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Adaptation and Sustainability Issues of Global Warming Consequences in Coastal Bangladesh

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Abstract

Global warming consequences and impacts of sea level rise characterise the recent evolution of the coastal environment. All of these resulted from 'greenhouse gases' caused mainly by the burning of fossil fuels. It is important therefore to reduce the reliance on fossil fuels and increase the use of renewable energy. Bangladesh is not a significant 'greenhouse gas' contributor, but is the victim of potential threats of sea level rise from global warming because of its natural physical setting in a coastal environment. It is projected that by 2050 the mean sea level may rise as much as 1.8 metres. This may result in the loss of up to 16% of the land that supports 13% of the country's GDP. This impact will change the present coastal water current and movement, precipitation and run-off, and also the tidal range of coastal Bangladesh. Some recent studies suggest that the tidal range in some parts of coastal Bangladesh has a good potential for producing tidal energy (an important source of renewable energy) by utilising the existent costly infrastructure of coastal embankment and sluice gates. Once this tidal energy is adapted in coastal Bangladesh, the future global warming will increase its further potentiality. Coastal Bangladesh is extremely resourceful and very important for the economic, environmental and cultural activities of the local as well as national and international community. Until now, most of the potential resources of this area have not been used properly, mainly due to lack of

electricity and integrated coastal management practices. Thus the discusses the global warming threats to coastal Bangladesh and how utilising the potentiality of tidal energy could mitigate these threats. The paper also presents a framework how tidal energy could be integrated with various potential coastal resources for the sustainable development of coastal Bangladesh.

Introduction

Global warming and sea level rise under the climate change scenarios are the two most important threats to global sustainability in the 21st Century. Global warming could raise sea level by expanding ocean water, melting mountain glaciers, and causing ice sheets to melt or slide into the oceans, and sea level rise could impact the low-lying coastal environment. Thus it could also impact on the socio-economic, environmental and cultural activities of the coastal environment. These impacts could be particularly severe for the poor countries, where management of the appropriate mitigation measures is very difficult because of lack of financial resources and appropriate global policies. According to the United Nations Environment Program (UNEP, 2002), "the world is at an environmental crossroads, where the choice between greed and humanity will decide the fate of millions of people for decades to come. The choices made today are critical for the forests, oceans, rivers, mountains, wildlife, and other life support systems upon which current and future generations depend". Mitigation involves actions to prevent or retard the greenhouse gas (GHG) emissions. Mitigation can only slow down the rate of climate change and cannot prevent its occurrence (Ahmed *et at.*, 1999). Therefore global warming and sea level rise situations would need some kind of adaptation systems. According to Carter (1996), adaptation means "any adjustment – passive, reactive, or anticipatory – that can respond to anticipated or actual consequences

associated with climate change". Adaptation has many meanings and different scientists define it in different ways, but in this paper we mainly use the following definition:

> "Adaptability refers to the degree to which adjustments are possible in practices, process, or structures of systems to projected or actual changes of climate. Adaptation can be spontaneous or planned, and can be carried out in response to or anticipation of changes in conditions" (Watson *et at.*, 1996).

The reason behind the climate change is GHG, which is mainly produced by fossil fuel emissions, and the continuing availability of conventional oil (one of the fossil fuels) on which modern global economies depend (Hansen *et at.*, 2000; IPCC, 2001; Rob, 2001). Either of these emissions is very dangerous for environmental sustainability. Increasing concentrations of carbon dioxide and other GHGs are expected to warm our planet by increasing the temperature by a few degrees Celsius (^{o}C) by a mechanism commonly known as the 'greenhouse effect'. Renewable energy can provide a substitute for fossil fuel and other non-renewable polluting sources of energy. The world continues to use electricity in ever-increasing amounts, despite the problems associated with power generation that uses fossil fuels. Therefore a shift from fossil fuels to renewable energy sources would be a strategic way to maintain environmental management and sustainable development at the climate change scenarios. It is important to mitigate GHGs and also to adapt alternative energy. Renewable energy is a generic term for electricity generated from clean, environmentally preferable energy sources such as wind, water, solar, tidal, energy-from-waste and energy-from-crops (bio-mass). Because of its low-to-zero carbon content, it offers an opportunity for citizens and corporations to act on their environmental concerns and to demonstrate support for public policies supporting renewable energy (Salequzzaman, 2002).

Global warming and sea level rises are supposed to impact on coastal environment, where presently 50-70% of the world's 6 billion people live, equal to the entire world's population of the 1950's (Rahman and Huq, 1998). The climate change impact includes inundation or submerging of existing infrastructure for food production, fisheries, forestry, tourism, recreation, transportation and others. Scientists believe that it is critical to integrate human activities with climate changes, in order to minimise future impacts on coastal and marine resources (Easterling III *et at.*, 1989). Therefore it is essential to implement appropriate technology that has the potential to mitigate GHGs or/and adapt with the changes of global warming and sea level rise. It is particularly important for countries, which are or will likely be affected by climate impacts, to be aware of the risks and potential consequences that future change will pose to their communities and their livelihoods[1], to develop and adapt the innovative low-cost locally available technologies.

Bangladesh is one of the most densely populated low-lying developing countries. It is likely to be severely impacted by the global warming that might occur in future. According to Chowdhury (2001), "(w)ith a global warming and concomitant one-metre sea level rise, nearly one-fifth of coastal Bangladesh will permanently go under water". At present, approximately a fifth of the country's total land mass is situated at low-lying coastal zones within 1 meter of the high water mark among the total coastal area (Huq, 2001a). Several studies projected that the mean sea level may rise as much as 1.8 metres by the year 2050 (Khan, 2001; Nutall, 2001). This may result in the loss of up to 16% of the land that supports 13% of the country's GDP (Chowdhury, 2001). Therefore, with a population of more than 50% of 130 millions total country population that live in the

[1] More information on the National Assessment of the Potential Consequences of Climate

coastal area, most of whom earn less than US$1 a day (the poorest people in the world), Bangladesh is in great danger (Huq, 2001a). "This impact will change the present coastal water current and movement, precipitation and run-off, and also the tidal range of coastal Bangladesh" (Salequzzaman, 2001). Therefore, the impacts of climate change and its adaptability in the context of coastal Bangladesh are very important. Up to now almost all studies have found that Bangladesh is likely to be severely impacted by climate change. Nevertheless until now good data on this matter is not the available (Huq, 1999). It is necessary to recognise the climate change impacts and that dealing with them is not just a special type of environmental problems, but something that is fundamentally tied to the country's sustainable development.

