Low-Carbon Society Development towards 2025 in

Bangladesh

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AIM
ASIA-PACIFIC INTEGRATED MODEL

Preface

Being a minute greenhouse gas (GHG) emitted and as the most affected country by climate change, the Government of Bangladesh (GOB) concentrates on implementing several adaptation and mitigation programmes. Considering the advantages of implementing mitigation technologies, the objective of this study is to give an initial vision of possible Low-Carbon Society (LCS) scenario in Bangladesh. LCS scenario consists of future changes in demography, transport, industry, energy demand, crop production, livestock number, landuse pattern and GHG emission from energy sector (residential, commercial, transport, industry and power) and non-energy sector (agriculture, forestry and other landuse, AFOLU) in 2025.

Bangladesh is an energy poor and agriculture based country. For Bangladesh, the concept of LCS for energy sector not only to reduce GHG emission, but also focuses on low-carbon energy mix and better energy efficiency which can meet the challenge of CO_2 emission reduction and improves economic productivity. For AFOLU sectors, LCS is to quantify future emission mitigation potential by using feasible mitigation technologies for developing sustainable agricultural system. This study used the Extended Snapshot tool (ExSS) developed by Kyoto University, Japan, in order to design quantitative future scenario of LCS. ExSS estimated the socio-economic activity level, energy demand, CO_2 emission and reduction potential by low-carbon measures. Agriculture, Forestry and Other Landuse Bottom-up (AFOLUB) model was developed by National Institute for Environmental Studies (NIES) and Kyoto University (KU), Japan, in order to project future GHG emission from AFOLU sectors and mitigation potential under several constraints for mitigation costs.

For Bangladesh, building LCS will be both a challenge and an opportunity. This report provides essential socio-economic information and efficient and cost-effective mitigation technologies for policy makers, administrators, stake-holders and academic researchers in integration of effective climate change mitigation actions in development policies of the country.

Yuzuru Matsuoka	Junichi Fujino	Abul Kalam Azad	Mirza Shawkat Ali
Professor	Senior Researcher	Professor	Deputy Director
Kyoto University, Japan	National Institute of Environmental Studies, Japan	Khulna University, Bangladesh	Department of Environment, Bangladesh

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Summary

This report aims to propose the scenario for realization of sustainable and low-carbon society development in Bangladesh. The study projects future GHG emission and propose potential low-carbon measures by using ExSS tool in energy sector and cost effective mitigation technologies by using AFOLUB model in non-energy sector for its possible implementation.

The methodology applied in energy sector includes:

1) Quantification of socio-economic activity level in 2025;
2) Development of CO_2 emission and reduction measures based on socio-economic assumptions and availability of technologies;
3) Projection of possible CO_2 emission and emission reduction by 2025.

Necessary information was taken from Bangladesh Bureau of Statistics, Planning division of Ministry of Planning, GOB (Government of People's republic of Bangladesh) and other sources (see reference in pp.42). Most of the energy and energy related information used in this report were collected from IEA (International Energy Agency).

The methodology applied in AFOLU sector includes:

1) Projection of agricultural harvested area, livestock number and landuse pattern by 2025;
2) Quantification of GHG emission by 2025 based on projection trend in (1) on agriculture, livestock and landuse condition;
3) Estimation of GHG emission potential under several Allowable Additional Costs (AAC).

Most information on agriculture, forestry and landuse was collected from Ministry of agriculture, GOB, Statistical year book, 2010 and yearbook of agricultural statistics, 2010 and FAOSTAT, 2011.

Using the above models, the "future trend

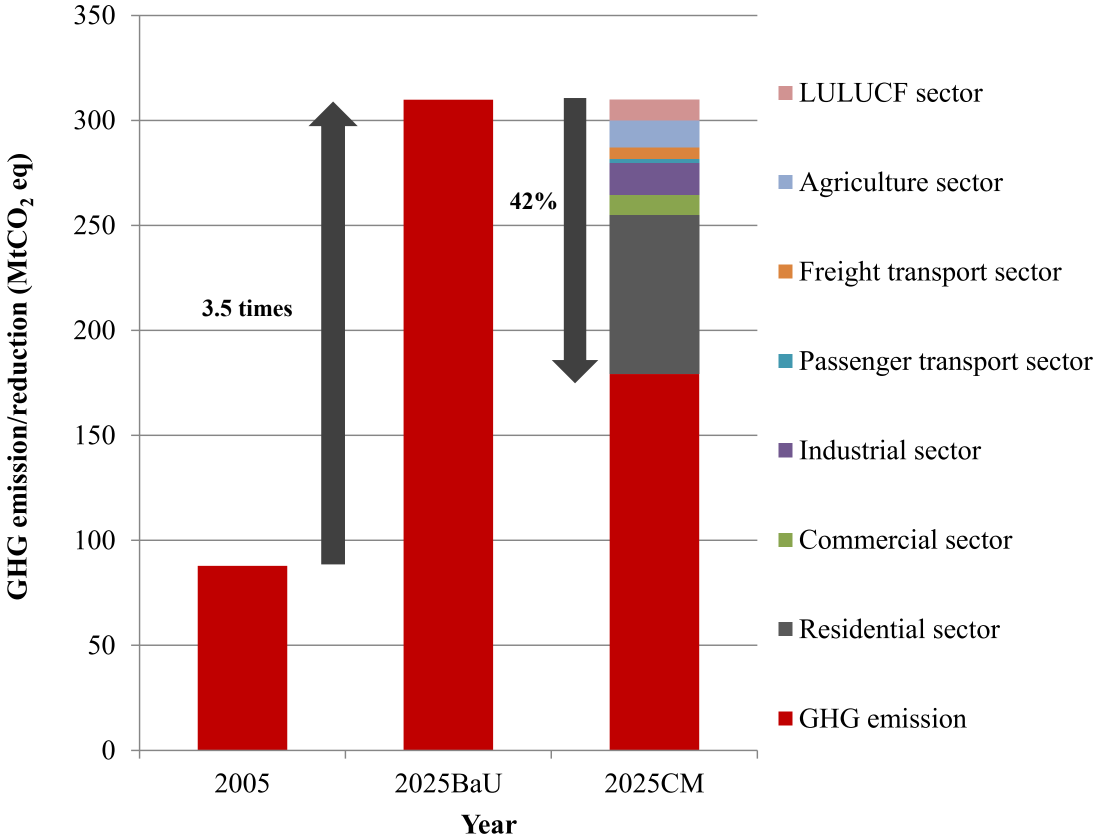

Fig. 1: GHG emission and reduction by reduction measures

of GHG emission" is projected based on:

1) 2025BaU (business-as-usual) without applying reduction measures in 2025 and
2) 2025CM (countermeasures) with the application of mitigation technologies in 2025 to reduce the GHG emission.

Those selected reduction measures introduced in 2025CM are efficient and will be compatible with the future situation of Bangladesh.

The main outcomes are as follows:

1) The annual GHG emission of Bangladesh was 87.9MtCO_2eq in the base year of 2005;
2) Under the scenario of 2025BaU (without mitigation technologies) the GHG emission will be increased to 308.9MtCO_2eq which is about 3.5 times larger than base year of 2005;
3) Under the scenario of 2025CM (with selected feasible mitigation technologies) the GHG emission will be reduced to 179.4MtCO_2eq which is about 42% smaller than 2025BaU (Fig. 1).

In 2005, the per capita GHG emission of Bangladesh was 0.6tCO_2 and it will be increased up to 1.7tCO_2 in 2025BaU. However it is still much lower than current per capita emission of most of the other countries and it will be reduced to 0.99tCO_2 in 2025CM. For GHG emission mitigation, several mitigation technologies are required, such as energy efficient lighting, air conditioner and cooking stove in residential sector and commercial sector, energy efficient boiler and motor in industrial sector, efficient transport vehicle and modal shift in transport sector and fuel switch, reduction of transmission loss in power sector, midseason drainage, dome digester, cooking fuel and lighting and replacement of roughage with concentrates in agriculture sector, management of existing production forest areas and planting long-rotation large timber trees in land use, land-use change and forestry (LULUCF) sector.

To develop low-carbon society in Bangladesh, a package of policies were formulated based on the above projection and Outline Perspective plan of Bangladesh, Making Vision 2021 a reality; National Energy Policy; National Renewable Energy Policy and Strategic Transportation Plans (Fig. 2). These policies are emphasized on fuel switch, introduction of renewable and nuclear energy in power sector, improve the energy efficient equipment, increment of public transport and improve traffic management system, sustainable agricultural system and increment of forest cover by reforestation program.

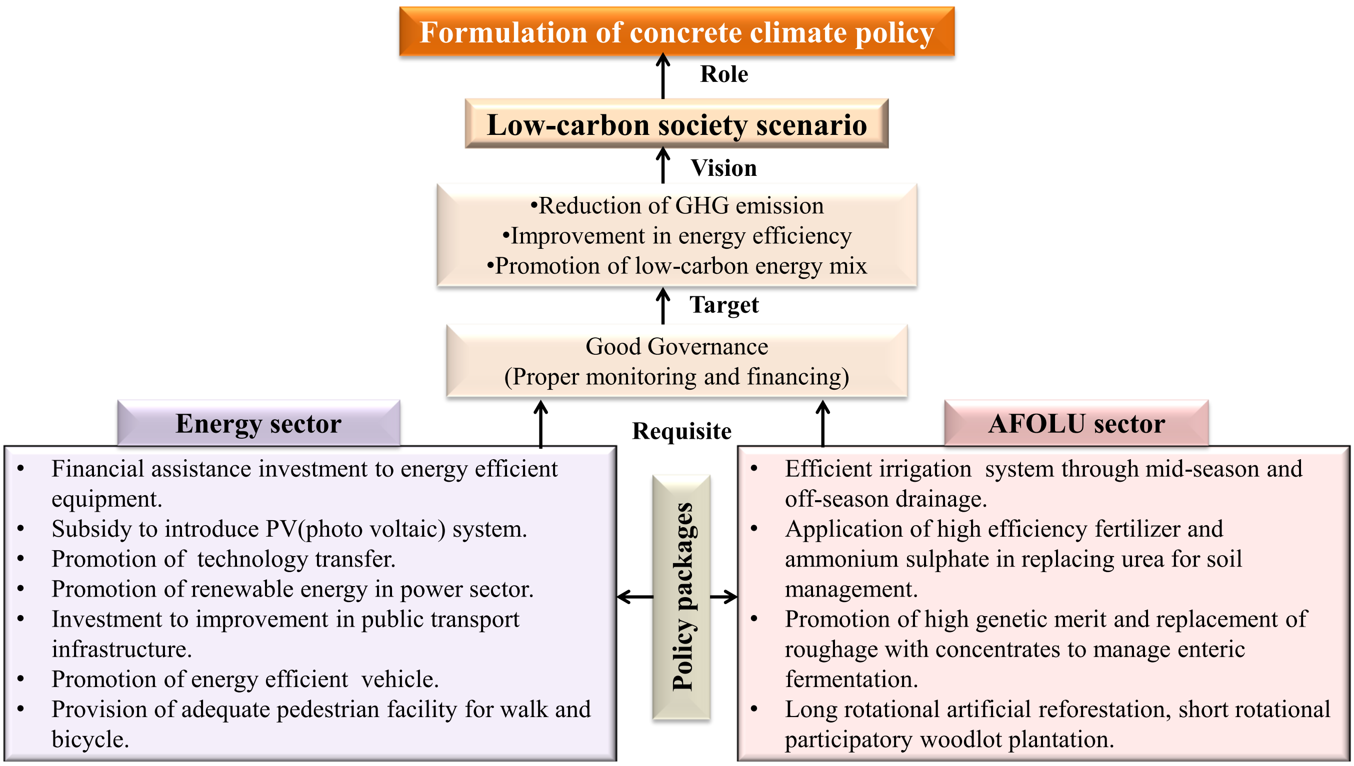

Fig. 2: Policy package for Low-carbon society in Bangladesh

About Bangladesh

General features

People's Republic of Bangladesh is an independent country in southern Asia (Fig. 3). Geographically Bangladesh faces the Bay of Bengal, an arm of the Indian Ocean, and is bordered by India and a tip of Burma. Bangladesh is the 8th most populous country with the population of 155 million people and 9th most densely populated country with 1,099 persons/km^2. The main religion practiced in Bangladesh is Islam (89.7%), Hinduism (9.2%), other religious groups including Buddhists (0.7%), Christians (0.3%), and Animists (0.1%). Bangladesh is divided mainly into seven divisions, Dhaka (capital), Khulna, Sylhet, Chittagong, Rangpur, Barisal and Rajshahi.

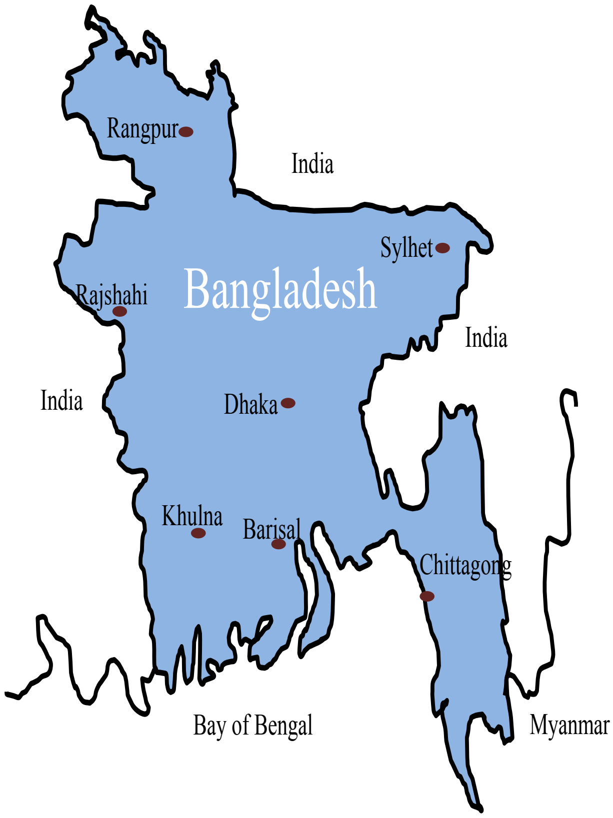

Fig. 3: Map of Bangladesh

Physiography

The country has an area of 144,000 square kilometers with extends 820 kilometers north to south and 600 kilometers east to west. Bangladesh lies almost entirely within the combined delta of the Ganges, Brahmaputra, and Meghna rivers and consists primarily of a low-lying alluvial plain. The land is relatively flat and about 67% nonurban areas are arable, with some mangrove forest, tropical rain forest and some woodland which cover about 16% of the total landmass. The highest point in Bangladesh is in Mowdok range at 1,052 meters in the Chittagong hill tracts to the south-east of the country. Cox's Bazar is the largest sea beach of having area 120 kilometers in the south of the country.

Climate

Bangladesh is a tropical monsoon country. The climate of Bangladesh is characterized by high temperature, heavy rainfall and excessive humidity during monsoon (June to September). The temperature is almost humid, warm and tropic all over the country. The annual mean temperature of this country is about 25^{0}C which range between 18^{0}C in January and 30^{0}C from April to May. The northern and southern parts of Bangladesh are relatively hotter than other parts of the country. Bangladesh has six seasons, namely summer, rainy, autumn, late autumn, winter and spring.

Agriculture

The country has agrarian economy, which comprises of about 19% of the country's gross domestic product (GDP) and employs about 45% of the total labor force. However the contribution of agriculture to the country's GDP has been steadily declining from 55% in 1970 to 31.6% in 1999 to 21.7% in 2009. The performance of this sector has an overwhelming on major macro-economic objectives like employment generation, poverty reduction, human resource development and food security. Being an agricultural country, Bangladesh cultivates significant amount of rice (Aman, Aus and Boro), jute, sugarcane, potato, pulses, wheat, tea and tobacco, which are the major crops, contributing about 72% of total production in the agriculture sector. Fisheries, livestock and forestry sub-sectors are contributing production of 10.3%, 10.1% and 7.3% respectively. Bangladesh is the largest producer of world's best quality jute, which also known as natural jute or raw jute. Rice being the staple food, its production is of major importance. Rice production stood at 30.7 million tons in 2007-08 fiscal year. However, Bangladesh is still in lack of sufficient food supply for the people and import dependent. Therefore, “Food for all” is now a prime commitment of the government towards the citizens to achieve the self-sufficiency in food grains by 2013 through increased agricultural production. Introduction of high yield verities (HYV) of crops, research and input distribution on production extension and policies, pursued by the government are yielding positive results. Often inefficient traditional farming system, excess fertilizer use without knowing its harmful effect and over exploitation of agricultural land may lessen the natural fertility of the soil.

Livestock

The performance of livestock sub-sector has great implication in the economic development of agro-based Bangladesh, as it contributes of 2.8% of GDP and shares about 17.2% in agriculture.

Fig. 4: Paddy field in Bangladesh

About 44% of the animal protein comes from livestock sources and shares about 4.3% of the total export, coming from the export of leather and leather goods. The 30% of the total tillage is still covered by livestock beside mechanical tillage. Fisheries & Livestock sectors with having growth rate 5.9% in 2009, employ 20% of population directly and 50% partially. Livestock is an integral part of the agricultural economy of Bangladesh, which provides nutrition, income, foreign currency (by exporting hides, skin, bones etc.), manure, fuel, transport for rural area and other social and cultural functions.

Fig. 5: Traditional plough

Forestry

Bangladesh is green, though it is a forest poor country. About 6.7% of the total land cover is called as public forest with very little natural forest, found in the Sundarban, Khulna. Homestead forests are mainly seen around the rural household areas.

Forestry is an important sector in Bangladesh’s economy. Forestry being a sub-sector of agriculture in Bangladesh which contributes to the national economy of about 1.8% of GDP, promotes ecological stability and meets rural household fuel demand. The total forest land includes classified, non-classified state lands, homestead garden, tea and rubber gardens. The total hill forest covers about 670,000 hectares which accounts for 44% of the total area managed by the Forest Department.

Fig. 6: Sundarban mangrove forest

Sundarban, the world's largest contiguous and natural mangrove forest of area of 6,017 sq. km, is about 4.1% of total area of Bangladesh (Miah, 2009). The forestry sector contributes about 5% of the total GDP of Bangladesh and about 2% (2001-2002) of the total labor. Excessive exploitation, erosion and loss of soil fertility lead the forest sector to a critical situation for ecological balance and biodiversity conservation.

Landuse

The pattern of landuse in Bangladesh has been greatly influenced by the growing population and expanding needs for settlement, cropland and industrial land. In landuse, arable land comprised of 55.4%, permanent crops is of 3.1% and other land (forests and woodlands, settlement, roads, barren land) of 41.5% in 2005.

Agricultural cropland areas in Bangladesh are influenced by seasonal features and climatic variables such as temperature, rainfall, humidity, daylength etc. It is reported that cultivable land has been declining by almost 1% per year due to increased habitation, industrial and commercial settlement, transport infrastructure and so on. The trend of declination is continuing. The performance of this sector has a remarkable impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development, food security and overall social development.

Fig. 7: Landscape

Economy

Chittagong seaport (nerve center of Bangladesh economy) and Mongla seaport are two main seaports, playing important role in the export and import activities of the country.

Bangladesh is ranked as the 43rd largest economy in the world with gross domestic product of US$257 billion, if purchasing power parity (PPP) is taken into account. The country's economy is mainly agriculture based. However, economy of Bangladesh is a rapidly developing market-based economy. Country's per capita income in 2010-2011 was US$818 or over taka 57,000. GDP per capita was 1700US$ in 2011. Among the Next Eleven or N-11 of Goldman Sachs and D-8 economies, with a gross domestic product of US$269.3 billion in PPP terms and US$104.9 billion in nominal terms. The economy has grown at the rate of 6-7% per annum over the past few years. More than half of the GDP is generated by the service sector; while nearly half of Bangladeshis are employed in the agriculture sector. Other goods produced are textiles, jute, fish, vegetables, fruit, leather and leather goods, ceramics, ready-made goods.

Fig. 8: Garment industry

The service sector of the country contributed about 43% (2009) of the country's GDP. In the industrial sector, main manufacturing industries are ready-made garments, cotton textiles, fertilizer, pharmaceuticals, wood products, iron and steel, chemicals and plastics. The manufacturing industry contributed 17% of the GDP in 2009 which is mainly dominated by ready-made garments. Bangladesh was ranked as the 4th largest garment exporter in the world among the 10 garment suppliers to the USA in 2010 by the World Trade organization.

Planning commission of Bangladesh, Ministry of Planning (2010) in Outline Perspective Plan of Bangladesh Making Vision 2021 a Reality, projected that the contribution of agriculture sector will be 15% (22% in 2009) by 2021, industry sector will be 40% (29% in 2009) in which manufacturing industry will be 30% (17% in 2009) by 2021 and service sector will be 45% (49% in 2009) in total GDP by 2021.

