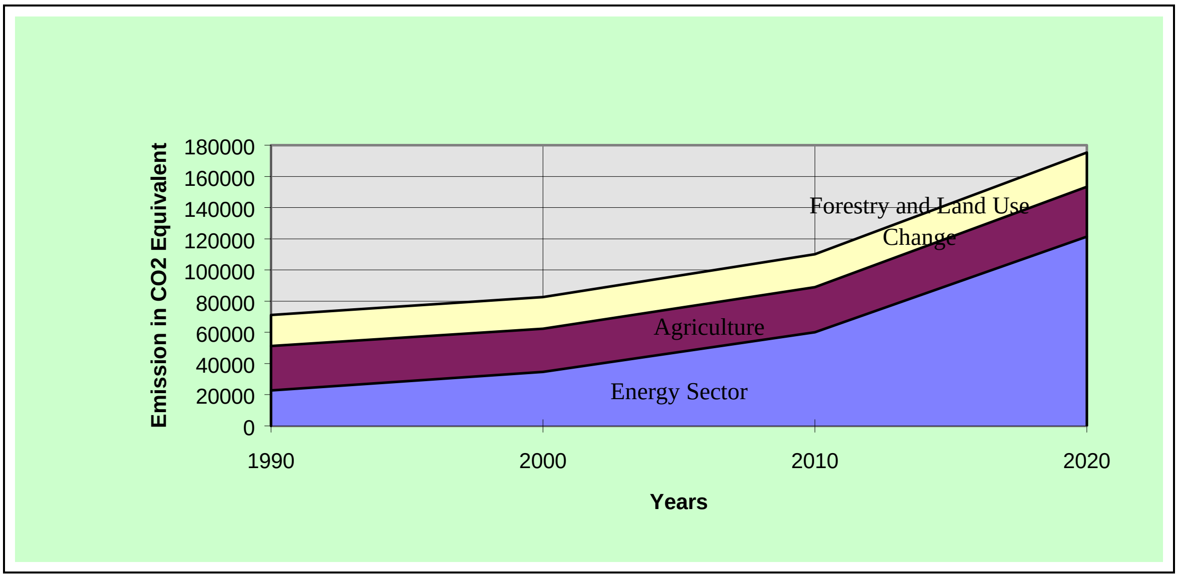
It is clear from the emission projection figure that the future emission from the forestry and land use change will increase. In the base year (1990) net emission in CO_2 equivalent is 19738 Kt and for the projection year (2013) is 21908 Kt. The incremental emission over the base year is only 10% which is 2170 Kt in CO_2 equivalent. The emission will not be higher enough over the base year due to the large afforestation rates under the government programmes. Major causes of this additional emission are the high rates of deforestation, demand of biomass energy etc.

c) Agriculture Sector

Greenhouse gas emission in future from rice agriculture will depend on the *changes in land use* specially changes in rice cultivation in wet condition and the *changes in livestock population* including its management practices. Two general assumptions may be considered: a) the past trend and performance and b) future demand, policy priority, achievement capabilities and availability of input. Future population in the country, changes in income and food intake pattern will determine the future demand of cereal and non-cereal food and other consumable items which in term will influence both rice cultivation and livestock management practices.

It is estimated that the total methane emission up to the year 2020 from the agriculture and livestock sub-sectors is 1527 Gg of which 638 Gg comes from crop agriculture, 8.8 Gg comes from field burning and remaining comes from livestock rearing. Methane emission from the rice agriculture will shrink due to the low rate of seasonal integrated flux from irrigated rice field compared to the others categories.

Figure 1.1 Greenhouse Gas Emission up to 2020 in Gg



1.4 GHG Mitigation Options and Opportunities

In the ALGAS study, optimisation modelling exercise was attempted for only the energy sector to find out the least-cost GHG mitigation options and opportunities. GHG mitigation opportunities for forestry and agriculture were assessed based on GHG reduction potential and incremental cost. The sector-wise GHG mitigation opportunities are summarised below.

a) Energy Sector

The low energy utilisation efficiency and the projected large increase in energy consumption emphasises the need for energy efficiency improvement measures in all sectors. In the short term therefore the scope of efficiency improvement by technologies which are standard in developed countries, is so great that it is unnecessary to pursue advanced technology options with positive cost per ton of carbon dioxide abated.

Even though the energy sector's share of the total 1990 GHG emission is 30%, it is the most important sector for mitigating GHG emission because

- The energy sector's emission will grow rapidly in proportion to the other sector's emission, and in 2020 will constitute 69% of the total
- The mitigation options for the other sectors are either limited or are too difficult to implement

By reviewing the 1990 and 2020 GHG emission inventories, more than sixty mitigation options were identified. In this study, first, LEAP was used to perform an energy demand projection. Following this an inventory of mitigation options relevant to the country were developed. In this identification process predominantly expert judgement was utilised the key element of which was the study of the disaggregated energy demand in the year 2020. After this, MARKAL, which is a linear programming optimisation model, was used to find the least-cost mix of mitigation options to satisfy the demand calculated using LEAP. Thus LEAP was used for the calculation of energy services demand up to the year 2020, which is exogenous to MARKAL.

The identified options were prioritised in a national workshop using three criteria, namely, National Priority, Social Acceptance and Barriers. A summary table presents the potential of GHG mitigation opportunities in Bangladesh which were modelled using MARKAL. It should be emphasised that the list has been constructed for one unit of the option. This table does not provide the total potential of abatement which is derived from the least-cost modelling. Therefore, table provides an initial assessment of the mitigation options.

For a number of reasons not all could be considered in the Least-cost modelling. The two main reasons why all options could not be considered are.

1. Lack of cost and/or efficiency data
2. The inability or difficulty of handling such options in the edition of MARKAL used

These options have been assessed using a spreadsheet to calculate the cost effectiveness and, expert judgement to calculate the abatement potential.