Bangladesh has a long coastal zone, most of which protected by embankment and sluice gates. In most cases, the coastal area of Bangladesh is situated in very remote areas and is not facilitated with electricity. Presently this area has expanded haphazardly and developed an unsustainable way of shrimp aquaculture (Salequzzaman, 2001). There is lack of integration practices and electricity supply (Bhatta and Bhat, 1998). Some recent studies suggest that the tidal ranges of some parts of coastal Bangladesh offer a good potential for producing tidal energy (an important source of renewable energy) by utilising the presently existing costly infrastructure of coastal embankments and sluice gates. In the long term global warming and sea level rise will have a devastating impact on Bangladesh. It might be possible to use this fact to advantage in the short and medium term (Huq, 2000) through the increase of tidal energy potentiality, as future sea level rise will need further construction

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Variability and Change is available at: http://www.nacc.usgcrp.gov.

of embankment to raise the present embankment's height. Future sea level rise may bring the opportunity to develop innovative technology of tidal power projects. Coastal Bangladesh is extremely resourceful and very important for the economic, environmental and cultural activities of the local as well as national and international community. Until now most of the potential resources of this area are either under-utilised or over-utilised, mainly due to both lack of electricity and integrated coastal management practices, which indicates that the present management system is unsustainable (Salequzzaman, 2001). Practically, lack of electricity is the main barrier for the sustainable coastal development (Cicin-Sain and Knecht, 1998) of Bangladesh. Tidal power could improve this situation. Besides, as tidal power is a kind of renewable energy and does not produce GHGs (Blue Energy, 2001; Day, 1994; Tidal Energy Inc., 2000; Tidal Impact, 2001, Salequzzaman *et at*., 2000; Corry and Newman, 2000), this innovative technology could be a kind of mitigation process for climate change impacts. Ironically, tidal energy is a clean renewable energy, which has a significant impact on GHG reduction processes and enhances the clean development mechanism (CDM)[2] of the Kyoto Protocol Agreement. In addition, it could establish an adaptation system for future impact of climate change scenarios in coastal Bangladesh by developing a special integrated approach with tidal power projects, which could also bring the sustainability of coastal management system of Bangladesh. There is also the need for an integrated water resource management to get adapted to the additional uncertainties from climate change (Chowdhury, 2001).

[2] The Clean Development Mechanism (CDM), which has the potential to bridge the North-South divide that has long characterised international climate change negotiations, is the principal means by which industrialised and developing countries could work together to promote sustainable development, lower the carbon intensity of new investments, and reduce the cost of meeting the Kyoto Protocol obligations.

From the above discussion, it is clear that Bangladesh needs to develop a practical plan of action to face the problems of climate change and the development challenges for environmentally sound sustainable coastal development. This will require a well-coordinated policy of scientific research and development for building the adaptive capacity in coastal Bangladesh. In particular, such capacity needs to be developed in the fields of disaster management, agriculture, water resource management, and coastal zone management (Huq, 2001). Therefore, the rest of this paper discusses the threats of global warming to coastal Bangladesh and examines the tidal energy potentiality in coastal Bangladesh for one of the mitigation and adaptation processes of climate change threat. Finally, the paper proposes a framework of integrating tidal energy with various potential coastal resources in Bangladesh for environmentally sound coastal development.

Sea Level Rise and Its Consequences

Ocean warming and thermal expansion will be the largest contributors to sea level rise during the 21st century. Nowadays, sea level rise is a well known subject to all concerned scientists, educationists, journalists, environmentalists and others. Over the decades, climate can influence sea level by heating and thereby expanding seawater. Concern about a possible acceleration in the rate of sea level rise stems from measurements showing the increasing concentrations of carbon dioxide (CO_2), methane (CH_4), chloroflurocarbons (CFC), and other gases released by human activities. Several hundred experts and scientific authors of the CSIRO Marine Research and the Antarctic Cooperative Research Centre in USA spent three years on climate change issues and suggested that if nothing is done to reduce these greenhouse gas emissions, global surface temperature is projected to increase by 1.4 to 5.8 ^{o}C over the period of 1990 to 2100 with an associated rise of sea level of 15 to 95 cm. (Khan, 2001). The projected

rate of warming is much larger than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years (Khan, 2001). These changes may lead to a number of potentially serious consequences for many agricultural regions, such as crop yields and productivity will decrease or vary frequently and significantly in different seasons in a year, or from year to year. Many of the world's poorest areas are included in this category, where biological diversity – the source of enormous environmental, economic, and cultural value – will be threatened by this rapid climate change. The composition and geographic distribution of unmanaged ecosystems will change as individual species respond to new conditions slowly. Species that cannot adapt quickly enough may become extinct which is an irreversible loss. However, the world's ocean levels will continue to rise even if greenhouse gas emissions are stabilised now. As a result, coastal storm surges would become an increasing threat to life and property. According to Titus (1987), "(c)onsiderable uncertainty also exists regarding the impact of a doubling GHGs. Physicists and climatologists generally agree that a doubling would directly raise the earth's average temperature by about 1^{o}C if nothing else changed".

As 50-70% of the global human population is currently living in coastal areas (Cicin-Sain and Knecht, 1998), future sea level rise, alterations in storm patterns, and higher storm surges could have significant effects. "About 46 million people are currently at risk by flooding in coastal areas as a result of storm surges" (Barnabè and Barnabè-Quet, 2000). In the absence of adaptation measures with current population size, a 50 cm sea level rise would impact from serious flooding or permanent inundation to about 92 million peoples, while a 100 cm rise would increase this number to 118 million (Khan, 2001). Practically in some places of the world, such as along the Atlantic Coast, climate change

impact has already happened. With oceans warming by up to 1°C (33.8 degrees Fahrenheit) per century in the North Atlantic, a major meltdown of vast Antarctic and Greenland ice sheets is the biggest potential contributor to rising this sea level (Khan, 2001). According to Watson (2002), "(t)he earth's temperature had already risen 0.6 °C (1.08°F) over the last 100 years and it has seen more floods and droughts around the world in the last decade. Sea levels were likely to rise to 9-88 cm (3.54-34.64 inches) over the same period". Melt water from mountain glaciers has contributed 2-7 cm since 1900. Parts of the Greenland ice-sheet are melting at up to nearly 42 cm (16.8 inches) per year, and the thinning is affecting ice at higher altitudes than expected (AFP, 2001). According to all statistics of climate change, it is now clear that the potential impacts of climate change will put stresses on the coastal development and coastal habitat, fishing, pollution, biodiversity, and other many coastal resources, particularly in low-lying coastal area like Bangladesh (Khan, 2001).

International Response to Climate Change Adaptation

The first Climate conference recognised climate change as a serious problem in 1979. It issued a declaration calling on the world's governments 'to foresee and prevent potential man-made changes in climate that might be adverse to the well-being of the humanity'. After that a number of intergovernmental conferences focusing on climate change were held in the late 1980s and early 1990s. Together with scientific evidence, those conferences helped to raise international concern about the issue. In December 1990, the UN General Assembly approved the start of treaty negotiations. As an outcome, the Inter-governmental Negotiating Committee for a Framework Convention on Climate Change met for five sessions and finalised the UN Framework Convention on Climate Change. Adopted in 1992 at the Rio Earth Summit, it included a legally non-binding, voluntary pledge that the major industrialised countries would reduce their greenhouse

gas emissions to 1990 levels by the year 2000. This is being attempted under the United Nations Framework Convention on Climate Change (UN-FCCC), which was signed by almost all the countries of the world at the Earth Summit at Rio de Janeiro, Brazil in 1992. The UN-FCCC implicitly accepted that developed countries had special responsibility for the mitigation of the problem and committed them to reduce their greenhouse gas emissions to the levels of 1990. However the UN-FCCC did not commit them to a timetable or any specific country-by-country reduction. This was done after a hard debate at the Third Conference of Parties (COP3) held in Kyoto in 1997, known as the Kyoto Protocol. Since the signing of the Kyoto Protocol, it has not yet come into force, as that requires at least 55 countries representing at least 55% of global greenhouse gas emissions to ratify it. The biggest hurdle to the ratification of the Kyoto Protocol is the reluctance of the United States Senate to ratify it. However, the US alone discharges one-third of the total of greenhouse gases and is the single biggest polluting country of the present world (Stossel, 2001).