Transport and communication

The transport sector of Bangladesh consists of a variety of modes. Three modes of surface transport, i.e. road, railway and water are widely used in carrying both passengers and cargo. 70% of the country's total passenger and cargo volume is carried by mechanized road transport mode, e.g. the 4.8 km long Bangabandhu Bridge (11th longest bridge in the world when constructed in 1998) establishing a strategic link between the east and the west part of Bangladesh and generating multifaceted benefits to the people. Center for Policy Dialogue (CPD, 2001) reported that the modal share of road sector significantly increased from 60% (Fifth Five Year Plan, 1997-2002) to more than 80% due to the construction of this bridge. In addition this bridge promotes inter-regional trade

Fig. 9: Rupsha Bridge, Khulna

and facilitating transmission of electricity and natural gas and telecommunication links. According to the Ministry of Communications (2010), Bangladesh Railways handled approximately 4% and inland waterway about 8% of the national passenger transport volume in 2005. Being cheap, safe, and environment friendly; inland water transportation is often the only mode that serves the poor, especially useful during periods of extensive flooding. Bangladesh is a wetland with a dense network of 700 rivers, canals and tributaries criss-crossing the country. Ministry of Communications (2010), reported that inland waterway covered 16% of annual freight transport volume in 2005. World Bank, 2011 reported that inland ports in Bangladesh handle about 40% of the nation's foreign trade.

Fig. 10: Traffic situation in Dhaka.

There are now 11 operational airports in Bangladesh. Of these, the airports at Dhaka, Chittagong and Sylhet serve international route.

Fig. 11: Rural transport

Power and Energy

Electricity is a key ingredient of socio-economic development of the country. In 2010, 47% of the total population had access to the power supply. The government in power system master plan, 2005 projected that about 62% and 72% of population access to electricity will be achieved by 2012 and 2014 respectively (Ministry of Planning, 2010). In order to meet the government's projection, generation growth rate should be 10% per year. GOB has declared its vision for power sector in 2010, total installed capacity of plant would be 7,000MW by the year of 2013, 8,000MW by 2015 and 20,000MW by 2021 to make the country free from load-shedding. Per capita electricity consumption was 220kWh in 2009 and it should be increased to 600kWh by 2021 to meet the vision. 63% of annual total power generation comes from public entities in which 46% from Bangladesh Power Development Board (BPDB) and private entities contribute the rest of 37% of total annual generation in 2010.

Fig. 12: Khulna Power plant

The government has planned to overcome possible difficulties and ensure the electricity for all by 2021 through public and private partnership (PPP).

Bangladesh has a significant reserve of natural gas (20.5 trillion cubic feet) (Ministry of Power, Energy and Mineral Resources, 2004) which is the main fuel (88%) for power generation. Energy and power division of Bangladesh (2010) indicates that the existing gas reserves will be able to meet the gas demand up to 2016 though with the present production capacity, it cannot meet the increasing demand of 5.6 billion cubic feet by 2025. About 3.3 billion tons of coal reserves comprising of 5 deposits at depths of 118-1,158 meters have been discovered so far. Out of which 4 deposits (118-509 meters) are extractable at present, being used mainly for one thermal power plant. Due to shortage of natural gas, the government has focused on diversification of energy source for power generation. Government has planned to install two coal-based power plants which will contribute about 2,600MW (1,300MW each) by 2015 to the national supply. The government, with the technical assistance of Russia, has made effective arrangement to establish a nuclear power plant with a capacity of 1,000MW by 2016.

Exploration activities carried out so far could not discover any significant oil deposit. Sustainable Energy Development Authority (SEDA) has approved national renewable energy policy (2008) that 5% of the total generation (450MW) would be added by 2015 and 10% of the total generation (1,600MW) by 2020 from renewable sources (Ministry of Planning, 2010).

Fig. 13: Roof-top solar panel of a rural house

The National Energy Policy (Ministry of Power, Energy and Mineral Resources, 2004) reported that biomass fuels play an important role in meeting the total energy need of the country. Unplanned and uncontrolled consumption of biomass fuels beyond their regenerative capacity is causing environmental degradation.

Background of "Low-carbon Society"

Concept of low-carbon society (LCS)

Low-carbon society in a developing country is a combined concept that can develop a sustainable model which can meet economic development, life style improvements, climate change effects mitigation through technology transfer, using renewable energy, utilizing funding and finally capacity building which contributes to the sustainable development of the total society. In that society, equal attention will be paid on environmental protection as well as other socio-economic security. The low-carbon society has some following attributes:

- Takes actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met.
- Makes an equitable contribution towards the global effort to stabilize atmospheric concentration of carbon dioxide and other greenhouse gas at a level that will avoid dangerous climate change through deep cuts in global emission.
- Demonstrates high levels of energy efficiency and uses low carbon energy sources and production technologies.
- Adopts patterns of consumption and behavior that are consistent with low level of greenhouse gas emission.

Low-carbon society concept not only serves the potential of CO_2 emission reduction but also efficient energy system for the country to proceed towards economic development. Bangladesh needs to shift to a low carbon development paradigm to facilitate the effective medium and long-term strategies for economic development and carbon trade.

Mitigation is not mandatory for Bangladesh, however, for survival of many of the citizens, GDP growth must be accelerated. As a result the requirement of energy services will substantially increase in the coming years. Also, the country will emit more CO_2 in comparison with the current emission. Therefore, mitigation measures should be identified and implemented to retain the current emission intensity, which can be increased in some decades.

Low-Carbon Society for Bangladesh

- Suppress CO_2 emission increase.
- Energy development (better energy efficiency, low-carbon energy mix etc.).
- Enhance economic growth (promote power supply with efficient energy management).
- Enlarge national development opportunity to enhance green economy.
- Poverty reduction by green development.
- Lessen the damages of climate change in the long-run.

Fig. 14: Natural disasters and man-made activities

Climate change actions in Bangladesh

Adaptation to Climate Change

Bangladesh is the most vulnerable country to climate change impacts in the world. Cyclones, storm surges, floods are now becoming so frequent and will be more severe in the upcoming years. Almost all sectors are likely to be affected by climate change. IPCC (2007) projected impact of climate change to Bangladesh as follows.

- 1 meter rise in sea-level will inundate 20% of landmass by 2100.
- Changes in precipitation pattern will lose about 8% of rice and 32% of wheat production through enhancing flood pollute ground water, increase salinity in crop land resulting by 2050.
- Temperature increases 1.4°C to 5.8°C will induce cyclone, drought etc.

Therefore, it is now inevitable to prepare adaptation plan against climate change to save the people and economy of Bangladesh. The work pressure will be reduced if there is a concrete national climate change policy. However, there is no concrete national climate change policy in Bangladesh that specifically aims the climate change risks.

Bangladesh government pays attention on climate change vulnerability with a vision to eradicate poverty and achieve economic and social wellbeing, through a Pro-Poor Climate Resilient Strategy. This strategy focuses on the adaptation and disaster risk reduction and also low carbon development, mitigation and technology transfer to build the capacity and spirit to meet the climate change challenges in the next 20 to 25 years. This strategy is mainly based on the four building blocks of the Bali Action Plan:

1) food security, 2) water security, 3) energy security, 4) livelihood security.

UNFCCC has launched four adaptation funds for developing countries, include:

- Least Developed Countries Fund (LDCF) helps to prepare National Adaptation Plan of Actions (NAPA).
- Special Climate Change Fund (SCCF) supports a number of climate change activities such as mitigation and technology transfer.
- GEF (Global Environment Facility) Trust Fund prioritizes adaptation.
- Adaptation Fund (AF) under Kyoto Protocol assists developing countries to carry out “concrete” adaptation plan.

GOB prepared the emission inventory and submitted to UNFCCC in 1994. The government has formulated the National Adaptation Plan of Actions (NAPA) and submitted to UNFCCC in 2005 to get Official Development Assistance (ODA) through LDCF. Implementation of NAPA is in process. Under the clean development mechanism (CDM), Bangladesh has established two authorities, National CDM Board and National CDM Committee and accepted four projects in waste and energy sectors in Bangladesh.

The government has formulated **Bangladesh Climate Change Strategy and Action Plan (BCCSAP),** 2008 which has been revised in 2009.

BCCSAP 2009 has identified six priority themes (T):

- T1. Food security;
- T2. Social protection and health;
- T3. Comprehensive disaster management infrastructure;
- T4. Research and knowledge management;
- **T5. Mitigation and low carbon development and**
- T6. Capacity building and institutional strengthening

Existing development policies in Bangladesh

Policy targets for socio-economic development

Millennium Development Goals (MDG) (General Economic Division, Planning Commission, GOB, 2009) -Target (2015) (selected issues):

- Goal 1: Eradicate Extreme Poverty and Hunger (below US$1 per day (PPP-values) - Reduce poverty level from 39% (2009) to 29% .
- Goal 2: Achieve Universal Primary Education. Net Enrolment Ratio in Primary Education 100%.
- Goal 3: Promote Gender Equality & Empower Women. Share of women in wage employment in the non-agricultural sector from 24.6% (2008) to 50%.
- Goal 7: Ensure Environmental Sustainability. Proportion of land area covered by forest (tree cover) 19.2% (tree density 10%) to 20% with tree density 70%.

National Energy Policy and vision on power sector in Bangladesh

In 2004, The Government of Bangladesh has released a draft, entitled as National Energy Policy (NEP). The NEP refers to "The importance of energy in socio-economic development" (Ministry of Power, Energy & Mineral Resources, 2004).

Considering the past experience, the objectives and targets are pointed for energy sector as Sixth Five Year Plan (SFYP) 2011-2015 (Ministry of Planning, 2010) with Vision 2021, as follows:

- Enhance and upgrade exploration and development of existing, new gas fields and possible gas resources into proven reserves.
- Integrate reservoir management in both public and private gas companies to provide reservoir data collection and supply security.
- Institute administrative, financial and legal reform in Petrobangla and companies.
- Reduce system loss and improve use efficiency.
- Improve supply security of petroleum products.
- Encourage public-private partnership for Liquid Nitrogen Gas (LNG) import and marketing.
- Exploration and distribution of indigenous oil and gas.
- Expand Liquid Petroleum Gas (LPG) use for domestic consumption to discourage piped gas.

The government's Power System Master Plan (2005) projects that 62% and 72% access to power will be achieved in FY-2012 and FY-2014 respectively (Ministry of Planning, 2010).

The following objectives for the sector have been aimed:

- Ensuring energy security.
- Improving the security, reliability and quality of electricity supply.
- Making the power sector financially viable and facilitating economic growth.
- Increasing the sector's efficiency and introducing a new corporate culture in the power sector entities.
- Using natural gas, coal and oil as the primary fuels for electricity generation.
- Ensuring a reasonable and affordable price for electricity and private sector participation.

GOB has defined its vision and policy statement in February 2000, "Electricity for all by 2021" in phases with the direction of the Article 16 of "The Constitution of the People's Republic of Bangladesh", to eliminate the inequality between the urban and rural areas standard of living. Government's Vision towards 2021 for electricity production is "electricity for all" by producing 8,500MW by 2013, 11,500MW by 2015 & 20,000MW by 2021.

Possibilities:

- Coal-based power plants using domestic and imported coal.
- Ruppoor Nuclear Power Plant.
- Availability of new gas both offshore and onshore.
- Public-Private Partnership Projects.
- Prospect of participation of local investors in the sector.

Renewable Energy Policy, 2008

Ministry of Power, Energy and Mineral Resources, Power division (2008) has published the National Renewable Energy Policy draft. The aims of renewable energy policy are to set policies aiming for developing renewable energy resources (solar, wind, hydro) to meet 5% of the total power demand by 2015 and 10% by 2020.

- Couple the potential of renewable energy resources and distribution of renewable energy technologies in rural, peri-urban and urban areas.
- Encourage and facilitate both public and private sector investment in renewable energy projects.
- Develop sustainable energy supplies.
- Scale up contributions of renewable energy to electricity production and heat energy.
- Promote appropriate, efficient and environment friendly use of renewable energy.
- Create enabling environment and legal support to encourage the use of renewable energy.
- Promote development of local technology in the field of renewable energy.
- Promote clean energy for CDM.

National Agriculture Policy (NAP), 1999

Ministry of Agriculture (MoA) has formulated policy document in 1999 in order to provide proper guidelines for various development activities relating to crop sector, which is the largest sector of agriculture. NAP has an overall objective, 18 subsidiary objectives and 18 programme areas (MoA, 2006). The overall objective of the national agriculture policy is to make the nation self-sufficient in food through increasing production of all crops including cereals and ensure a dependable food security system for all. Policy priority areas include crop production, fertilizer, irrigation, agricultural research, land use and so on. The MoA prepared the New Agricultural Extension Policy (NAEP) in 1996 in accordance with the agricultural policies and priorities set out in the fifteen-year perspective plan 1995-2010. The main goal of NAEP is to encourage the various partners and agencies within the national agricultural extension system to provide efficient and effective services which complement and reinforce each other in an effort to increase the efficiency and productivity of agriculture in Bangladesh.

The government also implementing programmes under agricultural policies (1999) in Bangladesh have expanded the use of high-yielding variety of rice seeds, fertilizers and shallow tube-wells for irrigation. Irrigation coverage increased dramatically from 22.5% in 1980-81 to 51.5% in 2000-01 (Kumar, 2008). The crop sector accounts for 12% of GDP and occupies over three-quarters of the cropped area. This development strategy results, rice production tripled from 11 million tonnes in 1972 with an annual growth rate of about 3% during 1990 to 32 million tonnes in 2009 and wheat exceeded production of 2 million. Maize production increased by 138% during the period 1995/96 to 1997/98 (Farouque, 2005).

Bangladesh has some future targets on agriculture that are as follows:

1) Self-sufficiency in food: 2013

2) Ensuring food security: 2017(a+a+n)

(a+a+n=Availability, accessibility and nutrition).

According to the National Commission of Agriculture report (unpublished), 7% of GDP growth need of 3.1% increase in demand for food crops. Targets are to increase storage capacities by building additional sizes of 50,000 tonnes by 2015 and 1 million ton by 2021 to facilitate safe storage of rice.

Research and Development for productivity increase making up to 20% higher production of hybrid rice through technological progress and stress tolerant varieties (salt and drought tolerance for rice as well as heat tolerance for wheat) (Ministry of Planning, 2010).

National Livestock Policy, 2005

A National Livestock Policy (Ministry of Fisheries and Livestock, 2007) was drafted in 1992, but it was not officially approved. Recently, the Ministry of Fisheries and Livestock has prepared new National Livestock Policy in 2005. There are two distinct objectives- supply of adequate livestock and livestock products for human consumption and supply of animal power and animal wastes for crop production and product processing (MoA, 2006).

Significant growth in the livestock sector has been observed, in which main contributor is commercial poultry sector. The demand for livestock products will be increased through the growing population, restrained growth of per capita income and higher income elasticity. The demand for milk, eggs, and mutton are increased by 6%, 5.2%, and 5.6% respectively with the growth rate of 4.4%. Annual growth rate for sheep and goat will be about 2%. There is a huge gap of 2 and 1/2 times, higher than country's milk production level, estimated in 2002. Therefore the target is to bridging this huge gap by 2021.

National Forest Policy, 1994

GOB has promulgated the National Forest Policy in 1994 and approved the Forestry Sector Master plan from 1995 to 2015. Both the documents have emphasized the afforestation program in the country with 20% coverage and increase the protected areas by 10% of the reserve forest land targeted in the Master plan by 2015 through the coordinated efforts of Government Organization (GO), Non Government Organizations (NGOs) and active participation of the people. One of the key objectives of the policy is to conserve soil and water resources and strengthening agriculture sector with the expansion of agro-forestry.

The Forestry Master Plan integrates various programmes for enhancing the involvement of rural population in forest sector activities. Its objectives include preserving existing values, conserving plants and animal variety and ensuring maximum benefit to local people (MoA, 2006). According to the Forest Act of 1927, 18% or 2.6 million hectares of forest land mass of the country is being managed by the Forest Department of Bangladesh. However, according to the Forest Department, recently this department controls 10.3% of land surface. In forestry sector, to sustain the ecological balance and to increase the employment opportunity from social and agro forestry expansion projects, increment about 2.84 million hectares of tree cover is of prime policy in this sector. The target is to increase forest cover 20% by 2021.

National Land Use Policy, 2001

The Ministry of Land has prepared the National Land Use Policy (NLUP) to fill-up an important policy gap in the country. The NLUP deals with land uses for several purposes including agriculture (crop production, fishery and livestock), housing, forestry, industrialization, railways and roads etc.

The Land Use Policy aims to ensure land use synchronization with the natural environment. The policy introduced a 'zoning' system in order to ensure the best use of land in different parts of the country according to their local geological differences to logically control the unplanned expansion of residential, industrial and commercial constructions. The main areas of land use in Bangladesh are agriculture, housing, forests, rivers, irrigation and sewerage canals, ponds, railways, commercial and industrial establishments, tea estates, rubber fields, horticulture gardens, the coastal belt, sandy riverbeds and char areas (MoEF, 2005).

Agricultural land is limited and is reducing about 1% per annum (MoEF, 2010). However, future growth of this sector will depend on the increment of the fertility of the land and efficiency of the irrigation. Also fallow land should be taken into consideration to expand the harvested crop land area. Urban growth rate is so alarming and has grown from 5% in 1961 to 25% in 2005. Therefore, the target is to reduce the burden of urban environment, decentralize the urban infrastructure and expand urban area with efficient urban planning and provide better urban facilities by 2021 (MoEF, 2010).

Future Socio-economic scenarios for ExSS and AFOLUB model

Socio-economic indicators

Quantified socio-economic activity level in 2025 is shown in Table 1 and 2. The population will be increased 1.3 times and GDP will be increased 3.5 times from 2025BaU than in 2005. Freight transport demand will be increased about 4.5 times with the increment of modal share of road vehicle which has the longer trip distance than other modes in 2025BaU.

Table 1: Estimated socio-economic indicators in 2025

Parameter	2005	2025BaU	2025CM	2025BaU/2005	2025CM/2005
Population (million)	140	180	180	1.3	1.3
No. of households (million)	29	43	43	1.5	1.5
GDP (trillion taka)	4	14	14	3.6	3.6
Gross output (trillion taka)	9	32	32	3.6	3.6
Primary industry (trillion taka)	2	5	5	2.7	2.7
Secondary industry (trillion taka)	4	15	15	3.8	3.8
Tertiary industry (trillion taka)	3	12	12	3.9	3.9
Passenger transport demand (billion passenger-km)	361	663	617	1.8	1.7
Freight transport demand (billion ton-km)	20	91	91	4.5	4.5

Output from agriculture and forestry will be decreased to 11% in 2025 from 16% in 2005 due to migrating the employment tendency from agriculture to industry or other service sector. Output from secondary industry will be increased by 3.8 times and contributes about 36% of the total output for the expansion of this industry in future by 2025.

Table 2: Output by industries in 2025

Industry	Output (billion Taka)		Ratio	Composition percentage	
	2005	2025	2025/2005	2005	2025
Agriculture and forestry	1	4	2.5	16%	11%
Fishing	0	1	3.2	5%	4%
Minning and Quarrying	0	1	3.9	2%	2%
Manufacturing	3	12	3.8	34%	36%
Construction	1	3	3.8	7%	8%
Electricity, gas & water	0	1	4.3	1%	2%
Wholesale and retail trade	1	2	3.5	8%	8%
Transport services	1	2	3.2	7%	6%
Real estate & renting business	0	2	4.0	6%	6%
Education and Health	0	1	4.7	3%	3%
Government services	0	1	5.4	2%	3%
Other private services	1	3	4.2	9%	10%
Total	9	32	3.6	100%	100%

Population

Population of Bangladesh in 2025 was collected from “Sectoral Need-based Projections in Bangladesh” (Bangladesh Bureau of Statistics, 2006). The population will reach 180 million in 2025 from 139 million (2005) (see Fig. 15).

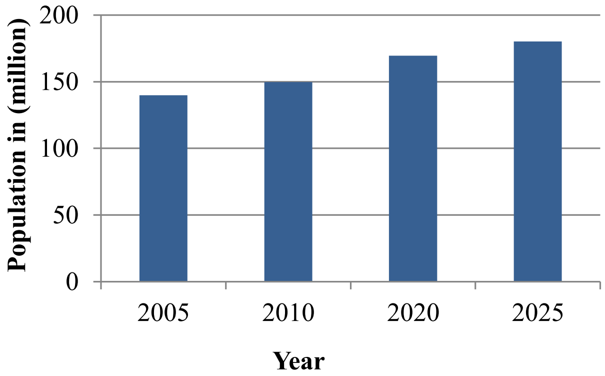

Fig. 15: Population

Households

This study assumes that in 2025 persons per household will be 4 persons in urban and 4.5 persons in rural households (4.9 persons in 2005). In 2025 there will be a significant increase in number of households, with a slight decrease in average number of persons per household and population increase. Number of households will rise from 29 million (2005) to 43 million in 2025 (Fig. 16).

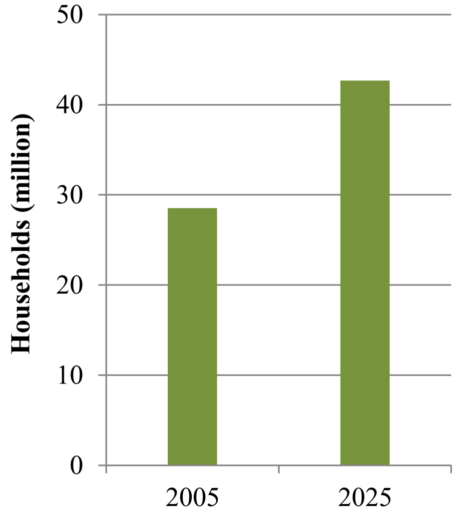

Fig. 16: Number of households

In order to modeling energy demand and CO_2 emission in future, several quantitative socio -economic assumptions were required as a premise. Socio-economic development strategies of Bangladesh are available in “Outline Perspective Plan of Bangladesh 2010-2021” (Ministry of Planning, 2010). Using above assumptions, detailed and consistent socio-economic indicators were projected using Extended Snap-shot (ExSS) tool.

