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Bernhard G. Gunter*

Abstract

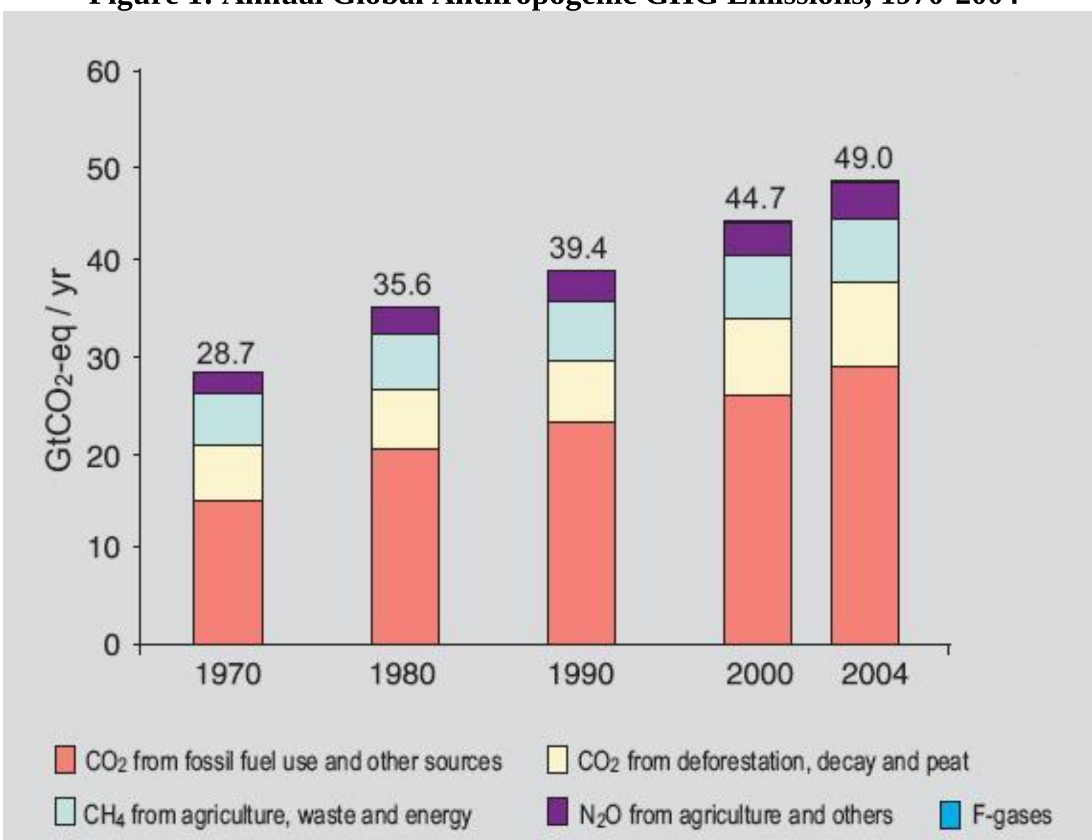
Bangladesh, a country with a population of 160 million, is currently contributing 0.14 percent to the world's emission of carbon dioxide (CO_2). However, mostly due to a growing population and economic growth (which both lead to an increase in energy consumption), Bangladesh's share in CO_2 emissions is—despite the increasing use of alternative energy—expected to rise sharply. This study uses the example of Bangladesh to illustrate the impact of low-income countries' energy neutral development on global CO_2 emissions in 2050 by using a set of alternative assumptions for population growth and GDP growth. It also shows how complex the determinants for (a) gains in energy efficiency and (b) changes in carbon intensity are in low-income countries.

* President, Bangladesh Development Research Center (BDRC) and Adjunct Associate Professor, Economics, Department, American University. I would like to thank the participants at the 5th bi-annual conference of the United States Society for Ecological Economics (USSEE), held in Washington DC, May 31-June 03, 2009 for useful comments. Additional comments are welcome; please send any communication directly to the author: president@bangladeshstudies.org.