Under the Kyoto Protocol Agreement of December 1997, 38 industrialised nations have agreed to cut their emissions of six greenhouse gases linked to global warming (UNFCCC, 2001). The countries, which ratify, must reduce emissions of carbon dioxide to an average of 5.2% below 1990 levels during the five-year period 2008 to 2012 (Gribbin, 2001). The Protocol contains new emissions targets for industrialised countries for the post 2000 period. The important commitments are as follows:

- Cuts in the three most important gases – carbon dioxide, methane, and nitrous oxide – will be measured against a base year of 1990. Cuts in three long-lived industrial gases – hydro fluorocarbons, per fluorocarbons, and sulphur hexafluoride – can be measured against either a 1990 or 1995 baseline.

- An international 'Emission Trading' regime is established allowing industrialised countries to buy and sell emissions credits amongst themselves.
- For the purpose of assisting developing countries in achieving sustainable development and industrialised countries in achieving compliance with their quantified emission limitation and reduction commitments a 'Clean Development Mechanism' (CDM) is defined. The CDM is designed to enable developing countries to trade carbon emission reductions to developed countries. Also it puts in place several new special funds including one for the least developed countries (LDCs) and one for concrete adaptation projects in developing country parties.

The developed countries are mainly responsible for global warming, instead the developing countries are stepping forward now to make the Protocol effective. At the COP4 in Buenos Aires, Argentina became the first nation, which declared to ratify the Kyoto Protocol Agreement. Presently, UK and other European countries, Japan, New Zealand and many other countries have agreed to ratify the Kyoto Protocol Agreement (Climate Action Network Australia, 2001). As the protocol stands now, developing country commitments are restricted to voluntary participation in CDM. Although USA and Australia have signalled intention to withdraw from the Kyoto Protocol Agreement, a recent news poll survey found that 80% of Australians believe that the Australian Government should ratify the Kyoto Protocol Agreement without the USA if necessary (Climate Action Network Australia, 2001). It shows that the world is ready to carry out the ratification of the Kyoto Protocol even without the USA.

The International Climate Change Negotiations have impacted different countries to reduce the GHGs, such as: the European Union had cut CFC use from 301,000 tonnes

to 4,200 tonnes from 1986 to 1998, the fall in the United States during this period was from 306,000 tonnes to 2,500 tonnes, and in Russia, it was from 100,000 to 1,000 tonnes. Japan had made the best progress of all, cutting use from 118,000 tonnes to zero. However, half a dozen developing countries were increasing CFC use, most notably China (Khan, 2001). According to the USA Department of Energy, Energy Information Agency on 1990 to 1999 carbon emissions, it is clear that China's emissions are dropping while Australia's and the USA's continue to increase. It shows that China decreased its CO_2 emissions by about 17% from 1997 to 1999 and is now back at its 1992 emission level. It also shows that during that same period the USA increased its fossil fuel related carbon emissions by 12%, and Australia' s emissions increased by about 5%. It also shows that emissions either dropped or stayed stable in Indonesia, North and South Korea, the Philippines, Thailand and Japan[3].

Causes and Cost of Climate Change

Greenhouse gases allow incoming solar radiation to pass through the Earth' s atmosphere but prevent most of the outgoing infrared radiation from the surface and lower atmosphere from escaping into outer space. This process occurs naturally and has kept the Earth' s temperature about 59°F warmer than it would otherwise be. So, global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases. A comprehensive assessment by the IPCC suggests that human activities are the primary cause to climate change. The burning of coal, oil and natural gas as well as deforestation and various agricultural and industrial practices are altering the composition of the atmosphere and contributing to climate change. These human activities have led to increase atmospheric concentrations of a

[3] http://www.eia.doe.gov/emeu/iea/carbon.html and http://www.eia.doe.gov/emeu/iea/tableh4 .html

number of greenhouse gases, including carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and ozone in the lower part of the atmosphere. Carbon dioxide is produced when coal, oil, and natural gas are burned to produce energy used for transportation, manufacturing, heating, cooling, and other applications. Among, all GHGs, burning of fossil fuel is the main cause for the climate change and global warming. The use of fossil fuel currently accounts for 80 to 85% of the carbon dioxide being added to the atmosphere (Khan, 2001). The atmospheric concentration of carbon dioxide has increased by 31% since 1750. The present carbon dioxide concentration has not been exceeded during the past 4,20,000 years (Rahman and Mallick, 2002). Besides, 80% of the current problem of global warming has been caused by industrialised nations reaching high living standards by burning fossil fuels (Reynolds, 2001). The USA emits 720 million tonnes CO_2 annually and has a per capita figure of 20.5 tonnes, which is the highest CO_2 pollution by individual country category. On the other hand, China and India, for example, have total annual emissions of 200 and 300 million tonnes respectively, but emissions per capita of 2.5 and 0.9 tonnes (Reynolds, 2001). Australians have produced 16 tonnes of CO_2 pollution per person and 306 million tonnes annually from fuel combustion in 1997. The average US household is responsible for emitting about 15 tonnes of carbon dioxide a year (Plotkin, 2002) [4]. According to Lovell (2002), 16 billion tonnes of carbon dioxide are belched into the air each year from fossil fuels.

Methane is the second most important of the greenhouse gases resulting from human activities. It is produced by rice cultivation, cattle and sheep ranching and by decaying material in landfills. Human activities have increased the concentration of methane in the

[4] The USA is the world's worst polluter.

atmosphere by about 145% above what would be present naturally. Nitrous oxide is produced by various agricultural and industrial practices. The atmospheric concentration of nitrous oxide has augmented by 17% since 1750 and continues to increase. Though under the regulation of 'Montreal Protocol' chlorofluorocarbon gases are decreasing, some other synthetic compounds, sulphur hexafluoride is also greenhouse gas, and their concentrations are currently increasing. On the other hand, depletion of the stratospheric ozone layer from 1979 to 2000 is estimated to have caused a negative radioactive forcing. As a result, the global surface temperature has increased since 1861. Again since late 1950s, the overall global temperature increases in the lowest 8 kilometres of the atmosphere and in surface temperature have been similar at 0.10C per decade (Khan, 2001). Satellite data also shows that there are very likely to have been decreases of about 10% in the extent of snow cover since the late 1960s. Global average sea level rose between 0.1 and 0.2 meters during the 20th century (Khan, 2001).

In addition of the above GHGs sources, volcanoes emit about 5 x 10^{11} kg of CO_2 to the air annually over long term. This amount is approximately 3% of that emitted by anthropogenic activity[5]. The global emission of carbon dioxide reached a new height of nearly 23,900 million tons in 1996 – nearly four times the 1950 total (Rahman and Mallick, 2002). According to James Hansen (Hansen *et al*., 2000), who is one of the world's leading experts on global warming, "' 'positive climateforcing' means global warming and ' negative climate forcing' means global cooling". He described that rapid global warming in recent decades has been driven by not only CO_2, but also by non-CO_2 greenhouse gases, such as chlorofluorocarbons (CFCs), CH_4 (methane) and N_2O (Hansen *et at*., 2000). This is because of the burning fossil fuels that not only gives off

CO_2, but also creates emissions of certain aerosols such as sulphates which have a negative climate forcing effect (Hansen *et at.*, 2000). Other aerosols such as black carbon particulates have a positive climate forcing effect. This interpretation does not alter the desirability of limiting CO_2 emissions, because the future balance of forcing is likely to shift toward dominance of CO_2 over aerosols (Hansen *et at.*, 2000).