Assumptions for the future socio-economic scenarios development by using ExSS, are described in Table 3.

Table 3: Socio-economic assumptions in 2025

Indicator	Assumption in 2025	Trend towards 2025
Population	In 2025 population will be 180 million (139 million, 2005).	1.45% increase per annum (2005-2025).
Demographic composition	In 2025 age group (0-14) will be 24% (34% in 2005), age group (15-64) 70% (59% in 2005), age group (65^+) 6% (6% in 2005).	Share of age group (0-14) will be decreased and age group (15-64) will be increased by 2025.
Population distribution	Urbanization rate will be increased from 25% (2005) to 41% in 2025.	People will migrate to urban centers in search for employment opportunities in industry or service sector.
Average number of persons per household	In 2025 it will be 4 and 4.5 urban and rural household respectively (average 4.9 in 2005 for both household).	Average number of persons per household will be decreased by 2025.
Modal share	Road vehicle-3% (2% in 2005), railway-0.1% (same as 2005), waterway- 0.2% (same as 2005), walk- 30% (49% in 2005) and bicycle- 65% (49% in 2005) in 2025.	Modal share of road vehicle and bicycle mode will be increased by 2025.
GDP	Average annual growth rate 7%.	Ministry of Finance reported that, GDP is average 6% from 2005 to 2010 and it will be increased 8% by 2015.
Industrial structure	Economic development will proceed through industrialization rather than agriculture.	In 2025, primary industry output will be decreased from 21% to 15% (2005), secondary industry output and tertiary industry output will be increased to 48% from 45% (2005) and to 37% from 34% (2005).

Economy

In 2025, GDP will be 14,351 billion taka which results about 3.65 times larger than in 2005. ExSS applies input-output (IO) analysis to project the future industrial structure. Table 4 shows changes in demand side of macro-economic indicators. Table 5 shows the future changes in private consumption of different industrial sectors.

Fig. 17 shows output from industries. The share of primary industry will be decreased from 21% (2005) to 15% in 2025. Share of secondary industry will be increased from 45% (2005) to 48% and tertiary industry from 34% (2005) to 37% in 2025.

Table 4: Macro-economic indicators (billion taka)

Indicator	2005	2025	2005/2025
GDP	3,933	14,351	3.6
GDP/capita (thousand taka)	28	80	2.8
Private consumption	3,111	12,028	3.9
Government consumption	204	788	3.9
Fixed capital formation	919	3,554	3.9
Export	756	2,922	3.9
Import	1,057	4,940	4.7

Table 5: Share of private consumption

Industry	2005	2025
Agriculture and forestry	10%	5%
Fishing	4%	2%
Minning and Quarrying	3%	4%
Manufacturing	56%	57%
Construction	0%	0%
Electricity, gas & water	2%	3%
Wholesale and retail trade	0%	0%
Transport services	3%	1%
Real estate & renting business	10%	11%
Education and Health	4%	6%
Government services	1%	3%
Other private services	7%	9%
Total	100%	100%

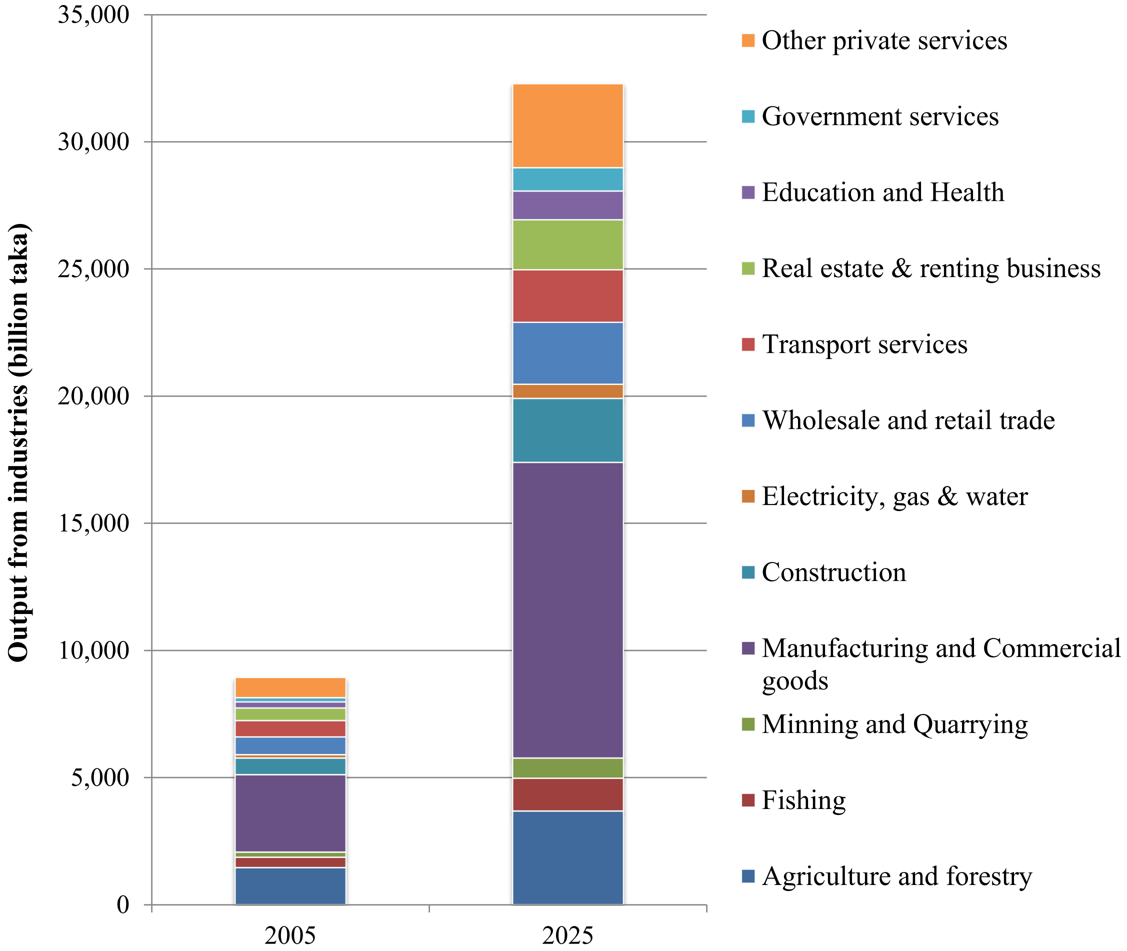

Fig. 17: Output from industries

Passenger transportation

The passenger transport demand in Bangladesh will be increased about 1.8 times from 361 billion passenger-km in 2005 to 663 billion passenger-km in 2025BaU. In 2025CM, transport volume will be slightly decreased to 617 billion passenger -km by adopting some low-carbon measures (see Fig. 18).

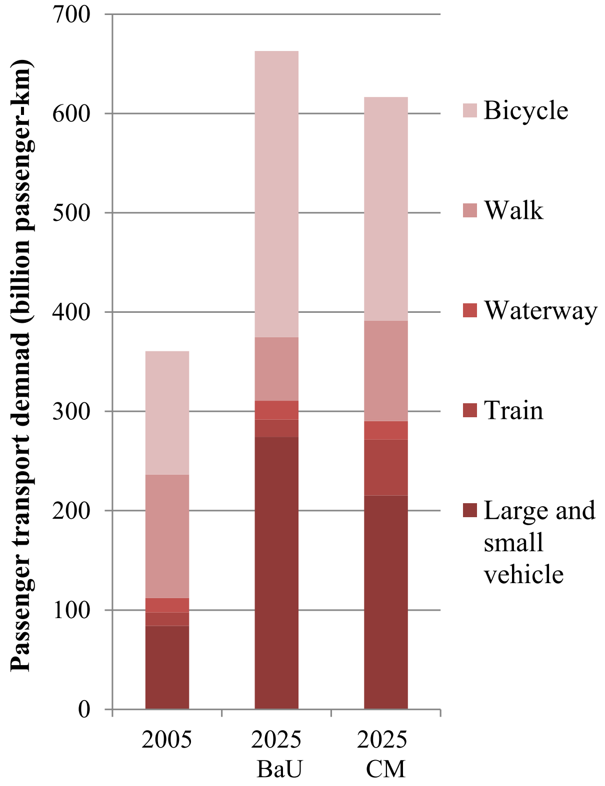

Fig. 18: Passenger transport demand

In 2025BaU, this study assumes that passenger transport modal share of vehicle and bicycle will be increased while share of walk is reduced. Private transport mode in road vehicle will be increased due to income growth and shortfall of public transport development. However, urban structure is assumed to be more compact than 2005, the average trip distances of road vehicle will be shorter than other transport in 2025BaU.

In 2025CM, under low-carbon measures, modal shift to railway was introduced. In addition, pedestrian road for walk and bicycle can be recommended as potential measure to reduce traffic jam and provide people a convenient and safe transport. Thus, 2025CM assumed modal share of walk will also be increased from BaU.

Freight transportation

Freight transport demand is also increased from 20 billion ton-km (2005) to 91 billion ton-km in 2025BaU (see Fig. 19) because of growth of industries.

In 2025BaU, freight transport demand will be increased about 4.5 times larger than in 2005. The transport demand depends on the industrial output which is 3.6 times (2025) larger than in 2005. Transport demand will be increased more than increase of output of industry because modal share of the road vehicles increased rather than freight waterway and railway for freight transport which will have the longer distance than other mode.

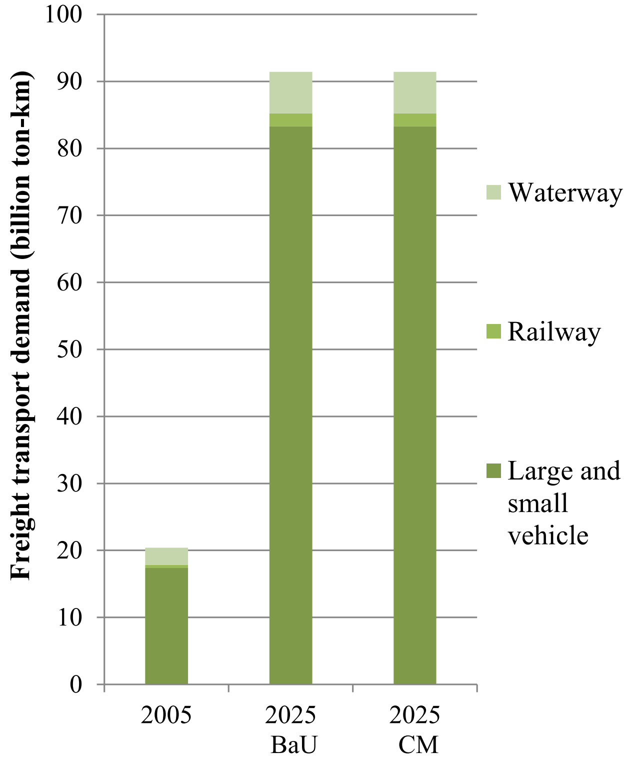

Fig. 19: Freight transport demand

Fig. 20: Freight transport

Crop harvested area

For the future projection on crop harvested area, this study considers the historical trend of production of individual crop from different literature surveys. According to the historical trend of the rice harvested area from 1970 to 2000, a drastic increment was observed of area from 9 million hectare to 10.7 million hectares. However, from 2000 to 2005, harvested area was slightly decreased. Again, from 2005 the rice harvested area was increased significantly from 10.5 million hectares to 11.3 million hectares and continued to 11.4 million hectares until year 2009. On the basis of the trend from previous to current in crop production, crop harvested area and also development strategies on crop production in MoEF (2010), this study assumes and projects the crop harvested area until 2025 for Bangladesh, shown in Fig. 21 and 22.

This study estimates crop harvested area by dividing the crop production (ton) by crop yield (ton/ha).

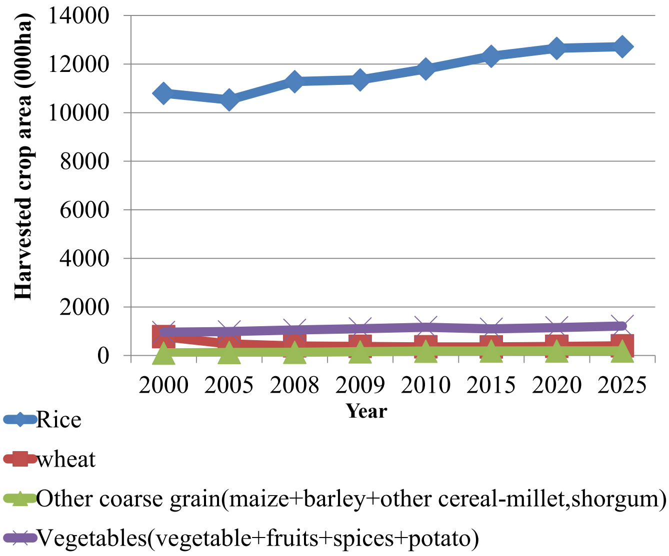

Fig. 21: Projected crop harvested area from 2000 to 2025

According to MoEF (2010) rice production in Bangladesh is expected to further increase from 30.7 million tonnes in 2007 to 35.4 million tonnes in 2015 and 36.8 million tonnes in 2021 respectively. This study extrapolates (see Fig. 21 and 22) the production data on 2025 by using the annual average growth rate from 2015 to 2021. Using these projected rice production data, this study projects the rice harvested area that will be increased to 12.6 million hectare in 2020 and 12.7 million hectare in 2025 respectively from 11.8 million hectare in 2010. This study simulates all other crops harvested area based on the same procedure. All other crops harvested area except sugar crop, keeping constant will be increased by 2025.

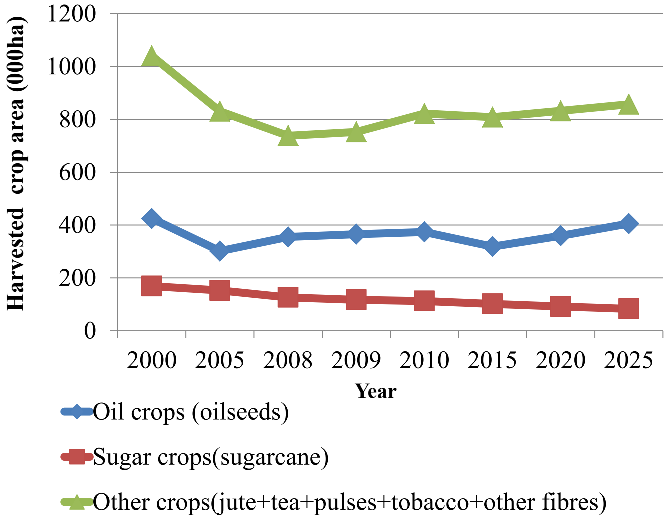

Fig. 22: Projected other crop harvested area from 2000 to 2025

Livestock number

"Outline Perspective Plan of Bangladesh Making Vision 2021 a reality", (Ministry of Planning, 2010) has projected future livestock number by 2015 and 2021. According to that report, recently, milk, egg and mutton demand has increased by 6%, 5.2% and 5.6% respectively. Based on such assumption, cattle, poultry and goat number are increased and buffalo and sheep number are kept almost constant by 2025 and projected livestock number by 2025 are shown in Fig. 23 and 24.

In this report, data on livestock and poultry number in 2015 is projected by using annual average growth rate from 2010 to 2015 and also projection on 2015, 2020 and 2025 used the same annual average growth rate from 2015 to 2021 respectively. For future projection of cattle and buffalo number from year 2015 to year 2025, the average annual growth rate of bovine animal from the projection table mentioned in the "Outline Perspective Plan of Bangladesh Making Vision 2021 a reality, 2010", is used. This study considers that bovine animals include cattle and buffalo.

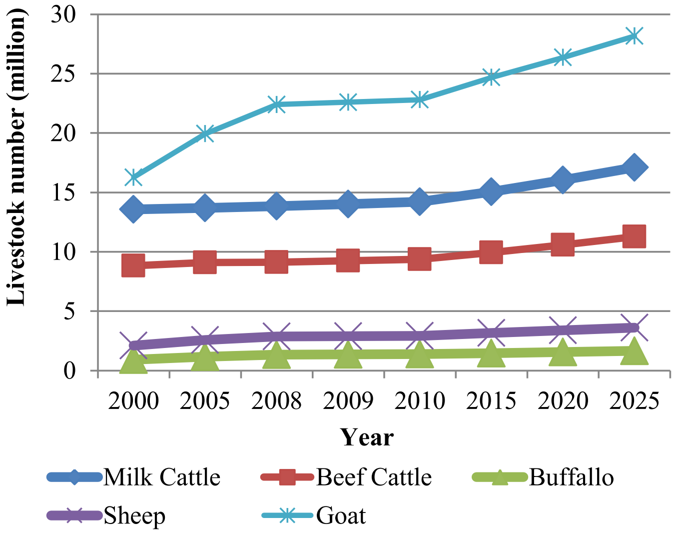

Fig. 23: Projected livestock number from 2000 to 2025

The cattle and buffalo number will be increased from 23 and 1.3 million in 2010 to 30 and 1.7 million by 2025 respectively. In addition, future projection of sheep and goat number from year 2015 to year 2025, the average annual growth rate of sheep and goat from the projection table mentioned in the above report, is used. In this study, goat number has significantly increased from 22.8 million in 2010 to 28 million by 2025.

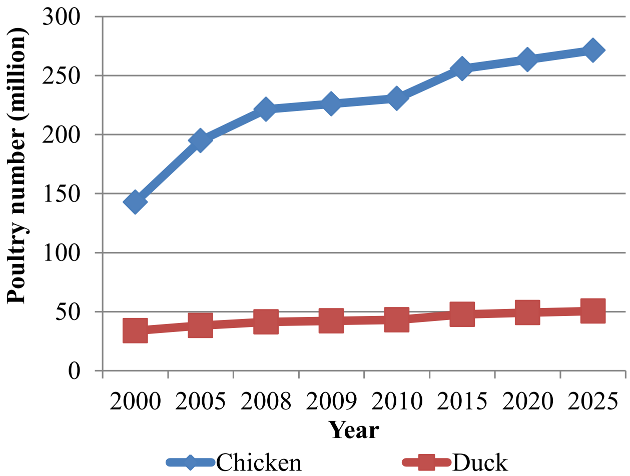

Fig. 24: Projected poultry number from 2000 to 2025

Future projection of chicken and duck number from year 2015 to year 2025 will follow the same procedure. Here, annual average growth rate of poultry was used as this study considers that it includes both chicken and duck number. Chicken number will be increased to 27 million by 2025.

Other landuse change

On the basis of above mentioned qualitative information from different literatures, this study projects the landuse change by 2025, shown in Fig. 25. Net cropped land will be decreased to 8.4 million hectare by 2025 from 8.8 million hectare in 2000. Projection of crop land in 2015 used annual average growth rate from 2009 to 2010. In 2020 and 2025, the area will be decreased by using growth rate from 2005-2010 to keep the consistency of growth. Therefore, crop land area will be decreased to face the growth of infrastructure development due to the population growth.

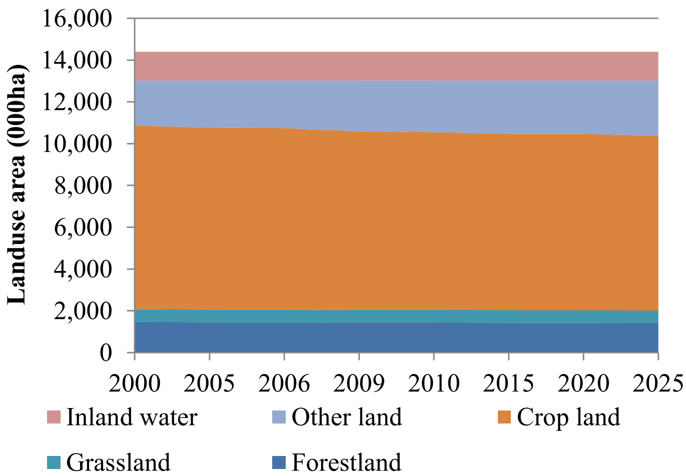

Fig. 25: Projected other landuse change from 2000 to 2025

Future projection of forest land in 2015 will use the annual average growth rate from 2000 to 2010. In 2020, production forest will be increased by 20% as taken from the projection data of rising of productive forest cover by 2021 from the report of "Outline Perspective Plan of Bangladesh Making Vision 2021 a reality, 2010". Other forest types are increased by using annual average growth rate of 2005-2010. By 2025, all other forest types are projected based on the annual average growth rate of 2000-2005.

Other land is defined as built up (urban and rural settlements, highways and others), wooded land and range land. Settlement will be increased drastically from 2.1 million hectare in 2000 to 2.6 million hectares by 2025 to meet the growing demand of housing. This study considers constant growth of grass land and inland water land without taking into account natural disaster and forest fire.

Energy demand and GHG emission

Energy demand (primary and final)

Projected result shows the total primary energy demand will increase from 20.5Mtoe in 2005 to 95.4Mtoe in 2025BaU, or about 4.6 times larger than 2005. By adopting energy-efficient low-carbon measures, energy demand will be decreased to 63.7Mtoe in 2025CM from 2025BaU (see Fig. 26).