Table 1.2 Summary of Potential GHG Mitigation Opportunities in Bangladesh[1]

	GHG Emissions Reduction Option	Potential Introduction[2] (year)	Estimated Investment Cost of Option[3] (US$/unit)	GHG Emissions Reduction[4] (Tonnes of CO_2-equiv./yr.)
Supply Options:	1. Combined Cycle	1999	140 million (210 MW)	67320
Demand Options:				
1. Efficiency Improvements	1. 4-Stroke 3-Wheelers	1999	2900	0.17
	2. Improved Biomass Cookstoves	1999	3.5	0.18
	3. Improved Kerosene Lamps	1999	1.9	0.005
	4. CFL	2002	21	0.036
	5. Efficient Refrigerators	1999	750	0.04
	6. Efficient Air Conditioners	1999	920	0.37
	7. Gas Boilers Retrofit (improved) Efficient	 2002 2002	 11500 15000	 26 38
	8. Improved Coal Boilers	2002	9200	31
	9. Improved Fuel Oil Boilers	2002	9200	26
	10. Improved Biomass Boilers	2002	6900	2.1
	11. Efficient Motors < 1HP 1-10 HP	 2002 2002	 80 190	 0.05 0.15
2. Demand-side Management	1. Metering of Natural Gas	1999	70	0.18
	2. Solar Reflective Glass Window	1999	330	0.06
	3. Housekeeping + Energy Man.	1999	11000	238
3. Process Improvement	1. Brickmaking	1999	700000	495
	2. Paddy Parboiling	1999	250	0.9

1. *These are initial assessment results and NOT modelled results*
2. *This is only suggestive because the introduction is dictated by MARKAL*
3. *This is the initial investment cost of the mitigation option and NOT incremental cost*
4. *GHG emission reduction compared to the baseline option*

b) Forestry Sector

Forest resources have been and are being degraded and depleted world-wide as a result of increasing demand of forest product, agricultural expansion and environmentally mismanagement. The existing forests in Bangladesh have no capacity to offset any GHG emissions. If appropriate plans are formulated, adequate investments are made and the ongoing social forestry programmes are enhanced the forestry sector will be able to offset GHG as carbon. Such measures will play a significant role in the country's economic growth in a sustainable manner.

There are three approaches towards increasing the carbon pool in forests: a) reforestation in previously forested areas and afforestation in newly accreted lands; b) enrichment of the existing "poor tree cover" forest land with artificial reforestation; and c) enforcement of the Forestry Act against encroachment and thus protect the existing forest resources. All of these approaches will help achieve the dual objectives of forest resources development and abatement of GHG emissions by increasing national sink capacity.

In Bangladesh, artificial reforestation and participatory coastal and sal plantation will be assessed for hill forest, inland forest and coastal areas. The following table represents the mitigation options that are considered for COMAP analysis with results.

Table 1.3 Feature of Mitigation Options

Options	Suitable Land	Global Goals	Rotation period (years)	Mean annual increment (MAI;m^3/ha)	Mitigation potential per ha (t of C abated)	investment $/tC abated
Long rotation Artificial reforestation (LR)	Hill Forest Land	Conserving forest C sink • Storing C in long term products	40	7.5	116	1.0
Medium rotation Artificial reforestation (MR)	Hill Forest Land	Conserving forest C sink • Storing C in long term products	20	12.5	92	1.2
Short rotation Artificial reforestation (SR)	Hill Forest Land	Conserving forest C sink	10	15	34	4.4
Medium rotation Sal plantation (MR-Sal)	Inland Forest Land	Conserving forest C sink • Storing C in long term products	20	12.5	98	1.5
Medium rotation Participatory coastal plantation (MR-PCP)	Littoral Forest Land/ Newly Accreted Char Land	Conserving forest C sink • Storing C in long term products	20	7	63	1.3
Short rotation Participatory woodlot plantation (SR-PWP)	Littoral forest land	Conserving forest C sink	10	15	34	3.4

C) Agriculture Sector

Agriculture is a subsistence activity in Bangladesh. The mitigation options in crop agriculture and livestock are not the same in nature due to spatially disperse livestock population and millions of farmers. According to the agricultural census of 1983-84, 70% of the farmsholding are small farms having less than 2.5 acres of land, 25% of the farmsholding are medium farms with more than 2.5 but less than 7.5 acres of land and the remaining are large farms having more than 7.5 acres of land. Small farmers in Bangladesh as elsewhere have a low risk taking capability.

Given the very large number of risk-aware farmers who need to be motivated to adopt the abatement options i.e. change a number of their present practices, several criteria should be applied for assessing the options. The first and foremost should be that the new practice must be shown to be clearly more profitable compared to the new one which indicates that output must rise because of the change. Second, the new practice must be easy to follow and adopt. If it involves too much additional effort or understanding of a complex system, it is likely to fail.

A summary of the mitigation options considered in the crop agriculture and livestock sub-sectors are presented in the table below:

Table 1.4 Mitigation Options in Rice Production and Livestock Rearing and Features

Mitigation options	Features of alternate practice (bullet points)	Methane emission reduction potential per ha or per animal or unit body weight	Impact on yield of milk or rice grain (% change)	Feasible target area or groups or population (ex: location, islands, small farmers. Dairy cooperatives)
Rice Agriculture				
Regulating Flooding in completely flooded land	• reduce CH_4 emission	40 kg/ha (20%)	5% increase	completely flooded area under irrigation project
Draining of water in two times	• reduce CH_4 emission	32 kg/ha (20%)	5% increase	rainfed flood prone and 50-100 cm standing water area
Wheat Cultivation in place of *Boro* rice	• reduce CH_4 emission	40 kg/ha (100%)	per ha yield is less than HYV rice	Except coastal area of Bangladesh
Livestock				
Molasses-Urea block/liquid	• reduce CH_4 emission • increase milk production • easy to handle	7 kg/animal (25%)	20% increase in milk	Improved dairy cattle in *Bathan*[2] and *Non-Bathan*[3] area.
Urea treated straw	• reduce CH_4 emission	2.3 kg/animal (10%)	20% increase in milk production	Local dairy cattle

The primary objective of the development of the mitigation options is to abate CH_4 emission from the livestock sector and rice cultivation in wet condition. In livestock sector, proposed mitigation option will not only decrease the CH_4 emission, but will also increase the milk production. Thus, improved livestock feed (molasses-urea) as a mitigation option can be introduced easily for the commercial dairy farms in a liquid form which is compatible with the existing feeding practices as

[2] *Bathan areas are riverside pastures that are flooded during the monsoon season. They are of high agricultural value and provided green forage for cattle.*
[3] *The Non-bathan areas do not have access to this seasonal grazing and therefore cattle are stall-fed on largely straw-based diets.*

well as offering direct financial benefits. Urea treated straw can be applied as feed for local dairy cattle which will increase milk production and reduce methane emission.