A report by insurers, which are members of the United Nations Environment Programme's (UNEP) Financial Services Initiative, found that global warming might cost the world $300 billion a year unless urgent efforts are made to curb emissions of carbon dioxide and the other gases linked with the 'greenhouse effect' (Nuttall, 2001). Ecosystem losses, including mangrove swamps, coral reefs and coastal lagoons, could run at over $70 billion by 2050. Such areas are vital nurseries for fish, upon which many poor communities rely for protein, as well as being homes to precious marine life. Agriculture and forestry could lose up to $42 billion worldwide if carbon dioxide levels reach twice their pre-industrial concentrations as a result of droughts, floods and fires. Natural disasters, including more frequent cyclones and hurricanes, could add a further $3 billion dollars to the globe' s climate-related bill. There are also expected to be losses and additional costs in the construction, transport and tourism industries but these have so far not been quantified (Nuttall, 2001). The economic costs will include:

- Dam and dyke-building to keep rising sea-level out of coastal cities and farmlands;
- Damages to farmlands and crops resulting from weather extremes created by GHG;
- Diminishment of fresh surface and groundwater drinking supplies in dry areas;
- Forest fire fighting costs, including loss of productive timber forests and loss of tourism from burned over areas;

[5] Source: URL: http://www.users.aber.ac.uk/jpg/volcano/volcintr.htm

- Reduction of salmon and other coastal fisheries affected by global warming; and
- Damage and repair costs to buildings, roads and infrastructure associated with extreme weather (cyclones and tornados).

Climatic changes could trigger worldwide losses totalling many hundreds of billions of dollars per year and most countries can expect their losses to range from a few tenths of a per cent to a few per cent of their gross domestic product (GDP) each year. Certain countries, especially Small Island States including Bangladesh, could face losses far exceeding 10 per cent (Nuttall, 2001).

Bangladesh Scenarios

General: Recent IPCC report (IPCC, 2001) has indicated that the likely rise in mean sea levels by 2100 will be more like 60 cm. The sea level rise affects the coastal inexorable physical process that will continue for centuries, land subsidence of local level, and impact in terms of rising salinity in the coastal lands and waters. Besides, droughts and floods are coming severely way as a consequence of climate change. Tropical cyclones will become more frequent as the consequences of this global warming. Recently it is reported that lakes in the Himalayas are filling very rapidly, because the rising temperature could burst its banks within a decade, sending walls of water crashing down into valleys (Slesser, 2001). As a result, glacial lakes are being filled up swiftly with water from the melting of glaciers and surrounding snowfields by rising temperature. Rising sea levels could mean the total disappearance of some island nations and large scale flooding of many coastal regions like Bangladesh where the majority of the world's population now live.

Bangladesh Case: Bangladesh has been formed by the Ganges-Brahmaputra delta that represents a kind of coastal belt, and is one of the world's most densely populated countries in the present world. According to IPCC, the sea level rise will be in the range of 15 cm to 95 cm by the year 2100. On the high end of sea level, the rise could be about 30 cm by the year 2030. Even a 10 cm sea level rise, which will happen well before the year 2030 by even the most cautious IPCC projections, will inundate 2,500 square km, about 2% of the total land area of Bangladesh. Patuakhali, Khulna and Barisal regions are at most risk from the sea level rise as the sea on an average will move in about 10 km (BSS, 2002). Other studies have estimated that a 1m rise in sea level will permanently inundate the low lying coastal area, covering 17% of Bangladesh's total land area, where some 20 millions people are living (Huq, 2001). The World Bank has reported that the sea level along the Bangladesh coast is rising at about 3 mm a year and the sea-surface temperature is showing a rising trend due to climate change (World Bank, 2001). The impact of a higher sea level on the coastal zone is likely to have several consequences including increased salinity of the coastal crop lands, dying of Sundari trees in the mangrove Sundarbans and even loss of coastal lands due to enhanced coastal erosion (Huq, 1999). All these impacts will exacerbate the already occurring problems of the coastal zone and need to be taken into account in coastal zone planning. Although people of Bangladesh have no major role in terms of measures to stabilise human induced greenhouse gas emissions leading to climate change, they remain on the receiving end to suffer from its consequences (BSS, 2002).

Ecosystem and biodiversity may be at the greatest risks of all possible impacts of climate change in Bangladesh, which has been facing formidable socio-ecological and

economic problems due to various reasons. Several key risks[6] to ecosystems and biodiversity are to be caused by the combination of high sensitivity to climate changes and low possibility for anticipatory adaptation measures (World Bank, 2001). The risks include low flow in dry season resulting in further salinisation of the Sunderbans, lower groundwater tables and river inflows, substantial drought stress and desertification in some sensitive parts in North-west Bangladesh, accentuating depletion of organic carbon from the topsoil, threatening the endemic species and higher water temperature that may change water conditions. Increased stress on ecosystems will reduce their resilience to changes or climate variability in terms of the biodiversity loss and lower agro-ecological productivity (World Bank, 2001). In addition, the possibility of more frequent and more intensive floods will be likely in Bangladesh, particularly through combination of monsoon rainfall with increased snowmelt from the Himalayan mountain range. Thus, the change in global climate will paradoxically cause both more flooding (in the wet season) and more droughts (in the dry season) in Bangladesh. The experts fear that at least 24 million people of coastal areas of Bangladesh will be directly affected by the climate change (Rahman and Mallick, 2002). Agriculture and fisheries, industry and trade, and communication will be severely disrupted and, have to face decimated fishing industry, increased flooding, and the loss of endangered animals, including the world's largest assemblage of Royal Bengal Tigers from the world heritage of the mangrove Sundarbans, 500 types of birds and 40 species of animals (Rahman and Mallick, 2002). According to World Bank (2001), Boro rice and wheat production could decline up to overall 32% and 31% from the country. However, both precipitation during the monsoon season together with enhanced river flows due to snowmelt in the Himalayas and drainage congestion due to higher sea levels (specially during high tide conditions) will mean that in future the annual monsoon floods are also likely to lead to a higher

[6] http://nation-online.com/200205/10/n2051001.htm

frequency of severe flooding. Thus the twenty-year flood event may become a fifteen-year or even a ten-year flood event (Huq, 1999). According to Saleemul Huq (Huq, 2001), “Bangladesh is likely to be amongst the most seriously affected and, in terms of total population at risk to climate change, it may be the most vulnerable country in the world”. Khan (2001) reported that 1-meter sea level rise could displace nearly 15 million people. Different scientists reported that climate change could be affected jointly on subsidence and sea level rise and resulted as the serious drainage and sedimentation problems in coastal Bangladesh. According to the World Bank study, the problems of drainage congestion, reduced fresh water availability, disturbance of morphological processes and increased intensity of disasters (extreme events) are the main future climate change issues of Bangladesh (BSS, 2002). The present limit of tidal influence is expected to move further upstream, where surface water and ground water salinity may cause serious water supply problems for drinking and irrigation over large areas. It was observed that this effect would be particularly strong in the coastal zone, covering about 30% of the country (BSS, 2002). Reduced fresh water availability would become a serious problem due to low river flows and increased evaporation and transpiration in the dry period. The additional effect of saline water intrusion in the estuaries and also into the groundwater stimulated by low level of river water flow and sea level rise will be significant in the coastal zone, where increased intensity of disasters including cyclone/storm surges, floods and droughts would become evident (World Bank, 2001). However, according to Khan (2001), projected impacts include:

- Land loss and population displacement;
- Increased flooding of low-lying coastal areas;
- Agricultural impacts resulting from inundation, salinisation, and land loss; and

- ¬ Impacts on coastal aquaculture.

