

**ALGAS**

**REVIEW OF GHG INVENTORY, IDENTIFICATION OF  
MITIGATION OPTIONS AND TAXONOMY OF  
MITIGATION OPTIONS**

**Draft Final Report  
ON TASK B.1 and B.2**

Prepared By

**BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY(BUET)**

In Association With  
**BANGLADESH CENTRE OF ADVANCED STUDIES (BCAS)  
BANGLADESH INSTITUTE OF DEVELOPMENT STUDIES (BIDS)**

And  
**BANGLADESH UNNAYAN PARISHAD (BUP)**

# CONTENTS

<b><u>Preface</u></b>	iii
<b><u>PART A</u></b>	
<b>Mitigation Options For The Energy Sector</b>	
1. Introduction	1
1.1 Review of GHG Emission Projection	2
2. Transport Sector	6
2.1 General	6
2.2 Freight Transport	7
2.3 Passenger Transport	8
3. Agriculture Sector	11
4. Residential Sector	13
4.1 Efficient Lighting	13
4.2 Space Cooling and Water Heating	14
4.3 Cooking	14
5. Commercial	15
6. Industry Sector	18
6.1 General Approaches	18
6.2 Process Improvement	21
6.2.1 Brickmaking	21
6.2.2 Paddy Parboiling	21
6.2.3 Textile	22
6.2.4 Pulp and Paper	22
7. Energy Supply Sector	24
7.1 Electricity Generation	24
7.2 Transmission and Distribution Losses	25
<b><u>Part B</u></b>	
<b>Taxonomy of Mitigation Options For The Energy Sector</b>	
8.1 Mitigation Options Classified According to Generic Groups	28
8.2 Implementation of Mitigation Options	31

8.3 Taxonomy by Gases	34
-----------------------	----

## **Part C**

### **Mitigation Options For The Non-Energy Sectors**

9.0 Mitigation Options For The Livestock, Waste And Land-Use Sectors	35
---	----

## **PREFACE**

### **Task B.1 Review of GHG Inventories to Identify Areas for Mitigation/Abatement Options of GHG Emissions**

### **Task B.2 Identify and Develop a Taxonomy of relevant National GHG Mitigation/Abatement Options**

This report has been prepared to fulfil the above tasks of the Bangladesh ALGAS study. However, it has not maintained the distinction in the task description between Tasks B.1 and B.2 as shown above. The reason for not doing so is that mitigation options have been identified in this report from an energy modelling exercise, where end-uses/devices are clearly identified with sub-sectors and sectors. This report is presented in three parts. Part A reviews the 2020 carbon dioxide emission and identifies mitigation options sector-wise and also presents the rationale behind the choice of a particular option. Part B presents a taxonomy of the mitigation options where the following are dealt with.

1. Classification of mitigation options according to generic groups
2. Implementation (short, medium or long term)
3. List of options which mitigate GHGs other than carbon dioxide (CH<sub>4</sub> and N<sub>2</sub>O)

It is worth pointing out that since Task B.2 requires a list of options by sector, it is automatically included in the Part A of this report.

Part C of this report identifies mitigation option options for all non-energy sectors. These sectors are, Agriculture (Livestock), Waste (Landfill) and Land-Use (Afforestation) sectors.

# **PART A**

## **MITIGATION OPTIONS FOR THE ENERGY SECTOR**

### **1. INTRODUCTION**

This part of the document seeks to identify the GHG mitigation options in the various energy sectors by reviewing the GHG emission projection up to the year 2020. In the following sections the mitigation options in the five energy demand sectors and the energy supply sector are identified and discussed. The basis for choosing these options were,

- efficiency of the existing end-use
- potential of mitigating carbon dioxide emission
- appropriateness of the proposed technology to the existing conditions
- cost of the option
- national priority

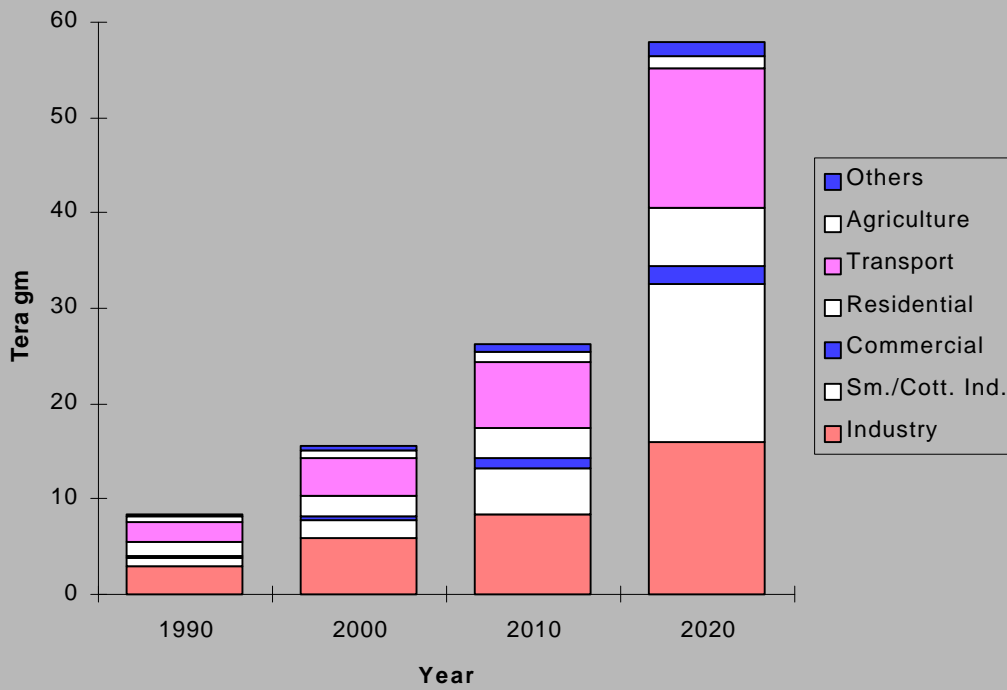
However, no formal procedure was used in the process. For each option identified, the efficiency improvement that can be achieved over the existing technology and the potential to mitigate carbon dioxide emission is indicated. The potential for mitigating carbon dioxide emission is shown in PJ because converting it to gigagrammes of carbon dioxide for electricity using options involves taking into account T&D losses, electricity generation losses and the fuel used to generate electricity. The potential for carbon dioxide emission reduction shown for each option is for one year only, i.e. the 2020 potential expressed in energy units (PJ) Strictly speaking this is not correct because potential refers to the total emission reduction that can be achieved during the period under consideration by a given mitigation option.

