"Bangladesh and the Copenhagen Accord: how much carbon dioxide might Bangladesh emit in 2050?"

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Bangladesh and the Copenhagen Accord: how much carbon dioxide might Bangladesh emit in 2050?

Abstract

Bangladesh, a country with a population of about 160 million, is currently contributing 0.14 percent to the world's emission of carbon dioxide (CO_2). However, mostly due to economic growth and the related increase in energy consumption, Bangladesh's share in CO_2 emissions is – despite an increasing use of alternative energy – expected to rise sharply. This study uses the example of Bangladesh to illustrate the long-term impact of population growth, rising income per capita, agglomeration, and improvements in energy efficiency on low-income countries' CO_2 emissions. Using a projection period until 2050, it shows that Bangladesh's emission would surpass a simple equity-based per capita emission limit consistent with the Copenhagen Accord if there are no changes in Bangladesh's carbon intensity and no gains in its energy efficiency, but that Bangladesh would stay below such a limit with some feasible improvements in energy efficiency.

Keywords: climate change, greenhouse gases, Copenhagen Accord, Bangladesh.
JEL Classifications: Q56, Q54, Q52.

Introduction

As is well-known by now, the concentration of so-called greenhouse gases (GHGs) in the earth's atmosphere have increased markedly as a result of human activities since 1750. While the concentration of all types of GHGs has increased in the atmosphere, the focus has been on CO_2, as it constitutes due to its large share and longevity the most important GHG. Most of the world's leaders have recognized the need to limit and ultimately reduce global CO_2 emissions, leading to the 15th United Nations Climate Change Conference (COP15) in Copenhagen, held from December 7-18, 2009.

"To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change"[1].

Even though the Copenhagen Accord has failed to provide a credible pathway for reaching this objective, we have some indication for how much global CO_2 emissions would need to be reduced to achieve this objective, as is reflected in the following quote and Figures 1 and 2.

"The chance of reaching the 2°C target falls with increasing greenhouse gas (GHG) concentrations in the atmosphere. The total concentration of GHGs can be expressed in terms of the radiative forcing (RF) of all gases as if it was caused by CO_2 alone (the so-called 'CO₂-equivalent concentration', CO_2e). According to Hare & Meinshausen (2006), there is about a 70% chance of achieving the target for a 400 ppm CO_2e, a 50% chance with 450 ppm CO_2e and a 25% chance with 500 ppm CO_2e"[2].

Figures 1 and 2 also show that there is a 50 percent chance to reach the Copenhagen Accord (i.e., to hold the increase in global temperature below 2 degrees Celsius) if we reduce the global GHG emissions to about 20 Giga tons of CO_2-equivalent ($GtCO_2$-eq) by 2050 and to about 10 $GtCO_2$-eq by 2100. While the Copenhagen Accord has stated that this reduction is to be achieved on the basis of equity and in the context of sustainable development, there is no agreement on what such an equitable basis is.

As pointed out in Neufeldt et al. (2009), both the 450 and the 400 ppm CO_2e concentration scenarios highlight the importance of (near) global participation in reducing CO_2 emissions, though the timing for the emission peaks will vary across countries based on their level of development. Consistent with previous United Nations Climate Change Conference agreements, the Copenhagen Accord (paragraph 2) states: "We should cooperate in achieving the peaking of global and national emissions as soon as possible, recognizing that the time frame for peaking will be longer in developing countries and bearing in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries and that a low-emission development strategy is indispensable to sustainable development."

[1] Paragraph 1 of the so-called Copenhagen Accord, available at: http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf.

[2] See Neufeldt et al. (2009, p. 4).
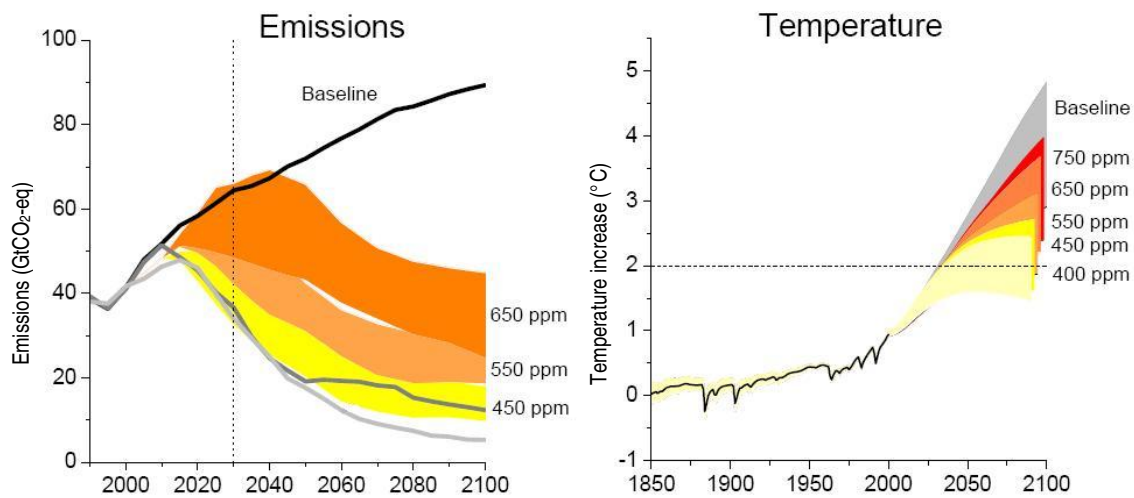
Source: ADAM-project and MAGICC calculations from Van Vuuren et al. (2008), as provided in Neufeldt et al. (2009, p. 5).

Fig. 1 and 2: Indication of emissions profiles and temperature outcomes of different stabilisation targets

The Government of India (2008, p. 2) has stated that "the principle of equity that must underlie the global approach must allow each inhabitant of the earth an equal entitlement to the global atmospheric resource" and that "India is therefore determined that its per capita greenhouse gas emissions will at no point exceed that of developed countries." Applying a per capita approach to the above limits on global GHG emissions would imply per capita emission limits of about two tons of CO_2eq in 2050 and one ton of CO_2eq in 2100.

This paper provides alternative projections for Bangladesh's future CO_2 emissions (based on a set of alternative assumptions about Bangladesh's population growth, income per capita, agglomeration, and improvements in energy efficiency) to assess if Bangladesh is likely to achieve the simple per capita limit that would be consistent with the Copenhagen Accord. Given that it seems likely that Bangladesh will use its large coal reserves for future electricity generation, we also discuss some issues related to Bangladesh's carbon intensity.

The paper is structured as follows. The next section provides some background on Bangladesh, including information on its current energy crisis and energy policy. The second section describes the methodology used for establishing different scenarios and projections. The third section presents the results, and the final section provides some conclusions.

1. Background

Bangladesh emerged as an independent country in 1971, after fighting a devastating independence war with Pakistan, from which it was geographically and ethnically disconnected. It is situated in the low-lying river deltas of the Ganges, Meghna, and Jamuna (Brahmaputra) and is − with nearly 160 million people on 144,000 square km (about the same size a New York state) − the world's most densely populated country (after excluding some small islands and countries with less than 1000 square km). Bangladesh has been officially identified by the United Nations (UN) as a least developed country (LDC), reflecting its low income, weak human assets, and high economic vulnerability. Bangladesh is also recognized worldwide as one of the most vulnerable countries to the impacts of climate change.

Bangladesh is in the midst of resolving a serious energy crisis, which is characterized by the demand for electricity surpassing that of supply by a large margin, leading to extensive load-shedding, which according to World Bank (2009, p. 75) resulted in a 10 percent loss of Bangladesh's gross domestic product (GDP). The decade-long electricity shortage has become worse in recent years as − mainly due to corruption − no new reliable electricity generation was added during 2002-2006 (see World Bank, 2008, p. 1).

In addition to extensive load-shedding, less than half of Bangladesh's population had access to electricity in 2006. Various sources provide conflicting information on the exact percentage of the population having access to electricity. The World Bank (2008, p. 39) has put the 2007 coverage at 43 percent, while a detailed study by the Center for Energy Studies (2006, p. 4) reported coverage to have been 32 percent in 2004. The International Energy Administration's *World Energy Outlook (WEO) 2006* had put Bangladesh's 2005 electrification coverage rate at 32 percent. Another recent study by Khandker, Barnes and Samad (2009) had put the 2005 access rate for rural electrification for its sample between 23 and 40 percent. The 38.5 percent used in this study for 2006 is the average of the information provided in the GTZ, WEO and World Bank studies

(taking the reported increase in the number of electricity customers into account.