1.5 Baseline and Abatement Scenarios to 2020

a) Energy Sector

MARKAL, a multi-period dynamic linear programming model was used to conduct the economic analysis of GHG mitigation options for the Bangladesh energy sector. In the model there is one energy supply block, one energy transformation block, energy services demand categories, and under each category there are one or more technologies or devices to meet that demand. Modelling for the other sectors were not attempted.

Scenario Assumptions

The baseline scenario assumptions used in this analysis are those stated in the recently published Participatory Perspective Plan for Bangladesh 1995-2010 and the National Energy Policy 1996. The key baseline assumption for population growth is that NRR = 1 will be achieved by the year 2005 and that the country will reach a population nearing 150 million by 2010[1]. In the National Energy Policy 1996, the country's GDP growth rate is assumed to be 6.4% in the year 2000, 7.7% in 2010 and 8.7% in 2020 which is the "reference economic growth scenario" as identified by the Policy. If this scenario becomes a reality then the implied GDP per capita would be about $254 in 2000, $416 in 2010 and $774 in 2020.

Baseline Scenario

Baseline scenario for the Bangladesh energy sector model constitutes all existing technologies plus committed or planned technologies. Baseline technologies are differentiated from mitigation/abatement technologies in that the latter set of technologies are available in the horizon but not considered to be adopted in the economy in the near/foreseeable future either because of their costs or social acceptability barrier.

Mitigation Scenarios

Two major approaches are followed to generate mitigation/abatement scenarios for the Bangladesh energy sector model. The first is the sectoral approach, in which all possible abatement options in a particular sector are considered without drawing any implication on the energy consumption or GHG emission that might have in other sectors as well. The second approach followed is the identification of cross-cutting mitigation/abatement options considering their possible adoption in different sectors at the same time. Considering all the sectors together and the technologies therein, we also attempted a comprehensive mitigation scenario. So the abatement scenarios in the Bangladesh energy sector modelling are:

a. Sectoral Scenarios

- Agriculture Sector
- Commercial Sector
- Industrial Sector
- Residential Sector
- Transport Sector

[1] NRR stands for net reproduction rate. An NRR = 1 means that each female upon dying leaves only 1 female to replace her.

- Power Generation Sector

c. Comprehensive Scenario

The comprehensive scenario in an amalgam of all sectoral and technology scenario.

b. Technology Specific Scenarios

- Compact Fluorescent Lights (CFLs)
- Efficient Boilers
- Efficient Motors
- Efficient Air-conditioners
- Efficient Refrigerators
- 4-Stroke Vehicles
- Metered Natural Gas

CO_2 Emissions and Alternative Scenarios

CO_2 emissions as estimated by the model for baseline as well as in some of the alternative scenarios for energy sector are shown in Table 1.5. The 1990 level estimate of CO_2 from this bottom-up model is 13.6 million tonnes accountable for commercial energy consumption only. In the top-down approach, earlier we observed such estimate to be about 14.3 million tonnes (BCAS 1996). Two explanations may be put forward for this discrepancy. First, the implicit assumption in the top-down approach is that whatever energy, in physical terms, supplied in that particular year had been consumed in full - nothing remained as stock or smuggled out of the border. Unless this assumption is verified, the top-down estimate may be considered as an overestimate. Second, data in the bottom-up approach model are far from reality due to incomplete coverage of the energy consuming units/technologies which more efficient than actual technology in the model to meet certain energy services demand etc. None of these problems can be over-ruled given the type of data we have worked with. So, which one estimate is correct or which one is under/overestimate cannot be vouched at this moment.

After 1995, many of the alternative scenarios register variations in CO_2 emission. The most pronounced effect is observed for the industrial sector mitigation technologies, primarily due to efficient boilers and efficient motors in this sector. Compact fluorescent lights reduce about 3 million tonnes of CO_2 over the period 1990-2020; efficient boilers reduce about 113 million tonnes; efficient motors about 10 mill tonnes and efficient power generation about 11 million tonnes. Other options like efficient ACs, efficient refrigeration 4-stroke vehicles and metered gas do not prove themselves to be major mitigation or GHG reducing options for Bangladesh. The comprehensive model, where all the mitigation/abatement options are considered simultaneously, shows the highest amount of CO_2 reduction over the modelling time period over the base line scenario (13%). The reasons for the differential CO_2 emission is of course due to lower energy consumption. For example, by 2020, the Comprehensive Scenario indicates a lower consumption of energy to the tune of just above 80 PJ compared to the Baseline Consumption of nearly 849 PJ Except for the Comprehensive or Industrial Sector interventions, however, the system-wide costs vary only a little.

Table 1.5 CO_2 Emissions in Alternative Scenarios

Scenarios	CO_2 Emissions (mill tonnes)								PV of Cost (billion US $)
	1990	1995	2000	2005	2010	2015	2020	Cum. (1990-2020)	
Baseline	11.63	23.29	35.74	48.16	60.30	75.96	89.06	1721	174.4
Commercial Sector	11.63	23.29	35.74	48.14	60.25	75.85	88.89	1719	175.7
Industrial Sector	11.63	23.29	30.91	41.44	51.86	66.11	78.81	1520	168.2

Residential Sector	11.63	23.29	35.74	48.15	60.26	75.89	88.96	1720	175.6
Transport Sector	11.63	23.29	35.73	48.14	60.25	75.88	88.92	1719	174.2
CFLs	11.63	23.29	35.74	48.13	60.23	75.80	88.80	1718	176.0
Efficient Boilers	11.63	23.29	32.49	44.01	55.59	70.43	82.71	1601	170.7
Efficient Motors	11.63	23.29	34.95	47.93	60.01	75.45	88.45	1709	172.6
Efficient Power	11.63	23.29	33.09	48.08	60.38	74.42	88.61	1698	171.9
Efficient ACs	11.63	23.29	35.73	48.14	60.26	75.90	88.98	1720	174.3
Eff. Refrigeration	11.63	23.29	35.74	48.15	60.27	75.89	88.96	1720	174.4
4-Stroke Vehicles	11.63	23.29	35.74	48.15	60.29	75.92	88.96	1720	174.4
Metered Gas	11.63	23.29	35.74	48.16	60.31	75.97	88.09	1721	175.4
Comprehensive	11.63	23.28	30.88	41.28	51.14	63.21	78.21	1498	169.0

b) Forestry Sector

Baseline Scenario

Programme define under status quo scenario of the forestry master plan was taken as a baseline for forestry sector. In the baseline scenario, artificial long rotation and short rotation plantation in the hill forest area were taken into account. Plantation in a participatory manner, only coastal and woodlot plantation were considered.