In 2005, dominating energy source was biomass which covered about 40% of total energy demand and the second was natural gas in 2005. This structure will be changed in 2025BaU. Coal consumption increased from 2% in 2005 to about 28% in 2025BaU, which are mainly consumed by industrial and power sector. This study shows the reduction of share of traditional biomass from 40% (2005) to 16% in 2025BaU.

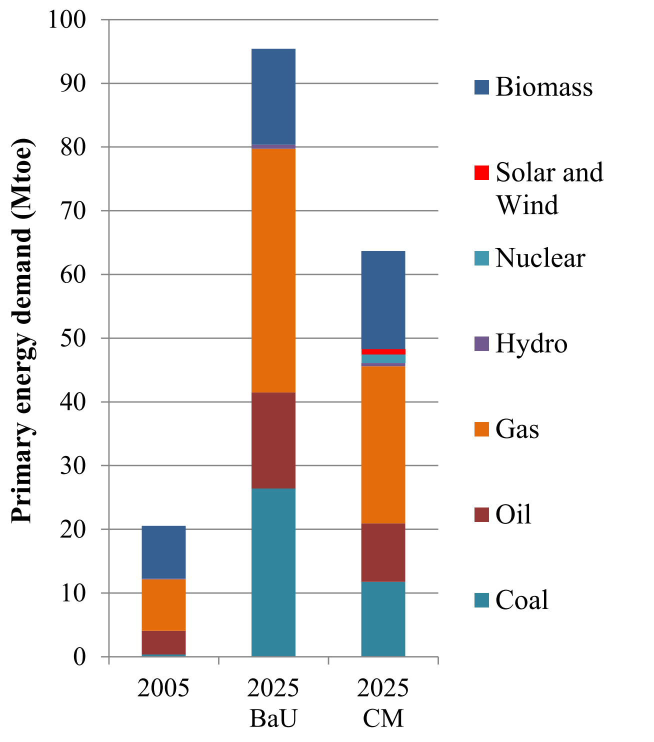

Fig. 26: Primary energy demand by fuel type (excluding non-energy use)

In demand side, largest share of energy was consumed by residential sector of about 68% in 2005 will be decreased to 66% in 2025BaU by using improved energy efficiency of household electric devices and electricity supply.

Due to the increased demand of transport, energy demand of transport sectors also increased significantly. Passenger transport demand will increase about 1.8 times and freight transport demand will increase about 4.5 times in 2025BaU from 2005, resulted 2.8 and 4.2 times higher energy demand in BaU2025 than 2005 respectively.

Energy consumption of industrial sector is 3.7Mtoe and transport sector is 1.5Mtoe of the total final energy demand in 2005 and increased about 3.5 times due to the increment of industrial production and 3.5 times due to rapid transport growth respectively (see Fig. 27).

In 2025CM, share of residential sector will be 66%, same as 2025BaU. Transport sector will consume about 6% and commercial sector 4% of the total energy demand.

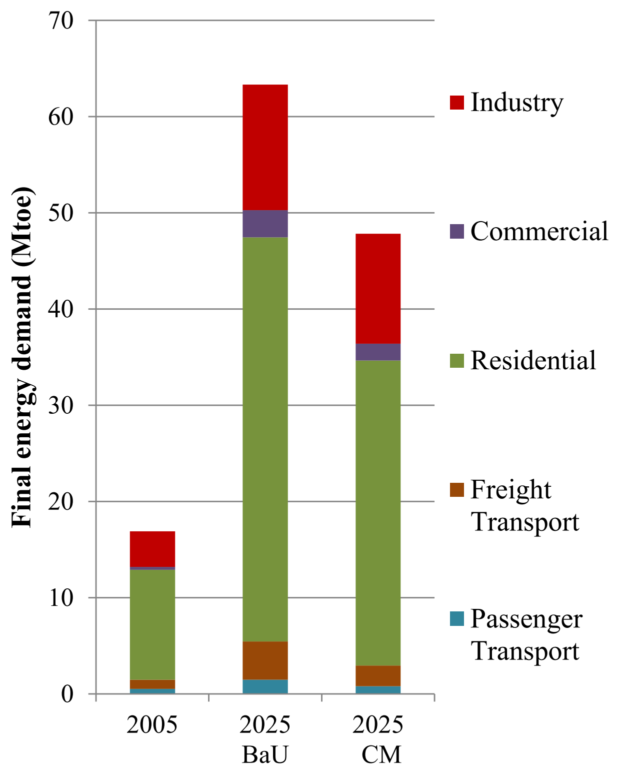

Fig. 27: Sectoral final energy demand

Power sector

Bangladesh has potential amount of coal reserves, to meet the government's target in power sector, coal will be the possible fuel instead of natural gas for electricity generation. Fig. 28 shows the growing usage of coal in 2025 for the generation of electricity to meet the target of the government that ensure electricity for all by 2021 (MoEF, 2010). In 2025BaU, share of coal consumption will be increased drastically and only hydro is considered as renewable energy for power generation.

This study also recommends the alternative fuel to reduce the CO_2 emission in 2025CM. This study introduces nuclear energy and renewables (solar and wind) and reduced share of coal for the reduction of CO_2 emission. However, in 2025CM the projected share of nuclear energy was not followed in "Outline Perspective Plan of Bangladesh, Making Vision 2021 a reality", (Ministry of Planning, 2010) due to the indeterminate future of the nuclear power plant.

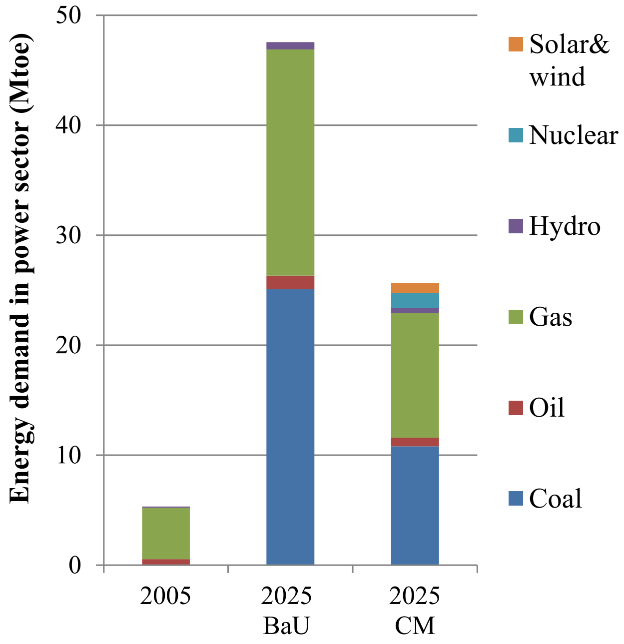

Fig. 28: Energy demand by fuel in power sector

Industrial sector

Energy demand in industrial sector (shown in Fig. 29) will be increased about 3.5 times with 74% increase of energy demand in manufacturing industry in 2025BaU from 2005. In 2025BaU, natural gas will contribute largest share of 74% increase of energy demand.

Due to the shortage of natural gas reserves, this study estimates about 40% decrease with applying feasible countermeasures in this sector in 2025CM. Also, coal and oil usage will be decreased by 30% and 23% respectively with similar electricity usage in 2025CM.

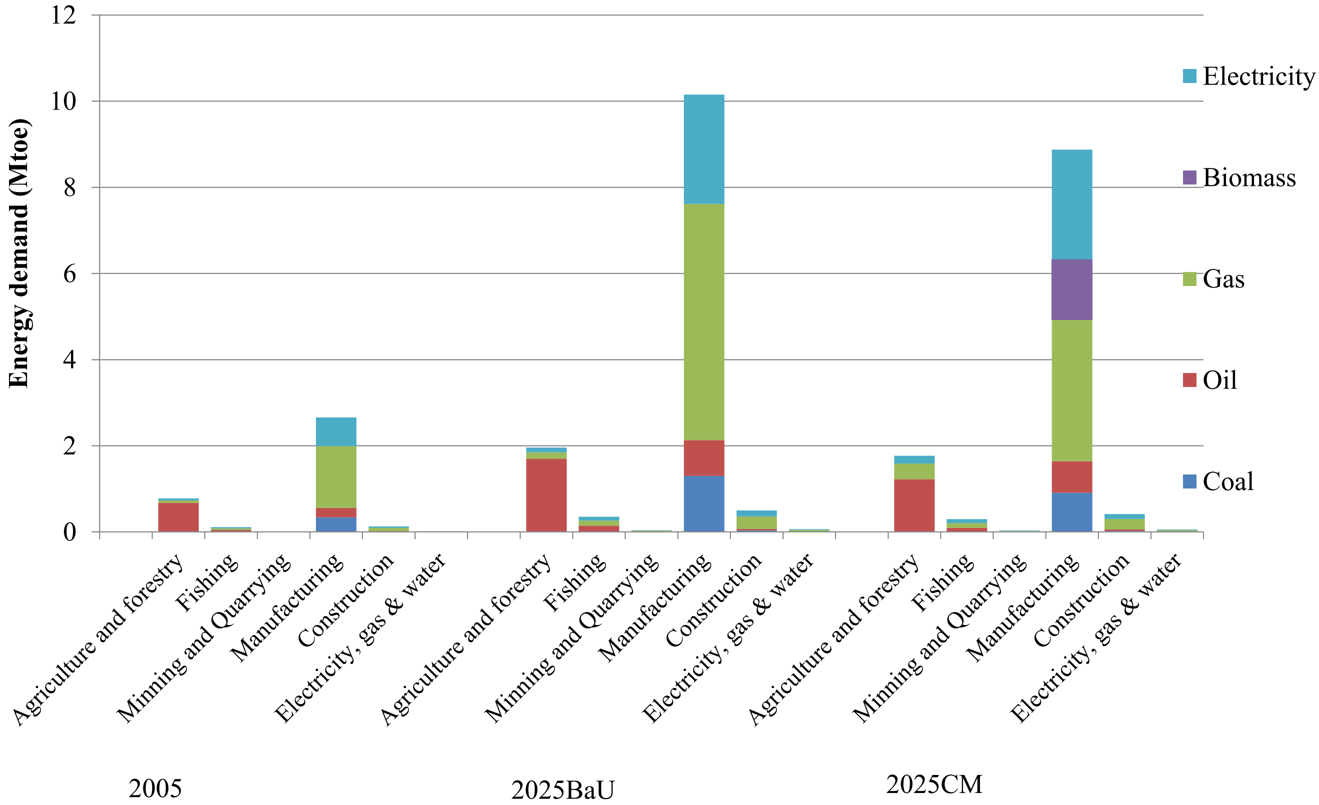

Fig. 29: Energy demand by fuel in power sector

CO_2 emission from energy sector

The CO_2 emission will be increased from 31.7MtCO_2 in 2005 to 240.7MtCO_2 in 2025BaU. CO_2 emission from different sectors is shown in Fig. 30.

In 2025BaU, the main contributor of CO_2 emission is residential and emits about 63% of total emission. Industrial sector, commercial sector and transport sector cover 23%, 7% and 7% respectively. In 2025BaU, CO_2 emission is increased more than GDP growth rate. The reasons are as follow: 1) In residential sector, biomass share is reduced and other fuels especially gas and coal (power sector) are increased. (see appendix). Therefore, even though the final energy demand was increased by only 3.7 times however, CO_2 emission was increased more about 12.6 times. 2) In power supply sector, coal increased its share (0% to 53%) (see appendix) while gas reduced from 88% to 43%.

In 2025CM, potential of emission reduction is about 45% of 2025BaU through introducing mitigation measures in 2025CM.

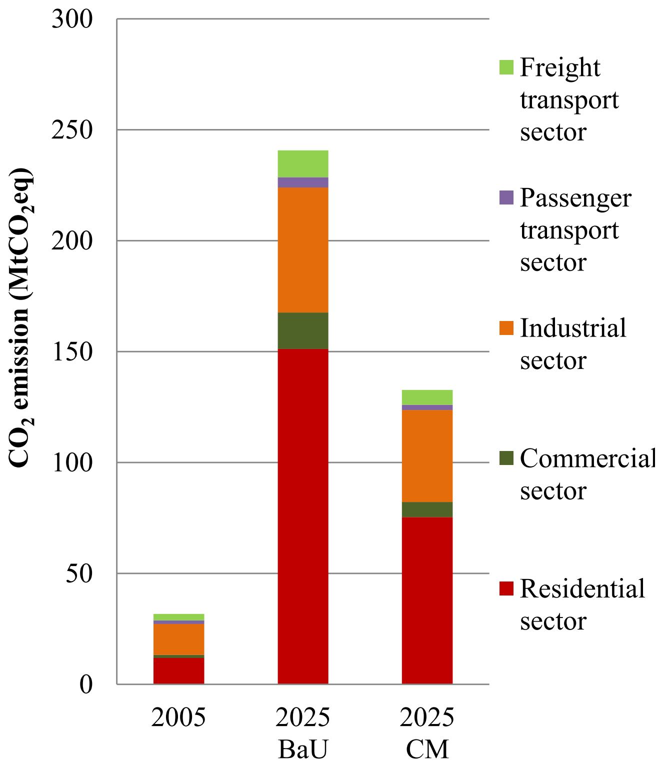

Fig. 30: CO_2 emission from energy sector

GHG emission from agriculture

Flooded agricultural land is the main source of CH_4 emission and nitrogenous fertilizer also contributes to N_2O emission in agricultural sector of Bangladesh. This study estimates GHG (CO_2, CH_4 and N_2O) emission from agriculture sector from 2000 to 2025, shown in Fig. 32. In this sector, the emission sources of rice paddy cultivation, enteric fermentation and manure management causes CH_4 emission and managed soil with applying nitrogen fertilizer and manure management emits N_2O. In Bangladesh, enteric fermentation accounted of highest amount of emission in agriculture about 11MtCO_2eq. of CH_4 in 2000. The share of irrigated rice paddy cultivation was only 40% in 2000, emitted 7MtCO_2eq, which about 18% of the total emission. Manure management (livestock dung and urine) contributed 11MtCO_2eq of N_2O, which shared 65% of the total N_2O emission in this sector. Application of nitrogen fertilizer in the context of managed soil, another source of N_2O emission contributed about 6MtCO_2eq/yr. The GHG emission gradually increased to 47MtCO_2eq in 2010 from 41 MtCO_2eq in 2000. It was assumed that increment trend would be continued up to 2025. About 38% of N_2O emission will be increased by 2025 compared to the emission in 2000 due to the increased dependency on the utilization of artificial fertilizer (mainly nitrogenous) to manage soil fertility and increment of crop yield. Livestock manure will contribute about 8.2MtCO_2eq of N_2O emission in 2025 from 6MtCO_2eq in 2000. In BaU case, total GHG emission in total agriculture sector will be increased about 1.4 times or 28% by 2025 from total GHG emission in 2000.

Fig. 31: Flooded paddy land

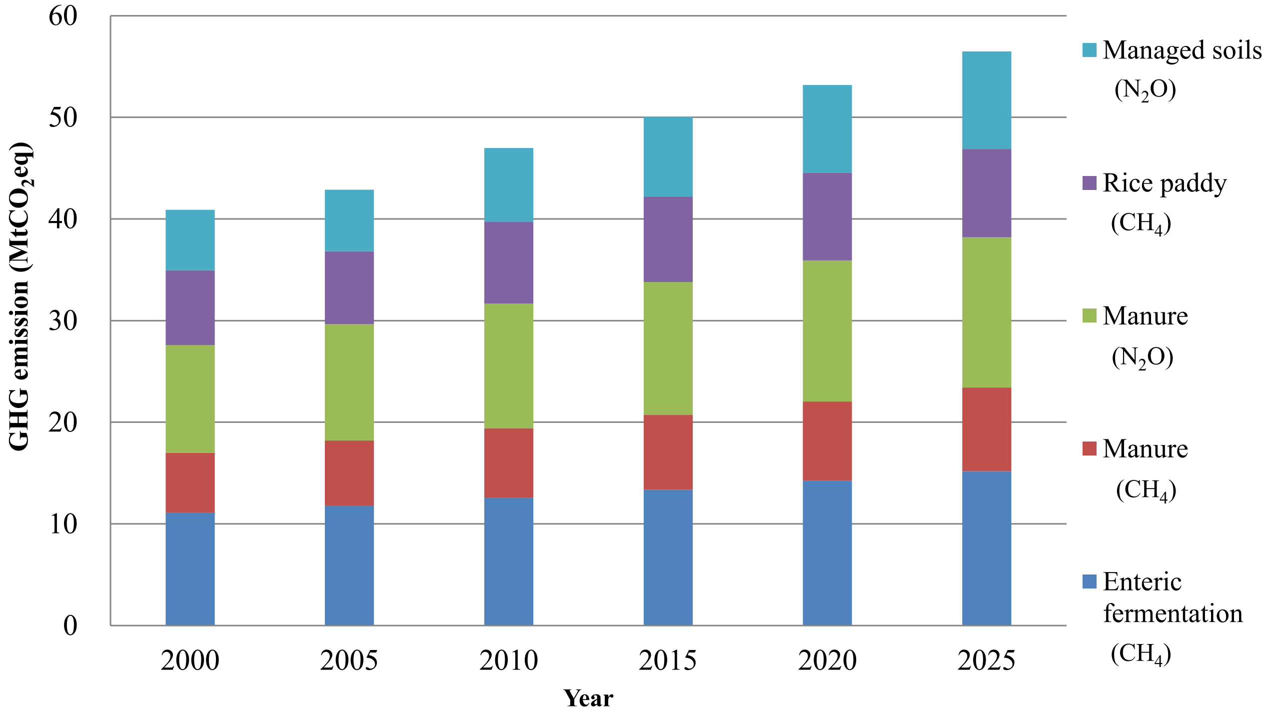

Fig. 32: Projected GHG emission from agriculture sector from 2000-2025

GHG emission from LULUCF sector

This study estimates CO_2 emission from LULUCF sector in Bangladesh from 2000 to 2025, shown in Fig. 33. Net emission from LULUCF sector was estimated about 13MtCO$_2$eq in 2000, mainly emitted from the forest and grassland conversion (3.6MtCO$_2$eq), emission and removal from soil (16MtCO$_2$eq) and emission ranges in forest and other woody biomass stocks as carbon sequestration (5.9MtCO$_2$eq). The emission was estimated to significant increase of 12% by 2010, due to substantial decrease in cropland and forestland area and considerable increase in settlement for growing population from 2000 to 2010. This trend will be discontinued by decreasing the emission to 12MtCO$_2$eq and 13MtCO$_2$eq by 2020 and 2025 from 15MtCO$_2$eq in 2010, with the government's several development strategies, especially 20% increment of production forest by 2021. Such development actions are expected to contribute in net sequestration of CO_2, which amounted to -6.4 and -6.4MtCO$_2$eq, in 2020 and 2025 respectively.

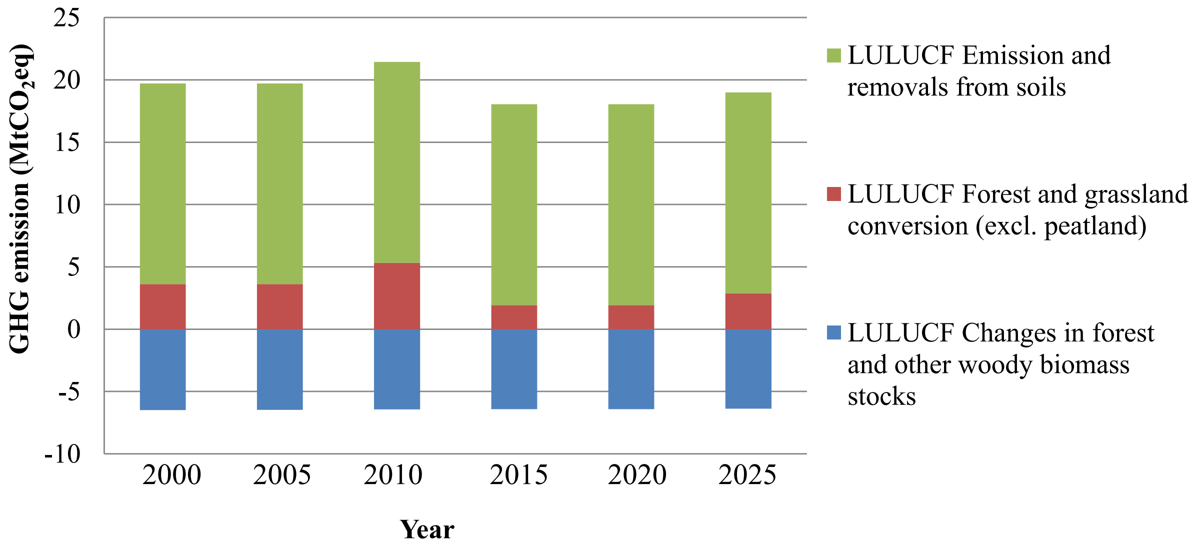

Fig. 33: Projected GHG emission from LULUCF sector from 2000-2025

Total GHG emission from and agriculture and LULUCF sector

The net total GHG emission in Bangladesh from agriculture and LULUCF sectors from 2000 to 2025 is shown in Fig. 34. The trend shows gradual increment from 2000 to 2025 except 2015, estimated the same emission as 2010 emission level.