Furthermore, an internal World Bank report by Gulati and Rao, quoted in the *Global Monitoring Report* 2009 (see World Bank and International Monetary Fund, 2009, p. 76), states that an estimated 45 percent of generated power is lost in Bangladesh due to technical and commercial inefficiencies. The 2007-2008 Caretaker Government and the current Government have taken drastic actions to reduce the energy crises, but with electricity demand currently growing between 8-10 percent per year, it will take some time until power supply will match power demand.

Table 1 shows some of key energy indicators for the world and for Bangladesh as well as Bangladesh's percentage share in the world/world average, based on data provided by the International Energy Administration (IEA) website. However, given that the IEA web-site does not provide any time series data, we then use the World Bank's *World Development Indicator 2008* data below. There are some differences in this data among different organizations. For example, the Energy Information Administration (EIA) has put Bangladesh's CO_2 emission at 42.7 million tons (Mt) for 2006, while the IEA had put it at 38.1 Mt.

In any case, despite constituting 2.4 percent of the world's population, Bangladesh contributes only 0.14 percent to the global CO_2 emission. The main reason for Bangladesh's low CO_2 emissions is its low energy consumption. Bangladesh's electricity consumption amounted to only 0.13 percent of global electricity consumption. An average Bangladeshi person consumes only about one twentieth of the world average per capita electricity consumption. The low emissions and low electricity consumption are of course both related to Bangladesh's low income per capita, which amounted to $470 in 2007[1].

Table 1. Key indicators (2006)

	World	Bangladesh	Percentage of Bangladesh
Population (million)	6,536	156,0	2,39
GDP (billion, 2000 US$)	37,759	65,5	0,17
GDP (billion, 2000 PPP$)	57,564	276,6	0,48
Energy production (Mtoe)	11,796	20,3	0,17
Total primary energy supply (TRES) (Mtoe)	11,740	25,0	0,21
Electricity consumption [= Gross production + Imports – Exports – Transmission/ Distribution losses] (TWh)	17,377	22,8	0,13
Electricity consumption per capita (MWht)	2,7	0,15	5,49
CO_2 emissions (Mt of CO_2)	28,003	38,1	0,14
CO_2 emissions per capita (tons of CO_2)	4,3	0,24	5,69
CO_2 emissions per GDP (kg CO_2/year 2000 PPP$)	0,74	0,58	78,4
Primary energy intensity [=TPES/GDP] (toe/thousands of 2000 PPP$)	0,49	0,14	28,6
Carbon intensity [CO_2/TPES] (tons of CO_2/toe)	2,39	1,52	63,6

Source: Extracted and calculated based on data provided on the website of the International Energy Administration (IEA), http://www.iea.org/Textbase/stats/, as extracted on May 7, 2009.
Notes: CO_2 = Carbon dioxide; Mt = Million of tons; toe = Tons of oil equivalent; TPES = Total primary energy supply; PPP = Purchasing power parity; MWh = Megawatthour (10 to the power of 6); Mtoe = Million of tons of oil equivalent; TWh = Terawatt hour (10 to the power of 12).

Bangladesh's contribution to global CO_2 emissions is even slightly below its share of world GDP[2], which is also reflected in its below-average energy intensity (defined as the total primary energy supply (TPES) divided by GDP) and below-average carbon intensity (defined as CO_2 emissions divided by TPES). The main reasons behind these lower-than-average ratios are that (1) about half of the Bangladeshi people do not have access to electricity, and (2) about 90 percent of Bangladesh's electricity generation comes from high quality natural gas (see World Bank, 2008, p. 24; and GTZ, 2005, Table 2), which results in lower carbon emissions than emissions from other fossil fuels.

As Table 2 shows, taking differences in income levels into account, Bangladesh is pretty much an average country with regards to using clean cooking fuel, electricity access, electricity generation per capita, and the overall energy development index (EDI). The EDI was constructed by creating a separate index for each indicator, using the actual maximum and minimum values for the countries covered. Performance is expressed as a value between 0 and 1, calculated using the following formula: Dimension index = (Actual value – Minimum value) / (Maximum value – Minimum value). The EDI is then calculated as the arithmetic average of the three values for each country.

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[1] See World Bank, Bangladesh at a Glance, available at: http://devdata.worldbank.org/AAG/bgd_aag.pdf.
[2] Bangladesh's share in world GDP is 0.17 percent if measured using market exchange rates and 0.48 if measured using PPP exchange rates.

Table 2. Ranking of selected developing countries by energy development index

Country	Clean cooking fuel index	Rank	Electricity access index	Rank	Electricity generation per capita index	Rank	Energy Development Index (EDI)	Rank
Tanzania	0,00	16	0,00	16	0,00	16	0,00	16
Bangladesh	0,10	14	0,25	14	0,02	15	0,12	15
Ghana	0,01	15	0,44	10	0,04	11	0,16	14
Cameroon	0,14	13	0,35	13	0,03	12	0,18	13
Senegal	0,43	8	0,25	15	0,03	13	0,24	12
Nigeria	0,30	10	0,40	12	0,02	14	0,24	11
Indonesia	0,22	12	0,48	9	0,09	8	0,26	10
Nicaragua	0,32	9	0,42	11	0,09	9	0,27	9
India	0,27	9	0,42	11	0,09	9	0,27	9
Bolivia	0,66	5	0,62	7	0,08	10	0,45	7
Thailand	0,58	7	0,91	5	0,36	5	0,62	6
China	0,60	6	1,00	1	0,31	6	0,64	5
Brasil	0,87	3	0,95	4	0,38	4	0,74	4
South Africa	0,78	4	0,65	6	1,00	1	0,81	3
Chile	0,89	2	0,98	3	0,59	3	0,82	2
Malaysia	1,00	1	0,98	2	0,61	2	0,86	1

Source: Compiled by authors based on data provided in Table 20.2 of *World Energy Outlook 2007.*

Looking at Bangladesh's historical trend of CO_2 emission per GDP (kg per 2005 PPP\$), Figure 3 shows a clearly increasing trend. This is consistent with the experience of most other least developed countries, though the trend is expected to reverse once income per capita reaches a certain threshold. India already has a declining trend in its CO_2 emission per GDP ratio. China has a sharply decreasing trend for many years, while the industrialized countries have shown moderately declining trends. Reflecting a combination of changes in energy efficiency/intensity and carbon intensity, the long-term trend of CO_2 emission per GDP is far from linear.
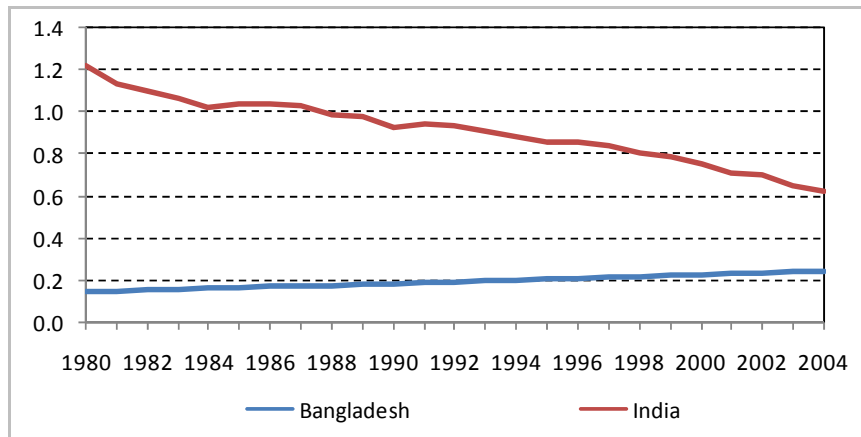
Source: World Bank, *World Development Indicators 2008* and calculations by authors.

Fig. 3. CO_2 emissions (kg per PPP S of GDP)

2. Methodology

There are many complex factors that influence a country's CO_2 emissions. Based on the latest IPCC synthesis report (IPCC, 2007, p. 5), "global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution". While future land-use changes will be relatively small in Bangladesh compared to some other developing countries, it is reasonable to conclude that increases in fossil fuel uses will be the driving force behind increases in Bangladesh's future CO_2 emissions. Hence, this allows us to focus our analysis on the growth of fossil fuel use. Indeed, given the complications related to estimating GHG emissions, it has become standard to estimate a country's CO_2 emissions by using the energy balances of the International Energy Administration (IEA) and the revised 1996 IPCC Guidelines.