## **1.1 Review of GHG Emission Projection**

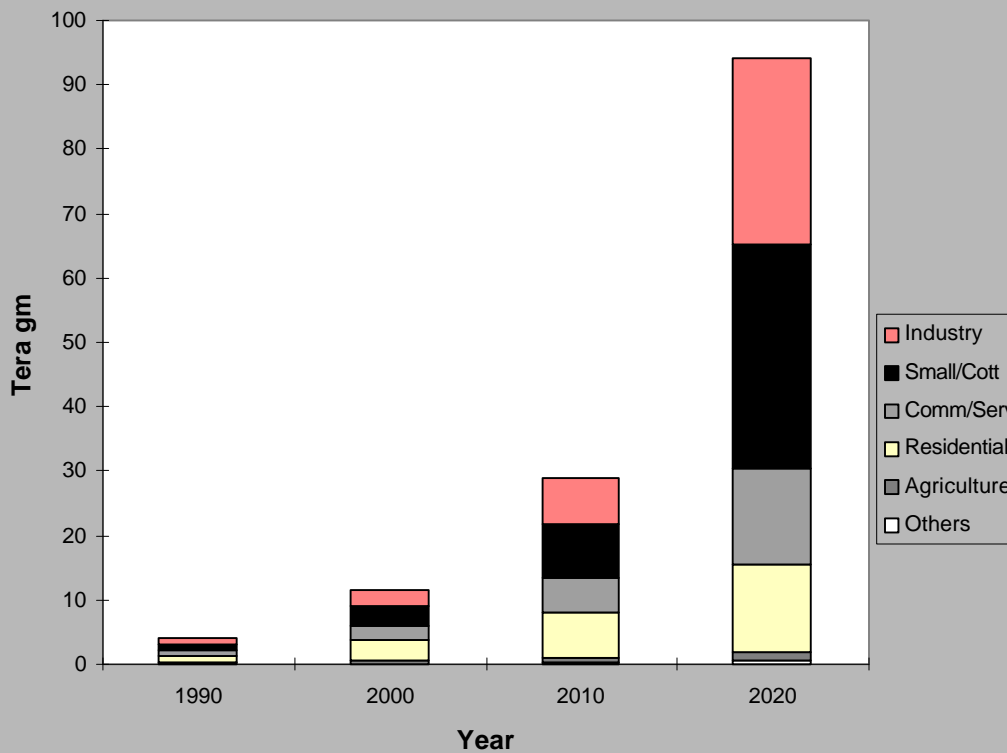
The carbon dioxide emission resulting from the demand sectors for the years 1990, 2000, 2010 and 2020 is shown in Figure 1a. As can be seen the largest emission is from the industry sector followed by the transport and residential sectors. This information however is somewhat misleading because Figure 1a does not include the emission due to electricity. Because of problems of double counting, emission due to electricity required for all sectors are accounted for in the energy supply sector. To rationalise the presentation of carbon dioxide emission from demand sectors, Figure 1b has been constructed. This figure proportionately distributes the emission due to electricity generation into the various sectors. The overwhelming contribution of the industry sector is again clearly evident but what is very interesting is that the residential sector is a significant emitter while the transport sector has no contribution. Thus when the carbon dioxide emission from Figures 1a and 1b are added (Figure 1c), a different picture emerges where the residential sector exceeds the transport sector. The residential sector therefore becomes an important sector to target, which otherwise may appear to be not so promising because of the rather diffuse nature of energy use in this sector.

It is obvious that mitigation options which are targeted towards the large carbon dioxide emitting sectors, will yield the maximum benefits. This implies that even a 5% saving in the industry sector will have a greater effect than a 25% saving in the agriculture sector. The same argument also applies to the different end-uses within each sector. Those end-uses which have large contribution to the total sectoral GHG emission should be targeted. For example, efficiency improvement of buses, whose share of the passenger kilometres in the year 2020 will be approximately 60%, will have a far greater impact than efficiency improvement of motor cars. Figure 2 presents some large carbon dioxide emitting end-uses. These end-uses must be included in the list of priority areas of emission reduction. For reasons discussed

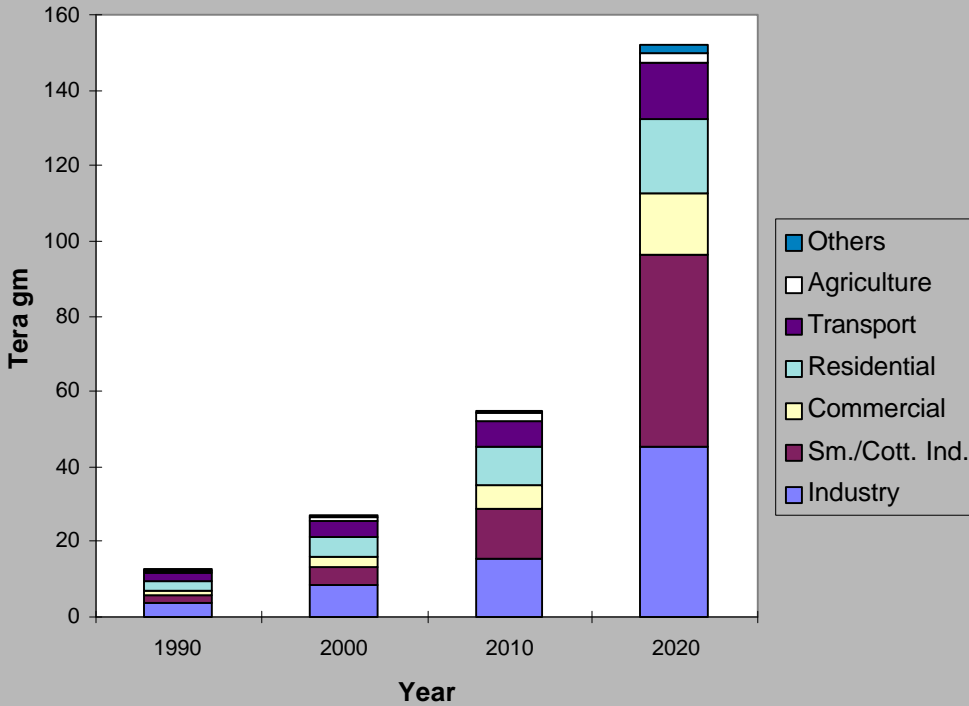
**Fig 1a Carbon Dioxide Emission From Different Demand Sectors**



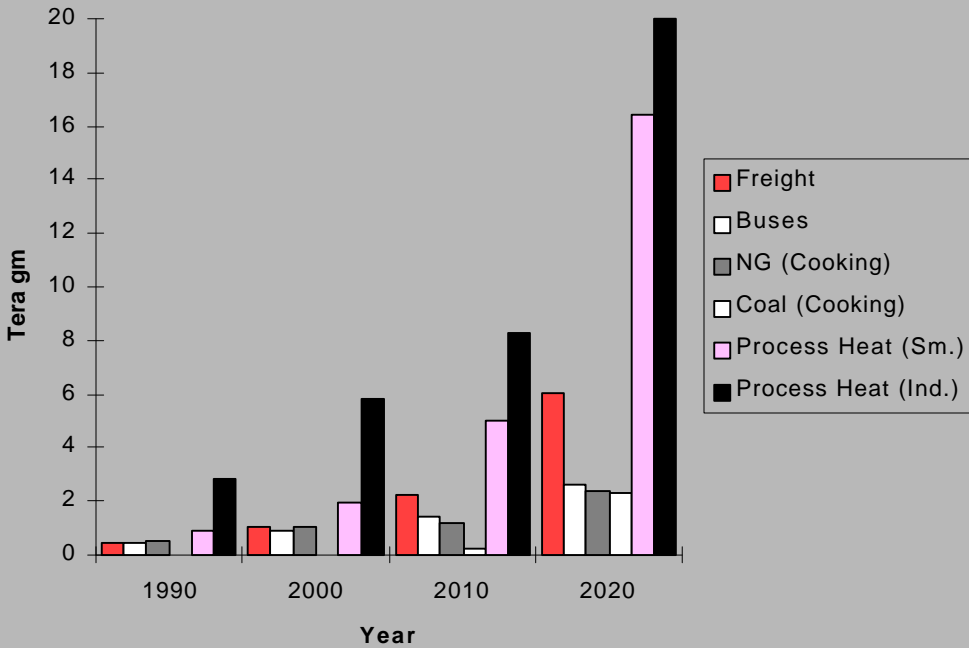
**Fig 1b Carbon Dioxide Emission Due to Electricity Use From Different Sectors**



**Fig 1c Carbon Dioxide Emission From Different Sectors (Includes electricity)**



**Fig. 2 Carbon Dioxide Emission From Selected End Uses**



earlier, Figure 2 does not include electricity use. If electricity use by all sub-sectors are taken into account then residential lighting (urban), and industrial electricity use for motive power will emerge as strong candidates for inclusion into the priority list.