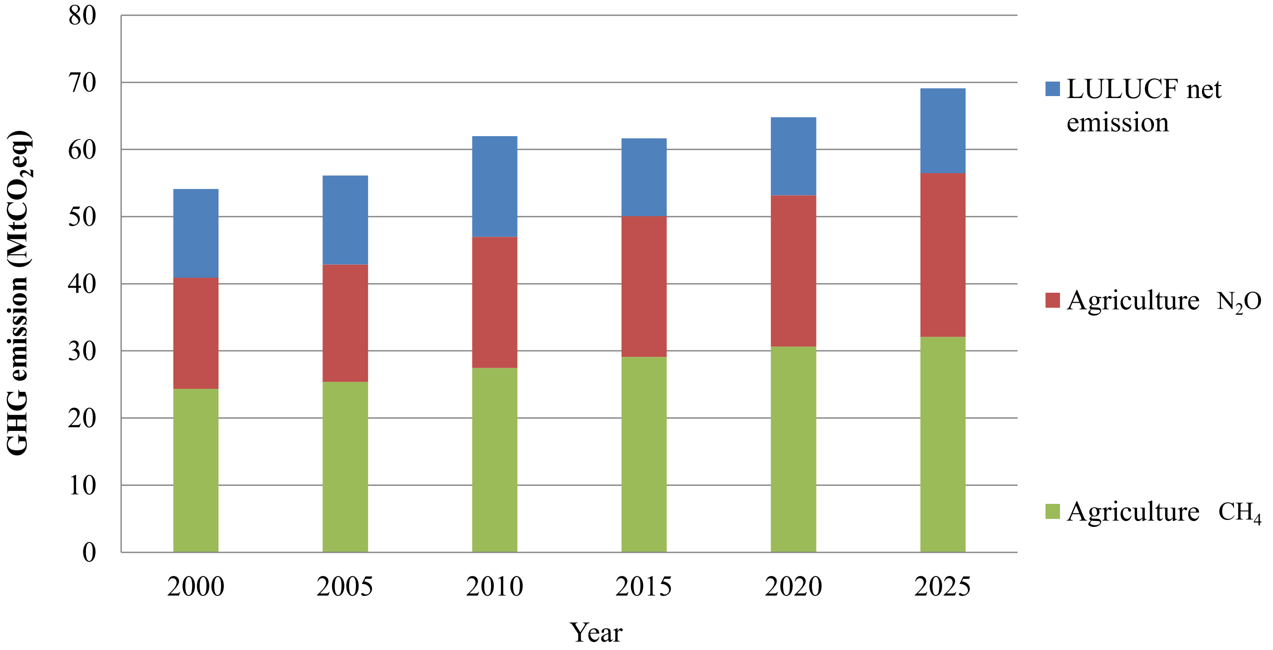

Fig. 34: Projected GHG emission from agriculture and LULUCF sectors from 2000-2025

Total GHG emission and per capita emission

The annual GHG emission of Bangladesh was estimated 87.9$MtCO_2eq$ in 2005. In 2025BaU the GHG emission will be increased to 309.8$MtCO_2eq$ which is about 3.5 times of 2005. In 2025CM the GHG emission will be reduced to 179.4$MtCO_2eq$ which is about 42% smaller than 2025BaU (Fig. 35).

In 2005, the per capita GHG emission of Bangladesh was 0.6tCO_2 which will be increased up to 1.7tCO_2 in 2025BaU. However it is still much lower than current per capita emission of most of the other countries, it will be reduced to 0.98tCO_2 in 2025CM (see Fig. 36).

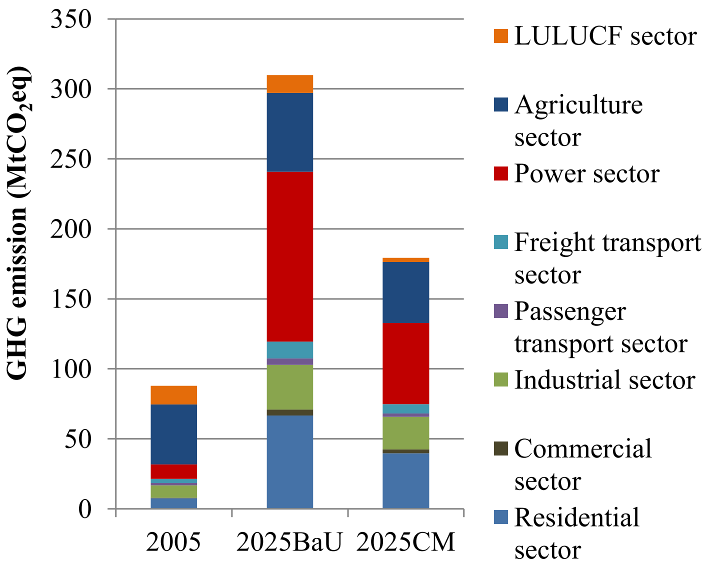

Fig. 35: Projected total GHG emission

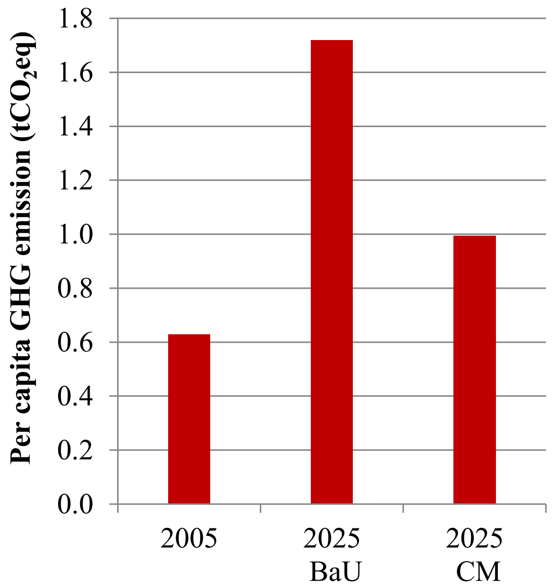

Fig. 36: Per capita GHG emission

Mitigation potential

Mitigation potential towards LCS in Bangladesh by 2025

The GHG emission in Bangladesh was 87.9MtCO_2eq in 2005. In 2025BaU, CO_2 emission will be increased to 309.8MtCO_2eq. However in 2025CM, the CO_2 emission will be reduced to 179.4MtCO_2eq by adopting mitigation measures.

In energy sector, residential sector is the largest CO_2 emission sector results the emission about 63% of total. The next is industrial sector 23%, commercial sector 7% and transport sector 7% in 2025BaU. The largest reduction of 70.8 MtCO_2eq can be achieved by improving energy efficiency, where residential and commercial sectors accounted 58.6MtCO_2eq, industrial sector 5.1MtCO_2eq and transport sector (passenger and freight) 7.1MtCO_2eq. The second largest reduction can be achieved by power supply (reducing transmission loss and fuel switch to renewables and nuclear) which contributes about 30.9MtCO_2eq. A sum of fuel switch (from oil to gas) in all demand sectors also will be contributed 5.8MtCO_2eq where major share is covered by residential, commercial and industrial sector by 5%.

In agriculture sector, CH_4 emission from enteric fermentation and manure management combinedly is projected to emit 23.4MtCO_2eq in 2025BaU, which is about 27% more than the emission in 2000. CH_4 from rice paddy field emits about 8.7MtCO_2eq. Manure management and soil management emits N_2O of about 24.4MtCO_2eq in 2025BaU, 32% more compared to the N_2O emission in 2000. In LULUCF sector, this model estimated the net emission of 12.6MtCO_2eq. In which changes in forest and other woody biomass stocks, forest and grassland conversion (excluding peat land) and emission and removal from soils contributes of about –6.4MtCO_2eq, 2.9MtCO_2eq and 16.1MtCO_2eq of CO_2 emission in 2025.

Fig. 37 shows the mitigation potential achieved by applying several mitigation technologies.

To reduce the GHG emission, the following mitigation measures are essential;

Residential and commercial sector;

- Energy efficient lighting (compact fluoresce lights, CFL) and electric fan.
- Efficient cooking system (improved cooking stove, using metered gas).
- Efficient refrigerator.
- Efficient cooling system.

Industrial sector;

- Energy efficient furnace, steam boiler and motor.
- Fuel switch from oil to natural gas.

Transport sector;

- Energy efficiency improvement in old and reconditioned engines of road vehicles.
- Modal shift from private vehicle to public transport and railway.

Power sector;

- Fuel Switch.
- Reduction of transmission loss.

Agricultural sector;

- Enteric fermentation.
- Manure management.
- Rice cultivation.
- Managed soil.

LULUCF sector;

- Long rotational artificial reforestation.
- Medium rotation participatory coastal plantation.
- Medium rotation sal plantation.
- Medium rotational artificial reforestation.
- Short rotational participatory woodlot plantation.

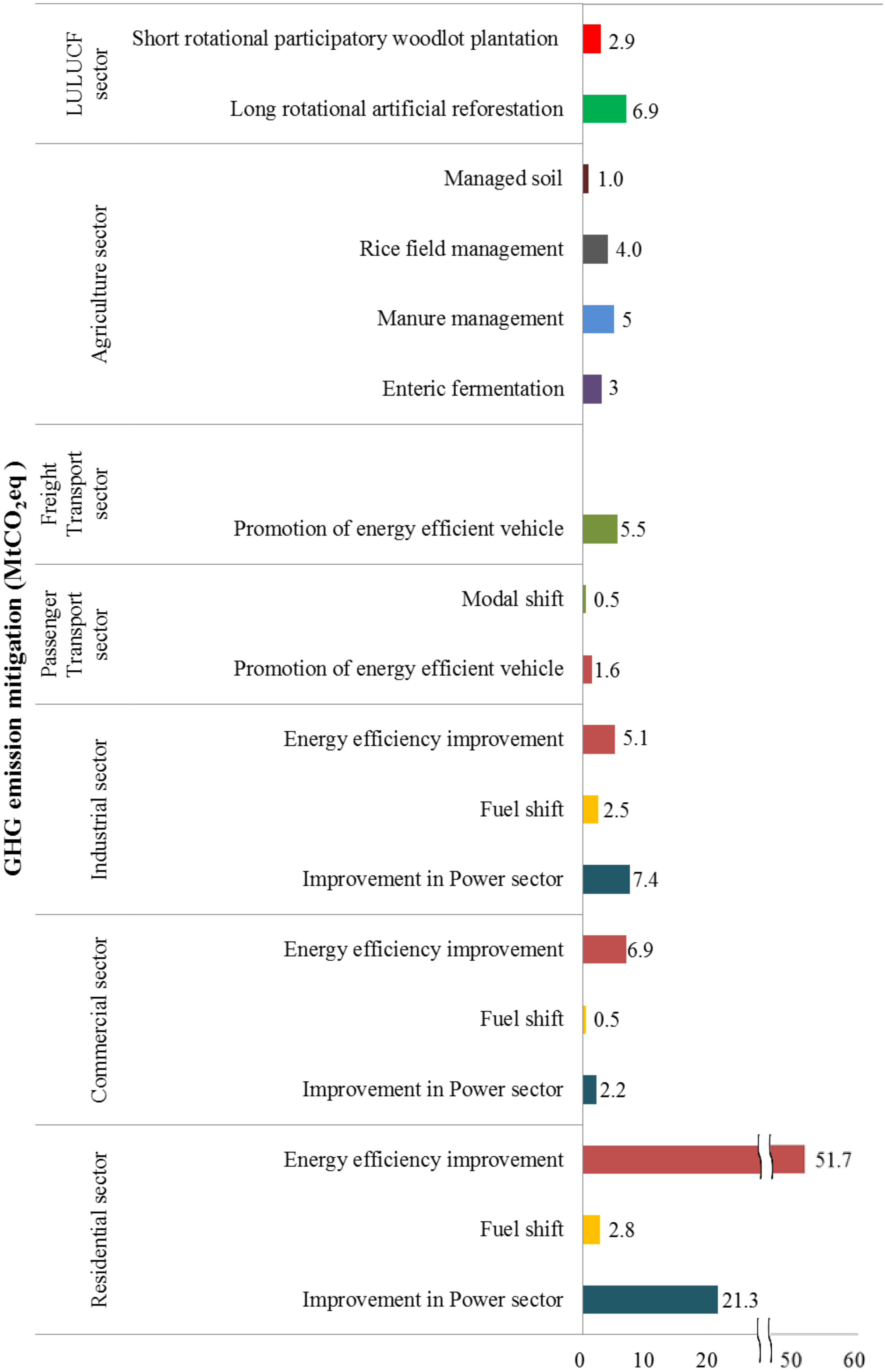

Fig. 37: GHG emission mitigation potential

GHG emission reduction measures

(a) Residential sector

The increment of energy demand in the residential sector depends on the population growth, number of households and per capita GDP. Population will increase to 180 million and number of household to 43 million in 2025.

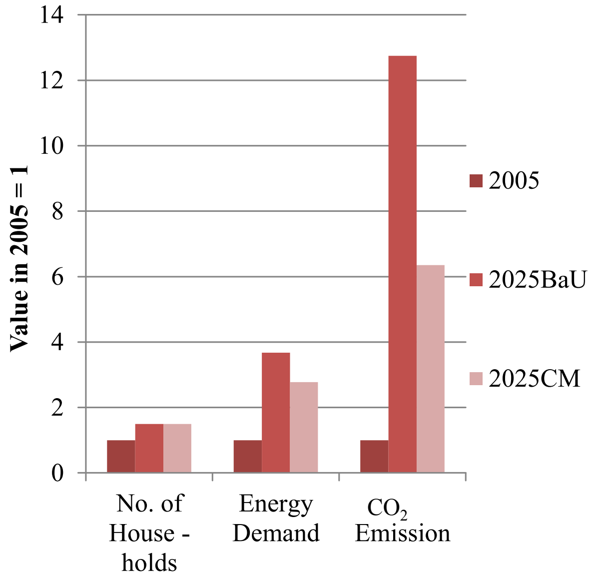

Fig. 38: Changes from 2005 to 2025 in residential sector

In 2025BaU, energy demand in residential sector will be increased to 42Mtoe which is about 3.7 times larger than in 2005. CO_2 emission will be increased to 151MtCO_2eq that is 12.8 times larger than in 2005. Relative changes in number of households, energy demand and CO_2 emission is shown in Fig. 38. Fig. 39 shows emission reduction in residential sector. About 76MtCO_2eq of CO_2 emission reduction can be achieved by adopting reduction measures e.g. energy efficiency improvement, fuel shift and improvement in power sector (it reduces emission from electricity generation which is consumed by residential sector). Efficient lighting, refrigerator and cooling have the most potential and cover 53MtCO_2eq or 71% of reduction of CO_2 emission in this sector. Fig. 40 shows the percentage of CO_2 emission reduction by energy service in residential sector in total GHG emission reduction. Residential sector including power supply will contribute about 58% reduction of CO_2 emission in total GHG emission. Using photo voltaic lights as lighting will share highest reduction of 27% in total GHG emission reduction.

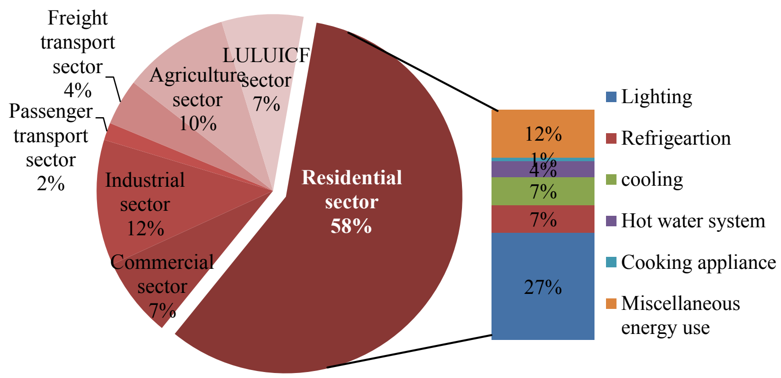

Fig. 40: Percentage of CO_2 emission reduction of energy sector in total GHG emission reduction

(b) Commercial sector

Energy demand in commercial sector is driven by growth of tertiary industry output. In 2025BaU, the output of the tertiary industry will be increased 3.9 times larger than in 2005 (Fig. 41)

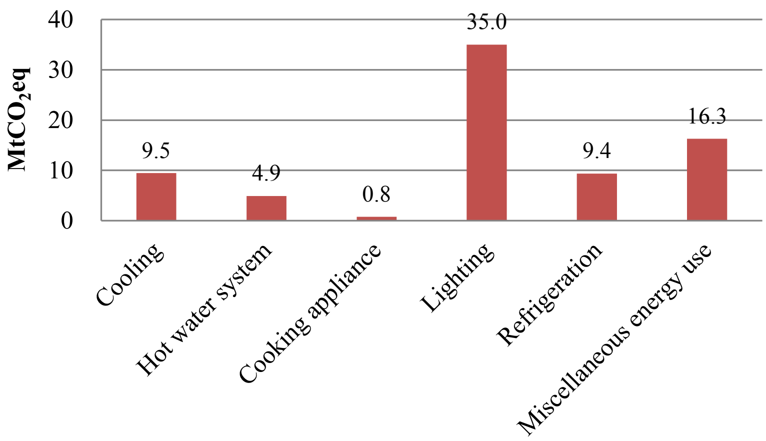

Fig. 39: CO_2 emission reduction by residential energy services in energy sector

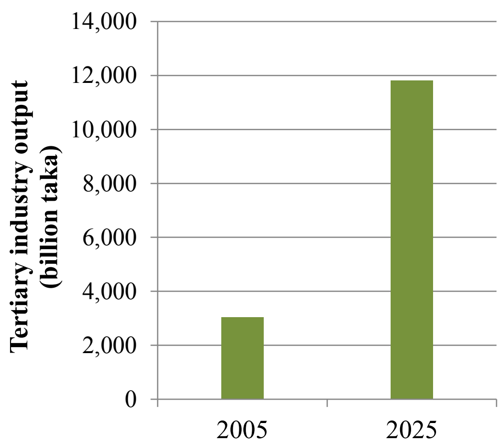

Fig. 41: Output from tertiary industries

and energy demand will be increased to 2.8Mtoe and CO_2 emission 16MtCO_2eq, which is about 9.5 and 11.6 times greater than 2005. Relation of changes in output, energy demand and CO_2 emission is shown in Fig. 42.

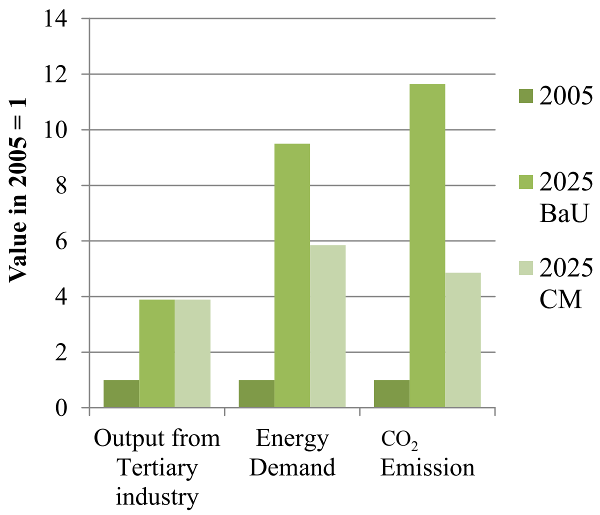

Fig. 42: Changes from 2005 to 2025 in commercial sector

In CM2025, reduction measures e.g. improvement in energy efficiency (electric devices, insulation buildings), efficiency improvement in power sector and fuel switch are the potential options for CO_2 emission reduction, reduces about 9.0MtCO_2eq and contributed about 8% of the total emission reduction from energy sector. Fig. 43 shows the reduction of CO_2 emission by energy service. Fig. 38 and 42 show that interestingly the energy consumption of commercial sector will be increased drastically compared to residential sector due to increased energy consumption in different commercial sectors (health, education, real-estate) in 2025BaU. This increase will be more than proportional to increase of number of household and output of tertiary industry because, when per capita GDP increased, energy demand per household and per output also will increase. It is consistent with observed trend of energy demand in Bangladesh since 2000. Fig. 44 shows the percentage of CO_2 emission reduction of 7% by energy service of commercial sector including power supply in total GHG emission reduction.

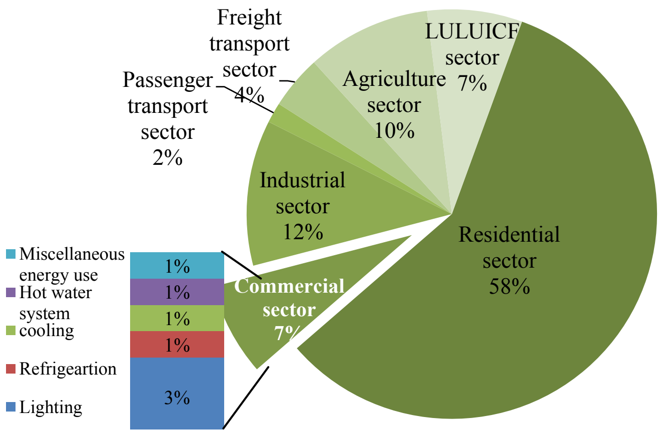

Fig. 44: Percentage of CO_2 emission reduction of energy sector in total GHG emission reduction

Reduction policy frame for residential and commercial sector is shown in Fig. 45.