There are many studies projecting global, regional and country-specific CO_2 emissions; see for exam-

ple various assessments by the Intergovernmental Panel on Climate Change (IPCC), the so-called Stern Review, and the International Energy Administration's annual World Energy Outlook (WEO). The WEO 2007 contains specific case studies for China and India; the WEO 2009 contains specific case studies for Southeast Asian countries. However, there is only one study (Azad, Nashreen and Sultana, 2006) that has provided some simple projections for Bangladesh's future CO_2 emissions. Azad, Nashreen and Sultana (2006) analyzed Bangladesh's energy consumption and estimated its CO_2 emission from combustion of fossil fuel (coal, gas, and petroleum products) for the period from 1977 to 1995. They showed that the consumption of fossil fuels in Bangladesh has been growing by more than 5 percent per year during their observation period. The proportion of natural gas in total energy consumption has been increasing, while that of petroleum products and coal has been decreasing. They estimated that the total CO_2 release from all primary fossil fuels used in Bangladesh amounted to 5.07 million tons (Mt) in 1977 and to 14.4 Mt in 1995. They then projected Bangladesh's CO_2 emission based on the 1977-1995 trend, which resulted in a projection of 293 Mt of CO_2 emissions in 2070. While no adjustments have been made for increasing energy efficiency, the projections have assumed that Bangladesh's future electricity generation will increasingly be based on natural gas and that the use of petroleum and coal would continue to decrease gradually.

Most of the early environmental impact literature, see for example Ehrlich and Holdren (1971) and Commoner (1972), concentrated on the so-called IPAT equation. It calculated the environmental impact (I) based on a simple multiplicative contribution of population (P), affluence (A) and technology (T), hence, $I=P*A*T$ (or IPAT). With regards to CO_2 emissions, the IPAT equation has been used for example in the *Third Assessment Report* of the IPCC (see McCarthy et al., 2001) and Ravindranath and Sathaye (2002) to decompose the changes in CO_2 emissions of various countries, including Bangladesh, see Figure 4.

More recent research, see Chertow (2001) and York, Rosa and Dietz (2003), suggested that the assumption of a simple multiplicative relationship among the main factors is not optimal and that approaches that allow for different weighting to be assigned to each factor are more successful in accounting for impact. York, Rosa and Dietz (2003) have also suggested that indicators of modernization (urbanization and industrialization) are important determinants for CO_2 emissions, beyond the determinants of population and GDP per capita (affluence). Given the difficulty to quantify and project modernization, we simply use population density (reflecting agglomeration) as a contributing factor to Bangladesh's CO_2 emissions. Furthermore, we also discuss the impact of gains in energy efficiency and changes in the carbon intensity on CO_2 emissions.
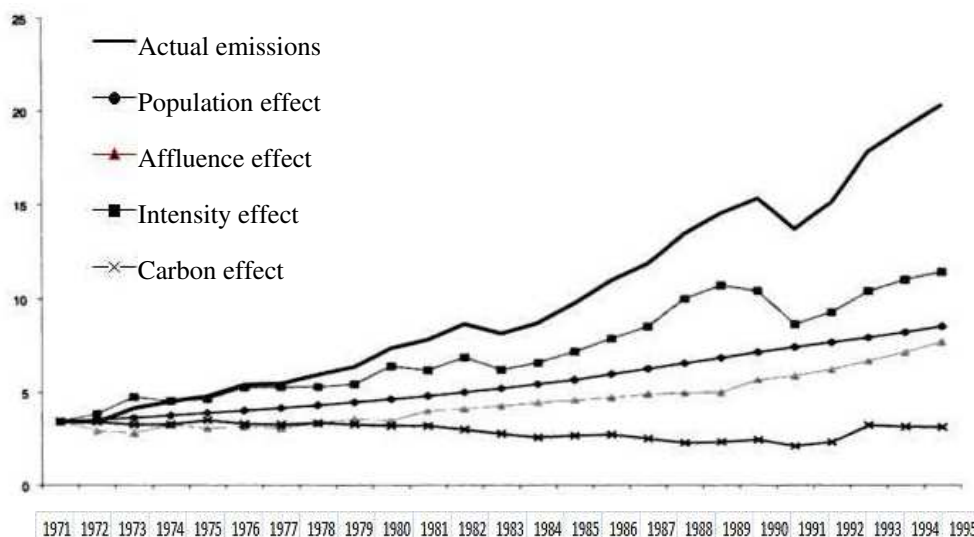
Source: Ravindranath and Sathaye (2002, Figure 3.3a, p. 46).

Fig. 4. Decomposition of the changes in Bangladesh's CO_2 emissions (in Mt), 1971-1995

2.1. Population growth, GDP growth, and modernization/agglomeration. When making long-term projections of CO_2 emissions for poor countries like Bangladesh, it is important to recognize that the projected population growth rate is not independent

from the level of income per capita, which is determined by the projected GDP growth rate. We use the United Nations (2004) population projections for 2050 for our benchmark population projections, and use then two alternative projections, one reflecting a

high-GDP-growth scenario that includes a slightly faster decline in population growth rates, and the other one reflecting a low-GDP-growth scenario that includes a slightly slower decline in Bangladesh's population growth rates. The actual (1980-2006) and projected populations are shown in Figure 5, reaching a population of, respectively, 254.6 million, 250.0 million, and 259.2 million in the benchmark, high-GDP-growth, and low-GDP-growth scenarios.
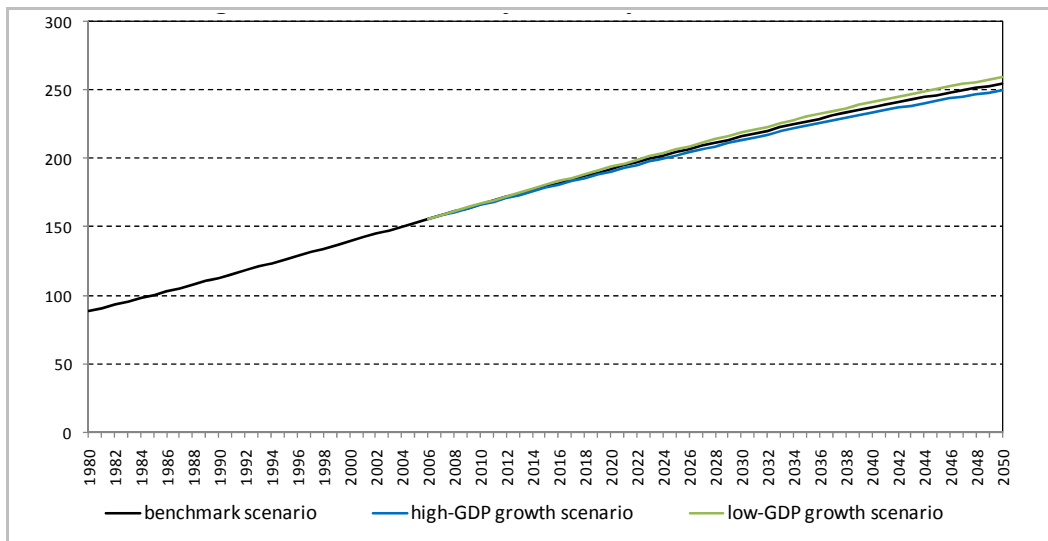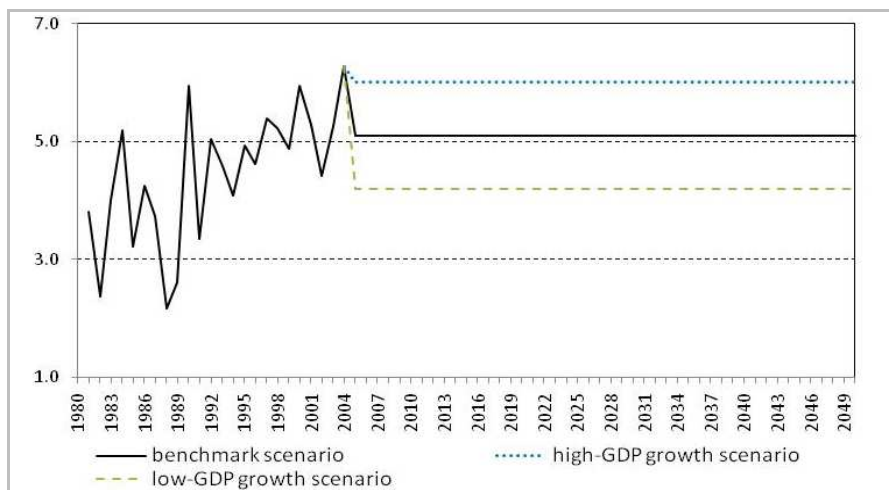

Source: World Bank *World Development Indicators 2008* database (providing the actual data), the United Nations (2004) projections for the benchmark scenario, and calculations by the authors.