Present and Past Symptoms of Climate Change: The coastal town of Khulna and part of Jessore are already facing long-term saline water inundation, increase of ground water salinity and other problems. The Sundarbans mangrove forests (the largest mangrove forest in the world) are showing signs of stress from rising salinity. The cyclone of April 1991 has killed over 100,000 people (mainly due to the associated tidal wave). The cyclone of 1970 was the worst in terms of loss of lives since records have been kept.

Greenhouse Gas Scenarios: The population of the US is nearly twice that of Bangladesh, where the economy and geographical size dwarfs that of Bangladesh. In terms of the GHG emissions (please see Table 1), the two countries are poles apart (Huq, 2001).

Table-1: CO_2 Emissions in USA, Japan, Europe and Bangladesh, 1996

Country	**Total CO_2 emissions**	**Per capita emissions**	**Total contribution since 1950**
USA	5,300,991	19,674	186,114,027
Bangladesh	22,959	190	269,959
Japan	1,167,666	9,284	31,157,964
Europe	6,124,896	8,414	264,991,558
World	**23,881,952**	**4,157**	**718,514,064**
(In percent of World total)			
USA	22.0	473.0	26.0
Bangladesh	0.001	0.05	0.004
Japan	5.0	223.0	4.3
Europe	26.0	202.0	37.0

Note: CO_2 emissions in thousand metric tons in 1996 from fossil fuel burning and cement manufacturing
Source: WRI, 2001

Table 1 shows that the USA accounts for 26% of global accumulated CO_2 over the last half-century, while Bangladesh accounts only for less than 0.004% (Huq, 2001). Through the increase of CO_2, IPCC provided an estimate in its findings on climate change in 1990 saying that the world will become 3.3^{o}C warmer (IPCC, 2001), where Bangladesh 0.5 to 2.0 ^{o}C warmer than today by 2030 (Rahman and Mallick, 2002).

Electricity Scenarios and other Characteristics of Coastal Bangladesh: The combination of freshwater and saltwater in coastal estuaries creates some of the most productive and richest habitats on earth; the resulting bounty in fish and other marine life can be of great value to the long coastal area of Bangladesh. On the other hand, it has an insignificant amount of power/electricity supply available. This is mainly due to its vulnerability to natural as well as artificial hazards. Ironically, Bangladesh is a country with the lowest usage of electricity (only 95 kilowatt hours [kWh] per capita) in the world (Salequzzaman *et al.* 2000), compared to the per capita electricity consumption of Norway (24,602.30 kWh), the United States (12,407.44 kWh), the United Kingdom (9,211.17 kWh), Australia (5,582.97 kWh), and even India (411.69 kWh).[7] Only 16 percent of Bangladesh's population have electricity, and in rural areas this drops to less than 5 percent (Huq, 1998). The availability of electricity in coastal villages is much lower than even the village level average, because of the poor socio-economic conditions and the remoteness of these areas from major population areas (Salequzzaman and Newman, 2001). The present land-use patterns of coastal Bangladesh are dominated by shrimp aquaculture. There is however growing evidence that the fast-growing shrimp aquaculture industry has threatened the ecological sustainability of the coastal environment, while the economic viability of the local communities dependend on it (Ahmed and Mirza, 2000; Alam, 2001; WCED, 1987).

The Bangladesh Water Development Board (BWDB) has constructed coastal embankments since 1958 to protect the coastal populations and their agricultural land from natural calamities, including floods and saline water intrusion. A crucial issue that has not been scientifically addressed is the adverse effects on the water system created by these embankments, including accelerated erosion at undesirable locations, unacceptable siltation patterns, siltation of drainage outlets, the loss of fish spawning grounds, and hindrance of commerce dependent on navigation (Barua, 1993). In the initial, post-construction stage of the coastal embankments, the BWDB banned the release of saline water into the polders (ponds surrounded by the embankments) from its canals along the embankment sides (Ahmed and Mirza, 2000). Later that embargo was lifted and many shrimp farmers in Khulna and Satkhira districts started shrimp aquaculture in the polders by discharging saline water from the nearby polders of inside embankments (ESCAP, 1992). Once coastal shrimp production started earning foreign currency, the Bangladesh government permitted saline water intrusion into some of the polders for shrimp aquaculture (Karim, 2000). Presently, coastal shrimp farmers are using these embankments for the facilities of shrimp aquaculture and haphazardly changing the original structures (Salequzzaman, 2001). Shrimp aquaculture has expanded randomly since the 1980s, and has led to environmental degradation in terms of destruction of mangroves, pollution of tidal rivers and inshore waters, salinisation of soils, loss of grazing grounds for livestock, and loss of freshwater sources for drinking water and other resources (Salequzzaman, 2001). Continuous storage of saltwater in the shrimp ponds alters the chemical properties of the pond water and surrounding soil, rendering it unsuitable for future crop production. The cropland ecosystem of coastal Bangladesh historically served as a source of renewable products, such as grain,

[7] See http://www.globastat.com/e37.htm.

horticultural products, and fish. Unfortunately, shrimp farming has affected the long-term viability of this physical environment in several ways (Huq, 1998). First and foremost, the conversion of land has lead to less prime land being available for agriculture. Due to increased soil and groundwater salinity, crop yields are shrinking, and freshwater bodies, grazing fields, and forests are decreasing and, even where trees remain, their growth is stunted (Salequzzaman, 2001). More than five million people living in the coastal areas are affected by this over-salinity in different ways (Karim and Aftabuzzaman, 1999).

The Bangladesh coast supports about 587,400 hectares of natural mangroves and a further 24,120 hectares of planted mangroves (Mahmood, 1986). Almost 50 percent of these were destroyed or lost between 1975 and 1997, due to the unplanned construction and unsustainable use of coastal embankments and the subsequent increase of coastal shrimp aquaculture (Salequzzaman and Bhuiyan, 2000). The degradation of this mangrove ecosystem has resulted in the depletion of native fish and shrimp stocks by negatively affecting the nursery grounds of the post-larvae and juveniles, and also caused the disappearance of other native species of birds and fish (Gain, 1998). The destruction of mangrove forests has resulted in increased vulnerability from cyclones and tidal waves, salinity intrusion, and greater evaporation and acidification of surface water (Salequzzaman and Bhuiyan, 2000; ESCAP, 1992). Poor people are engaged in shrimp fry collection randomly along the coastal area, often leading to destruction of shrimp habitat. The freshwater apple snail (*Pila globosa*) population is now decreasing every year due to the unorganised and unsustainable exploitation for shrimp prawns feed supply. Presently, the snail is overexploited and

listed as an endangered species by IUCN[8] Bangladesh (Salequzzaman 2001). In addition of these problems, high levels of groundwater salinity were found in the villages of Bagerhat and Gopalgonj districts in the summers of 1997 to 1999 (Salequzzaman, 2001). This indicated that wells closer to shrimp ponds/ghers were highly saline. Salinity as high as 34 percent (1gm/kg) was found in a water-well located within a distance of three metres from the sampled shrimp pond (Salequzzaman and Bhuiyan, 2000).