The discussion so far have not included the energy supply sector. If this sector is brought into consideration then for Bangladesh electricity generation and transmission and distribution losses of electricity must be included in the list of priority areas (rationale provided in section 7). The priority areas for GHG emission mitigation for Bangladesh are therefore

1. **Electricity Generation**
2. **Transmission and Distribution Losses of Electricity**
3. **Industrial Process Heat**
4. **Industrial Motive Power**
5. **Industry - Process Improvement**
6. **Freight Transport**
7. **Passenger Transport**
8. **Residential Cooking - Urban and Rural**
9. **Residential Lighting**

This report has not restricted itself to identifying mitigation options only for the priority areas. Greater emphasis however has been laid on these areas. The reason for including mitigation options outside the priority areas is that some very good options exist outside the priority areas. For example, the commercial sector has an excellent potential for cogeneration, and the agriculture sector has a good potential for retrofitting irrigation pump-sets. Clearly, none of these belong to the priority areas. Because mitigation options have been suggested outside the priority areas, a sector-wise identification procedure was preferred. The following sections identify the options which satisfy the criteria discussed in the beginning of this section. In the following sections wherever appropriate while identifying mitigation options a review of carbon

dioxide emission by the particular end-use or device is presented. This report has been prepared on the basis of the 2020 carbon dioxide emission projection for all sectors.

## **2. TRANSPORT SECTOR**

In Bangladesh both mechanised and non-mechanised means of transportation are used, and all three modes - road, rail and water are prevalent. With growing mechanisation and energy use non-mechanised modes of transport are diminishing. Over the next two and a half decades this shift will add to the demand for mechanised transport. In the last two decades, the transport sector has undergone some dramatic changes. From its pre-eminent position in the early seventies, rail transport has diminished in importance, and today (1993) it represents a mere 10% of the total passenger kilometres and 13% of the total ton kilometres. On the other hand, road transport has experienced a tremendous boom. Water transport has however managed to retain its share of the total load. The mitigation options in the transport sector are discussed in the following three sections. The first section discusses options which apply generally to both passenger and freight transport. The second and the third sections discuss mitigation options in the freight and passenger transport respectively.

### **2.1 General**

Road transport accounts for 7.6% of the total CO<sub>2</sub> emission of which buses represent 27% and trucks 52%. Even though road transportation is the most popular mode of transport, large inefficiencies are associated with it. Some of the causes of inefficiency are given below.

- (1) Poor condition of roads
- (2) Lack of proper vehicle maintenance
- (3) Badly managed traffic flows
- (4) Use of very old vehicles
- (5) Bad driving practices

Measures which address these causes especially for trucks and buses could bring about large energy savings. A bundle of measures which includes vehicle maintenance, road improvement and better traffic management can be implemented to realise substantial energy saving benefits.

In the general category measures which reduce transport demand should also be explored. Two very prominent measures are (i) improvement of telecommunications (telephone, fax, etc.), and (ii) urban development which locates the workplace, home and shopping/leisure centres into self contained units. Bangladesh is a country whose urban development can be considered to be in its infancy. This makes the second option a very feasible and attractive one. Road improvement and better traffic management are infrastructure development options and are no doubt very expensive propositions. Moreover, the energy saving benefits are diffuse and very difficult to quantify. The main thrust for including these measures is the national priority. The benefits which the government is aspiring for includes, economic growth and development, better quality of life and less urban congestion and pollution.

## **2.2 Freight Transport**

Table 2.1 presents the freight transport demand projection for the three modes. As can be seen freight transport will experience a 5.6 times growth in the business-as-usual scenario, and most of this growth will occur in the road transport. Table 2.1 also presents the energy intensities of the three modes of freight transport.

**Table 2.1**

### **Energy Intensities of The Three Modes of Freight Transport**

<b>MODE</b>	<b>Energy Intensity (GJ/t.km)</b>	<b>1995 ton-kilometres</b>	<b>2020 ton-kilometres</b>
Trucks	$2.178 \times 10^{-3}$	$5.22 \times 10^9$	$40.35 \times 10^9$
Rail-freight	$0.342 \times 10^{-3}$	$0.64 \times 10^9$	$0.64 \times 10^9$
Cargo Vessels	$0.918 \times 10^{-3}$	$3.04 \times 10^9$	$8.65 \times 10^9$

It is clear from Table 1 that the most fuel inefficient mode of transport is the most popular one. The scope of reducing energy consumption by an intermodal shift from road to rail, and road to water is very large. To achieve this shift, large investments must be made in the rail and water sectors, and these two modes of transport must be encouraged by providing incentives while road transport must be discouraged.

### **2.3 Passenger Transport**

In Bangladesh, as with freight transport, all three modes are prevalent in passenger transport. In urban transport there is substantial contribution of non-mechanised vehicles. Table 2.2 presents some relevant information on passenger road transport.

**Table 2.2**  
**Road Transport Vehicles Characteristics (1992-93)**

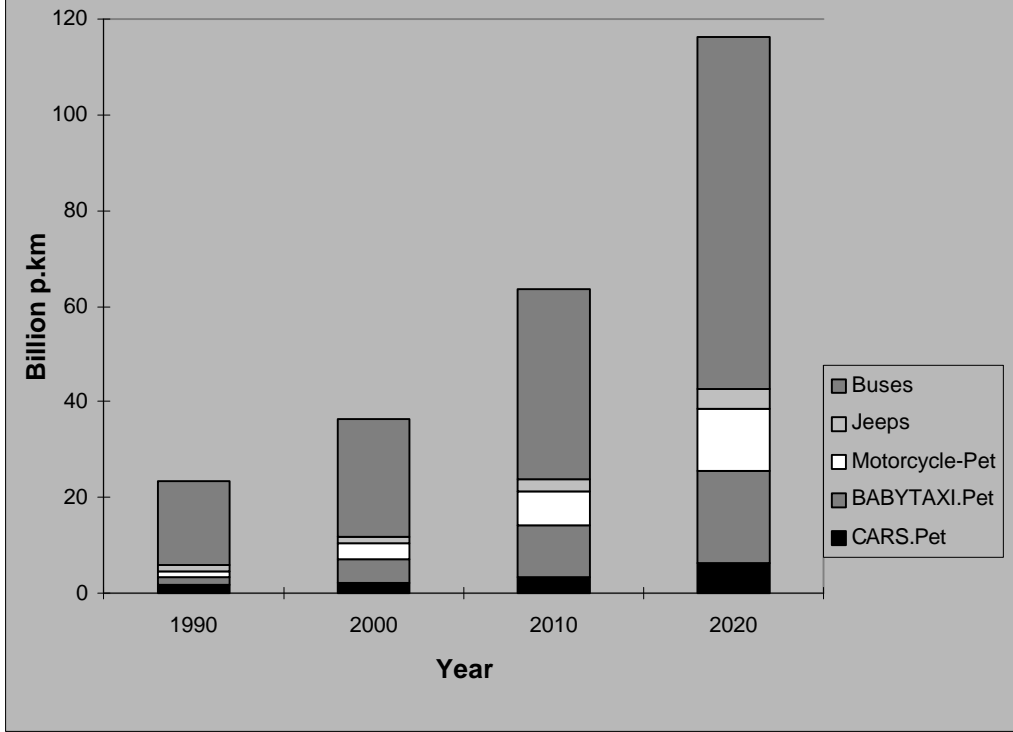
<b>Vehicle Type</b>	<b>Number of Vehicles</b>	<b>Average Number of Passengers</b>	<b>Percent of Total Mech. Road Pass-km</b>	<b>Litres of fuel per Pass-km</b>
Bus-Intercity	4,888	53	30.35%	0.00528
Bus-Local	7,372	54	33.78%	0.00545
Minibus	8,188	30	21.83%	0.00667
Jeeps-Diesel	30,140	3	2.21%	0.04167
Cars-Petrol	45,306	3	3.32%	0.03704
Baby Taxis	28,581	3	5.20%	0.02667
Motorcycle	138,709	1.5	3.40%	0.03333
Rickshaw	411,411	2		
<b>TOTAL</b>	<b>674,595</b>			

Reference      GOB (1995)