Fig. 5. Actual and projected population (in million)

With regards to GDP growth, we use the recent projections by Hawksworth and Cookson (2008) as our benchmark scenario and use then two alternative projections, reflecting high- and low-GDP growth scenarios. Hawksworth and Cookson (2008) have put the real GDP growth rate in United States dollar (US$) terms at 7 percent, and the real GDP growth rate in purchasing power parity (PPP) terms at 5.1 percent. This relative high growth rate reflects Bangladesh's accelerating growth rate from 2002-2008, but is far above Bangladesh's historical record (see Figure 6).


Source: Authors' assumptions based on World Bank *World Development Indicators 2008* database.

Fig. 6. Actual and projected GDP growth rate (percent) (with GDP measured in constant 2005 PPPS)

The difference between expressing GDP growth rates in US$ and PPP terms is important especially for our purpose as living standards are more accurate for calculating the impact of GDP growth on CO_2 emissions than using US$-based GDP growth rates. Our high-growth scenario reflects a real GDP growth rate of 6.0 percent in PPP terms (which is equivalent to about 8 percent growth in US$ terms), while our low-growth scenario reflects a real GDP growth rate of 4.2 percent in PPP terms (equivalent to about 6 percent growth in US$ terms). As shown in Figure 7, the less than one percent differences to the benchmark scenario make quite a difference over the long projection period.
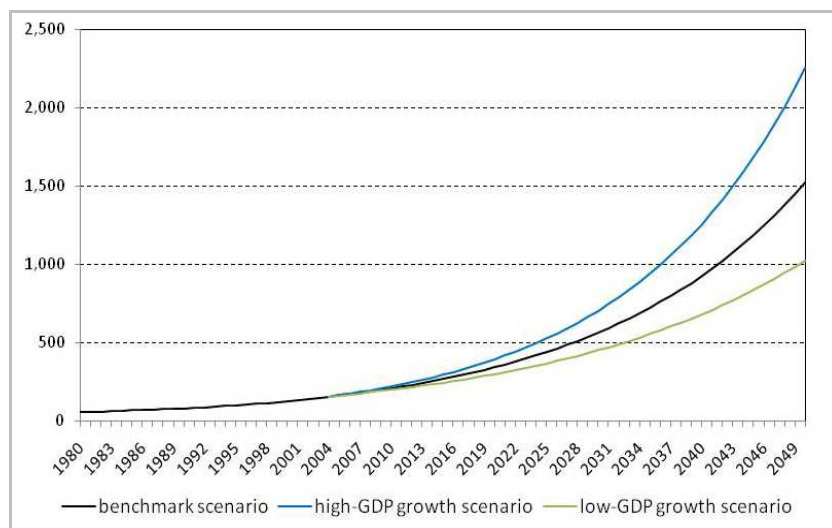
Source: World Bank *World Development Indicators 2008* database (providing the actual data), the Hawksworth and Cookson (2008) projections for the benchmark scenario, and calculations by the authors.

Fig. 7. Actual and projected GDP (PPP, constant 2005, billion)

The combination of population and GDP growth rates implies that GDP per capita will, at the end of the projection period (in year 2050), reach $5,982 (in constant 2005 PPP$) in the benchmark scenario, $9,018 in the high-growth scenario, and $3,956 in the low-growth scenario. The considerable differences in 2050 GDP per capita levels under the three different scenarios are mostly due to the slight differences in GDP growth rates. For example, applying the lower population growth rate to the benchmark GDP growth scenario would result in a GDP per capita level in 2050 of $6,092 (in constant 2005 PPP$), while applying the higher population growth rate to the benchmark GDP growth scenario would result in a GDP per capita level in 2050 of $5,876 (in constant 2005 PPP$).

There is a large literature on economic agglomeration, which describes the benefits that firms obtain when locating near each other. It typically is related to the idea of economies of scale and network effects, though it can also be used as economic ag-glomeration at the country level that contributes to a country's CO_2 emission. We simply use the increasing population density to approximate the CO_2 emission resulting from agglomeration/modernization.

2.2. Gains in energy efficiency/intensity. In addition to the uncertainty resulting from unknown future GDP and population growth rates, there is considerable uncertainty about Bangladesh's future CO_2 emissions due to highly uncertain changes in Bangladesh's future energy efficiency. There even is a lack of consistent and reliable historical data on Bangladesh's energy intensity. The following paragraphs provide some information on certain aspects of energy efficiency without claiming to provide a comprehensive picture. Based on information provided in the WEO 2007, the primary energy intensity has fallen at about 1.5 percent at the global level during 1990-2005. The reduction was slightly higher in developing countries (about 1.6 percent) than in the high-income OECD countries (about 1.1 percent), see Figure 8.
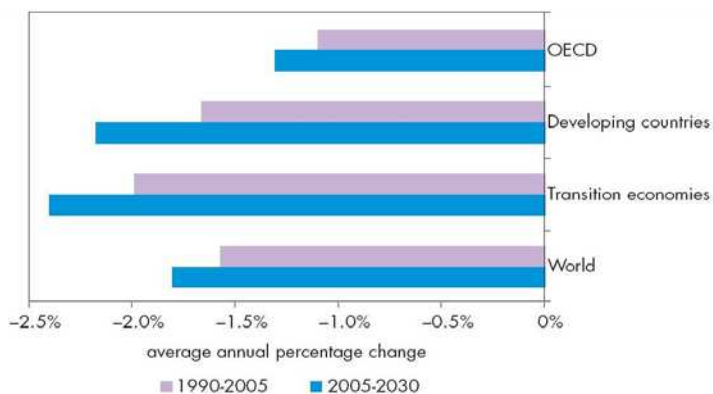
Source: *World Energy Outlook 2007*, Figure 15, p. 79.

Fig. 8. Past and future progress in primary energy intensity (without adopting new policies to improve energy efficiency)

The WEO's projections are that these past trends continue to hold for the period of 2005-2030. The explanation provided in the *WEO 2007* for the accelerated decline in energy intensity is largely due to faster structural economic change away from heavy manufacturing and towards less energy-intensive service activities and lighter industry. However, given that Bangladesh never had any significant heavy manufacturing, this argument may not be applicable for changes in Bangladesh's energy intensity.

Indeed, based on the decomposition provided by Ravindranath and Sathaye (2002) shown in Figure 4 above, Bangladesh's energy intensity has increased during 1970-1995 and contributed to Bangladesh's CO_2 emissions during that time. Relative to the other effects shown in the decomposition (population, affluence, and carbon intensity), the impact of energy intensity has been the most volatile, and for some years, there has even been a decline. Reviewing Bangladesh's energy policy and actions, a report by the Center for Energy Studies (CES) (2006, p. 5) states that Bangladesh's new National Energy Policy compared to the old policy is "more positive about conservation, energy efficiency and renewable energy" and "having realized the potential of energy saving light bulbs, the Government took an initiative to replace all incandescent bulbs with energy saving ones in public buildings, but the program is progressing at an extremely slow pace. [...] There exists huge potential in Bangladesh for energy saving bulbs because the largest peak in the daily load curve is the evening peak, which is mostly lighting."

Another important factor that needs to be taken into account is the rapidly increasing access to electricity, which is likely to increase Bangladesh's energy intensity. Increases in the percentage of people having access to electricity will increase electricity consumption beyond GDP and population growth rates. As explained above, taking the lack of reliable data on the current electricity coverage into account, we estimate that the access rate to electricity amounted to about 38.5 percent in 2006. Hence, reaching 100 percent access by 2020 (as is the Government's repeatedly stated goal) would imply that coverage would need to increase by 4.4 percentage points for each year following 2006, until reaching 100 percent in 2020.

Given that the actual annual increase in coverage amounted to only about 1.8 percentage points during 2004-2007[1], the 2020 target would imply that the future increase in coverage would need to more than

double that of recent years. Even if it takes a few years longer to reach universal coverage, it is clear that the increasing access rate will negatively affect Bangladesh's energy intensity until full coverage is reached. The uncertainty about the year when full electricity coverage will be reached is not that critical for the projected 2050-level of Bangladesh's CO_2 emission as this uncertainly reflects mostly a different path for reaching the 2050-level and as the more determining factor for Bangladesh's CO_2 emission is the carbon intensity of Bangladesh's energy supply. We will discuss this issue further when examining Bangladesh's future carbon intensity. Energy prices will of course also impact energy efficiencies, but given that future energy prices are impossible to predict accurately, energy prices are not explicitly considered.

Given the significant uncertainties related to Bangladesh's future energy efficiencies, we will use the following three alternative *energy efficiency scenarios*:

♦ *Scenario 1* assumes that there are no improvements and no deteriorations in Bangladesh's energy efficiency/intensity.
♦ *Scenario 2* assumes that the improvements in Bangladesh's 2050 energy efficiency will approach the current energy efficiency level of the European Union (EU).
♦ *Scenario 3* assumes that the improvements in Bangladesh's energy efficiency until 2050 will approach the energy efficiency level the EU is expected to achieve by 2030 under the *WEO 2007*'s alternative policy scenario.