Due to the above situations and destructive shrimp aquaculture practices, several communities have lost their traditional livelihoods. In the process, shrimp aquaculture has led to social conflicts over land tenure and use rights, leading to the marginalisation of the small rice farmers, who have been forced to lease their land to large shrimp farmers. The problem has led to irreparable damage to the environment and the socio-cultural ethos in the shrimp aquaculture areas. Practically, Bangladesh contributes about 5 percent of the total global cultured shrimp production (BBS, 2000). The growth rate of the exports of this sector has been 4,900 percent over the last two decades (Karim, 2000). Every year the negative impacts grow and begin to challenge the productivity of this industry. For example, lots of raw shrimp and other coastal fish have been wasted due to the lack of cold storage facilities and lack of electricity supply in remote coastal areas (Salequzzaman, 2001). Also, the coastal shrimp aquaculture industry in Bangladesh seems to have outgrown itself compared to the rate of infrastructure development required to support it. Shrimp producers still have to depend on out-of-state suppliers for seed larvae and feed. These supplies may be expensive and also may not be available on time, affecting the overall profitability of shrimp farming (Salequzzaman and Bhuiyan, 2000). International markets are becoming more competitive, with increased production in almost every shrimp-producing country in the

[8] International Union for Conservation of Nature and Natural Resources

1990s (Cooksey, 1995). If this trend continues, market prices could decline in the future, affecting the industry's economic viability. The above analysis outlined a series of major ecological and social impacts that have arisen from coastal embankments and unrestricted, unplanned shrimp aquaculture, and also from future climate change and sea level rise. What is required is a new approach that can enable a sustainable solution for coastal development in Bangladesh, i.e. climate change adaptations and a solution which restores or protects the ecological base, improves the social situation and, simultaneously, is able to provide long-term economic improvement (Cicin-Sain and Knecht 1998). Tidal power may be an important missing link that enables the future climate change adaptations and sustainable coastal development to be accomplished simultaneously.

Adaptability and Sustainability Issues in Bangladesh

At the most basic level, Bangladesh is likely to be impacted by climate change by a number of factors including droughts, floods, cyclones and long-term sea level rise. In the short term this means that its people are likely to be hit by more and more natural disasters in the coming years. The first and most effective measure would be to improve disaster preparedness. Dealing with or adapting to climate change in the long term can bring immediate benefits in the short term to protect people and property from adverse natural calamities (Huq, 2000). In the longer term there is a need to incorporate accounting for climate change into Bangladesh development strategies and plans, and incorporate the issue of adaptation to climate change onto development plans. A preliminary study along these lines has recently been undertaken with support from the World Bank. It has identified several areas of long-term planning which incorporate adaptation to climate change, including coastal zone management, water sector planning and agriculture sector planning (Huq, 2000). There is an urgent need for

Bangladesh to develop mechanisms to better adapt to the climate change impacts and sea level rise, particularly along the country's coastal area. The possible adaptation could be:

- To develop technically feasible, low-cost, locally available, affordable and appropriate devices to live with water-related extremes;
- A general change of paradigms is needed in order to reduce the human vulnerability against these water-related extreme events, such as anticipation and prevention, which are more effective and less expensive than reaction in emergency;
- There is no single universal remedy against water-related extremes and it is necessary to use a site-specific mix of measures, including structural and non-structural ones;
- Due to the complexity of interacting pressures, an integrated, participatory and holistic approach should be taken for the whole adaptation system;
- An immediate challenge in coastal Bangladesh is the necessary to improve flood and cyclone protection by developing a strong coastal embankment system. For this purpose, the existing embankment could be strengthened by further civil engineering construction, and an integrating system with other resources for cost minimisation and appropriateness could be developed;
- To enhance the coordination, competence, tasks and responsibilities among different agencies and departments by acting across administrative boundaries, and assuring participation of stakeholders; and
- Finally, to strengthen the activity of preparedness systems, such as risk assessment, watershed management and increasing water storage, and add technology utilisation of the expected consequences of climate change situations.

The above adaptation system would have to be on a long-term rather than short or medium term basis. In the interest of the country's sustainable development, recently the World Bank argued for an anticipatory long-term strategy for Bangladesh rather than a reactive approach in meeting the impacts of climate change (World Bank, 2001). According to the International Council for Science for the UNEP-sponsored Global Environmental Outlook 2000 (GEO-2), integrated policies and inter-sectoral approach are needed to achieve sustainable development (Rahman and Mallick, 2002).

As the climate change caused mainly by the developed world, keeps impacting worse developing countries, the developed countries should do two things (Simms, 2001): firstly stop the GHGs emission, and secondly provide compensation for the harm caused to low lying developing countries such as Bangladesh. Bangladesh is a less developed country, which has no adequate financial and qualified human resources, and cannot cope with hydrological extremes without foreign and international assistance. Therefore, Bangladesh needs an effective assistance from the more developed world. The financial services initiative of the UN Environment Program (such as the Kyoto Protocol) estimates that the extra economic costs of disasters attributable to global warming are running at more than $300 billion annually (Simms, 2001). The best guess of development groups is that climate change could cost developing countries up to $9.3 trillion over the next 20 years (Simms, 2001).

Tidal Power Plant is the Possible Option for Adaptation to Climate Change and Sustainable Development in Coastal Bangladesh: The energy sector is the biggest current and potential source for GHGs emissions around the world. Although Bangladesh emits less than 0.1% of global greenhouse gas emissions (compared to 24% for the United States), it is nevertheless taking steps to reduce its future emissions

through the development of renewable energy (Huq, 2001a). In addition, because Bangladesh has only been able to supply electricity to less than a quarter of its rural population, this means that most of the future energy infrastructure can be developed by using relatively clean energy technologies, such as solar, photovoltaic or tidal (Huq, 2001).

Bytes (2001) states that "the average global sea level rise will be between 9 and 88 centimetres between 1990 and 2100, while global average surface temperatures are projected to rise as much as 5.8 ^{o}C". Many scientists argue that for coastal Bangladesh impacts of cyclones and their frequency will increase under a global warming scenario. The intensity and destructive power of cyclones in the future are likely to be greater as the sea surface temperature (a critical factor in determining whether a given cyclone will be accompanied by a devastating tidal wave) is likely to be higher with global warming (Huq, 2001). According to Saleemul Huq (1999) "even if the frequency of cyclones does not increase, the severity of cyclones will definitely increase as these are a function of the sea surface temperature, particularly tidal storm surges". The impact of elevated global temperatures will increase the South Asian monsoon rains in Bangladesh, and is likely to become more erratic with climate change. Therefore more frequent and more intense floods are likely to occur in Bangladesh, particularly through the combination of monsoon rainfall with increased snowmelt from the Himalayan mountain range. The melted ice from ice caps could raise the sea level by as much as 6 m, enough to drown coastlines, cause higher tides, generate more powerful storm surges and change the ocean currents (Hotz, 2001). Byrnes (2000) reports that rising sea levels and melting ice sheets around polar caps are being blamed for the worst floods to hit Asia in 50 to 100 years. The monsoon rains would increase the risk and vulnerability of coastal

communities. Therefore, climate change, intensity of cyclones, storms and tidal surges would require early warning systems, stronger adaptation, better shelter and better techniques to protect people from disasters. Bangladesh should focus more on the adaptation strategies, rather than on mitigation, as adaptation to climate change is the question of the country's physical security. In addition, development of risk-management approaches is promising to be useful in developing strategies for adapting to climate change. The country needs to develop a concerted plan of action to face the problems of climate change and the development challenges they present. Huq (2001) points out: "This will require a well-coordinated policy for scientific research and development, focusing particularly on building adaptive capacity. In particular, such capacity needs to be developed in the fields of disaster management, agriculture, water resource management, and coastal zone management. For example, Bangladesh and the Netherlands are both low-lying deltaic countries, but the Netherlands has the financial, scientific, and technological capacity to build higher sea walls, whereas Bangladesh does not".