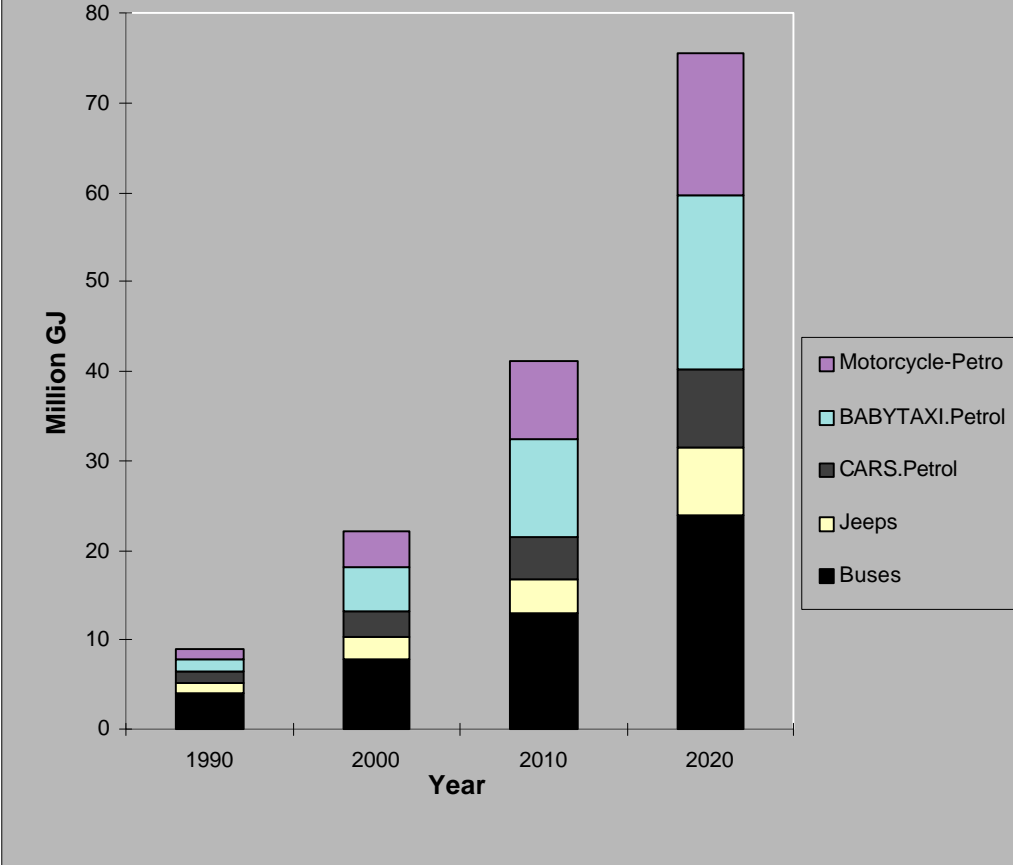
Not shown in Table 2.2 is one type of vehicle which in the last ten years or so has grown tremendously. These are large three-wheelers (called TEMPOS) carrying 8-12 passengers. As can be seen from Table 2.2, the urban mass transport system is not well developed with emphasis on smaller vehicles - mini-buses and three-wheelers. Mass transits like trams, trolley buses, light rails and underground railway have not been developed. Figures 3 and 4 present the passenger kilometres and energy requirement projections respectively for urban road transport. As can be seen from Figure 3 there will be a large demand for passenger transport by cars, jeeps, three-wheelers and motorcycles. The reason behind this large increase is the poorly organised mass transit system. Figure 4 shows that the energy requirement for cars, jeeps, baby taxis (three-wheelers) and motorcycles put together are comparable to the energy requirement for buses even though the passenger kilometres are much smaller (Figure 3). Stemming the growth of individual transport vehicles by developing a good mass transit system consisting of larger buses, trolley buses etc., and on the long run underground railway, can be a mitigation option. Good mass transit system will slow down the growth of cars, jeeps and motorcycles and may even displace mini-buses and three-wheelers. The rationale for advocating expensive options like underground railway is derived from the national priority. The escalating problems of pollution and congestion in the main urban centres will need to be tackled with great urgency.

In Bangladesh, three-wheelers are an important category of urban road transport vehicles, and are also the single largest cause of urban pollution due to their two-stroke engines. These fast moving vehicles occupy the position of taxis in Bangladesh. The high taxes on motor vehicles are a deterrent to the development of a taxi service in the cities of Bangladesh. In the BAU scenario therefore there will be a large growth in the demand for Baby Taxis due to the projected urbanisation. Replacing two-stroke engines by four-stroke ones can be an excellent mitigation option in the short term. In the long term, these three-wheelers can shift to compressed natural gas (CNG) thus realising further CO<sub>2</sub> reduction benefits.

**Fig 3 Passenger Kilometers For Different Vehicles**



**Fig. 4 Energy Requirement For Different Vehicles**



The use of alternative transport fuels like compressed natural gas (CNG) can be a mitigation option. At present a very limited number of gasoline engines are being converted to run on CNG. To realise the full benefits of lower fuel consumption, engines designed specifically for CNG should be employed. The conversion of transport vehicles to run on CNG has a high government priority because it displaces imported liquid fuel by indigenous natural gas.

The prospect of mitigation options like advanced design motor vehicles and the scrapping of vehicles which are more than 5-10 years old, are fairly slim for obvious reasons. However, the use of fuel efficient smaller motor cars can be considered. All mitigation options discussed in this section with the efficiency improvement possible and the potential of carbon dioxide emission (shown as PJ) reduction are summarised in Table 2.3.

### **3. AGRICULTURE SECTOR**

As mentioned earlier and shown in Figure 1 the agriculture sector is insignificant in terms of carbon dioxide emission in the year 2020. The mitigation options in this sector are also fairly limited. The following mitigation options however do exist in the agriculture sector as short term measures.

- (1) Retrofitting irrigation pump-sets with frictionless foot valves and PVC pipes
- (2) Efficient pump-sets

The first option arises out of the fact that the existing system incurs large frictional losses due to an inefficient foot valve, and due to the flow through metal pipes. This option has been chosen because the retrofit technology is simple and inexpensive. All mitigation options discussed in this section are summarised in Table 3.1.

**Table 2.3 Mitigation Options in the Transport Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT <sup>1</sup>	2020 POTENTIAL PJ
1	Vehicle Maintenance <sup>2</sup>	10%	8
2	Road Improvement (minor) <sup>2</sup>	5%	4
3	Improved Traffic Management <sup>3</sup>	10%	3
4	Improved Telecommunications <sup>4</sup>	10%	5
5	Integrated Urban Development <sup>3</sup>	20%	6
6	Modal Shift of Freight From <sup>5</sup> Road to Rail Road to Water	1.9*10 <sup>-3</sup> GJ/t.km 1.3*10 <sup>-3</sup> GJ/t.km	25 12
7	Development of Mass Transit System <sup>6</sup>	1*10 <sup>-3</sup> GJ/p.km	10
8	2-Stroke to 4-Stroke Engines (three wheelers)	30%	6
9	CNG <sup>7</sup> three-wheelers	20%	4
10	CNG <sup>7</sup> Buses, Trucks and Water Passenger and Cargo Vessels <sup>8</sup>	20%	8

## NOTES

1. Efficiency improvement values shown are applicable only when options are applied singly. If two or more options are applied simultaneously then the overall efficiency will be lower than the addition of the values
2. Applies to all road vehicles. Potential is 50% of the maximum
3. Applies to urban transport only. Potential is 50% of the maximum
4. Applies to all passenger transport modes Potential is 50% of the maximum
5. It is assumed that all three modes of transport will have equal shares
6. Passenger kilometres shift from cars, jeeps, baby taxis and tempos to regular buses. It is assumed that there will be a shift of 25% of the load
7. In addition to energy saving there is carbon dioxide emission reduction in shifting to natural gas
8. Potential is 25% of the maximum

**Table 3.1 Mitigation Options in the Agriculture Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT	2020 POTENTIAL PJ
1	Retrofit Pump-Sets with Frictionless Foot Valves and PVC Pipes	30%	3
2	Efficient Pump-sets	10%	1

## **4. RESIDENTIAL SECTOR**

### **4.1 Efficient Lighting**

The most important mitigation option in the residential sector is efficient lighting, in particular, compact fluorescent lamps (CFL). The inclusion of CFL as a mitigation option stems from the following considerations.