For the modelling purpose, it was assumed that the present actual forest[2] area will be degraded at a rate of 20880 ha per annum till 2013. It is assumed that 182.6 and 87.6 thousand ha new plantation will take place in the state forest land and private land respectively. It also assumed that the present management practices will remain for the next 20 years. The COMAP model used to determine carbon fixation and cost effectiveness to assess the forestry sector mitigation options.

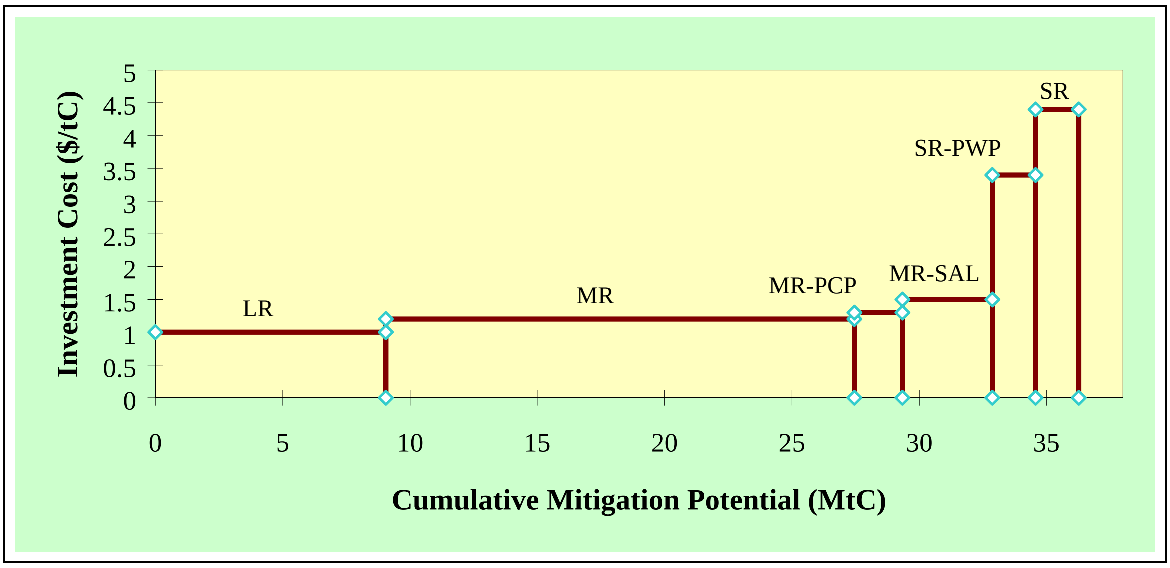
Mitigation Scenario

Programme define under scenario-1 of the forestry master plan was taken as a mitigation scenario for greenhouse gas abatement from forestry sector. In the mitigation scenario, artificial long rotation, medium rotation and short rotation plantation in the hill forest area were considered. It also considered coastal and woodlot plantation in a participatory manner.

Mitigation options or scenarios were developed based on the available land for each mitigation option and to meet timber and fuelwood demand. From Forestry Master Plan (FMP), Scenario-1 is considered as base for deforestation rate, plantation programme, etc. It assumed that the present actual forest area will be degraded at a rate of 15865 ha per annum till 2013. On the other hand 463.8 thousand ha new plantation will take place in the state forest land with various rotation period. In addition to that 105.7 thousand ha new plantation will take place in the private land. The COMAP model was used to determine carbon fixation and cost effectiveness of six artificial regeneration. Mitigation potential and investment costs are presented in the figure below.

Figure 1.2 Mitigation Potential and Investment Cost of Mitigation Scenario

[2] Actual forest land is not the legal status of forest land. Its includes natural medium to poor dense forest, natural poor dense forest, scattered trees & denuded, parks and sanctuary and plantation.



C) Agriculture Sector

Baseline Scenario Assumptions

Under baseline scenario same assumptions have been considered that were made for the projection of GHG up to 2020. The main points of the assumptions are as follows:

- future GHG emission will depend on the *changes in land use* specially changes in rice cultivation in wet condition and the *changes in livestock population* including its management practices. Area under rice cultivation is expected to fall significantly in future.
- growth in total output is hoped to result from increasing productivity rather than increase in cropped acreage and shifting land from local variety to the HYVs of rice. It is assumed that rice area will be 10.4 million ha by 2000, 10.29 million ha by 2010 and 9.3 million ha by 2020 (BARC, 1995). Adding traditional non-mechanised irrigation, the total irrigated area could be increased to 6.2 million ha.
- it is estimated that the total number of cattle population will be 19.7 million by 2000, 17.4 million by 2010 and 16.45 million by 2020. Number of buffalo population will be 0.99 million by the year 2000, 1.5 million by 2010 and 2.17 million by 2020. Goat and sheep population will be 55.7 and 2.74 million by the year 2020 respectively. Chicken and duck population will be about 705 million by the year 2020.

Abatement Scenario Assumptions

All together five mitigation options were considered under GHG abatement scenario. In rice agriculture, 50% of the cultivated area under rainfed flood prone, completely irrigated flooded area and area with less than 100 cm water depth is assumed to be feasible for mitigation options. Total 1005 thousand hectors of rice cultivated area is considered under mitigation options for the year 2020.

In the livestock sector, supplement of urea molasses for the improved cattle in milk and urea treated straw for local dairy cattle in milk were considered for mitigation option. Total 665 thousand improved and 2159 thousand local dairy cattle are considered for urea molasses and urea treated straw respectively for the year 2020. Only variable cost and incremental yield of milk is accounted for analysis.

Mitigation Scenario

Five mitigation scenarios were proposed to reduce methane emission from the rice agriculture and livestock population. A summary of the options is given below:

Option 1: Regulating Flooding in completely flooded land of an irrigated area. Total 145 thousand hectors are assumed to be feasible for the option for the year 2020.

Option 2: Draining out of flood water from rainfed flood prone rice cultivated area. Total 665 thousand hectors are assumed to be feasible for the option for the year 2020.

Option 3: Alternative cropping i.e. wheat cultivation in place of *Boro* rice is dropped from least-cost mitigation analysis because the option is not economically viable.