Bangladesh has a long coastal area with two to eight metres in tidal height (head) rise and fall (BIWTA, 1999). Coastal Bangladesh, particularly Khulna, Barisal, Bagerhat, Satkhira and Cox's Bazar regions are geographically extensive deltaic areas equipped with levees and sluice gates (ESCAP, 1992; Barua, 1993). Thus it has some large tidal sites and many channels of low tidal range in a large number of deltaic islands where barrages and sluice gates already exist. These coastal areas are protected by embankments, which have been constructed since 1958 for protection from natural disasters such as flooding and tidal surges. Therefore the present infrastructure may be used for electricity generation by applying simple, small-scale tidal technology with

widespread applications (Brinkworth, 1998). The potential for tidal power in the region is significant, and the barrages necessary for creating controlled flow through turbines are also needed for flood control (Lewis, 1963; ISTP, 1999; Elliott, 1996). This avoids the problem of high capital cost as the engineering is either already there or is needed for cyclone protection in any case (Salequzzaman and Newman, 2001). In this application, three elements are needed. The first required element is the use of an undershot paddlewheel design with simple civil construction that would enable the placement of wheels at appropriate locations in the levees/barrages (Brinkworth, 1998). The existing technology of undershot paddlewheels is historical, and generally needs a greater head for energy production (ISTP, 1999). The second element is the use of recently developed, variable speed, electricity generation equipment, attached either directly to the wheel or via a simple gearing-up mechanism (Day, 1994). The third element is the use of existing electronic controllers, appropriate for small-scale machines, to regulate the power output from variable water flow (Brinkworth, 1998). The use of the existing flood control barrage system for the generation of “small-scale” tidal energy has obvious advantages in terms of avoiding the large civil engineering costs normally associated with the establishment of tidal energy systems (ISTP, 1999; Salequzzaman and Newman 2001). The preliminary concept design allows for installation of an undershot tidal wheel in each of the available sluice gates (Corry and Newman, 2000). The wheel would be linked to a generator and this would feed electricity into a local grid to serve the community. The tidal creeks would act as the reservoir; they are filled on the incoming tide via the tidal wheel, and then the water is released back through the wheel on the ebb tide (Brinkworth, 1998). This system will produce electricity for most of a daily cycle. The daily operation of the system ensures that the creek system is maintained and available to drain water from the island in the event of excess rain

(ISTP, 1999). Therefore the project also offers improvements to the islands' flood control capabilities. The tidal wheels can be made locally, making them comparatively inexpensive to build and install. It is assumed that environmental impacts would be minimal, because of the already-existing tidal barrages that were built for flood protection and have already affected an impact on the surrounding environment (Newman *et al.* 1999). Therefore, it becomes possible to utilise tidal power without the high capital cost of paying for the coastal engineering normally required.

Tidal power plant mitigates GHGs emissions into the atmosphere. The tidal power plant (TPP) could be integrated with various coastal resources (e.g. integration of agricultural and shrimp aquaculture with TPP) for enhancement of sustainable coastal development of Bangladesh. The whole development could be organised by participatory community-based organisation. An environmental impact assessment (EIA) system could be applied for identification and mitigation of the significant environmental consequences of tidal power plant. The proposed tidal power plants for coastal Bangladesh will act responsibly in reducing their own GHG emissions. In doing so, Bangladesh can tap into various international funding avenues such as the Clean Development Mechanism (CDM) for investments.

Climatologists and different environmental scientists have identified the climate change adaptation targets for Bangladesh. These include ecosystem, biodiversity, coastal resources, fresh water resources, agriculture and human health (World Bank, 2001). An integrated tidal power project for coastal Bangladesh will include the hatchery system, which could decrease indiscriminate catch of coastal fishery, such as shrimp, prawn, snail, many fishes and other biodiversity. The hatchery system will multiplicate these

aquatic animals and thereby protect many threatened ecosystems and biodiversity. The integrated tidal power project also includes massive and intensive afforestation around the project area and coastal embankment area, known as green belt. The afforestation includes endangered endemic plant and forest species of the country. According to Philip Sutton (Sutton, 2000), ecological sustainability is impossible unless the atmospheric concentration of CO_2 can be brought down below 300 ppm (parts per million). It is now 360 ppm and could double within 100 years or so if no action is taken to contain the rapid growth in emissions. In the integrated tidal power project, water treatment plant will constitute the primary treatment, where nutrients fertilise the polluted water and, grow plankton and sometimes plankton blooms. Plankton blooms occur on the surface of the water and rely on photosynthesis for its growth through the utilisation of carbon dioxide, a key greenhouse gas. This process stores carbon dioxide in the cells of the water vegetation, where it ends up as feed for fish or other aquatic animals. Plankton feeding fish eat this plankton and provide more food for the diminishing populations of fish. Through this process, more fish would start growing in places where the fish population has already declined as well as storing carbon dioxide in plankton will mitigate GHGs emission (Plotkin, 2002). The action required even to stabilise the atmospheric CO_2 concentration at current levels is quite severe because global emissions would have to be reduced to zero in about 60 years and then CO_2 would actually have to be removed from the atmosphere by the use of sinks, i.e. planting of trees. This should be followed by mandatory replacement by a fully renewable energy supply (Sutton, 2000).

Policy Approach to the Cost of Tidal Energy: Any kind of innovation could involve higher price. Tidal power will be comparatively expensive because the initial investment

costs are high. However, there is a tendency among the environmental groups to jump to renewable energy because of environmental sustainability. In the long run, the cost of tidal power will decline soon, because of comparatively more longevity of tidal power plant and its insignificant amount of operational cost (Day, 1994; Salequzzaman and Newman, 2000). Therefore, the government should give some kind of subsidiary to this sector and also develop a mandatory approach to buy tidal power or any kind of renewable energy. Different countries have already adapted such type of systems. In Australia, energy retailers who fail to meet the target reduction will be fined up to A$15.00 for each ton of carbon dioxide equivalent (Nichols, 2002). Like CO_2, NO_X is also a kind of GHG and is produced significantly from fossil fuel (coal or oil) based power plant and vehicle, particularly from diesel. The cost of NO_X emission credits is $4-50$/pound in California, USA (ANA, 2001). In Australia, the black coal fired power stations would have to be built at a cost of around A $1.4 million per MW of capacity, which will emit possible GHGs that will accounts as 0.9 tonnes of CO_2/MWh electricity[9]. Tidal power plant does not produce any sort of NO_X emissions, which contribute to smog and associated illnesses such as asthma.

Sources of Finance for Coastal Tidal Power Adaptation: The formation of the Clean Development Mechanism (CDM) would enable developing countries to trade their unused entitlements of GHG emissions to developed countries and the resulting funds to be used for the purposes of sustainable development, targeted at the most vulnerable countries; and for specific adaptation purposes. These developments are of potential significance to Bangladesh, because the funds are to be allocated specifically for most vulnerable countries, in which Bangladesh certainly falls, and for adaptation, which has

[9] For details, please contact to Anna Reynolds, Climate Action Network Australia, URL: http://www.climateaustralia.org, email: anna@climateaustralia.org

direct relevance to Bangladesh. Climate change impact on coastal Bangladesh is expected to be costly, and CDM will be a significant funding source for integrated tidal power projects.

In the Kyoto Protocol, financial mechanisms are of three types, namely international emissions trading, joint implementation and the Clean Development Mechanism. Under the Bonn Agreement, the outcome from COP6 (Conference of Parties 6) has generally been positive for the above emissions trading and related activities. Small scale renewable and energy efficiency projects will benefit from simplified CDM rules and procedures. The rules and procedures for the accounting of GHGs have finalised in Marrakesh[10]. The board of COP7 recommend to COP8 simplified modalities and procedures for small-scale CDM project activities on renewable energy projects with a maximum output capacity equivalent of up to 15 megawatts and energy efficiency improvement projects that reduce energy consumption on the supply and/or demand side by up to the equivalent of 18 giga watt hours per year (GWhy); or other projects that both reduce anthropogenic emissions by sources and directly emit less that 15 kilotonnes of CO_2 equivalent (Beck, 2002).