1. the replacement technology is simple and can be purchased off the shelf
2. saving per device is extremely large
3. other than cost there is no barrier to its implementation
4. being a peak end-use device it saves on peak generating capacity

The high cost of CFLs make it a very difficult technology to disseminate. In Bangladesh the problem is compounded by a near 100% tax on CFLs. This option is therefore a long term option. Until the barriers are removed, the cheaper intermediate mitigation option of replacement of incandescent bulbs by fluorescent lamps (40W) is a good measure. Under the category of efficient lighting, advanced fluorescent lamps (36W) and electronic ballast should also be considered as short and medium term mitigation options.

In this sector there exists the possibility of saving a large quantity of kerosene. Most of the lighting demand in rural areas is met by a very inefficient kerosene wick lamp. It has been shown that very simple modification can save 25-50% of the kerosene used. Saving per lamp may be very low but the cumulative effect can be very large because there are at least two kerosene lamps in every rural household. The other lighting options for rural areas are PV lanterns and low wattage CFLs. These devices, in addition to saving energy will substantially improve the service provided which at present is extremely poor because of the low lumen output of the existing kerosene wick lamps. PV lanterns hold special promise because many areas in Bangladesh is not served by the grid. If the cost of transmission and distribution facilities along with the

environmental benefits are factored in, this option can compete with kerosene lamps. Provided that electricity generation efficiency is high and transmission and distribution losses low, there is energy saving in switching from wick lamps using kerosene to CFLs using grid electricity.

## **4.2 Space Cooling and Water Heating**

Bangladesh is a hot and humid country, and naturally with growing prosperity space cooling using air-conditioners will figure prominently. These devices consume an enormous amount of energy. Efficient air-conditioners now available can save up to 30% energy. Since these devices are used by wealthier households, the higher cost of efficient devices should not be a deterrent. With regards to other household devices, the prospect of penetration of efficient ones are doubtful mainly because the cost to saving ratio is not very attractive.

With increasing prosperity water heaters are becoming more and more common. This demand can be met by solar water heaters. Given that the heating load (i.e. temperature difference between inlet and outlet) in Bangladesh is not very high, solar water heaters can be expected to perform satisfactorily.

## **4.3 Cooking**

Cooking constitutes a large demand category. At present most of the demand is for biomass. Substantial saving of biomass can be achieved if improved cookstoves are used. Since deforestation and loss of soil quality are two major concerns in Bangladesh, this measure will address these issues effectively. From a CO<sub>2</sub> mitigation point of view it is important to target woodstoves rather than stoves which use agricultural residue and dung.

The business-as-usual scenario shows that to meet the shortfall of biomass fuels, coal would be introduced as a cooking fuel, and will become a significant carbon dioxide emitter in the year 2020. Mitigation option must be targeted towards this demand. Efficient cookstoves for coal can be a good mitigation option. Other mitigation options are the introduction of kerosene and LPG as a replacement fuel for both coal and biomass. The use of commercial fuels to replace a biofuel can be a mitigation option because the combustion of biomass produces other GHGs like CH<sub>4</sub> and N<sub>2</sub>O in addition to CO<sub>2</sub>.

In the commercial energy side, the most prominent efficiency improvement that is possible is the metering of natural gas. At present natural gas is charged on a flat rate basis on the number of burners. This leads to wasteful consumption. Often these burners are left on for no other reason than to save a few matchsticks.

All mitigation options discussed in this section is presented in Table 4.1

## **5. COMMERCIAL SECTOR**

In the commercial sector lighting and air-conditioning are two very significant demands. The use of compact fluorescent lamps for lighting and efficient air-conditioners for space cooling are the mitigation options. With economic growth and development the load for space cooling will increase substantially. For large commercial installations what is very promising is co-generation. From strictly an energy of point view, the merits of cogeneration can hardly be overemphasised. Bangladesh has a fairly good supply of natural gas which can be used very conveniently to run cogeneration systems consisting of electricity generation and absorption refrigeration air-conditioning running on waste heat. This will be particularly attractive for large hotels, supermarkets and office blocks. This concept

**Table 4.1 Mitigation Options in the Residential Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT	2020 POTENTIAL PJ
1	Replacement of Incandescent Bulbs by Fluorescent Lamps (40W) <sup>1</sup>	40%	5
2	Replacement of Incandescent Bulbs by Compact Florescent Lamps <sup>2</sup>	80%	5
3	Replacement of Fluorescent Lamps by Advanced Fluorescent Lamps (36W) <sup>3</sup>	10%	1
4	Replacement of Conventional Ballast by Electronic Ballast <sup>3</sup>	30%	1
5	Efficient Kerosene Lamps <sup>4</sup>	25%	4
6	PV Lanterns <sup>4</sup>	--	2
7	Low Wattage CFLs <sup>4</sup>	90%	2
8	Efficient Air-Conditioners <sup>5</sup>	30%	1
9	Replacement of natural gas heaters by Solar Water Heaters <sup>5</sup>	--	.25
10	Improved Biomass Cookstoves <sup>6</sup>	50%	144
11	Metered Domestic Natural Gas	50%	22
12	Efficient Coal Cookstoves <sup>7</sup>	25%	2.5
13	LPG/Kerosene Cookstoves to Replace Coal Cookstoves <sup>8</sup>	25%	1.25
14	LPG/Kerosene Cookstoves to Replace Biomass Cookstoves <sup>9</sup>		15

NOTES

1. Potential is 50% of urban households
2. Potential is 25% of urban households
3. Potential is 50% of fluorescent lamps
4. Replaces existing wick kerosene lamps. PV and CFL potential is 15% of the maximum. For the case of CFL, there will be energy use at the power generation stage which is not shown here
5. The potential values are assumed values
6. Potential is 50% of the maximum. The potential shown is PJ of biomass

7. Potential is 25% of the maximum. In addition to the energy savings there is carbon dioxide emission reduction because LPG/Kerosene are less carbon intensive fuels
8. Potential is 50% of the maximum
9. Potential is 10% of the maximum. The use of the commercial energy (LPG/Kerosene) used is not shown because the potential value shown is PJ of biomass

can also be applied to a whole locality like a commercial Centre where district cooling can be employed. This is a very feasible option for Bangladesh because in the next two decades many new commercial installations will be constructed. The major drawback of cogeneration is that the demand for heat and power are not always balanced. Therefore careful early planning is crucial to its success. Such early planning is easily possible in Bangladesh because large scale air-conditioning of commercial installations is yet to begin.

Very closely allied to the option of efficient air-conditioners is the design of buildings to minimise space cooling load. This can be achieved in a variety of ways of which measures which reduce heat loss or gain through windows and walls are the most promising ones. In particular the use of reflective glass windows, extra wall insulation and ceramic solar reflective wall coatings can save a large amount of energy. It is worth mentioning that efficient lighting also reduces air-conditioning load and therefore if all air-conditioning efficiency improvement measures are implemented simultaneously, substantial energy saving can be realised.

Use of wood for commercial cooking in rural areas and many urban centres is common. The use of improved cookstoves for wood holds good promise. The rationale behind this mitigation option is exactly the same as improved cookstoves for the residential sector. This option is very important because the wood used in the commercial sector comes from forests whereas in the residential sector it comes from, in most cases, village woodlots and homestead.

Many commercial installations like hotels and hospitals use a large quantity of hot water. This demand can very easily be met by solar water heaters. In section 4.2 the

feasibility of this option has been discussed. All mitigation options discussed in this section is summarised in Table 5.1.