Option 4: Urea molasses in a liquid form for improved dairy cattle. Total 665 thousand cattle population are assumed to be feasible for the option up to 2020.

Option 5: Urea treated straw for local dairy cattle. Total 2159 thousand cattle population are assumed to be feasible for the option up to 2020.

1.6 National Least-cost GHG Abatement Curve

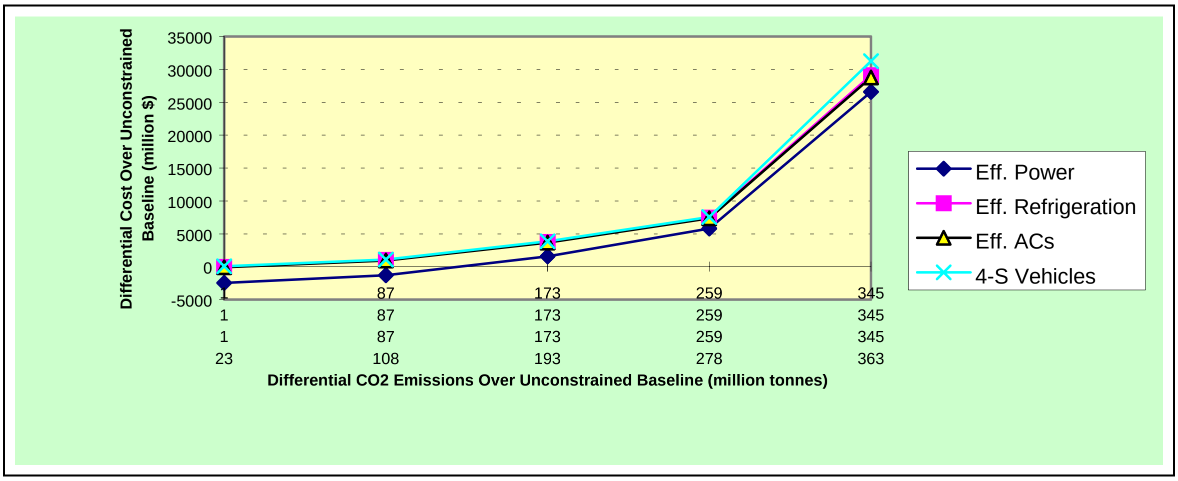
a) Energy Sector

CO_2 Emission Reduction Initiative (CERI) Curve has been developed for the energy sector only. No other sectoral CERI curves for the forestry, crop agriculture and livestock sectors have been attempted. Consequently, no attempt has been made to estimate any national CERI Curves for the sectors in an integrated manner.

CERI Curves illustrate the trade-off between CO_2 emissions reduction in some selected scenarios and associated costs. To generate points to draw CERI curves, hypothetical constraints have been imposed on CO_2 emissions and let the model estimate the lowest system costs to realise such objectives.

In the model, for each scenario 4 hypothetical constraints have been put on cumulative (over the modelling time horizon) CO_2 emissions level, e.g., 5%, 10%, 15% and 20% reduction over the unconstrained case and generated 4 points in addition to the no constraint (0% reduction) point. The model then minimises the energy system costs subject to that constraint over the modelling time horizon and discounts the cost stream to calculate into present value in 1990. Each of these constraints associated with the estimated cost thus gives a point for the CERI curve. A summary picture of some technology specific mitigation/abatement CERI curves is presented in figure 1.2. It shows that not all options have a positive cost in the economy-some do have negative costs i.e. they result in net benefit to the economy.

Figure 1.3 Baseline and Technology Specific CERI Curves



Least-Cost GHG Mitigation Options

The Table 1.6 provides the reduction of emission of CO_2 from the unconstrained base case and the associated cost (in $) per tonne of the reduction under different mitigation scenarios for different constraints on the cumulative emission.

Table 1.6 Cost per tonne ($) of CO_2 emission reduction by mitigation scenarios over the unconstrained Base case

Scenarios	Cumulative (1990-2020) CO_2 emission reduction (mn mt)									
	No constraint		5%		10%		15%		20%	
	CO_2	$/mt	CO_2	$/mt	CO_2	$/mt	CO_2	$/mt	CO_2	$/mt
Baseline	0	-	86	12	172	22	258	29	344	89
Commercial sector	2	642	88	27	174	29	260	34	346	88
Industrial sector	201	-31	277	-20	353	-13	429	-6	505	0
Residential sector	1	1205	87	26	173	29	259	35	345	90
Transport sector	2	-84	88	10	174	21	260	28	346	60
Power generation	23	-107	108	-12	193	8	278	21	363	73
CFLs	3	523	89	29	175	31	261	35	347	91
Efficient boilers	120	-31	200	-15	280	-6	360	1	440	7
Efficient motors	12	-148	97	-8	183	11	268	21	374	72
Efficient ACs	1	-107	87	11	173	21	259	28	345	83
Efficient refrigerators	1	-28	87	12	173	22	259	29	345	84
4-stroke vehicles	1	42	87	13	173	22	259	29	345	91
Metered gas	0	1207	86	24	172	29	258	34	344	97
Comprehensive	223	-24	298	-16	373	-9	448	-2	523	4

It is clear from the table that the estimated cost (in $/tonne CO_2 emission reduction) varies quite substantially from one to another for different levels of emission constraints. The unconstrained case of each mitigation scenario produces the extreme results such as very high and positive cost or a negative cost, also sometime very large in absolute magnitude. This is because in the unconstrained case, the model is not forced to reduce any amount of CO_2 emission but may be utilising some efficient, new technologies for which the investment in the initial periods is accounted for in the total system cost. Such an investment in the initial periods ensures the availability of the abatement technology for its whole lifetime and thus it is possible to reduce more and more quantum of CO_2 emission without any further investment in the subsequent periods. This is reflected in the rapidly reduced $/tonne estimates with moderately stringent CO_2 emission constraint. With more stringent constraints, the model has to include investment in more and more efficient but costlier technology and thus the $/tonne estimates for most stringent emission reduction constraint are in cases much higher than for moderately stringent constraints.