Besides CDM of the Kyoto Protocol, the Global Environment Facility (GEF) has also funded climate change mitigation projects. However, in order to take advantage of the opportunities from the international negotiations on climate change, Bangladesh must do a number of things, such as recognise the issue of climate change in the medium to long term basis and prepare for it accordingly. In the short term, it needs to recognise the opportunities as they open up and use its own resources to maximum benefit.

[10] For details URL: http://www.unfccc.int/cop7/documents/accords_draft.pdf

Therefore, a combination of political and methodological issues of climate change needs to be developed.

Recommendation Strategies for Climate Change Adaptation in Coastal Bangladesh

It is clear that Bangladesh is prone to sea level rise due to global warming and climate change. There has been a record rise in the temperature level in the country due to the warming of the climate globally. During recent years, Bangladesh has also witnessed some of the most devastating floods, tidal surges, cyclones, tornadoes, droughts and other natural disasters, but Bangladesh is committed to the protection of the environment and demonstrates this in every possible manner within limited resources. Bangladesh has signed most of the inter-governmental conventions and protocols in the field of environment, and is doing its best to implement their provisions. Coastal Bangladesh has been suffering from severe lack of electricity, and thereby this area is far behind from modern facilities and development. In this situation, the most important step will be for the government of Bangladesh to appreciate the importance of climate change as a development issue in the short, medium and long terms, not just an environmental issue for the long term, and to develop appropriate scientific and strategic planning initiatives keeping this in view.

There is a possibility to establish tidal power plants at the existing situation in coastal Bangladesh by utilising its embankment and sluice gate. Future climate change scenarios indicate that sea level will definitely increase. Therefore, it will be needed to further raise the height of coastal embankment to protect the coastal peoples and resources. In this paper we propose a tidal power plant that could be integrated with different coastal resources for a better ecologically sustainable coastal development. In

this new type of development, changes will be required to agricultural and forestry practices, particularly the use of land and water, to protect the environment as it responds to climate change. However the following types of strategy could be developed for the better sustainable coastal development of Bangladesh.

- ***Changes of attitude of the people and its government:*** The government needs to change the existing institutional and political attitudes as to how to phase in energy-intensive industries from the renewable energy sources (such as tidal power), how to change the behaviour of the energy supply industries (through structural changes, changes to market rules, changes in taxes and subsidies, and changes in the allocation of costs), how to change the behaviour of energy consumers (through education, access to finance and price signals), and how to ensure that more energy-efficient buildings and appliances are available on the local market, little real change can be expected.
- ***Long-term strategy:*** Climate change adaptation in coastal Bangladesh needs long-term strategy rather than a reactive short-term approach. International organisations also identified that Bangladesh needs the long-term view for meeting the impacts of climate change for the greater interest of the country's sustainable development (World Bank, 2001).
- ***Activation of Kyoto Protocol and other international negotiations:*** Industrialised countries, including USA, the European Union, Russia, Japan and Australia, emit 55% of the whole GHGs emissions. Although USA has denied ratifying the Kyoto Protocol, the treaty can still come into force (Hinrichs-Rahlwes, 2001). Once ratified, the deal will set legally binding targets on the world's richer nations to cut GHGs. The Kyoto mechanisms are the provisions of developed countries responsible for most of the GHGs emissions (Tony Beck Consulting, 2002). Once operation of the

CDM is left to the market forces alone, CDM projects and transfer of technology (e.g. tidal power) will tend to be concentrated in developing countries such as Bangladesh. Besides, according to the successful negotiation of the Bonn Agreement, there will be active cooperation with developing countries under the United Nations Framework Convention on Climate Change (UNFCCC) aimed at capacity building, technology transfer and adaptation[11]. The World Bank already launched the Prototype Carbon Fund (PCF) in January 2000, with a potential capital of $150 million, the world's first market-based mechanism of emission reduction efforts[12]. Industrialised countries and multilateral organisations can also help Bangladesh to better cope with the challenges of climate change (Huq, 2001). Bilaterally Bangladesh has good relations with a number of industrial countries.

- ***Raising awareness:*** Awareness is an important factor for public movement and community participation. There is a need to increase awareness of the emerging problems of climate change and sea level rise, consequently how this sea level could be mitigated or adapted with more resource utilisation (such as integrated tidal power projects) in coastal Bangladesh. All the key stakeholders, such as policy makers, academics, technocrats, and the general public must be involved in this awareness program. More importantly, such public awareness campaigns should focus on taking advantage of the country's indigenous knowledge and experience in coping with such extreme events that have occurred in the past, and using that to prepare for the future eventualities.
- ***Initiative of research and development programs:*** Adaptation or mitigation of climate change scenarios should come through extensive research and development

[11] Paula Dobriansky, Under Secretary of State for Global Affairs, Statement at COP6, Bonn, 23 July 2001

programs. Tidal power project is the outcome from such an innovative research in coastal Bangladesh, but there is need for further research for its boarder application throughout all the coastal areas of Bangladesh as well as other coastal areas. Investment in research and development could come from developed countries, which are predominantly responsible for climate change. As the USA is a major contribution of GHGs and Bangladesh is the victim of its consequences, the USA (and other developed countries for that matter) could support a research and development program through utilising the considerable Bangladeshi expertise (Huq, 2001). This would focus primarily on looking at adaptation options and building adaptive capacity.

- ***Training and educational programs:*** At this moment, nobody has any practical experience on what sort of consequences would be coming from climate change. Scientists have described different consequences from climate change. These scenarios should be communicated the other people for adequate precaution. Ironically, coastal Bangladesh has already experienced some of the impact of climate change, such as salinisation, more frequent cyclones and tidal surges with a significant sea rise during specific seasons of the year. Training and educational programs should include how the situation could be adapted for the coastal peoples and their resources, to provide better security and how the changing situation could be utilised in a better way (e.g. integrated tidal power project).

Conclusions

The issue of climate change is the biggest threat in the 21st century. Although Bangladesh has insignificant contribution to GHG, the country is a most vulnerable

[12] Personal communication to Dr. Mizan R. Khan, who wrote COP6 at The Hague. The author is Policy Specialist at the UNDP-supported Sustainable Environment Management Programme (SEMP), implemented by the Ministry of Environment and Forest of Bangladesh.

country. If climate change is true, Bangladesh is definitely impacted by sea level rise, particularly in the low-lying coastal region. The coastal peoples already lack all types of modern facilities, including electricity. The future climate change adds more burdens and problems to coastal peoples and their resources, which needs appropriate adaptation and mitigation measures. The research recommends a coordinated response in Bangladesh's overall adaptation to climate change with specific crosscutting measures affecting a number of sectors at a time. The response can be obtained at three different levels, namely coordinated institutional response; research needs, management and dissemination, and international positioning and representation. Integrated tidal power project is put forward as such an appropriate innovation that has both advantages of mitigation of GHGs and adaptation technology. Future sea level rise will increase tidal power output, which is clean and renewable. This integrated tidal power project will solve many problems that exist at present in coastal Bangladesh. It will also be a probable candidate for climate change adaptation and CDM for financing. Therefore, it is necessary to recognise the climate change impacts and that dealing with them is not a special type of environmental problem only, but something that is fundamentally tied to the country's sustainable development.

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