**Table 5.1 Mitigation Options in the Commercial Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT	POTENTIAL PJ
1	Replacement of Fluorescent Lamps by Compact Fluorescent Lamps <sup>1</sup>	50%	7
2	Efficient Air-Conditioners <sup>1</sup>	30%	3
3	Co-generation <sup>2</sup>	--	5
4	Reflective Glass Windows and Wall Insulation <sup>3</sup>	20%	1
5	Improved Cookstoves <sup>4</sup>	50%	1
6	Replacement of natural gas heaters by Solar Water Heaters <sup>5</sup>	--	.25

NOTES

1. Potential is 80% of the maximum
2. The potential of cogeneration is very difficult to estimate because both electricity and heat are the outputs. The maximum potential is probably close to 15 PJ. Potential shown is therefore one-third of this value
3. This option saves on electricity needed for air-conditioning. The maximum potential is probably 2 PJ. The potential shown is therefore 50% of this value
4. Potential is 50% of maximum. Potential is PJ of biomass
5. Potential is a assumed value

## **6. INDUSTRY SECTOR**

### **6.1 General Approaches**

The industry sector will be overwhelmingly the largest consumer of energy in the year 2020. The diverse nature of the industry sector makes it very difficult to target specific industries. The process of industrialisation has just began in Bangladesh making it very difficult to predict which industries will gain in prominence. The mitigation strategy

should adopt a generic approach. High efficiency motors and boilers must form the backbone of the mitigation strategy in the industry sector. In general, motors are efficient devices, and efficient ones improve efficiency by only 10% or so. But studies have shown that when the full assembly which includes the belt drives, adjustable speed drives and the devices which motors drive like pumps, fans and compressors are all improved upon, approximately 30% efficiency improvement is possible.

As can be seen from Figure 5, process heat accounts for 21% of the carbon dioxide emission in the year 2020. Efficiency improvement in this end-use will yield substantial benefits. Boilers in Bangladesh are very poorly designed and maintained. Good combustion control along with adequate insulation can reduce fuel consumption significantly. The control of excess air, good instrumentation and process control are the technical options. Since over 80% of the energy consumed in industries fall within the two categories of process heat and motive power, it may be adequate to pursue these general options instead of attempting to improve complete processes which may prove to be rather difficult. However, there are a few industries which are readily identifiable as good candidates for mitigation. These are discussed individually in greater detail later.

In the general approach to all industries, other than efficient motors and boilers, are the mitigation options of efficient lighting, housekeeping (including energy management) and co-generation. In Bangladesh as in many developing countries, energy management is extremely poor. Many studies have conclusively shown that in almost all industries between 10 and 20% energy saving is possible by implementing a variety of very well established standard housekeeping measures. The potential of this option will remain high in the next two and a half decades because new industries to avoid the high first cost of efficient technologies will opt for energy inefficient processes and practices. Insufficient knowledge about energy issues and lack of proper maintenance generally cause most industries to become energy inefficient within a short time after

going into production. The business-as-usual scenario has therefore projected the industrial energy requirement by keeping all 1990 fuel consumption coefficients constant. This is one of the reasons why the energy demand for the industrial sector shown in Figures 1a and 1b is so high. This makes housekeeping a good option for the industry sector. Studies in Bangladesh and many other developing countries have shown that the saving can be realised at relatively low cost.

The most promising option in the industry sector of Bangladesh is co-generation. In theory this option has so much potential that it can overshadow all other options. Since the industry sector is by far the largest CO<sub>2</sub> emitting sector and very few process improvement mitigation options can be identified, this option should be pursued vigorously and in all earnest. The following two reasons make cogeneration a very relevant mitigation option.

- (i) Due to the chronic shortage of electricity many industries have resorted to captive power generation
- (ii) Centralised electricity generation efficiency is very low and transmission and distribution losses are very high

In Bangladesh today even without co-generation, it is more energy efficient to generate electricity in decentralised locations because gas engines can achieve efficiencies as high as 39.5%. Policies which allow industries to sell excess power to the grid can in theory ensure that waste heat from gas engines or turbines be used for process heat. As can be seen from Figure 5, this can amount to 21% of the total carbon dioxide emission in the year 2020. This option can not only save primary energy now required for process heat, it can increase electricity generation capacity in the country and at the same time deliver to the utilities a large amount of electricity critically needed for the other sectors. The reason why cogeneration is not such an attractive proposition in developed countries is that electricity is very cheaply and reliably obtained from the grid. Thus the initial investment for power generation equipment is not justified.

Moreover, inexpensive natural gas is not available in all places. Since the process of industrialisation has just begun in Bangladesh, by locating new industries which have large requirement of process heat with other industries in a compact industrial zone, the cogeneration potential can be very effectively utilised.

As with the residential and commercial sectors a portion of the low grade hot water demand can be met by solar water heaters.

## **6.2 Process Improvement**

### **6.2.1 Brickmaking**

The energy intensity for brickmaking in Bangladesh is 42 MJ/brick. The best process available has an energy intensity of 5 MJ/brick. Brickmaking is one industry in Bangladesh which should be considered for process improvement. This industry is projected to grow quite rapidly because of the large demand for bricks in the rapidly growing residential and commercial sectors. Despite its importance, brickmaking in Bangladesh is a cottage industry and very primitive technology is employed. The simple technology of the existing process and extremely high returns on investment make it a very lucrative industry. It is unlikely that without intervention this industry will modernise. This industry consumes a large quantity of firewood and is probably the single largest cause of deforestation at present. In the long term it may be expected that firewood would be replaced by commercial energy. Process improvement in this industry can be a very attractive mitigation option. Modernisation of this industry will save a large quantity of firewood in the short term and in the medium and long term it will save a large quantity of commercial energy.

### **6.2.2 Paddy Parboiling**

Paddy parboiling is a large activity in Bangladesh. Rice husks from the milling process are burned in very crude furnaces to generate steam in equally crude boilers.

Tremendous scope exists for process improvement. The large quantity of biomass thus saved can either be used for other purposes or returned to the soil to improve soil quality. One process improvement which is gaining popularity is briquetting of rice husks for controlled combustion. Efficiency improvements up to 50% have been claimed.

### **6.2.3 Textile**

The textile industry will no doubt experience a large growth due to the demand of the large population and the export oriented garment industries. Because of the demand for various grades of textile, especially the cheaper variety, many industries will opt for inexpensive technologies and would be very reluctant to shift from the conventional technology. New technologies for spinning (friction spinning, airjet spinning) can be implemented in place of the existing technology, which is ring spinning. This will lead to lower energy consumption.

### **6.2.4 Pulp and Paper**

Increased commercialisation, growing literacy and population will certainly increase the demand for paper and paper products. Even though forest products are scarce, this energy intensive industry will nevertheless grow on domestic recycled paper, imported recycled paper, and other fibres like jute and rice stalks. The growth of many small industries especially for low grade paper and boards has been projected. These industries will inevitably opt for batch digestors. The use of continuous digestors as opposed to the existing batch digestors can save energy.

All mitigation options discussed in this section is presented in Table 6.1.

**Table 6.1 Mitigation Options in the Industry Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT	2020 POTENTIAL PJ
<b>GENERAL APPROACHES</b>			
1	Replacement of Fluorescent Lamps by Compact Fluorescent Lamps <sup>1</sup>	50%	2
2	Efficient Motors including Improved Drives, ASD + Efficient Compressors, Fans and Pumps <sup>2</sup>	30%	12
3	Efficient Boilers (improved combustion control) <sup>3</sup>	20%	15
4	Housekeeping (including energy management) <sup>4</sup>	15%	18
5	Co-generation <sup>5</sup>	--	43
6	Solar Water Heaters <sup>6</sup>	--	.5
<b>PROCESS IMPROVEMENT</b>			
7	Brickmaking <sup>7</sup> Coal Firewood	80%	10 40
8	Paddy Parboiling <sup>8</sup>	50%	22
9	Textile <sup>1</sup>	15%	2
10	Pulp and Paper <sup>8</sup>	40%	7.5

NOTES

1. Potential is a assumed value
2. Probably only 50% motors fall under this option. Potential is 50% of this value
3. It is assumed that 25% of all boilers can be improved upon
4. It is assumed that 25% of all industrial energy use can be improved upon
5. Cogeneration potential is difficult to estimate because the electricity produced will result in a saving in the power generation sector. It is assumed that 25% of the electricity used can be generated by using the fuel used to supply process heat. The potential is therefore PJ of electricity saved
6. Potential is a assumed value
7. It is assumed that this industry will be modernised such that there will be a 80% efficiency improvement. Furthermore, the process will use only coal. Thus the biomass saved is the total projected biomass. Because of efficiency improvement there will also be some coal saving
8. It is assumed that 50% of the existing process can be brought under a improvement scheme. The potential shown is PJ of biomass
9. It is assumed that 50% can be brought under this option

## **7. ENERGY SUPPLY OPTIONS**

### **7.1 Electricity Generation**

The supply side of the energy system of Bangladesh is a glaring example of inefficient operation. In 1990 the overall power generation efficiency was 26% and the total T&D system loss was 40%. The scope of efficiency improvement in the generation side is very large. Approximately 80% of the power is generated using natural gas. By merely shifting to combined cycle power generation for baseload the efficiency can be improved significantly. In the short and medium term therefore combined cycle power generation is the most obvious mitigation option. In the longer term, the scenario is not so clear because existing natural gas reserves are projected to be exhausted by the year 2015. Figure 6 shows the carbon dioxide emission projection for power generation for a business-as-usual scenario where coal and furnace oil has completely replaced natural gas. IGCC and pressurised fluidised bed combustion should be the long term mitigation options. If new reserves of natural gas are discovered a very prospective long term option would be fuel cells.