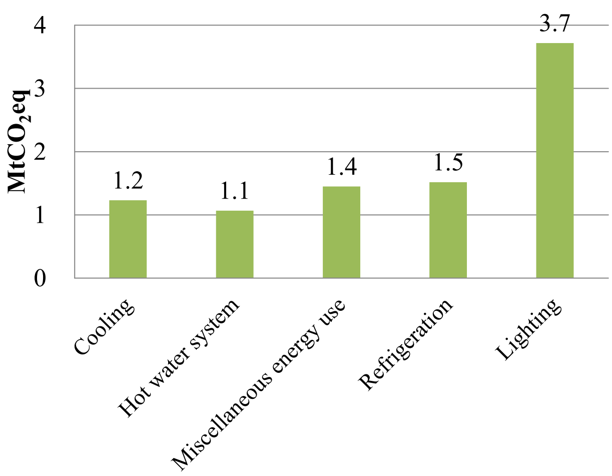

Fig. 43: CO_2 emission reduction by commercial energy

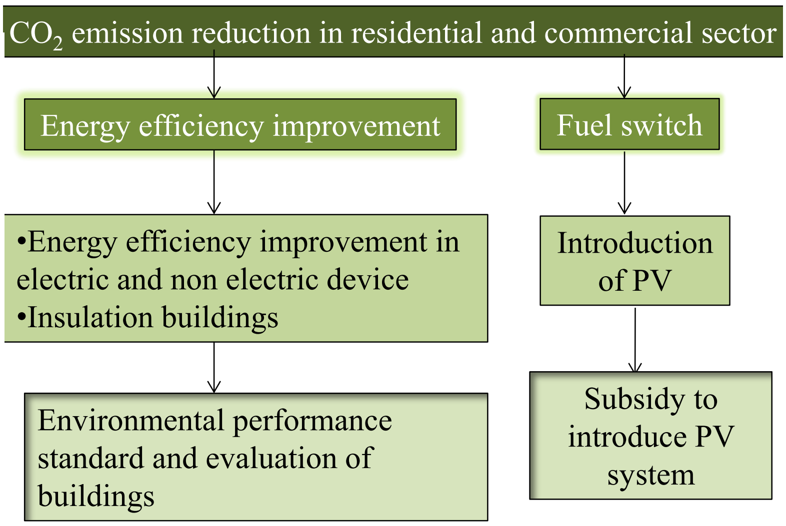

Fig. 45: Reduction policy frame for residential and commercial sector

(c) Industrial sector

"Industrial sector" in this study comprises of primary and secondary industries. This report assumed that GDP growth rate will be 7% by 2025. The outputs of the industries will be increased to 20,464 billion taka in 2025, which is 3.5 times larger than 5,897 billion taka in 2005. Energy demand in industrial sector increases to 13.1Mtoe in 2025 from 3,700ktoe in 2005. Relation of changes in number of household, energy demand and CO_2 emission is shown in Fig. 46. Without adopting any low-carbon measure in 2025BaU; the CO_2 emission will be increased to 56MtCO_2, about 4 times larger than in 2005. In 2025CM, by adopting low-carbon measures e.g. energy efficiency improvements and fuel switch, CO_2 emission will be decreased to 41MtCO_2. Fig. 47 shows the reduction options by energy services for emission reduction in industry. The energy demand by energy service by energy type in industry is shown in Table 6. Fig. 48 shows that industry including power supply contributes 12% CO_2 emission reduction in total GHG emission reduction.

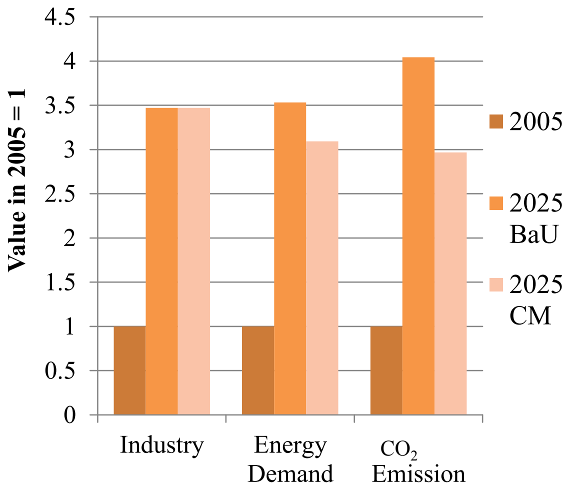

Fig. 46: Changes from 2005 to 2025 in industry

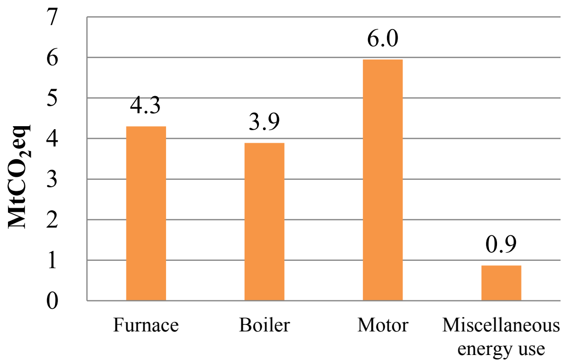

Fig. 47: CO_2 emission reduction by industrial energy services in energy sector

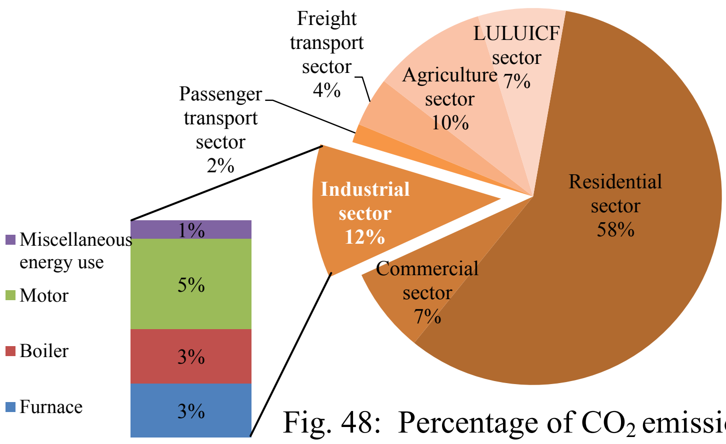

Fig. 48: Percentage of CO_2 emission reduction in total GHG emission reduction

Table 6: Energy service demand by fuel in industry (Mtoe)

2005	Coal	Oil	Gas	Biomass	Electricity	Total
Furnace	0.2	0.1	0.6	0	0.1	1.0
Boiler	0.1	0.4	0.8	0	0	1.4
Motor	0	0	0	0	0.6	0.6
Others	0	0.4	0.2	0	0.1	0.7
Total	0.4	1.0	1.6	0	0.8	3.7
Share	9%	26%	44%	0	21%	100%
2025BaU						
Furnace	0.7	0.4	2.3	0	0.3	3.6
Boiler	0.5	1.3	3.0	0	0	4.8
Motor	0	0	0	0	2.3	2.3
Others	0.1	1.1	0.8	0	0.4	2.4
Total	1.3	2.7	6.1	0	2.9	13.1
Share	10%	21%	47%	0	22%	100%
2025CM						
Furnace	0.5	0.2	1.2	0.3	0.3	2.5
Boiler	0.3	1.0	2.0	1.0	0	0
Motor	0	0	0	0	2.2	2.2
Others	0.1	0.9	0.8	0.1	0.5	2.4
Total	0.9	2.1	4.0	1.4	3.0	11.4
Share	8%	18%	35%	12%	26%	100%

Fig. 49: Power industry and ready-made garments

(d) Power supply sector

In this study, 2025BaU followed the projected composition of energy mix in existing planning, (Planning commission, 2010) without applying any renewable energy except hydro power. On the other hand, in 2025CM, reduction measures e.g. reduction of transmission loss and fuel switch from non-renewable to renewable energy (solar, hydro, nuclear energy) reduced the emission by 30.9MtCO_2 and contributed about 29% of total CO_2 emission reduction. In 2025CM, nuclear energy and renewables (solar, wind) and less share of coal reduce CO_2 emission. Fig. 50 shows the CO_2 emission in 2025BaU and emission reduction of 52% in 2025CM in power sector, considering the application all sector's reduction measures in power. Composition of possible energy mix for power generation is shown in Table 7. Reduction policy frame for industrial and power sector is shown in Fig. 51.

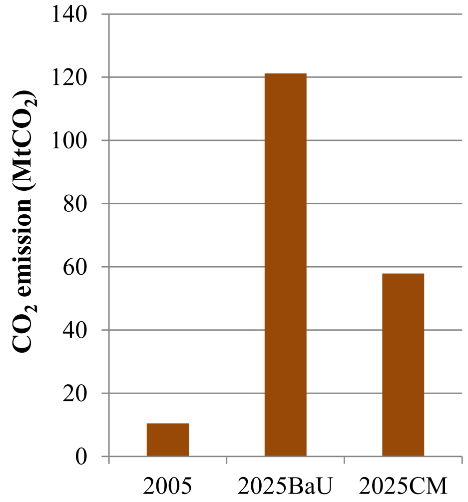

Fig. 50: CO_2 emission by power sector

Table 7: Power supply indicators (Mtoe)

2005	Coal	Oil	Gas	Hydro	Nuclear	Solar&Wind	Total
Fuel input	0	0.5	4.7	0.1	0	0	5.3
Generation	0	0.1	1.7	0.1	0	0	2
Own-use(5.2%)	0	0	0.1	0	0	0	0
Transmission-loss(8.2%)	0	0	0.1	0	0	0	0
Final consumption	0	0.1	1.5	0.1	0	0	2
Share	0%	10%	88%	2%	0%	0%	100%
2025BaU							
Fuel input	25.1	1.2	20.6	0.6	0	0	48
Generation	9.0	0.3	7.5	0.6	0	0	17
Own-use(5.2%)	0.5	0	0.4	0	0	0	1
Transmission-loss(6.3%)	0.6	0	0.5	0	0	0	1
Final consumption	8.0	0.3	6.6	0.6	0	0	15
Share	53%	3%	43%	1%	0%	0%	100%
2025CM							
Fuel input	10.8	0.8	11.3	0.5	1.3	0.9	26
Generation	3.9	0.2	4.1	0.5	1.3	0.9	11
Own-use(5.2%)	0.2	0	0.2	0	0.1	0	1
Transmission-loss(5.3%)	0.2	0	0.2	0	0.1	0	1
Final consumption	3.5	0.2	3.7	0.5	1.2	0.8	10
Share	42%	3%	44%	2%	5%	3%	100%

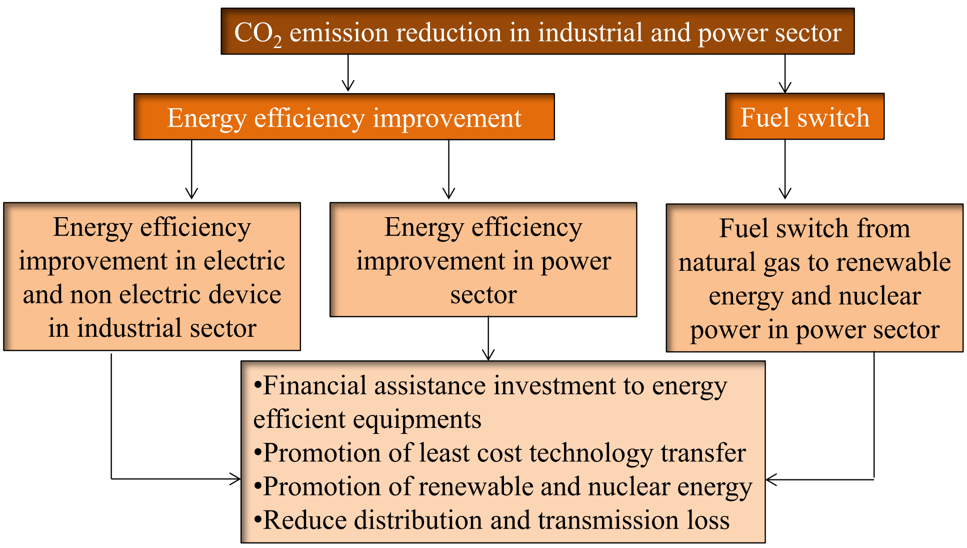

Fig. 51: Reduction policy frame for industrial and power sector

(e) Transport sector

In passenger transport sector, the transport volume will be increased from 361 billion passenger-km in 2005 to 663 billion passenger-km in 2025, resulting about 1.8 times larger than 2005. Passenger transport volume increases due to the rapid growth of population and increased use of private vehicles. In 2025BaU, the energy demand will be increased from 530 to 1.5Mtoe or 2.8 times larger than 2005.

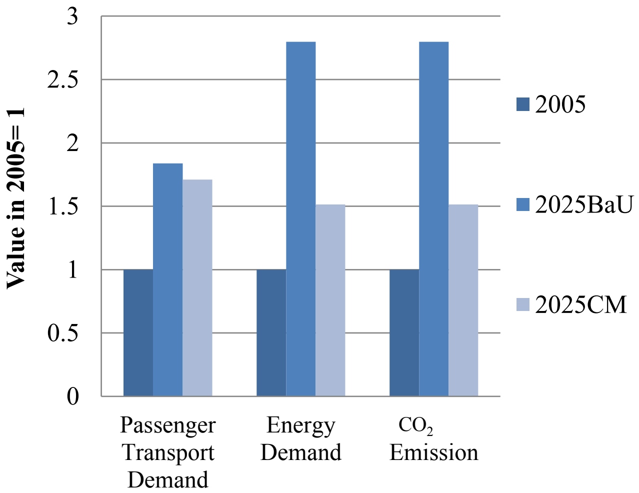

Fig. 52: Changes from 2005 to 2025 in passenger transport sector

The CO_2 emission from passenger transport will be increased to 4.6MtCO_2 in 2025BaU from 1.6MtCO_2 in 2005. However, in 2025CM, by adopting possible reduction measures e.g. energy efficiency improvement of vehicle and modal shift (Fig. 52 and 53) the emission will be reduced to 2.5MtCO_2 which contributes about 3% of total CO_2 emission reduction. In freight transport sector (see Fig. 54), freight transport volume will be increased from 20 billion ton-km in 2005 to 91 billion ton-km in 2025. Energy demand and CO_2 emission in freight transport will be increased to 3.9Mtoe and 12MtCO_2 in 2025BaU. 16% of freight transport depended on inland waterway and 80% on road vehicle in 2005, however, in BaU2025, share of road vehicle is increased to 84% while share of inland waterway decreases, due to the improvement in structural improvements of road and bridge construction in the country (e.g. Padma multipurpose bridge (2011-2015) which will facilitate the social, economic and industrial development of underdeveloped regions of the country). In CM2025, energy efficiency improvement contributes reduction of 6.6MtCO_2 or 5% of the total emission reduction. In total GHG emission reduction, passenger and freight transport results small amount of 2% and 4% of CO_2 emission reduction respectively. Reduction policy frame for transport sector is shown in Fig. 55.

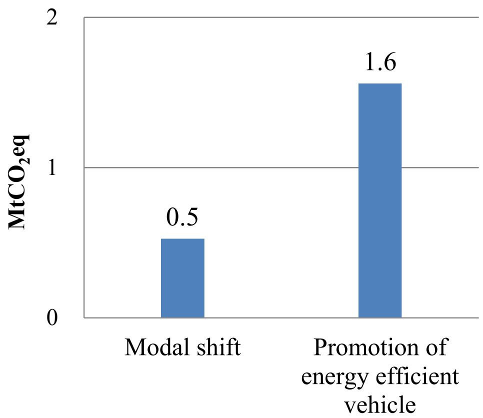

Fig. 53: CO_2 emission reduction in passenger transport sector

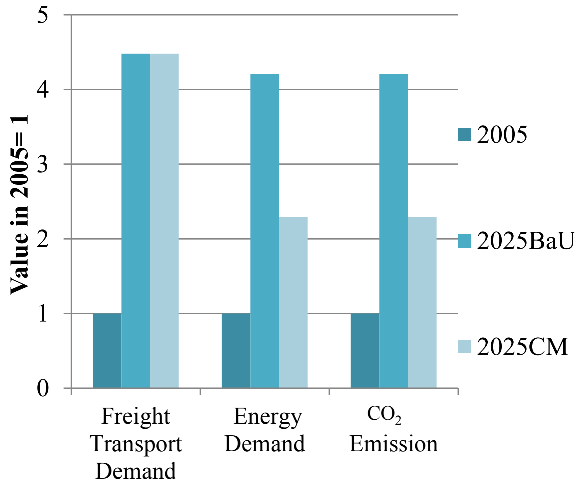

Fig. 54: Changes from 2005 to 2025 in freight transport sector

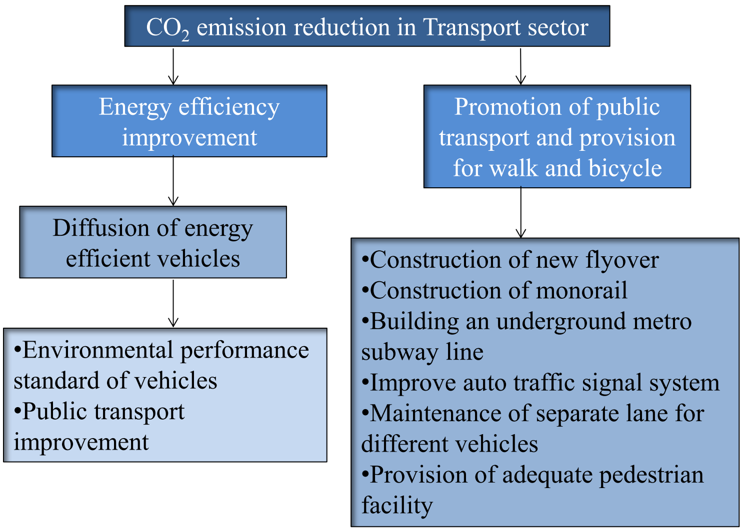

Fig. 55: Reduction policy frame for transport sector

(f) Agriculture sector

This study applies several available reduction measures to estimate mitigation potential under Allowable Abatement Cost (AAC), with range of <0 to >100US$/t$CO_2$eq for GHG emission reduction by 2025. There are three types of reduction measures taking negative or zero cost, which are called "No Regret Technologies" (AAC is less than 0US$/t$CO_2$eq): Midseason drainage (MD), Dome digester, cooking fuel and light (CFL) and replacement of roughage with concentrates (RRC). AAC <0US$/t$CO_2$eq will provide 10Mt$CO_2$eq of mitigation potential without application of any reduction measure. Under 10US$/t$CO_2$eq of AAC, mitigation potential will be 12.8MtCO_2eq High Efficiency fertilizer applications (HEF), off-season incorporation of rice straw (OIR), replace urea in fertilizer with ammonium sulphate (RAS), tillage and residue management (TRM) will be applied from 0US$/t$CO_2$eq to 10 US$/tCO_2eq of AAC. High mitigation cost measures will contribute higher mitigation potential. Within the range <100 US$/t$CO_2$eq to >100 US$/tCO_2eq, the above reduction measures will be applied with expensive technologies like high genetic merit (HGM) and daily spread of manure (DSM). The AFOLU model breakdowns of estimated mitigation potential in 2025 under AAC from <0 to <100US$/t$CO_2$eq with the application of a set of reduction measures.The allowable additional mitigation cost <0US$/t$CO_2$eq will be 10Mt$CO_2$eq under <10US$/tCO_2eq potential will contribute 12.8MtCO_2eq or 23% of reduction from the BaU emission in 2025. However, allowable additional mitigation cost <100US$/t$CO_2$eq and >100US$/tCO_2eq show the significant reduction in GHG emission about 21% and 38% respectively from the BaU in 2025 in Bangladesh. Fig. 56 shows the mitigation potential at various allowable additional mitigation cost.