In Bangladesh context, several conclusions for drawing up an abatement strategy may be arrived at from the results of the model runs. These are as follows:

a) Industries appear to be the most promising sector for mitigation, whether as a whole sector or in terms of improvement of efficiency of energy using technologies/equipment such as boilers or motors. Interventions in the industrial sector serves to achieve several goals at the same time such as lowering energy consumption and lowering cost of manufacturing.

b) Power generation should be another priority area for intervention, not simply because the present technology is old and inefficient and has to be replaced in any case, but also and probably more importantly because the option helps in using the domestic gas at a negative cost to the economy. Note that optimising the use of thee domestic gas is a major policy of the Government of Bangladesh.

c) The transport sector should also be encouraged to improve its efficiency. Here too, the imperatives of cutting down on the energy consumption of a large consumer at a negative cost apply. Furthermore, it helps in lowering foreign exchange costs of imported gasoline.

d) The efficient cooling devices for refrigeration and air-conditioning should be encouraged as much as possible. Here, however, the savings are very small.

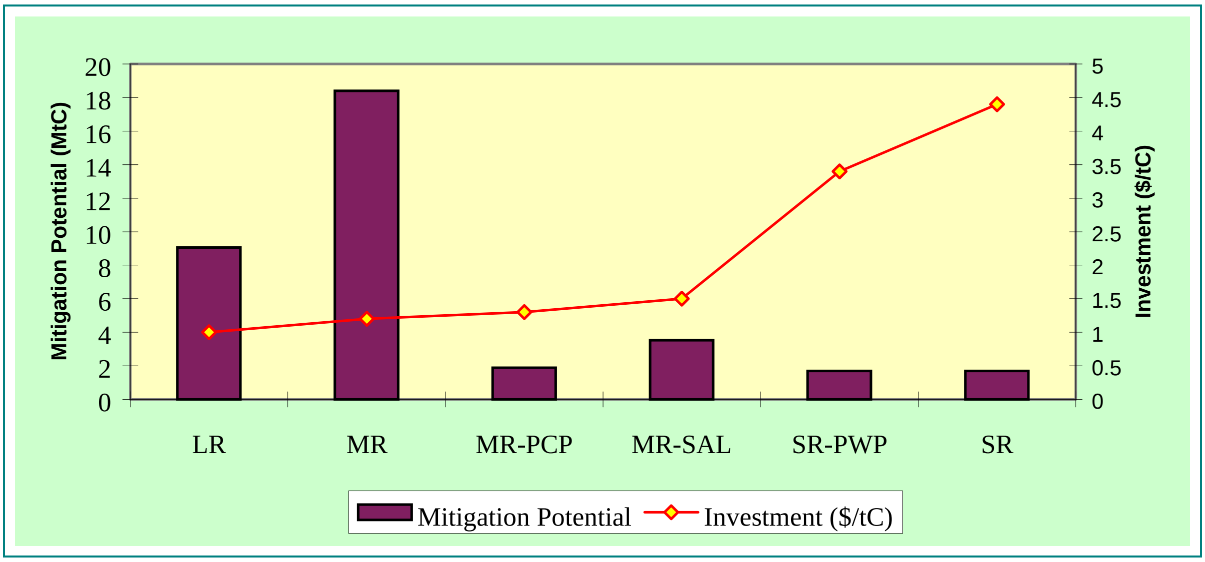
Not all of these, however, may be easy to implement. Some with the most promising prospects may be difficult to be implemented while those with probably small impacts may be implemented sooner than later. On the basis of these criteria one may have a short, medium and long-term time frame of implementation of the abatement strategy.

b) Forestry Sector Least-Cost GHG Abatement Strategy

In Bangladesh, overall investment to implement the mitigation scenario in terms of $/tC abated is less than the baseline scenario. Relationship between carbon uptake and the cost per ton carbon abated of the mitigation options is presented in Figure 1.4. It is found that artificial reforestation with long and medium rotation and participatory coastal plantation with medium rotation are low cost options followed by medium rotation Sal plantation. Cost of short rotation woodlot and hill forest plantation are very high compared to the others options.

In terms of investment $/tC abated and mitigation potential of the considered options, artificial long and short rotation plantation in the hill forest area found most least cost followed by medium rotation medium rotation participatory coastal and sal plantation. Short rotation plantation cost $/tC abated is higher compared to the others options. Total investment of long and medium rotation hill plantation is 31.55 million dollars with 27.45 MtC abated potential.

Figure 1.4 Cost of Carbon and Abatement Potential of Mitigation Options



C) Agriculture Sector Least-cost GHG Abatement Strategy

National objective of the agricultural sector is to increase the productivity and real income of farming families in the rural area on a sustainable basis. Self sufficiency in foodgrain production through per hector increase productivity is the main concern due to the shrinking trend of net cropped area and increasing demand of foodgrain. Both regulating flood and draining out of water will increase production of rice. Therefore, the options can be introduced to back foodgrain production.

In livestock sector, one of the main objective is to increase the milk supply through improvement of breed, feed and disease control. At present, government has a small scale motivation programme of use of urea treated straw for cattle fattening. Therefore, application of urea molasses as a supplement and urea treated straw can easily be introduced through the agricultural extension activities.

1.7 National GHG Abatement Action Plan

Proposed Time Frame for Implementation of Abatement Strategy

The proposed time frames for implementation may be the following :

- Short-term (1998-2005),
- Medium-term (2005-2015), and

Given that the pay-offs are very high, it is recommended that in the energy sector *an all-out measure be taken for industrial energy use efficiency* be it in boilers or by improved motors. Note, however, that energy costs are not high in industries compared to other costs which may be one reason why the industrial managers may not be much willing to invest resources in such efforts. This is a classic case where *social costs of inaction are much higher than the private costs* and should be remedied by using the classic instruments of tax and similar other measures so that the costs are equalised.

Table 1.7a : Summary of National Least-Cost Abatement Strategy Initiatives in Energy.

Implementation Time	GHG Abatement	Potential Emissions	Cost of Initiative

Frame	Initiative	Reduction (mt of CO_2 equivalent)	(US$/mt of CO_2)
Short-term (1998-2005)	Industry Boiler Motors Power Transport 4-stroke	505 440 354 363 346 345	0.18 7 72 73 60 91
Medium-term (2005-2015)	Industry Boiler Motors Power Transport 4-stroke Domestic Commercial CFL AC Refrigeration Met. Gas	505 440 354 363 346 345 345 346 347 345 345 344	0.18 7 72 73 60 91 90 88 91 83 84 97
Long-term (beyond 2015)	Comprehensive	523	4

Source : Estimated by the ALGAS team

Table 1.7b Summary of Least-Cost Abatement Strategy Initiatives in Forestry.