The alternative policy scenario of the *WEO 2007* (p. 66) "takes into account those policies and measures that countries are currently considering and are assumed to adopt and implement, taking account of technological and cost factors, the political context and market barriers. Macroeconomic and population assumptions are the same as in the Reference Scenario. Only policies aimed at enhancing energy security and/or addressing environmental problems, including climate change, are considered. While cost factors are taken into consideration in determining whether or not they are assumed to be implemented, policies are not selected according to their relative economic cost-effectiveness. Rather, they reflect the proposals actually under discussion in the current energy-policy debate."

2.3. Changes in Bangladesh's carbon intensity. The factors determining a country's carbon intensity are even more complex than the factors determining a country's energy efficiency. Past changes in Bangladesh's carbon intensity (shown in Figure 9) were partly determined by changes in Bangladesh's fuel composition used for Bangladesh's electricity generation.

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[1] This annual increase in coverage of 1.8 percentage points is calculated based on the number of total customers reported in World Bank (2008), Table 2 (p. 11), taking into account that the total number of potential customers has (due to population growth) also been increasing.
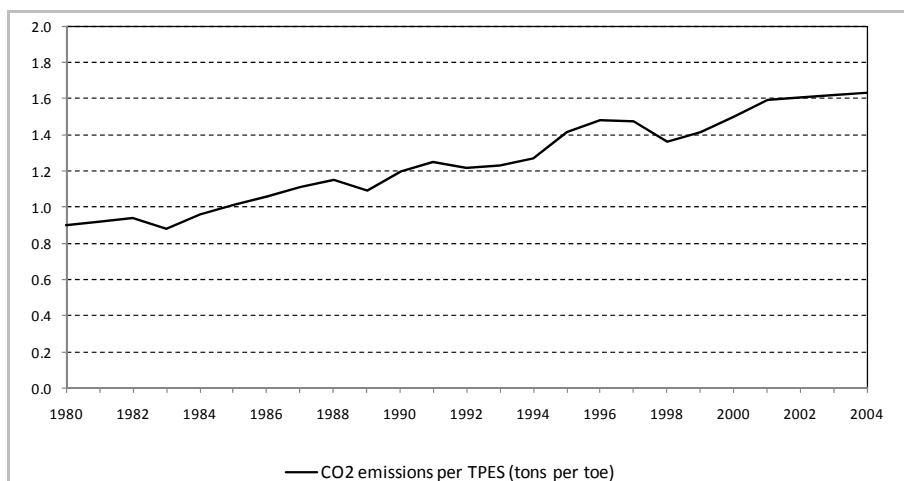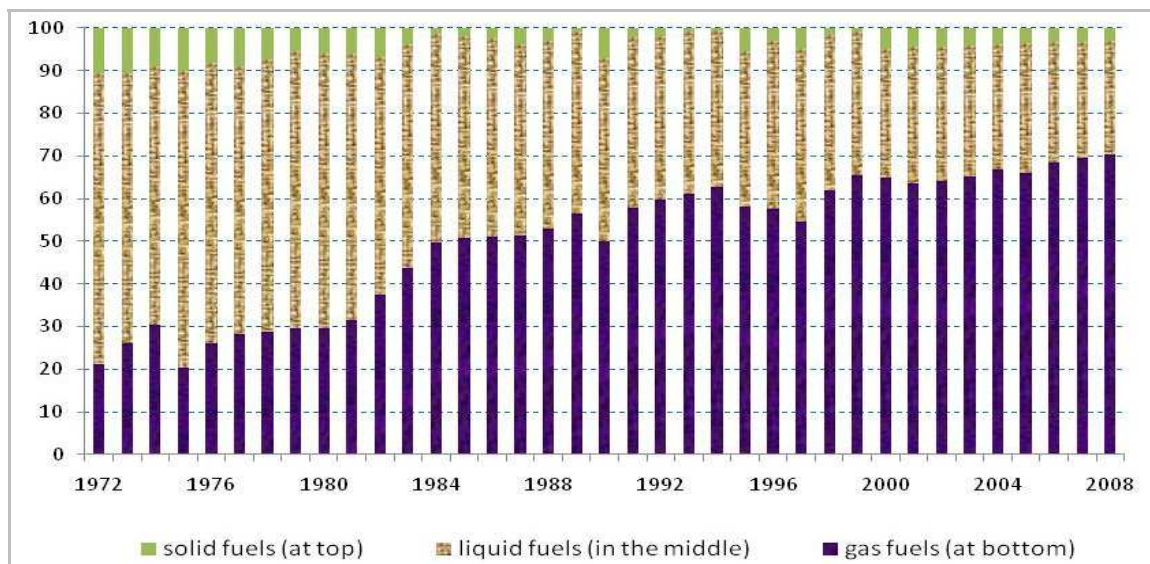
Source: Calculated by authors based on CO_2 and primary energy supply data of WDI 2008.

Fig. 9. Actual carbon intensity, 1980-2004 (defined as CO_2 emissions per total primary energy supply)
[in tons of CO_2 per tons of oil equivalent]

In addition, it is also clear that any alleviation of the current extensive load shedding will reduce Bangladesh's carbon emission as the reduction in load shedding will reduce the use of carbon intensive generators. The same argument applies also for the substitution effect resulting from increasing Bangladesh's electricity coverage. However, given that access to electricity typically also results in an increase in energy consumption, the net effect on carbon emission from increasing Bangladesh's electricity coverage is far from conclusive.

However, it is likely that Bangladesh's current fuel composition for producing electricity (in which natural gas amounts to about 90 percent, see Figure 10) will change as given the energy crisis Bangladesh currently faces, plans to use the substantial reserves of domestic coal for Bangladesh's electricity generation are becoming more and more realistic. The main controversy is related to an open cast coal mine in Phulbari (in the northwest Dinajpur district), which would entail relocating thousands of people and have various detrimental environmental implications, including an acceleration of Bangladesh's carbon intensity (see Lang (2008) for further details).

Source: Calculated by the authors based on CDIAC data posted by Marland, Boden and Andres on August 27, 2008 at: http://cdiac.ornl.gov/ftp/trends/emissions/ban.dat.

Fig. 10. Percentage shares of CO_2 emmisions from gas, liquid, and solid fuels

Being one of the most vulnerable countries to climate change, Bangladesh is fully aware of the need to conserve energy and to decrease the carbon intensity in the generation of the urgently needed electricity. Yet, Bangladesh's short-term economic and political costs resulting from not using its coal for the generation of electricity are far higher than the longer-term costs resulting from Bangladesh's mar-

ginal contribution to climate change. This also explains why there are no specific plans for using the more costly renewable energy at any significant level for the publicly generated electricity. Renewable energy is more costly at current economic prices as they do not take into account the various environmental externalities, including the severe costs of climate change. However, solar energy is generated at increasing rates by individuals, especially in the rural areas that are not connected to the electricity grid. According to World Bank (2008, p. 2), over 200,000 solar home systems have been introduced in Bangladesh.

Bangladesh's plans to make use of its coal reserves are consistent with increased coal uses in other countries (including China and the United States). According to the *WEO 2007*, the global demand for coal has increased by about 2 percent over the last few years and its share in global energy demand has been projected to increase from 26 percent in 2006 to 29 percent in 2030, with about 85 percent of the increase in global coal consumption coming from China and India. Hence, emissions from coal-fired power stations were the primary cause of the surge in global CO_2 emissions in the last few years. As stated in *WEO 2007* (p. 51), "clean coal technology, notably CO_2 capture and storage (CCS), is one of the most promising routes for mitigating emissions in the longer term. [...] CCS could reconcile continued coal burning with the need to cut emissions in the longer term – if the technology can be demonstrated on a large scale and if adequate incentives to invest are put in place." Given that it is highly uncertain

by when this technology will be applied in Bangladesh, we have to be careful about being neither too optimistic nor too pessimistic about the CO_2 reduction resulting from such new technologies.