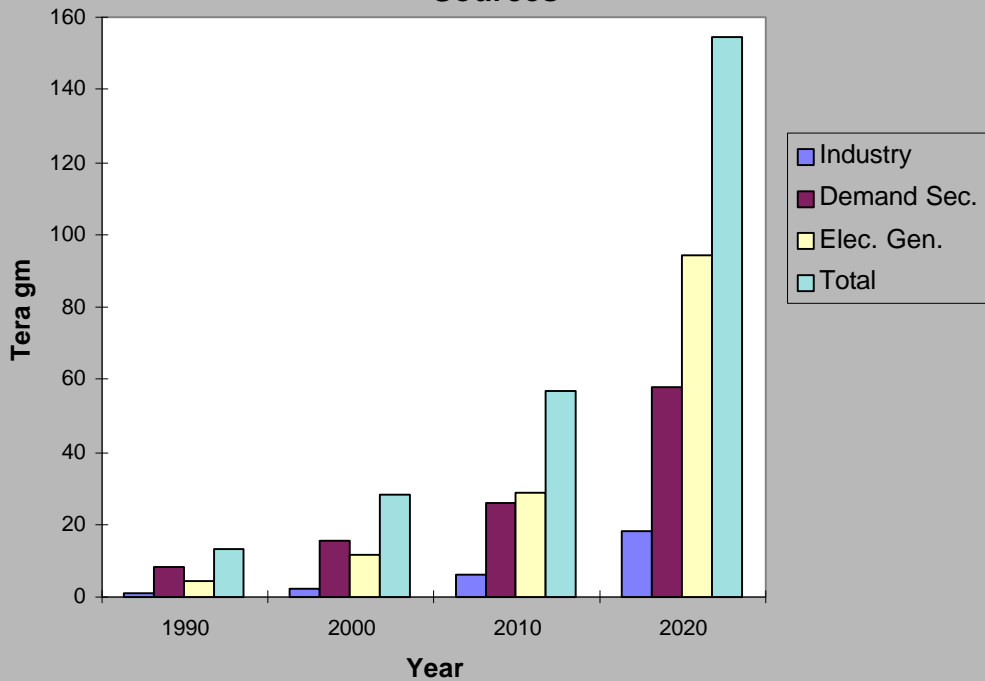
The large T&D losses and the high cost of T&D infrastructure development especially for remote areas where electricity demand is very low, make decentralised power generation an attractive option. Decentralised power generation using piped natural gas can make natural gas pipeline economically viable which otherwise becomes a losing investment. For remote areas the above facts about T&D also make renewables and hybrids attractive options.

## **7.2 Transmission and Distribution Losses**

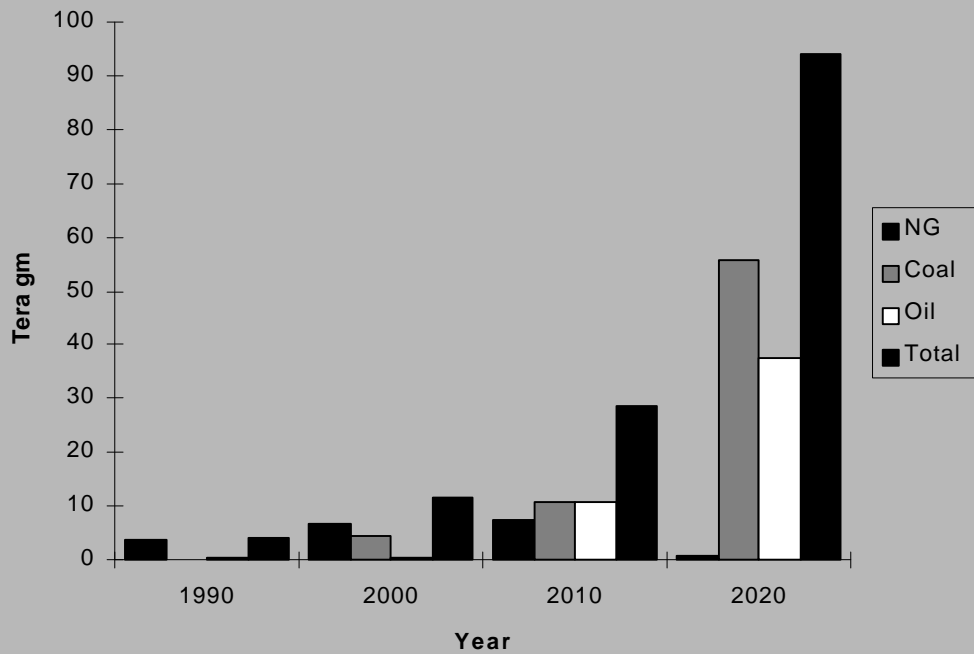
Reduction of transmission and distribution losses (popularly known as system losses) can be a very promising mitigation option. However, one must be cautious in evaluating its potential. This is because a large portion of it is pilferage and hence consumption. It may be argued that if those responsible for the pilferage were forced to pay for their full consumption they would probably exercise caution and get motivated towards eliminating wasteful consumption and practice conservation. The so called "technical system loss" is really what should be considered under mitigation. The existing transmission and distribution system is old and inefficient. A good portion of the "technical system loss" can be easily removed by very simple maintenance and upgradation of technology. It is worth emphasising that the "technical system loss" in many countries including some developing ones is below 10%. If one assumes that this loss in Bangladesh is 20%, then by simply achieving a performance level of existing successful utilities, 10% saving on net electricity generation can be obtained by using only standard technologies.

All mitigation options discussed in this section are summarised in Table 7.1.

**Fig. 5 Carbon Dioxide Emission from Different Sources**



**Fig. 6 Carbon-dioxide Emission From Power Generation**



**Table 7.1 Mitigation Options in the Energy Supply Sector**

No.	OPTIONS	EFFICIENCY IMPROVEMENT	2020 POTENTIAL PJ
<b>ENERGY SUPPLY OPTIONS</b>			
1	Combined-Cycle (SHORT TERM) <sup>1</sup>	40%	64 (2010)
2	IGCC (MEDIUM and LONG TERM) <sup>2</sup>	30%	150
3	Pressurised Fluidised Bed (MEDIUM) <sup>3</sup>	30%	150
4	Fuel Cells (LONG TERM) <sup>4</sup>	20%	120
5	Decentralised Power Generation including natural gas engines, PV, Wind and Renewables + Diesel/Natural Gas Hybrids <sup>5</sup>	--	50
<b>TRANSMISSION AND DISTRIBUTION</b>			
6	Improved Maintenance (SHORT TERM) <sup>6</sup>	20%	10
7	Rehabilitation (SHORT TERM) <sup>6</sup>	20%	10

NOTES

1. The potential is shown is for 2010 because natural gas is projected to be exhausted by 2020
2. The efficiency improvement is over the 32% efficiency for steam thermal coal plants. The potential is 50% of the total power generation using coal
3. The efficiency improvement is over the 32% efficiency for steam thermal fuel oil plants. The potential is 50% of the total power generation using fuel oil
4. This option will only be possible if large reserves of natural gas can be found. The efficiency improvement is over the combined-cycle option
5. It has been assumed that 5% of the total electricity will be generated by decentralised options particularly by renewables
6. These standard measures will cause efficiency to improve

# PART B

## TAXONOMY OF MITIGATION OPTIONS FOR THE ENERGY SECTOR

### 8.1 Mitigation Options Classified According to Generic Groups

In Part A mitigation options in the five energy demand sectors and the energy supply sector has been identified sector-wise. The sub-sectors to which they apply have also been indicated. In this part of the report the options are classified according to the following generic groups to which they apply.