I. 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. It is possible to distinguish between four GHGs: (i) carbon dioxide (CO_2), (ii) methane (CH_4), (iii) nitrous oxide (N_2O), and (iv) F-gases, which during 1970-2004 amounted, respectively, to 76.7 percent, 14.3 percent, 7.9 percent, and 1.1 percent.[1] While the concentration of all four types of GHGs has increased in the atmosphere, the focus has been on CO_2, as it constitutes due to its large share the most important GHG. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2007a, p. 2) states that the concentration of CO_2, increased from a pre-industrial value of about 280 parts per million (ppm) to 379 ppm in 2005. This implies an increase of 35 percent in the concentration level. While this increase in the concentration level may not seem to be very large, fact is that relatively small changes in the concentration level of GHGs have significant impacts on the earth's temperature. Looking at the level of emissions instead of concentration levels, global CO_2 emissions nearly doubled in the last 40 years. This is shown in Figure 1 for selected years from 1970 to 2004.

Figure 1: Annual Global Anthropogenic GHG Emissions, 1970-2004



Source: Intergovernmental Panel on Climate Change (IPCC) (2007a) Figure SPM.3.a.

[1] See Intergovernmental Panel on Climate Change (IPCC) (2007a), p. 5, Figure SPM.3.b.

Bangladesh, which is one of the world's poorest countries, emitted about one tenth of the world's CO_2 emissions in 2006, despite the fact that its 160 million people represent about 2.4 percent of the world's population.[2] The reason for Bangladesh's low CO_2 emissions is due to Bangladesh's low energy consumption, amounting in per capita terms to only about one twentieth of the world average per capita electricity consumption, which is due to Bangladesh's low income per capita level of $470.[3] Though there are many studies projecting global, regional and country-specific CO_2 emissions,[4] 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 of 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 emission 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.

This paper provides a set of alternative projections for Bangladesh's future CO_2 emissions, based on a set of alternative assumptions about (i) Bangladesh's population growth rates and (ii) Bangladesh's growth rate of gross domestic product (GDP). It will also discuss some of the key issues related to possible improvements in Bangladesh's energy efficiency. Furthermore, given that it is seems likely that Bangladesh will use its large coal reserves for future electricity generation, the paper 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 third section describes the methodology used for establishing the different scenarios and the subsequent projections. The fourth section presents the results, while the fifth section provides some conclusions.

II. 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[5]—the world's most densely populated

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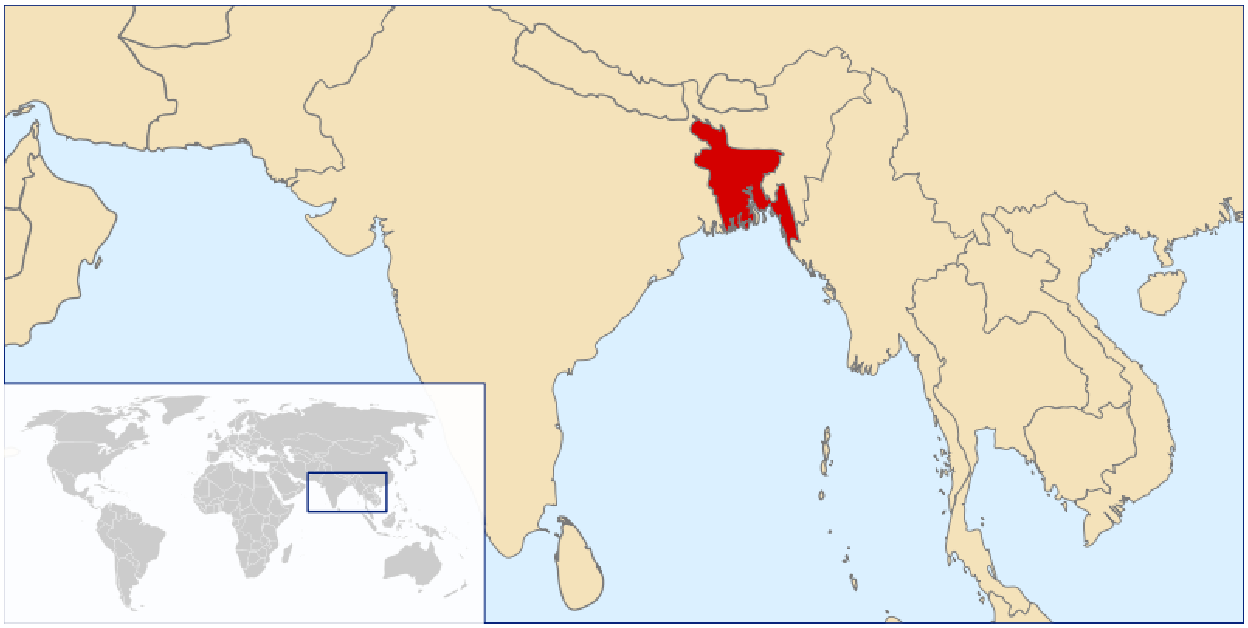
[2] See Table 1 below for further details and references.
[3] As of 2007, see World Bank Bangladesh at a Glance, available at: http://devdata.worldbank.org/AAG/bgd_aag.pdf.
[4] See for example the various assessments by the Intergovernmental Panel on Climate Change (IPCC), the so-called Stern Review, and the International Energy Administration's annual *World Energy Outlook*. The *World Energy Outlook 2007* contains specific case studies for China and India; the forthcoming *World Energy Outlook 2009* will contain specific case studies for South East Asia.
[5] Which is equivalent to 55,598 square miles; or about the same size as Iowa (145,744 square km) and New York state (141,299 square km).