Based on the decomposition of Ravindranath and Sathaye (2002) shown in Figure 4 above, Bangladesh's carbon intensity has declined slightly during 1970-1995. While the overall trend is consistent with the disaggregated data on CO_2 emissions resulting from gas, liquid, and solid fuels provided in Figure 10, there are various inconsistencies for specific years as well as the overall trend as calculated from the World Bank's 2008 World Development Indicator (WDI) database. The data provided by the Carbon Dioxide Information Analysis Center (CDIAC) is partly also inconsistent with the calculations on percentage shares of CO_2 emissions provided in a Government of Bangladesh (GoB) (1997) report. Based on GoB (1997), gas contributed 60.4 percent, liquid fuel contributed 32.4 percent, and solid fuels contributed 7.2 percent to the 1990 CO_2 emission. Given the partly inconsistent historical data, the highly uncertain outlook and for reasons of simplicity, we keep Bangladesh's carbon intensity initially constant for our three energy efficiency scenarios described in the last section.

2.4. How to put it all together. It is useful at this point to look at the historical trend of Bangladesh's CO_2 emission after controlling for population, affluence, and agglomeration (that is, dividing the CO_2 emission by population, GDP per capita, and population density), which we define as Bangladesh's CO_2 base emission:

$$CO_2 \ base \ emission = \frac{CO_2 \ emission}{Population \cdot GDP \ per \ capita \ (PPP) \cdot Population \ density}. \tag{1}$$

The historical trend from 1980-2004 of Bangladesh's CO_2 base emission (see Figure 11), shows – despite some volatility – a remarkable long-term stability. This has three important implications.

♦ First, the long-term stability of Bangladesh's CO_2 base emission indicates that during the last 25 years, the combined impacts of energy efficiency and carbon intensity did not affect Bangladesh's CO_2 emission. In other words, population, affluence, and agglomeration have been the key determinants for changes in Bangladesh's CO_2 emission.

♦ Second, given that Bangladesh's carbon intensity has decreased significantly during the last 25 years, Bangladesh's energy intensity must have increased in order to keep the CO_2 base emission stable.

♦ Third, we can use the 25-year average of Bangladesh's CO_2 base emission to estimate Bangladesh's future CO_2 emission for any level of (1) population, (2) GDP per capita, and (3) agglomeration; past and future. Figure 12 shows the actual and estimated CO_2 emissions of Bangladesh from 1980-2004.
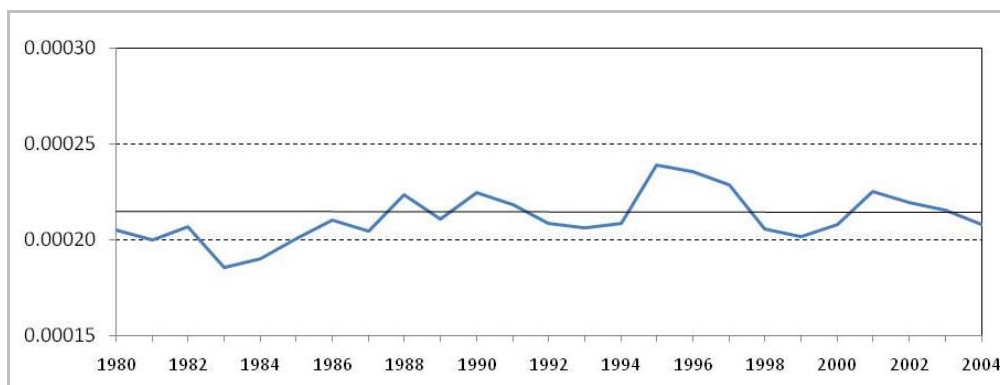
Source: Calculations by the authors based on *World Development Indicators 2008*.

Fig. 11. CO$_2$ emissioms (1980-2004)
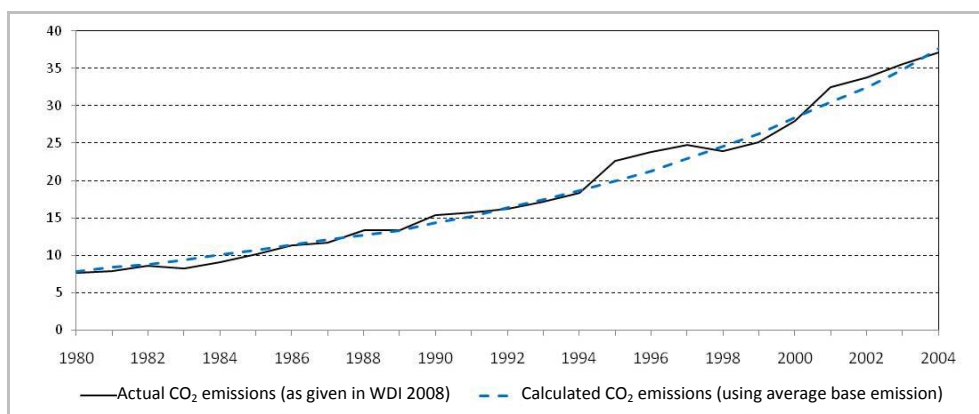
——Actual CO$_2$ emissions (as given in WDI 2008)   – – Calculated CO$_2$ emissions (using average base emission)

Source: Actual CO$_2$ emissions based on *World Development Indicators 2008;* and calculations by the authors based on 25-year average base emission and population, GDP per capita, and population density provided in the *World Development Indicators 2008*.

Fig. 12. Actual versus estimated CO$_2$ emission (Mt)

Hence, once we have projected Bangladesh's CO$_2$ emission for a specific level of population, income per capita and agglomeration, we can then refine the projections by taking into account the three different energy efficiency scenarios (1 to 3) as follows:

♦ For *Scenario 1* (the case of assuming a constant energy efficiency), Bangladesh's CO$_2$ emission is calculated by multiplying the CO$_2$ base emission with the population, GDP per capita, and population density levels.

♦ For *Scenarios 2 and 3*, we will also use the given reduction in the energy intensity to calculate how much primary energy Bangladesh would have required to achieve the given GDP level, and then apply Bangladesh's carbon intensity to calculate what the new level of CO$_2$ emissions would be with the higher energy efficiency.

To avoid any confusion about the results from the various GDP growth and population growth scena-

rios with the various energy efficiency scenarios, we will subsequently refer to:

♦ Projections A for the CO$_2$ projections resulting from energy efficiency scenario 1;

♦ Projections B for the CO$_2$ projections resulting from energy efficiency scenario 2; and

♦ Projections C for the CO$_2$ projections resulting from energy efficiency scenario 3.

3. Results

3.1. Projections A: constant energy efficiency/intensity. *Projections A* provide Bangladesh's CO$_2$ emissions for the benchmark, high-growth and low-growth scenarios and the assumptions that there will be no improvements (and no deteriorations) in Bangladesh's energy efficiency/intensity. The projections (see Figure 13) show sharp increases in CO$_2$ emissions due to sharply increasing energy demand by the growing and more affluent population.
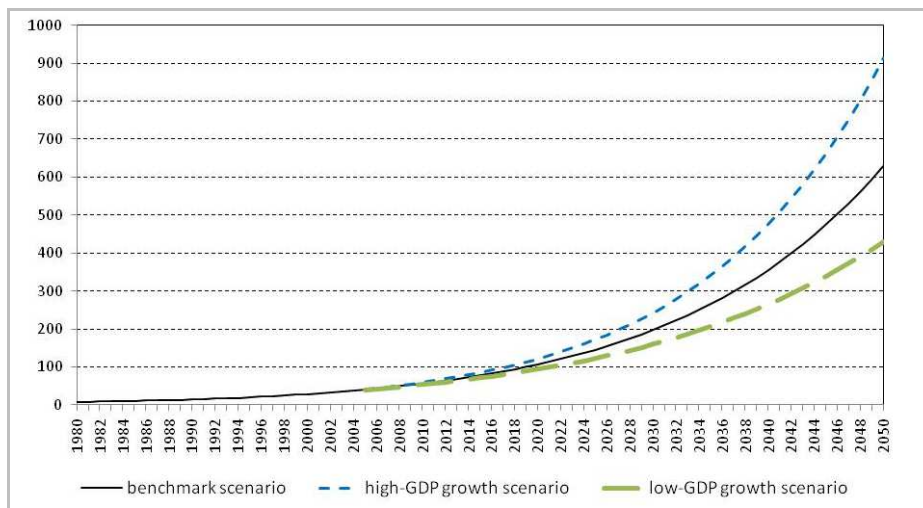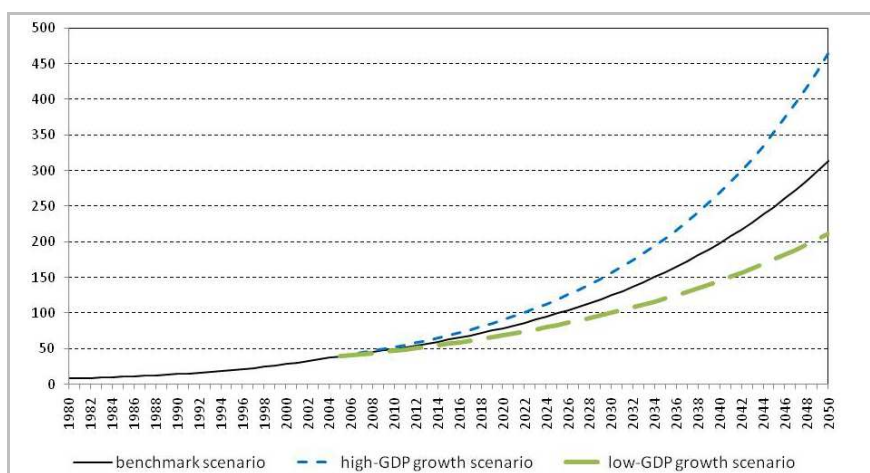
Source: Calculations by the authors.