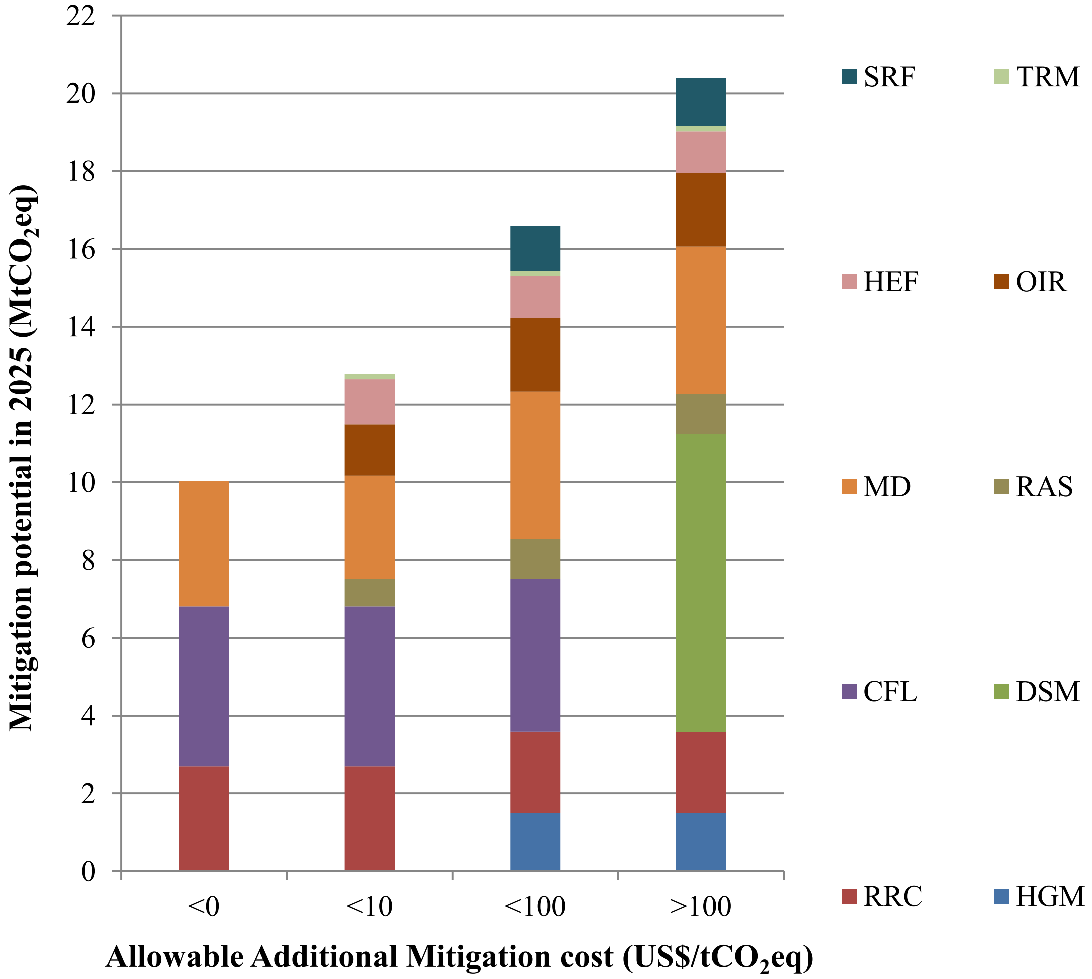

Fig. 56: Mitigation potential in 2025 under different AAC in agriculture

Under AAC <10US$/t$CO_2$eq applied reduction measures will reduce about 12.8MtCO_2eq, which results about 23% of total mitigation potential in agricultural sector in 2025. In this case, RAS, MD and OIR will be anticipated to reduce 4.7MtCO_2eq, results about 37% of total mitigation potential under of cost constrain of AAC <10US$/t$CO_2$eq in agricultural sector. However, these reduction measures will contribute 6.7MtCO_2eq of mitigation potential under the AAC <100 US$/t$CO_2$eq and AAC >100 US$/tCO_2eq respectively. Therefore, the additional cost for installation is high. Fig. 57 shows the mitigation potential under AAC <10US$/t$CO_2$ in agriculture. This model estimated mitigation potential from 2000 to 2025 based on the input data and future assumption. Mitigation potential of 10MtCO_2eq in 2000 will be increased to 12.8MtCO_2eq in 2025. Among applied reduction measures, CFL, RRC from livestock sector and MD in rice paddy cultivation contributed larger mitigation potential of 3MtCO_2eq, 2.1MtCO_2eq and 2.2MtCO_2eq respectively. It showed an increasing trend to contribute in mitigation potential of 3.4MtCO_2eq, 2.2MtCO_2eq and 2.5MtCO_2eq in 2010 respectively. These reduction measures are assumed to contribute further with rising trend in mitigation potential of 11% and 14% in 2020 and 2025 respectively. The largest mitigation potential of 75% in 2020 and 74% in 2025 will be provided by the combination of CFL, RRC from livestock sector and MD in rice paddy cultivation. However, in livestock sector for enteric fermentation CFL has greater potential than RAS, contributed about 32% and 21% higher mitigation potential in 2025 from 2000. In rice paddy cultivation, the potentiality of OIR will be reduced from 50% in 2000 and 2025 with the combination of MD. Therefore, MD and OIR significantly reduced emission of 3.3MtCO_2eq in 2000 in total mitigation potential and will increased to 4MtCO_2eq in 2025. Reduction measures, such as HEF has small mitigation potential in total. For Bangladesh, CFL, RRC in livestock sector and MD and OIR in rice paddy cultivation are supposed to be cost-effective reduction measures to gain the higher mitigation potential in overall agriculture sector. Fig. 58 shows the share of GHG emission mitigation in total GHG emission reduction. This study estimates about 10% mitigation potential, achieved by agricultural sector in total reduction.

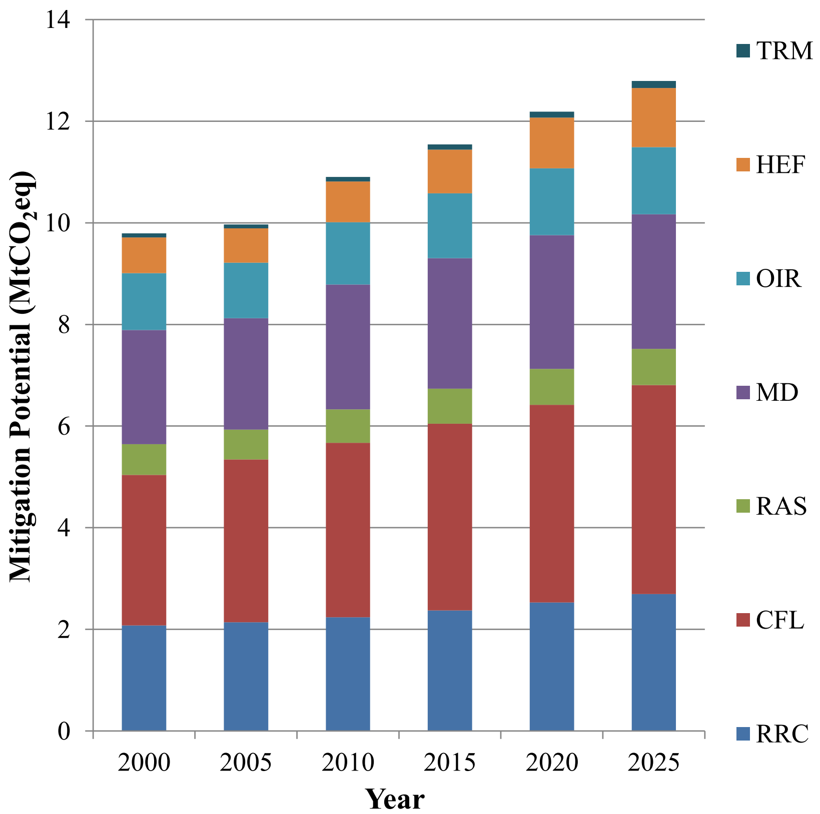

Fig. 57: Mitigation potential under AAC <10US$/t$CO_2$ in agriculture

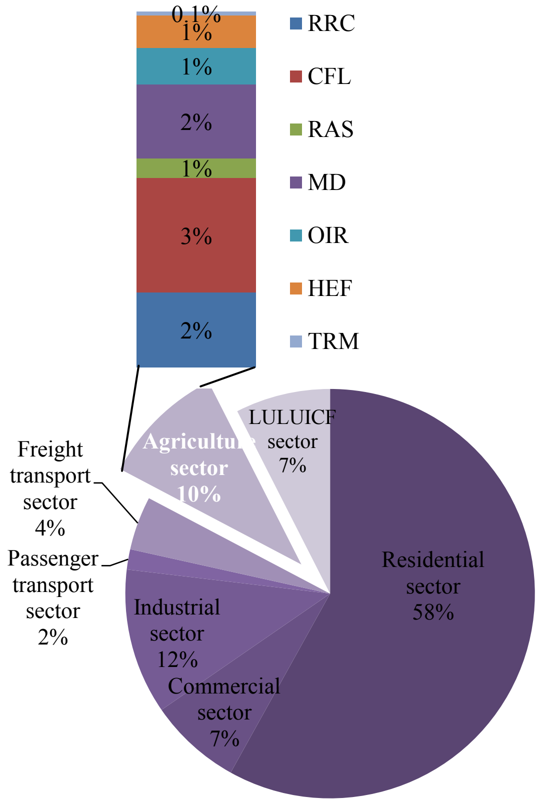

Fig. 58: Share of GHG emission reduction in agriculture in total GHG emission reduction

(g) LULUCF sector

For LULUCF sector in Bangladesh, we do not have relevant specific data on mitigation potential of available reduction measures. Several reports explained about mitigation technologies and mitigation cost implicitly. This study collects data from those reports and estimated the mean mitigation potential by SQF (maximization of cumulative mitigation in the whole time period, from present to the future). In general sense, SQF is the recursive explanation where the reduction measures will be selected per year without consideration of the future, known as realistic assumption. This study estimates the mean mitigation potential achieved by mitigation technologies under wide range of maximum allowable mitigation cost 1millionUS$ to 150millionUS$ from 2000 to 2025, shown in Fig. 59.

Within this time period, reduction measures such as long rotational artificial reforestation, medium rotational artificial reforestation and short rotational participatory woodlot plantation are estimated to have the largest mean mitigation potential of about 23.6MtCO_2eq, 0.69MtCO_2eq and 2.62 MtCO_2eq respectively under mitigation cost 150millionUS$ in 25years. Therefore, these are the most cost effective mitigation technologies for Bangladesh through which mitigation of GHG emission in LULUCF sector are anticipated to achieve about 100% from LULUCF BaU emission in 25 years with high mitigation cost. High mitigation cost contributes as sink for emission reduction more than the emission in BaU case. Due to the lack of data on area selection for the application of each reduction measure, this model estimated reduction measures will be applied in whole forest area. The best technologies and applied area will be chosen by the model. In total GHG emission reduction, this sector contributed 7% of mitigation potential of GHG emission reduction and in which long rotational artificial reforestation and short rotational participatory woodlot plantation resulted 5% and 2% under mitigation cost 25millionUS$ respectively.

Other reduction measures such as medium rotation participatory coastal plantation medium rotation sal plantation did not have any significant mitigation potential for Bangladesh in this study within this range of allowable mitigation cost.

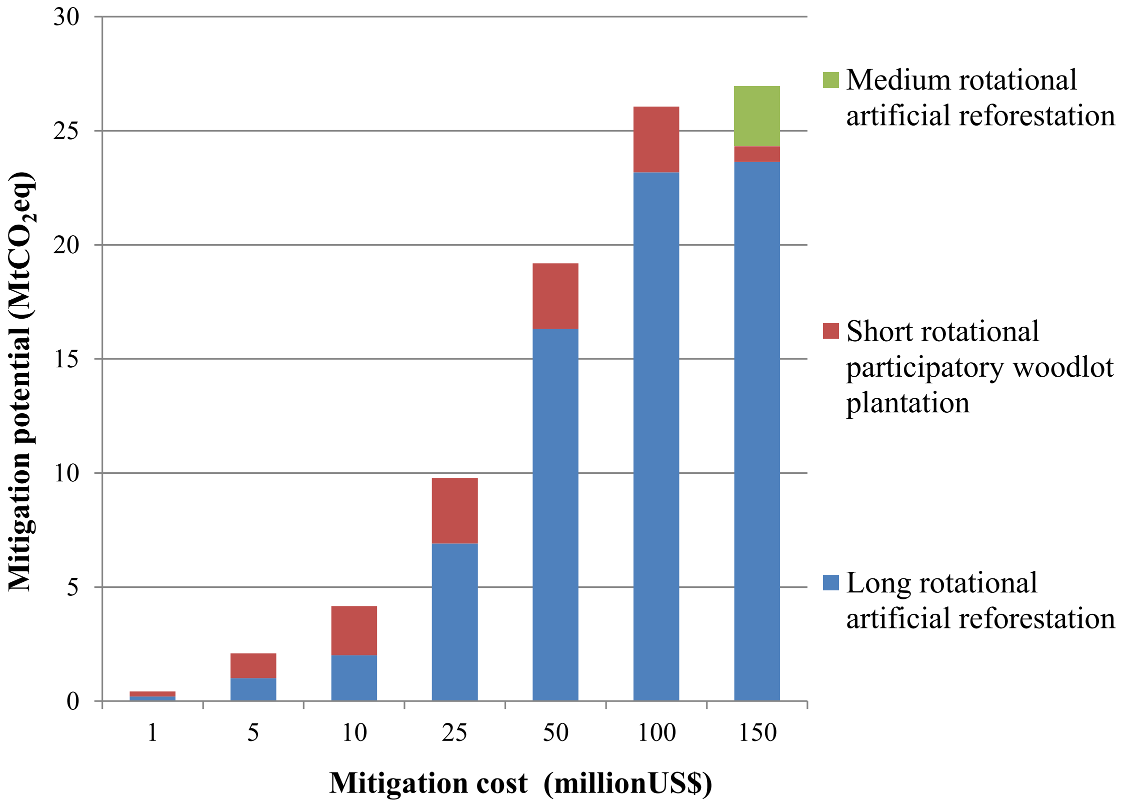

Fig. 59: Mitigation potential in LULUCF sector

Actions toward GHG emission reduction

For Bangladesh, building a low-carbon society will be both a challenge and an opportunity. The concept of low-carbon society is not only to reduce GHG emission, but also focuses on better energy efficiency which then improves economic productivity. In this study, GHG emission can be reduced about 42% in 2025CM by adopting some effective and feasible reduction measures. However, it will take long time and enough funding from different national and international organizations to accept and implement reduction measures. Therefore, Bangladesh needs to move to a low carbon paradigm to facilitate the effective medium and long-term strategies for economic development and also set a GHG emission reduction target. Raising knowledge and changing behavioral attitude of the general public towards low-carbon society is also an important issue for realization the good image of its implementation in Bangladesh. Brief overviews of possible actions and emission reductions are shown in Table 8.

Fig. 60 shows the GHG emission reduction from different sectors.

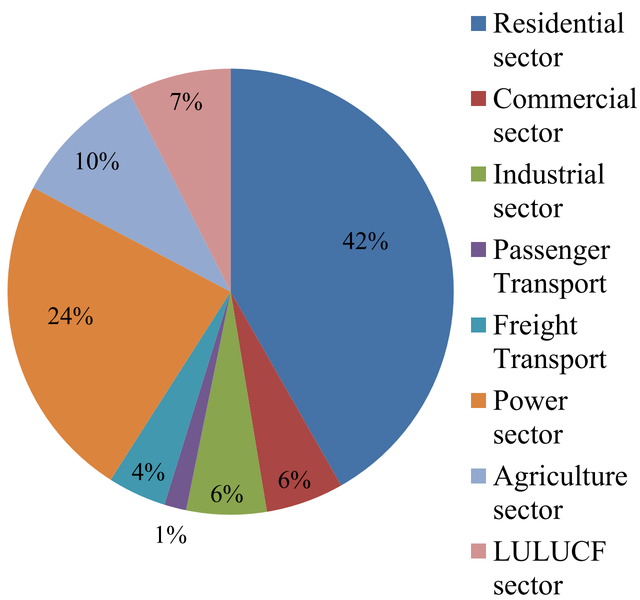

Fig. 60: Share of sector wise emission reduction in total GHG emission reduction

Table 8: Summary of proposed actions for GHG emission reduction

Actions	GHG emission reduction ($MtCO_2eq$)	(%)
1. Energy efficiency improvement in residential and commercial sector	59	45%
2. Energy efficiency improvement in industrial sector	5	4%
3. Fuel switch in residential, commercial and industrial sector	6	4%
4. Promotion of energy efficient vehicles (passenger+freight transport)	7	5%
5. Modal shift in passenger transport sector	1	0.4%
6. Fuel switch and reduction of transmission loss in power sector	31	24%
7. Rice field management (Midseason drainage+Off-season incorporation of rice straw+Replace urea with ammonium sulphate) in agriculture sector	5	4%
8. Manure management (Dome digester for cooking fuel and light) in agriculture sector	4	3%
9. Enteric fermentation (Replacement of roughage with concentrated feed)	3	2%
10. Managed soil (High efficiency fertilizer application+Tillage and residue management) in agriculture sector	1	1%
11. Long rotational artificial reforestation + Short rotational participatory woodlot plantation) in LULUCF sector	10	7%
Total GHG emission reduction ($MtCO_2eq$)	131	100%

Methodology

Extended Snapshot (ExSS) tool

Procedure of LCS scenario development

In order to create a low-carbon society scenario, we developed a method based on the idea of "Back Casting", which sets a desirable goal first, and then seek the way to achieve it. Fig. 61 shows overview of the method.

(1) Setting framework: Framework of a LCS scenario includes; target area, base year, target year, environmental target and number of scenarios. Among them, the base year is compared with target year. The target year should be far enough to realize required change, and near enough to imagine the vision for the people in the region. In this study, we set the target year of Bangladesh is 2025. This is also a suitable time span for a LCS study for making realistic relation with the draft published by Ministry of Planning (2010) "Outline Perspective Plan of Bangladesh Making Vision 2021 a Reality". As an environmental target, we targeted CO_2 from energy use because it will be a main source of GHG emission from Bangladesh in 2025.

(2) Assumptions of socio-economic situations: Before conducting quantitative estimation, qualitative future image should be written. It is an image of lifestyle, economy and industry, land use and so on.

(3) Quantification of socio-economic assumptions: To estimate Snapshot based on the future image of (2), values of exogenous variables and parameters are set. Using those inputs, ExSS calculates socio-economic indices of the target year such as population, GDP, output by industry, transport demand and so on.

(4) Collection of reduction measures: To collect counter measures which are thought to be available in the target year. For example, high energy-efficiency devices, transport structure change such as public transport, use of renewable energy, energy saving behavior and carbon sink. Technical data is required to estimate their effect to reduce GHG emission. In this research we employed the reduction measure showed in preceding study (Japan's study).

(5) Setting introduction of counter measures: Technological parameters related to energy demand and CO_2 emission, in short energy efficiency, are defined.

(6) Estimation of CO_2 emission in the target year: Based on socio-economic indices and assumption of measures' introduction, GHG emission are calculated.

(7) Proposal of policies: Propose policy set to introduce the measures defined. Available policies are depended on the situation of the country. ExSS can calculate emission reduction of each counter measure. Therefore, it can show reduction potential of reduction measures which especially need local policy. It can also identify measures which have high reduction potential and therefore important.

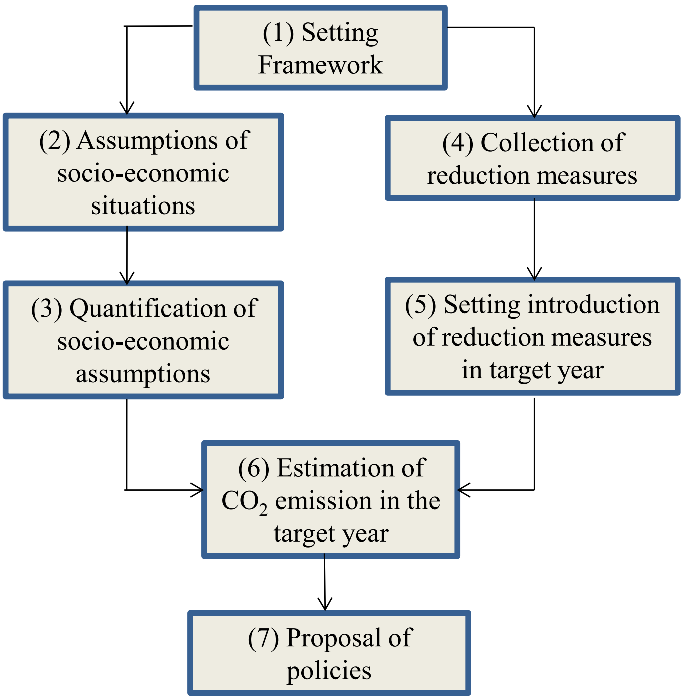

Fig. 61: Procedure of LCS scenario creation

Quantitative estimation tool “ExSS tool”

Fig. 62 shows the structure of the ExSS tool with input parameters and exogenous variables. ExSS is a system of simultaneous equations. Given a set of exogenous variables and parameters, solution is uniquely defined. In this simulation model, only CO_2 emission from energy consumption is calculated, even though, ExSS can be used to project other GHG and environmental loads such as air pollutants. In many LCS scenarios, exogenously fixed population data are used. To determine output of industries, input-output approach is applied.

Passenger transport demand is estimated from the population and freight transport demand whereby it is a function of output by manufacturing industries. Floor area of commerce is determined from output of tertiary industries.

Other than driving force, activity level of each sector, energy demand by fuels determined with three parameters. They are energy service demand per driving force, energy efficiency and fuel share. Diffusion of counter measures changes the value of these parameters, and so GHG emission.