Implementation Time Frame	GHG Abatement Initiative	Potential Emissions Reduction (MtC)	Cost of Initiative ($/tC)
Short-term	• Feasibility Study • Long rotation artificial reforestation (LR) • Medium rotation participatory coastal plantation (MR-PCP)	 1.7 0.75	 1.0 1.3
Medium-term to long-term	• Medium rotation artificial reforestation (MR) • Medium rotation Sal plantation (MR-Sal) • Medium rotation participatory coastal plantation (MR-PCP) • Long rotation artificial reforestation (LR)	18.4 3.53 1.14 7.35	1.2 1.5 1.3 1.0

Least-Cost GHG Abatement Projects

Since many of the GHG emissions abatement technologies are yet to be used in Bangladesh, there exists high potential for abatement in many ways and for various sectors. Moreover, there are possibilities of formulation of some policies which would reduce GHG emissions to a significant extent. Mitigation options were selected for consideration subject to the availability of proven technologies and their institutional and social acceptance. In the final selection of the projects, however, two distinct features were considered: a) national priority irrespective of the financial feasibility and b) financial cost-benefit performance as indicated by the MARKAL and COMAP model.

ALGAS project therefore developed six investment projects three of which have been identified by the modeling exercise (gas based power, four stroke engine and compact fluorescent lamps). Others include cooking stoves (identified under national prioritisation exercise), CNG vehicles (as part of a renewed effort due to an increased pricing of gasoline) and photovoltaics (as an example of spatially diffuse system of renewable technology). A summary of priority GHG mitigation projects presented in Table 1.8.

Policy and Regulatory Needs

The policy and regulatory needs should now be obvious. The needs may be expressed as follows:

a) There is a serious gap in terms of coordination among economic and environmental objectives. The gap is more serious in case of the understanding and coordination of the linkages between GHG abatement activities and measures which are economically highly profitable. As a result, environmental measures are thought of more as an addendum rather than an inter-linked one. Areas where such a lack of understanding is actually hampering the cause of economic development include raising efficiency in industrial energy use and increasing the efficiency of the power generation system in the country.

b) Various regulatory policies and measures in force in the country are often too vague to be of much use in actual practice and leave wide scopes for interpretation and therefore their abuse through legal loopholes. These policies, rules and regulations should therefore be examined closely for such loopholes, enough explanatory clarifications be provided and guidelines more clearly laid down. A case in point is the National Energy Policy and the newly promulgated regulations for putting the Energy Conservation Act, 1995 into effect. The former needs to take the issue of GHG mitigation more seriously and the scope of the latter should be broadened to include emission of GHGs.

c) There appears to be two major reasons for the lack of understanding and lack of action. First and foremost little awareness exists among the policy makers about the importance of the issue of environment in general and that of GHG abatement in particular as these impinge upon economic development and vice versa. This is caused mainly by the lack of institutional capability arising out of inadequacy or absence of requisite trained manpower and institutional mandate. There should therefore be a major awareness-raising campaign among the policy-makers and the people at large. Adequate and proper training should be provided to the officials in charge of operationalising various policies and regulations.

Table 1.8 Summary of Priority GHG Mitigation Projects

Project Title	Sectors	Key Objectives of the Project	Economic rate of return	Estimated Incremental Costs of CO2 Mitigation	Non-quantifiable Benefits
Efficient Power Generation : Power Sector	Power Sector	To meet the present as well as future demand for electricity for industrial development and rural electrification.	14.45%	US$ 466 million	Intensification of industrial activity and production; irrigation in

		To reduce import dependence of fuel and enhance use of indigenous resources. Achieving economic development through industrialisation by meeting the demand.			agriculture; awareness building and mass education involving electronic media; social & economic change particularly in rural areas; other social benefits associated with availability of electricity and etc.
Dissemination of Improved Cooling Stoves in Rural Areas in Bangladesh	Domestic Sector	To increase energy efficiency and save bio-mass fuel; To help rural poor people to increase savings by saving fuel costs; To improve health situation of the rural women working in kitchen; and	NPV cost = US $ 0.59 mil; NPV saved cost = US $ 1.04 mil	US $ 3.5 million	Save time for cooking; lowering health hazards due to smoke for the women; natural balance benefits due to less deforestation for firewood etc.
Conversion of Petrol-Driven Cars to CNG-Driven Cars	Transport	To ensure savings by replacing imported fuel with cheaper indigenous fuel; To reduce emission from car exhausts and achieve higher environmental quality standards; and To enhance institutional and infrastructural capacity to provide the service as many cars as possible in future.		US $ 3.75 million	Enhanced engine life, less pollution in terms of smoke, lead particulate and suspended solid matters, saving O & M costs etc.
Replacement of Incandescent Bulbs with Compact Fluorescent Lamps	Energy (Domestic)	To save consumption of electricity for lighting; To increase energy efficiency; To limit use of gas and other feedstocks in power generation for lighting; and To face the present shortage of electricity supply without affecting its usage functions.	NPV cost = US $ 15.1 per CFL unit	US $ 3.5 million	Brings satisfaction by offering brighter lumen, saves efforts in frequent changes of bulbs etc.
Solar Electricity with Photovoltaic (Solar) Systems	Renewable Energy (Domestic)	To generate/increase availability of electricity to isolated rural people to improve their quality of life; To promote environmentally sound renewable energy resource development and reduce dependence on traditional energy; Facilitate popular participation and participation of the private sector in advancing commercialisation of solar PV systems; and To catalyse rapid penetration of solar PV systems within the framework of a least-cost rural electrification programme.	NPV cost = 14.65 mil US $; NPV saved cost = 1.3 mil. US $	162.0 million US $	Facilitate reading at night; increased possibilities for recreation and small scale productive activities at night; better security from theft etc.
Phasing out two-stroke engines with four-stroke engines for auto-rickshaws	Transportat ion	To phase- out the less-efficient highly polluting auto rickshaws with high efficiency vehicles; To ensure fuel savings by replacing two-stroke engines with four-stroke engines; To reduce emission of GHGs and other air pollutants from vehicular exhausts and achieve higher environmental (air) quality standards.	NPV of net benefit = 13.51 (US $, single unit basis) B:C ratio = 1.032	6.49 million US $	Improves air quality

Specific Measures and Institutional Needs

Given the above general policy and regulatory needs, there are likely to arise in the near future specific needs for putting into effect various policy recommendations, particularly those which have been discussed earlier in this report. Some of these are discussed below.