Fig. 13. Actual and project CO_2 emission (Mt) of Projections A

To give some perspective on these projections:

♦ the projected 2050 level of the benchmark scenario (628 Mt of CO_2 emissions) is about one tenth of what the United States is currently emitting with an only slightly higher population than what Bangladesh is projected to have in 2050[1];

♦ the projected 2050 level of the high growth scenario (913 Mt of CO_2 emissions) is about 80 percent of what India's 1.1 billion people emitted in 2005 (1147 Mt), which implies that Bangladesh's projected per capita CO_2 emissions of 3.6 tons is about three times India's current per capita CO_2 emissions (which according to the *WEO 2007* is 1.2 tons);

♦ the projected 2050 level of the low growth scenario (431 Mt of CO_2 emissions) is about 38 percent of what India emitted in 2005.

3.2. Projections B: approaching the EU's current energy efficiency. *Projections B* provide Bangladesh's CO_2 emissions for the benchmark, high-growth and low-growth scenarios and the assumptions that the improvements in Bangladesh's energy efficiency will approach the current energy efficiency level of the EU (which is 15 percent below Bangladesh's current energy intensity (0.14 toe per thousands of 2000 PPP$)) and 75 percent below the world's current energy intensity (0.49 toe per thousands of 2000 PPP$). The projections (see Figure 14) still show sharp increases in CO_2 emissions, again due to sharply increasing energy demands by the growing and more affluent population, however, the improved energy efficiency cuts the 2050 levels for the three scenarios in slightly more than half of *Projections A*.

Source: Calculations by the authors.

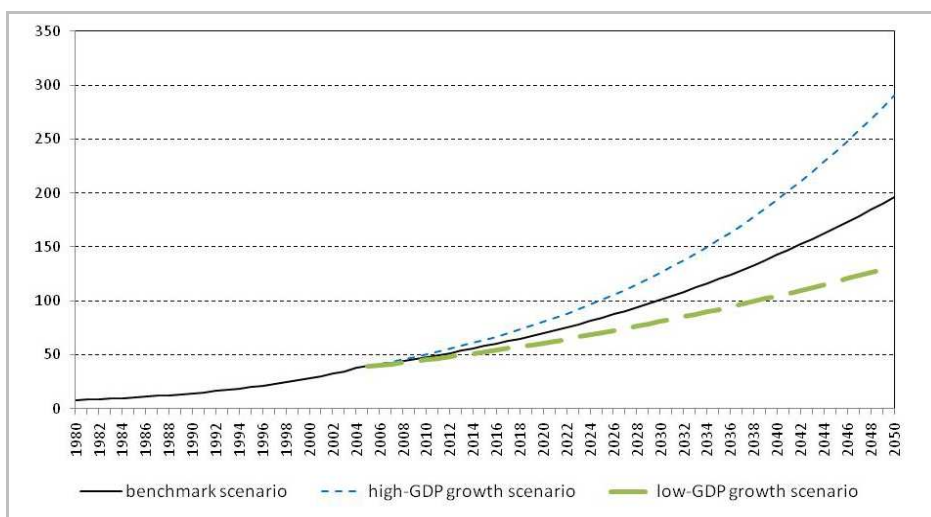**Fig. 14. Actual and projected CO_2 emission (Mt) of Projections B**

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[1] Based on *WEO 2007*, the United States emitted 5,789 Mt of CO_2 in 2005, and the emission was estimated to grow at 1.0 percent per year during 2005-2015 without the adoption of specific climate change policies.

To give again some perspective of these projections:

♦ the projected 2050 level of the benchmark scenario (292 Mt) is about one twentieth of what the United States is currently emitting with an only slightly higher population than what Bangladesh is projected to have in 2050;

♦ the projected 2050 level of the high growth scenario (433 Mt) is about 38 percent of what India's 1.1 billion people emitted in 2005 (1147 Mt), which implies that Bangladesh's projected per capita CO_2 emissions of 1.73 tons is about three times India's current per capita CO_2 emissions (1.2 tons); and

♦ the projected 2050 level of the low growth scenario (197 Mt) would imply that Bangladesh's projected per capita CO_2 emissions of 0.76 tons in 2050 is about 63 percent of India's current per capita CO_2 emissions (1.2 tons).

3.3. Projections C: approaching the EU's 2030 energy efficiency. *Projections C* provide Bangladesh's CO_2 emissions for the benchmark, high-growth and low-growth scenarios and the assumptions that the improvements in Bangladesh's energy efficiency of 2050 will approach the energy efficiency level the EU is expected to achieve by 2030 under the *WEO 2007*'s alternative policy scenario. It would imply that Bangladesh's 2050 energy efficiency is nearly half of its current energy efficiency (0.14 toe per thousands of 2000 PPP$) and 84 percent below the world's current energy efficiency (0.49 toe per thousands of 2000 PPP$). Most energy experts would agree that such an increase in Bangladesh's energy efficiency is highly unlikely, especially as it is not even clear if the European Union will achieve this level of energy efficiency by 2030. However, given that Bangladesh will have an additional 20 years (from 2030 to 2050) to reach such energy efficiency, it is a possible case. Hence, Figure 15 provides a useful illustration of a lower bound of Bangladesh's CO_2 emissions until 2050.

Source: Calculations by the authors.

Fig. 15. Actual and Projected CO_2 Emission (Mt) of Projections C

Bringing Bangladesh's 2050 energy efficiency to a level which the European Union is expected to achieve by 2030 under the *WEO 2007*'s ambitious alternative policy scenario would imply that the 2050 levels of Bangladesh's CO_2 emissions will be about 29 percent of what they would be in the no efficiency improvement case for each of the three scenarios.

♦ The projected 2050 level of the benchmark scenario (183 Mt) would be about five times Bangladesh's current CO_2 emission (38 Mt), though due to the increase in energy efficiency, only a threefold increase in per capita emissions.

♦ The projected 2050 level of the high-GDP-growth scenario (270 Mt) would be seven times Bangladesh's current CO_2 emission, though only 4.5 times in terms of per capita emissions.

♦ The projected 2050 level of the low-GDP-growth scenario (123 Mt) would be about 3 times Bangladesh's current CO_2 emission, though only twice in terms or per capita emission.

3.4. Projections for different degrees of energy efficiency. Figure 16 shows Bangladesh's projected CO_2 emission for the benchmark scenario and our three alternative assumptions on Bangladesh's progress in energy efficiency. The benchmark scenario assumes a real GDP growth rate of 5.1 percent (in PPP terms; which is equivalent to a real GDP growth rate of 7 percent in US$ terms) and population reaching 254.6 million in 2050, which implies that GDP per capita will reach $5,982 (in constant 2005 PPP$) in 2050. Our three alternative assumptions on Bangladesh's progress in energy efficiency are: (1) no improvement,

(2) reaching the EU's current energy efficiency in 2050, and (3) reaching the energy efficiency the Euro-

pean Union is expected to achieve by 2030 under the *WEO 2007*'s ambitious alternative policy scenario.
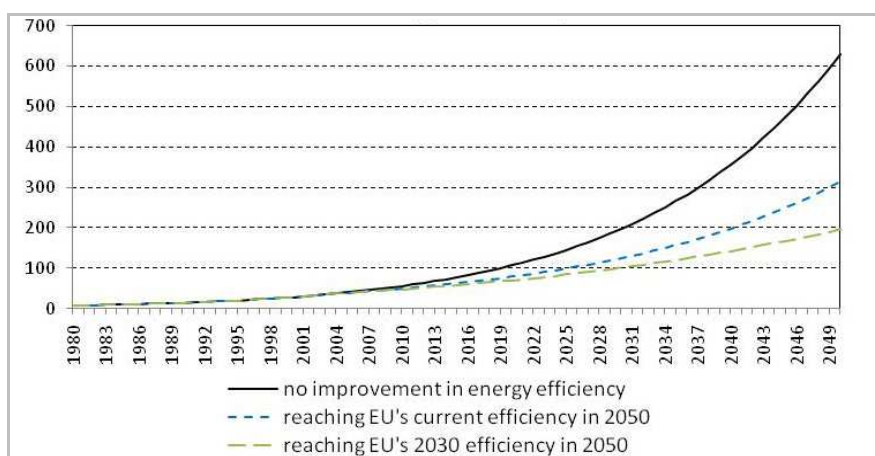
Fig. 16. Actual and projected CO_2 emission (Mt) for different energy efficiency scenarios

Figure 16 shows the tremendous contribution improvements in energy efficiency make to lowering CO_2 emissions compared to the case of no improvements in energy efficiency:

♦ If Bangladesh reaches the EU's current energy efficiency by 2050, which might not be very ambitious, Bangladesh's projected CO_2 emissions would be less than half to the emissions under the no-energy-efficiency-gains scenario.