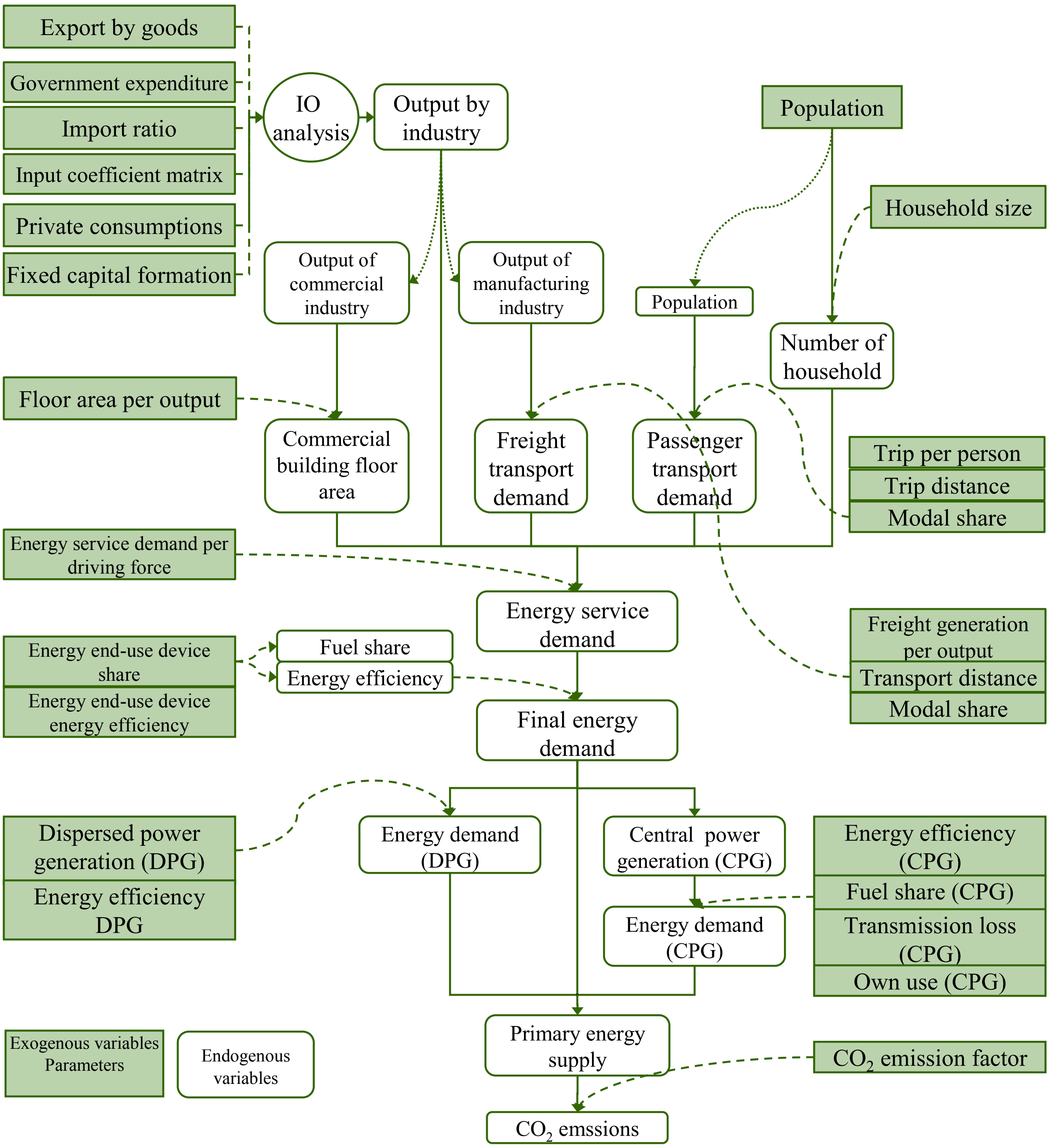

Fig. 62: Structure of ExSS

AFOLUB Model

The AFOLUB model (see Fig. 63) is a bottom-up type model for calculating GHG emission and mitigation potentials in AFOLU sectors at the national/regional level, based on detailed information of specific mitigation countermeasures. The emission and mitigation are calculated using a function of Allowable Abatement Cost for GHG emission mitigation (AAC) which is a representative parameter representing a willingness of GHG reduction under several constraints for mitigation costs and mitigation potential, based on future assumptions of production in agriculture and livestock industry and land use change given exogenously. The model illustrates selection of GHG mitigation options (technologies) based on economic rationality. Since the selection depends not only on evaluation methodologies of cost and mitigation but also dependency among technologies, we considered the dependency in the model. We prepared several evaluation methodologies and we compared and analyzed differences among amounts of technologies under several constraints of minimum amount of mitigation or maximum cost in each year.

The AFOLUB consists of two models; Agriculture/Bottom-up (AG/Bottom-up) and LULUCF/Bottom-up.

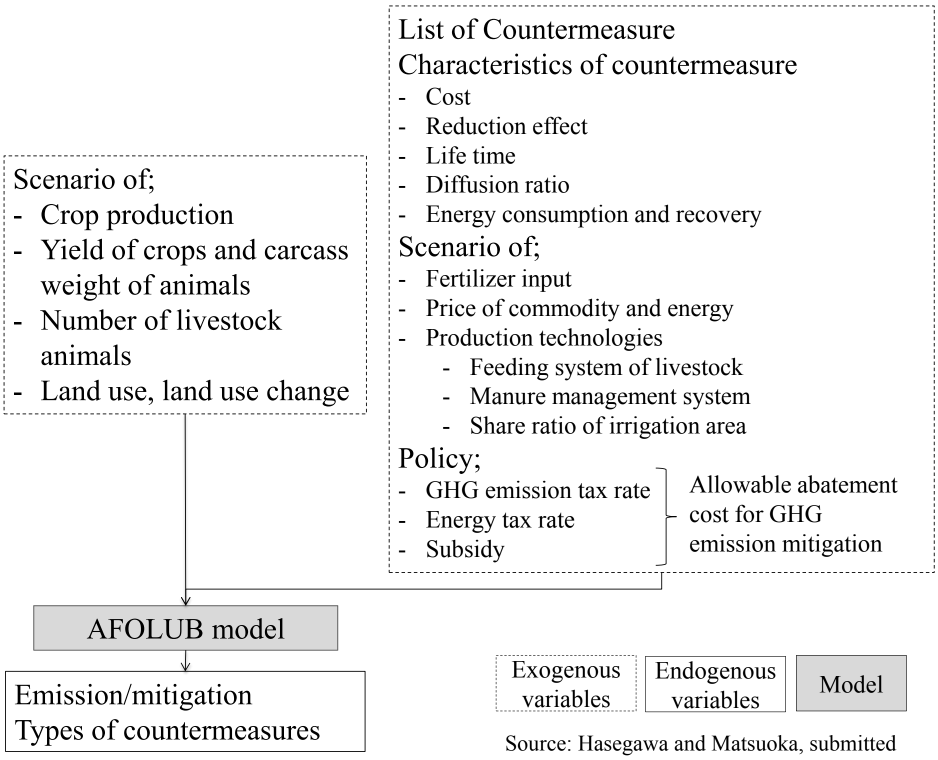

Fig. 63: AFOLUB model

AG/ Bottom-up model

The AG/Bottom-up model (Fig. 64) calculates GHG emission, combination of mitigation technologies and their mitigation in agricultural production and energy consumption of agricultural machines. This module is based on the assumption that producers produce commodities to supply the amount of productions given exogenously. The countermeasure application term is divided into several periods and the producers select ways of producing commodities and combinations of mitigation countermeasures in order to maximize their profit. The profit is defined by benefit minus cost plus benefit by bioenergy sales. Production is calculated as a multiplication of productivity (i.e. crop production per unit area and carcass weight) and quantity of activity (area of cropland and number of livestock animal). There is a linkage between production and activity yields. Yields are defined as production of commodities per unit activity. It is, for example, crop production per unit area harvested and carcass weight of livestock animals. It is taken into account that yields may be changed due to application of countermeasures.

For example, yield may be decreased by fertilizer reduction and carcass weight of livestock animal may be increased by improvement of feed systems. The model takes into account impacts of climate conditions on crop yields.

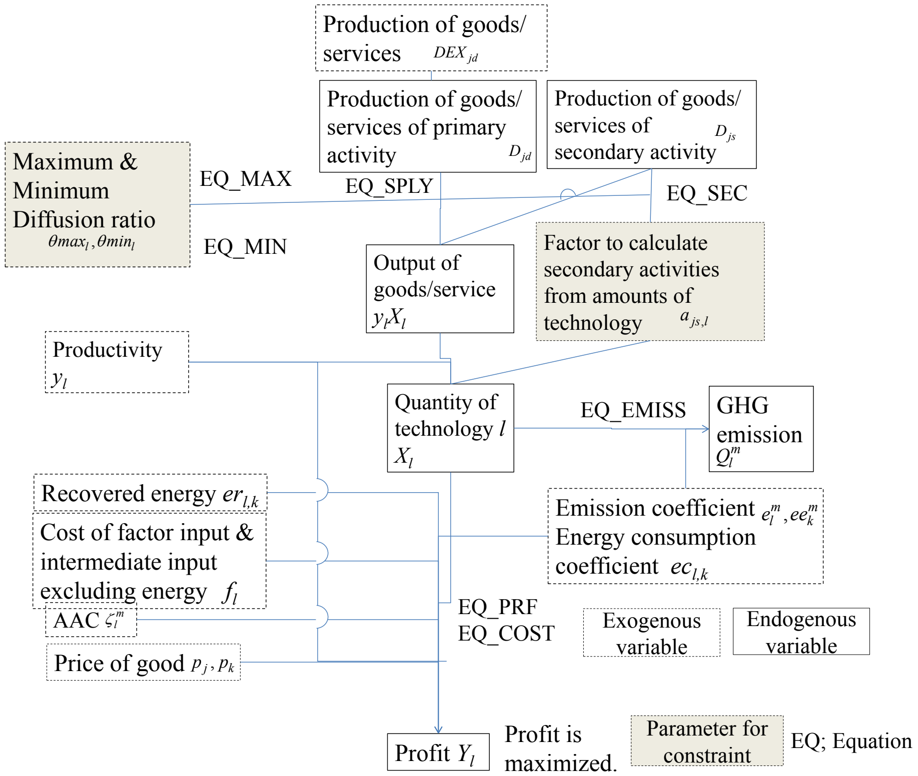

Fig. 64: Framework of AG/Bottom-up

LULUCF/Bottom-up model

LULUCF/Bottom-up model (Fig. 65) calculates GHG emission and the mitigation potentials in Land Use and Land Use Change and Forestry (LULUCF) sectors. The emission is caused by carbon stock change, fires and disturbance. Assumption of future land use change is given exogenously. As same as AG/Bottom-up, LULUCF/Bottom-up determines combination of technologies in order to maximize profit. The LULUCF/Bottom-up does not take into account benefit from activity (i.e. improved land use and wood production). The module calculates total mitigation impacts in an assumed period since mitigation impacts of some countermeasures last in the long term after application.

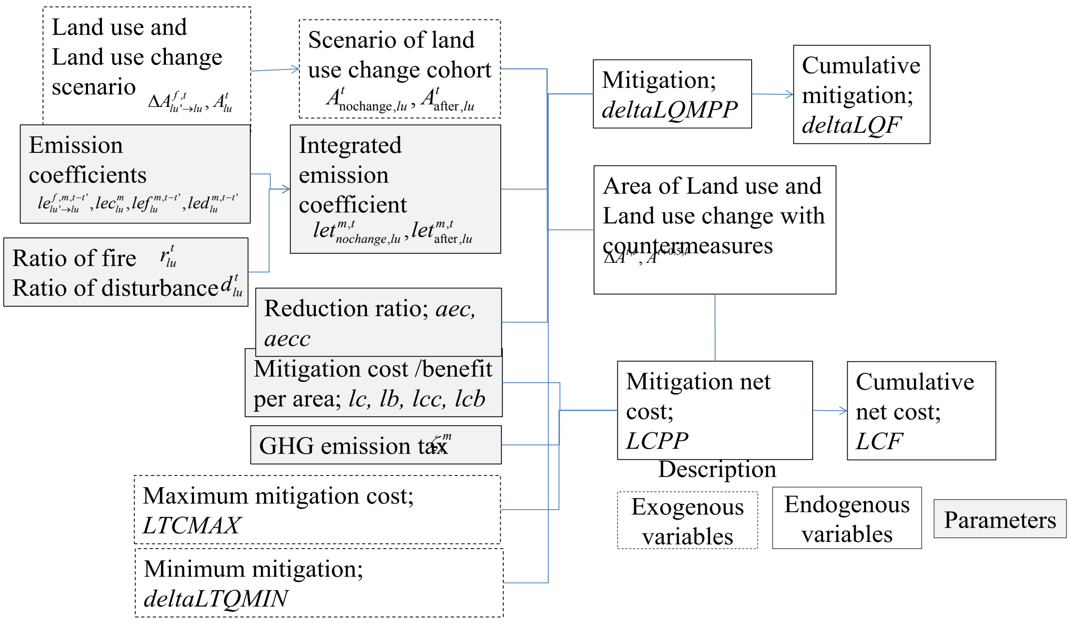

Fig. 65: Framework of LULUCF/Bottom-up

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Data Tables

Input-Output table in 2005 of Bangladesh (million taka)

	Agriculture and forestry	Fishing	Minning and Quarrying	Manufacturing	Construction	Electricity, gas & water	Wholesale and retail trade	Transport services	Real estate & renting business	Education and Health	Government services	Other private services	Total intermediate consumption	Private consumption	Government consumption	Gross domestic capital formation	Export	Import	Total Final Demand	Total Gross Output
Agriculture and forestry	335,157	4,165	0	810,007	48,644	0	0	0	0	446	0	31,278	1,229,697	326,131	0	9,107	21,000	-126,590	229,647	1,459,345
Fishing	1,000	41,950	0	164,100	0	0	0	0	0	0	0	5,396	212,446	130,042	0	28,152	34,336	-89	192,441	404,887
Minning and Quarrying	25,155	12,801	10,955	72,284	12,148	6,354	14,039	20,843	25,596	3,212	2,871	21,633	227,890	103,758	0	-7,874	2,589	-123,461	-24,988	202,902
Manufacturing and Commercial goods	171,899	94,759	24,079	373,676	173,974	19,108	46,558	83,650	48,564	31,599	9,598	88,524	1,165,986	1,737,732	0	294,328	626,338	-781,982	1,876,416	3,042,402
Construction	5,720	0	4,303	4,152	3,067	785	5,272	22,035	8,514	1,053	1,074	4,737	60,712	0	0	595,508	0	0	595,508	656,219
Electricity, gas & water	685	4,934	8,391	21,521	21,825	9,439	397	5,934	1,229	263	264	1,758	76,640	62,557	0	0	0	-8,472	54,086	130,725
Wholesale and retail trade	161,329	77,767	38,980	408,148	0	15,144	0	0	0	0	0	0	701,368	0	0	0	0	0	0	701,368
Transport services	85,116	0	37,298	317,074	14,765	12,789	19,750	19,746	0	0	3,237	1,934	511,708	104,164	0	0	25,607	0	129,771	641,479
Real estate & renting business	2,653	1,255	14,453	37,594	0	663	24,776	29,063	35,543	4,410	1,959	27,790	180,160	312,269	0	0	0	0	312,269	492,430
Education and Health	43,133	0	0	0	0	0	0	0	0	0	6,150	4,709	53,992	110,643	89,996	0	0	-15,515	185,124	239,115
Government services	132	358	2,581	103	879	647	950	1,675	2,610	563	656	927	12,081	19,408	113,831	0	22,240	0	155,479	167,560
Other private services	53,865	12,708	16,101	138,515	25,987	11,351	26,880	46,226	48,049	19,794	16,473	150,182	566,132	204,229	0	0	23,551	-767	227,013	793,145
Total Intermediate Input	885,845	250,697	157,142	2,347,174	301,288	76,280	138,623	229,172	170,105	61,339	42,281	338,868	4,998,813	3,110,933	203,827	919,221	755,661	-1,056,877	3,932,766	8,931,578
Labour	233,866	46,898	13,428	273,962	143,520	12,310	351,752	247,947	177,242	109,039	90,541	285,922	1,986,427							
Land	339,626	107,292	0	0	0	0	0	0	0	0	0	0	446,918							
Capital	0	0	26,300	392,015	206,097	31,629	210,230	164,327	145,016	68,737	34,738	159,761	1,438,851							
Indirect Tax	8	0	6,032	29,251	5,313	10,506	764	34	67	0	0	8,595	60,570							
Total Value Added	573,500	154,190	45,760	695,228	354,931	54,445	562,746	412,308	322,325	177,776	125,279	454,277	3,932,766							
Total Gross Input	1,459,345	404,887	202,902	3,042,402	656,219	130,725	701,368	641,479	492,430	239,115	167,560	793,145	8,931,578							

Input-Output table in 2025 of Bangladesh (million taka)

	Agriculture and forestry	Fishing	Minning and Quarrying	Manufacturing	Construction	Electricity, gas & water	Wholesale and retail trade	Transport services	Real estate & renting business	Education and Health	Government services	Other private services	Total intermediate consumption	Private consumption	Government consumption	Gross domestic capital formation	Export	Import	Final Demand	Total Gross Output
Agriculture and forestry	845,645	13,258	0	3,094,344	186,696	0	0	0	0	2,107	0	130,214	4,272,265	659,530	0	35,209	81,192	-1,366,082	-590,151	3,682,115
Fishing	2,523	133,550	0	626,886	0	0	0	0	0	0	0	22,464	785,423	262,226	0	108,845	132,752	-279	503,545	1,288,968
Minning and Quarrying	63,470	40,751	42,867	276,137	46,623	27,113	48,660	67,129	102,626	15,164	15,642	90,058	836,240	461,298	0	-30,444	10,011	-483,166	-42,301	793,939
Manufacturing and Commercial goods	433,722	301,667	94,219	1,427,495	667,718	81,531	161,371	269,415	194,717	149,199	52,303	368,529	4,201,886	6,838,882	0	1,137,963	2,421,615	-2,977,929	7,420,532	11,622,418
Construction	14,431	0	16,837	15,860	11,772	3,352	18,274	70,969	34,136	4,972	5,852	19,720	216,174	0	0	2,302,414	0	0	2,302,414	2,518,588
Electricity, gas & water	1,729	15,707	32,835	82,213	83,766	40,273	1,375	19,111	4,928	1,241	1,439	7,318	291,936	302,005	0	0	0	-36,148	265,857	557,793
Wholesale and retail trade	407,054	247,575	152,526	1,559,184	0	64,618	0	0	0	0	0	0	2,430,956	0	0	0	0	0	0	2,430,956
Transport services	214,758	0	145,945	1,211,269	56,667	54,571	68,453	63,598	0	0	17,637	8,052	1,840,948	126,091	0	0	99,003	0	225,095	2,066,043
Real estate & renting business	6,695	3,996	56,555	143,616	0	2,830	85,874	93,606	142,508	20,823	10,673	115,693	682,868	1,291,524	0	0	0	0	1,291,524	1,974,391
Education and Health	108,830	0	0	0	0	0	0	0	0	0	33,512	19,605	161,946	692,390	347,953	0	0	-73,258	967,085	1,129,031
Government services	334	1,141	10,098	395	3,374	2,761	3,293	5,394	10,464	2,656	3,576	3,858	47,344	339,649	440,106	0	85,986	0	865,741	913,085
Other private services	135,909	40,456	63,000	529,148	99,738	48,432	93,168	148,883	192,653	93,463	89,767	625,219	2,159,837	1,054,223	0	0	91,057	-3,200	1,142,079	3,301,916
Total Intermediate Input	2,235,100	798,100	614,882	8,966,547	1,156,353	325,481	480,468	738,104	682,032	289,625	230,401	1,410,730	17,927,825	12,027,818	788,059	3,553,988	2,921,618	-4,940,063	14,351,420	32,279,245
Labor	590,074	149,302	52,543	1,046,574	550,834	52,524	1,219,179	798,575	710,651	514,851	493,385	1,190,310	7,368,802							
Capital	856,921	341,566	102,910	1,497,554	791,007	134,959	728,662	529,255	581,441	324,555	189,300	665,094	6,743,224							
Indirect Tax	20	0	23,603	111,742	20,393	44,830	2,648	108	267	0	0	35,782	239,394							
Total 'Value Added	1,447,015	490,868	179,056	2,655,871	1,362,235	232,313	1,950,488	1,327,939	1,292,359	839,406	682,684	1,891,186	14,351,420							
Total Gross Input	3,682,115	#######	793,939	11,622,418	2,518,588	557,793	2,430,956	2,066,043	1,974,391	1,129,031	913,085	3,301,916	32,279,245							

Final energy consumption by fuel type by sectors (ktoe)

2005	Coal	Oil	Gas	Biomass	Electricity	Total
Residential		750	1,616	8,296	768	11,430
Commercial			159		138	297
Industry	350	950	1,621		779	3,700
Passenger Transport		530				530
Freight Transport		940				940
Total	350	3,170	3,396	8,296	1,685	16,897
2025BaU						
Residential		5,665	10,049	15,043	11,256	42,013
Commercial			1,509		1,313	2,822
Industry	1,337	2,727	6,100		2,904	13,068
Passenger Transport		1,483				1,483
Freight Transport		3,958				3,958
Total	1,337	13,832	17,658	15,043	15,473	63,344
2025CM						
Residential		3,350	8,097	13,996	6,261	31,704
Commercial			1,187		550	1,737
Industry	938	2,097	4,040	1,407	2,960	11,443
Passenger Transport		803				803
Freight Transport		2,156				2,156
Total	938	8,406	13,324	15,403	9,772	47,842

Primary energy demand by fuel type (ktoe)

	Coal	Petroleum	Gas	Hydro	Nuclear	Solar/ wind	Biomass	Total
Energy demand								
2005	350	3,704	8,078	111	0	0	8,296	20,539
2025BaU	26,420	15,070	38,231	648			15,043	95,413
2025CM	11,751	9,178	24,667	513	1,310	873	15,403	63,696
Percentage distribution								
2005	2%	18%	39%	1%	0%	0%	40%	100%
2025BaU	28%	16%	40%	1%	0%	0%	16%	100%
2025CM	18%	14%	39%	1%	2%	1%	24%	100%

Low-Carbon Society Development towards 2025 in Bangladesh

November, 2012

Team Members

Kyoto University, Japan

Tahsin Jilani*

Kei Gomi

Yuzuru Matsuoka

National Institute of Environmental Studies, Japan

Tomoko Hasegawa

Junichi Fujino

Khulna University, Bangladesh

Abul Kalam Azad

Department of Environment, Bangladesh

Mirza Shawkat Ali

**Corresponding Author*

Contact Address:

Tahsin Jilani

Department of Environmental Engineering

Kyoto University, Kyoto 615-8540, Japan

Tel: 81-75-383-3370 (off)

Email: tahsinku@yahoo.com