Awareness campaign : With the help of the Ministry of Environment, the Department of Environment and the Ministry of Science and Technology, the Ministry of Information should launch a major awareness-raising campaign regarding the necessity of environmental conservation and GHG abatement and their links with the process of economic development in the country. There should be a separate targeted campaigns for senior policy-makers. A major topic of information should be the commercial availability of technology which are efficient and at the same time cheap to acquire and operate.

Industrial energy use efficiency: This is possibly the most important sectoral measure from the view point of GHG abatement. Yet, industrialists hardly notice the need for raising such efficiency. Private entrepreneurs may also therefore need to be made aware of the benefits they may reap and the way this may be done. If necessary, tax breaks, credit or some such measures may be adopted. The Directorate of Industry should be involved in putting such measures into effect and if necessary the Directorate's institutional capacity and human resource may be upgraded through training and other means.

To implement gas based power generation: There are government institutions involved in gas based power generation. The regulatory framework should be altered in such a manner that the private sector entrepreneurs including the foreign investment companies can invest for such development and generate power. However, one has to be careful regarding the technology that are proposed to be brought in. The implications of such technologies if these are based on less efficient processes should not be accepted. It should be kept in mind that a power plant operates for many years. So in the name of quick solutions, one should not accept apparently cheap technologies which are costlier in the long-run due to their inefficiency. The relevant government institutions need some human resource development and upgradation in dealing with the entire operation and monitoring of such investment activities by the private entrepreneurs.

To disseminate improved cooking stoves: There is an opportunity for a GO-NGO collaborative activity. At present the BCSIR is involved in disseminating the cooking stoves; but, their success so far has been rather limited. The role of information ministry and electronic media should be emphasized here.

Conversion of petrol-driven vehicles into CNG-driven vehicles: There is an ongoing project under the relevant government institution. The capacities of both the plants involved in CNG production and installation of conversion units along with the size and quality of the manpower of those institutions/agencies need to be enhanced. The Information Ministry has a role in taking up an awareness campaign in popularising the CNG driven vehicles.

Replacement of incandescent bulbs with CFL: Regulatory framework is to be established first. The existing tariff structure should be evaluated and the cost-benefit of offering some rebate on tariff up to a certain period should be analysed. The "building code" for large government and industrial sectors should be changed to accelerate the use of CFLs. If an entrepreneur comes forward to manufacture such items inside the country, the company may be offered some tax exemptions in some form or other.

Solar electricity with PV system: Since the Rural Electrification Board (REB) is already involved with a pilot phase of such a project, the proposed activity might be considered as an extension of the pilot work. The tariff structure, however, should be reevaluated and import tax rationalised to make PV panels more cost effective.

Two-stroke to four-stroke engines for auto-tricycles: The import duty for four-stroke engines may be lowered or waived for a certain period. On the other hand the import tariff on two-stroke engines could be more stiff to discourage their imports. The Roads Division may consider a phasing out plan for the existing two-stroke engines.

1.8 Conclusion and Recommendations

The issue of greenhouse gas emissions and the need to reduce it is not at present a high priority within government. Indeed it is unlikely that there is any real appreciation or understanding of this issue amongst top policy makers specially amongst economic policy makers. However, there is a growing understanding of these issues amongst the professionals both within government as well as outside the government relating the vulnerability of Bangladesh to climate change and the need to carry out some actions to reduce the GHG emissions. In order to make this a higher priority amongst policy makers a number of steps can be taken including the following.

- Highlighting the importance of reducing greenhouse gas emissions to high level economic policy makers.
- Implementing the identified GHG Abatement projects as part of the GHG Abatement Strategy
- Institute enabling policy change to allow the GHG Abatement Strategy to be implemented.
- Strengthen national capacity to analyse and update both GHG emission inventories as well as GHG Abatement Strategies.
- Incorporate GHG Abatement options into different sectoral strategies including energy and transport industries.

Thus the implementation strategy may be summarised as follows :

- Ensure that the government starts to develop a National Climate Change Strategy as required under UNFCC
- Ensure that the ALGAS outputs are used as inputs to the National Climate Change Strategy
- Prepare and implement an awareness raising programme on GHG abatement including media exposures, publications, workshops and seminars.
- Prepare and implement pilot projects for both GHG abatement and improved energy utilisation
- Publicise the results of such pilot projects

Implementation of the strategy will of course require financial resources. There are number of sources for such financial resources. The main sources are described below with a possible strategy for engaging each one of them.

a) <u>Government of Bangladesh</u> : The Government of Bangladesh has very little funds of its own which is expended mainly in running its own machinery. Nevertheless it should be possible to allocate certain funds, particularly for personnel in key government agencies e.g. the Department of Environment, Ministry of Energy, etc. who would continue to act as the focal point for Climate Change related activities (including updating the GHG Emission Inventory)

b) <u>Traditional International Donors</u> : Bangladesh receives sizeable financial aid from a number of multilateral (e.g. World Bank and ADB) and bilateral donors (e.g. British, Japan, Netherlands, etc.), while the bulk of their aid (approximately US $ 2 billion annually) goes for non-environmental sectors (including poverty alleviation, infrastructure, etc.). Nevertheless it should be possible to tap such resources for GHG Abatement projects and activities (e.g. the awareness raising campaign).

c) <u>Non-traditional International Sources</u> : So far Bangladesh has not received any funding from the Global Environment Facility (GEF) other than a project on Coastal Bio-diversity which has been approved (but not yet implemented) and through the ALGAS study. There is tremendous scope for Bangladesh to tap financial resources from GEF as well as other non-traditional financial mechanisms such as AIJ, etc. This should be particularly suitable for Pilot Projects which will need to be prepared properly enabling Bangladesh to obtain funds from such non-traditional sources.

d) Private Sector : A major part of the future development strategy of Bangladesh is envisaged for the private sector. This is particularly true for the energy, transport and industrial sectors. Thus it is imperative that future investments by the private sector be done using environmentally sound technologies which lead to GHG Abatement. This will require a suitable regulatory and legal framework to encourage the private sector investments to be used in the best manner.

Finally a well thought out strategy requiring technical as well as financial resources and a practical implementation plan engaging all the key sectoral sectors of the government and non-government, national and international can lead to a successful implementation of the strategy outlined above.