♦ If Bangladesh reaches the EU's 2030 energy efficiency by 2050, which is ambitious though feasible, Bangladesh' increase in CO_2 emissions would be less than one third of the increase under the no-energy-efficiency-gains scenario.

Conclusions

Though Bangladesh contributes currently only 0.14 percent to the world's CO_2 emissions, in 2050, the world will be a very different animal. Bangladesh is expected to be the seventh most populous country with

an income per capita (in constant 2005 PPP$) between $4,000 to $9,000 (with $4,000 reflecting the low GDP growth scenario and $9,000 reflecting the high GDP growth scenarios). Our projections (summarized in Table 3) show that for an average GDP growth rate of 5.1 percent per year (in 2005 PPP terms) Bangladesh's CO_2 emission in 2050 (amounting to 628 Mt) would have increased nearly 15 times its 2005 value if there are no improvements in Bangladesh's energy efficiency and no changes in Bangladesh's carbon intensity.

On the other hand, keeping the same assumptions except reaching the EU's 2030 energy efficiency in 2050 would result in Bangladesh's CO_2 emission of 183 Mt (which is seven times its 2005 value). Our projections imply far higher CO_2 emission levels than what Azad, Nashreen and Sultana (2006) projected based on the 1977-1995 emission trend, as we applied (reflecting the more recent trend) higher GDP growth rates, which not only affect income per capita but also energy consumption and CO_2 emissions.

Table 3. Key indicators of CO_2 emission for 2005 and 2050

	World				India				Bangladesh (baseline scenario)					
	WEO reference scenario		WEO alternative scenario		WEO reference scenario		WEO alternative scenario		No improvement in energy efficiency		Reching EU's current efficiency in 2050		Reching EU's 2030 efficiency in 2050	
	2005	2050	2005	2050	2005	2050	2005	2050	2005	2050	2005	2050	2005	2050
CO_2 emission (Mt)	26,620	60,243	26,620	41,111	1,147	7,743	1,147	4,381	40	628	37	292	37	183
CO_2 emission (% of world)	100	100	100	100	4,31	12,85	4,31	10,66	0,15	1,04	0,14	0,71	0,14	0,44
Population (million)	6,462	8,900	6,462	8,900	1,095	1,531	1,095	1,531	153	255	153	255	153	255
Population (% of world)	100	100	100	100	16,9	17,2	16,9	17,2	2,4	2,9	2,4	2,9	2,4	2,9
CO_2 emission per capita (tons)	4,12	6,77	4,12	4,62	1,05	5,06	1,05	2,86	0,26	2,47	0,24	1,15	0,24	0,72
CO_2 emission per capita (% of world)	100	100	100	100	25,4	74,7	25,4	61,9	6,4	36,5	5,9	24,9	5,9	15,5
CO_2 emission per GDP (kg/2005PPPS)	0,48		0,48		0,47		0,47		0,25	0,41	0,25	0,19	0,25	0,12

Source: CO_2 emissions for India and the World based on the WEO 2007; populations for 2050 based on UN (2004); all other based on WDI 2008 and calculations by authors (as explained above).

Yet, it needs to be stressed that Bangladesh's projected CO_2 emissions in per capita terms (shown in Figure 17 and Table 3) would still be (1) 40 percent below the current per capita average of the world for the case of no energy efficiency gains or (2) 82 percent below the current world average for the case of reaching the EU's 2030 energy efficiency in 2050.
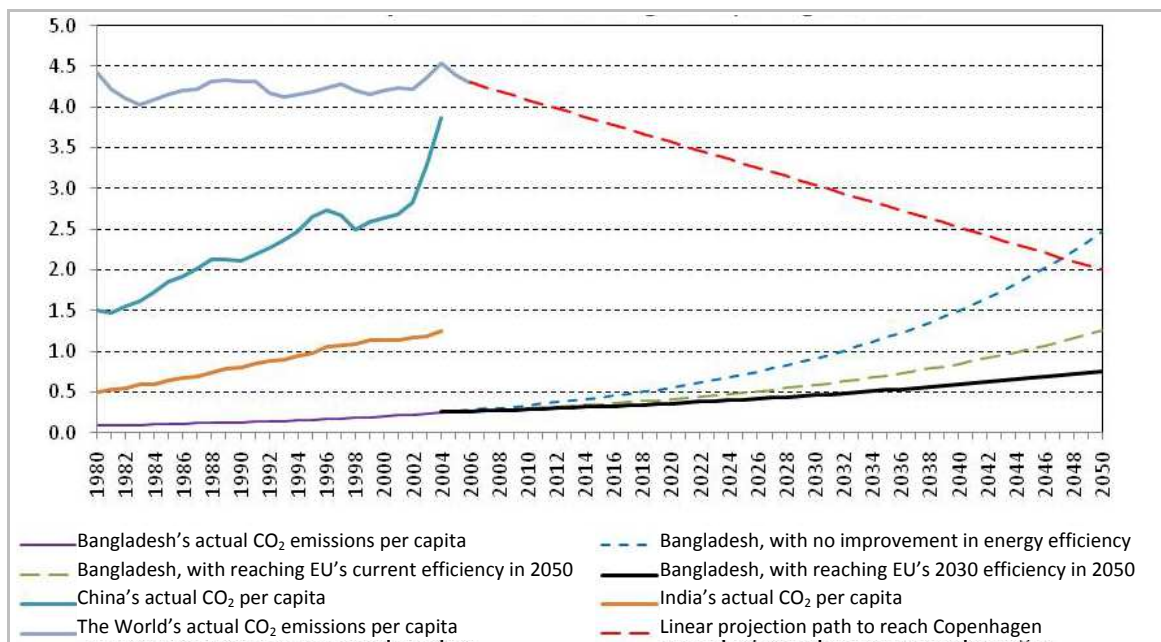
Source: Actual CO_2 emissions based on *World Development Indicators 2008*; projections based on the authors' calculations.

Fig. 17. Actual CO_2 emission per capita (in tons) for Bangladesh, India, China, and the world; Bangladesh Projections for different energy scenarios; and linear projection path for reaching the Copenhagen accord

Figure 17 also shows the actual per capita emissions for Bangladesh, India, China and the world average since 1980. The comparison of these actual per capita emissions illustrates how low Bangladesh's emissions have been in per capita terms. Furthermore, Figure 17 shows the linear projection path of the world's per capita emission that is consistent with reaching the Copenhagen Accord. Comparing these per capita emission projections with the per capita limits implicit in the Copenhagen Accord shows that Bangladesh would overshoot the per capita limits if there are no improvements in Bangladesh's energy efficiency, while Bangladesh would remain within the 2050 limit as long as it reaches the EU's current energy efficiency by 2050. While some increases in developing countries' CO_2 emissions are unavoidable, it will be important to minimize these increases as far as possible by providing appropriate technologies to these countries.

Finally, comparing the implications of different GDP growth rates on Bangladesh's CO_2 emissions (Figures 10-12), our projections have shown that just one percentage point lower GDP growth implies about 30 percent less CO_2 emissions by 2050, in basically all three energy efficiency scenarios. This could be interpreted as that lower GDP growth rates are helpful to stabilize the world's CO_2 emissions. However, this clearly is the wrong interpretation of the projection results as lower GDP growth rates provide an only temporary delay in CO_2 emissions. Taking into account that lower GDP growth rates imply higher population growth, low GDP growth will actually increase CO_2 emissions in the long-term. Higher GDP growth rates will increase CO_2 emissions faster, but will then also imply that the peak of CO_2 emissions will be reached earlier and due to the lower population, at a lower emission level. In other words, development can be considered to contribute to lower long-run CO_2 emissions.

Acknowledgements

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