1. Efficiency improvement by retrofitting existing end-use devices
2. Efficiency improvement by replacing existing devices by efficient ones
3. Efficiency improvement by either retrofitting or replacing associated components
4. Shifting to an entirely different device which is more energy efficient
5. Fuel switching
6. Structural/Behavioural changes which require less energy
7. Process Improvement
8. Renewables
9. Others

In each category, the sub-sectors to which the mitigation option applies is indicated. In this classification, options which apply to more than one sector can readily be seen. The sectors to which the sub-sectors belong have been indicated by suitable abbreviations and shown in parenthesis. Thus (T) implies the transport sector. Due to the fact that a generic classification has been made some options had to be split up. For example, the option efficient motors and drives was split up into the energy consuming device, which is the motor, and associated components, which are the belt drives, ASDs and pumps, fans, compressors, etc.

**Table 8.1 Mitigation Options in the Energy Demand Sectors  
Classified According to Generic Groups**

Efficiency improvement by retrofitting existing end-use energy devices	Vehicle maintenance for both passenger and freight	Road (T)
	Insulation and Combustion control for boilers	Process Heat (I)
Efficiency improvement by replacing existing devices by improved or efficient devices	Replacement of 2-Stroke engines by 4-Stroke engines in three-wheelers	Road (T)
	Efficient motors	Irrigation (A) Motive Power (I)
	Incandescent replaced by Fluorescent (40W)	Urban (R)
	Incandescent bulbs replaced by CFL	Urban (R)
	Fluorescent lamps (40W) replaced by CFL	ALL (C) Lighting (I)
	Advanced Fluorescent (36W)	Urban (R)
	Electronic Ballast	Urban (R)
	Efficient Air-Conditioners	Urban (R) ALL (C)
	Efficient Coal Cookstoves	Rural (R)
	Improved kerosene Lamps	Rural (R)
	Improved Biomass Cookstoves	Rural (R) ALL (C)
	Efficiency improvement by either retrofitting or replacing associated components in the end-use system	Road Improvement
Frictionless foot-valves and PVC pipes		Irrigation (A)
Building design to minimise heat gain		ALL (C)
Efficient pumps		Irrigation (A) Motive Power (I)
Efficient Fans, Compressors, Belt drives, ASD		Motive Power (I)

Shifting to a different device which is more energy efficient in supplying the same energy service	Trucks replaced by Rail	Road (T)
	Trucks replaced by Cargo vessels	Road (T)
	Modal shift from Cars, Jeeps, Tempos, Baby Taxis, Motorcycles to Regular Buses	Road (T)
	Low Wattage CFL to replace kerosene lamps	Rural (R)
Fuel Switching	CNG Vehicles including three-wheelers	Road (T)
	Kerosene to replace Coal and Biomass	Rural (R)
	LPG to replace Coal and Biomass	Rural (R)
Structural/Behavioural changes which require less energy	Improved Telecommunication	ALL (T)
	Integrated Urban development	Road (T)
Process Improvement	Brickmaking	(I)
	Paddy Parboiling	(I)
	Textile	(I)
	Pulp and Paper	(I)
Renewables	Solar water heaters	Urban (R) ALL (C) Process Heat (I)
	PV Lanterns	Rural (R)
Others	Better traffic management	Road (T)
	Metering of natural gas	Urban (R)
	Cogeneration	ALL (C) ALL (I)
	Housekeeping	ALL (I)

## **8.2 Implementation of Mitigation Options**

In this section an effort has been made to indicate when a particular option may be implemented. The table below shows whether an option is a short, medium or long term option by a tick sign in the appropriate box. Thus options which cannot be implemented for quite some time will have a tick sign only on the long term box.

**Table 8.2 Implementation of Mitigation Options**

<b>MITIGATION OPTION</b>	<b>SHORT</b>	<b>MEDIUM</b>	<b>LONG</b>
<b>TRANSPORT</b>			
T1 Vehicle Maintenance	√	√	√
T2 Road Improvement	√	√	
T3 Better Traffic Management	√	√	√
T4 Improved Telecommunications	√	√	√
T5 Integrated Urban development			√
T6 Modal shift from road to rail		√	√
Modal shift from road to water		√	√
T7 Mass Transit System	√	√	√
T8 2-Stroke to 4-Stroke	√		
T9 CNG three wheelers		√	
T10 CNG Vehicles (Buses, Trucks, etc.)		√	√
<b>AGRICULTURE</b>			
A1 Retrofitting irrigation pump-sets	√		
A2 Efficient motors	√		

<b>MITIGATION OPTION</b>	<b>SHORT</b>	<b>MEDIUM</b>	<b>LONG</b>
<b>RESIDENTIAL</b>			
R1 Incandescent replaced by Fluorescent	√	√	
R2 Incandescent replaced by CFL		√	√
R3 Advanced Fluorescent	√	√	√
R4 Electronic ballast	√	√	
R5 Improved kerosene lamps	√	√	√
R6 PV Lanterns		√	√
R7 Low wattage CFLs			√
R8 Efficient air-conditioners		√	√
R9 Solar water heaters	√	√	√
R10 Improved biomass cookstoves	√	√	√
R11 Metering natural gas	√	√	√
R12 Efficient coal cookstoves			√
R13 LPG/Kerosene to replace coal cookstoves			√
R14 LPG/Kerosene to replace biomass cookstoves		√	√
<b>COMMERCIAL</b>			
C1 Fluorescent replaced by CFL	√	√	√
C2 Efficient air-conditioners		√	√
C3 Cogeneration	√	√	√
C4 Building design (AC load reduction)		√	√
C5 Improved Cookstoves	√	√	√
C6 Solar Water Heaters	√	√	√

<b>MITIGATION OPTION</b>	<b>SHORT</b>	<b>MEDIUM</b>	<b>LONG</b>
<b>INDUSTRY</b>			
I1 Fluorescent replaced by CFL	√	√	√
I2 Efficient motors + drives + pumps, etc.	√	√	√
I3 Efficient boilers	√	√	√
I4 Housekeeping + energy management	√	√	√
I5 Cogeneration	√	√	√
I6 Solar Water Heaters	√	√	√
I7 Brickmaking	√	√	
I8 Paddy parboiling	√	√	
I9 Textile		√	√
I10 Pulp and paper	√	√	√
<b>ENERGY SUPPLY</b>			
ES1 Combined cycle	√	√	
ES2 IGCC			√
ES3 Pressurised fluidised bed		√	√
ES4 Fuel cells			√
ES5 Renewables and Hybrid	√	√	√
ES6 T&D improved maintenance	√	√	√
ES7 T&D rehabilitation	√	√	√

### **8.3 Taxonomy by Gases**

Almost all options considered in this report have dealt with energy reduction and hence carbon dioxide emission reduction. Most of these options due their to lower energy consumption also reduce other GHGs by a small amount. However, there are a few options among these which predominantly reduce GHGs other than carbon dioxide. The table below lists these options and indicates the GHG emission they mitigate.

**Table 8.3 Mitigation Options Which Reduce Emissions of Methane and Nitrous Oxide**

<b>MITIGATION OPTION</b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>
R10 Improved biomass cookstoves	√	√
R14 Kerosene cookstoves to replace biomass cookstoves	√	√
R14 LPG cookstoves to replace biomass cookstoves	√	√
C5 Improved biomass cookstoves	√	√
I7 Brickmaking	√	√
I8 Paddy parboiling	√	√