country (after excluding some small islands and countries with less than 1000 square km). As shown in Figure 2, Bangladesh borders with India on the east, west and north; with Myanmar (formerly called Burma) in the south eastern part of Bangladesh; and with the Bay of Bengal in the south. 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.

Figure 2: Location of Bangladesh



Source: http://en.wikipedia.org/wiki/File:LocationBangladesh.svg

Bangladesh is in the midst of resolving a serious energy crisis. Despite that only 38.5 percent of Bangladesh's population had access to electricity in 2006,[6] the demand for electricity surpasses 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 Bangladeshi business sales. 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.[7] Furthermore, an internal World Bank report by Gulati and Rao (2006), quoted in the World Bank's *Global Monitoring Report 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

[6] Various sources provide conflicting information: the World Bank (2008a, p. 39) has put the 2007 coverage at 43 percent, while a detailed study by the Centre for Energy Studies (2006, p. 4) reported coverage to have been 32 percent in 2004. Taking the increase in the number of electricity customers into account (as it is reported in the World Bank, 2008a), the 2007 coverage could have been only 37.6 percent. 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 implies the average of the information provided in the GTZ, WEO and World Bank studies.

[7] See World Bank (2008a), p. 1.

Government (that came to power in January 2009) 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: 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 (TPES) *(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 *(MWh)*	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 CO2/ 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).

Acronyms used in this table:

CO_2 = carbon dioxide
Mt = million of tons
toe = tons of oil equivalent
TPES = Total Primary Energy Supply
PPP = purchasing power parity
MWh = megawatt hour (10 to the power of 6)
Mtoe = million of tons of oil equivalent
TWh = terawatt hour (10 to the power of 12)

Table 1 shows some of the key energy indicators for the world and for Bangladesh as well as the percentage share of Bangladesh in the world or of the world average.[8] As already mentioned, despite constituting 2.4 percent of the world's population, Bangladesh contributes—due to its low income per capita—only 0.14 percent to the global CO_2 emission. Bangladesh's contribution to global CO_2 emissions is even slightly below its share of world GDP,[9] which is also reflected in its below-average energy intensity and below-average carbon intensity, defined respectively, as

[8] Table 1 provides the data as provided by the International Energy Administration (IEA) website as the IEA provides the most recent data (2006). However, given that the IEA website does not provide any time series data, we then use the World Bank's World Development Indicator 2008 data below. There are significant 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.

[9] 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.

the total primary energy supply (TPES) divided by GDP, and CO_2 emissions divided by TPES. The main reasons behind Bangladesh's lower-than-average energy-related ratios are that (i) about half of the Bangladeshi people do not have access to electricity and (ii) about 90 percent of Bangladesh's electricity generation comes from high quality natural gas,[10] which results in carbon emissions far lower than the emissions from other fossil fuels. As Table 2 shows, taking the impact of income levels into account, Bangladesh is pretty much an average country in terms of using clean cooking fuel, electricity access, electricity generation per capita, and the overall energy development index (EDI).[11]

Table 2: Ranking of Selected Developing Countries by Energy Development Index

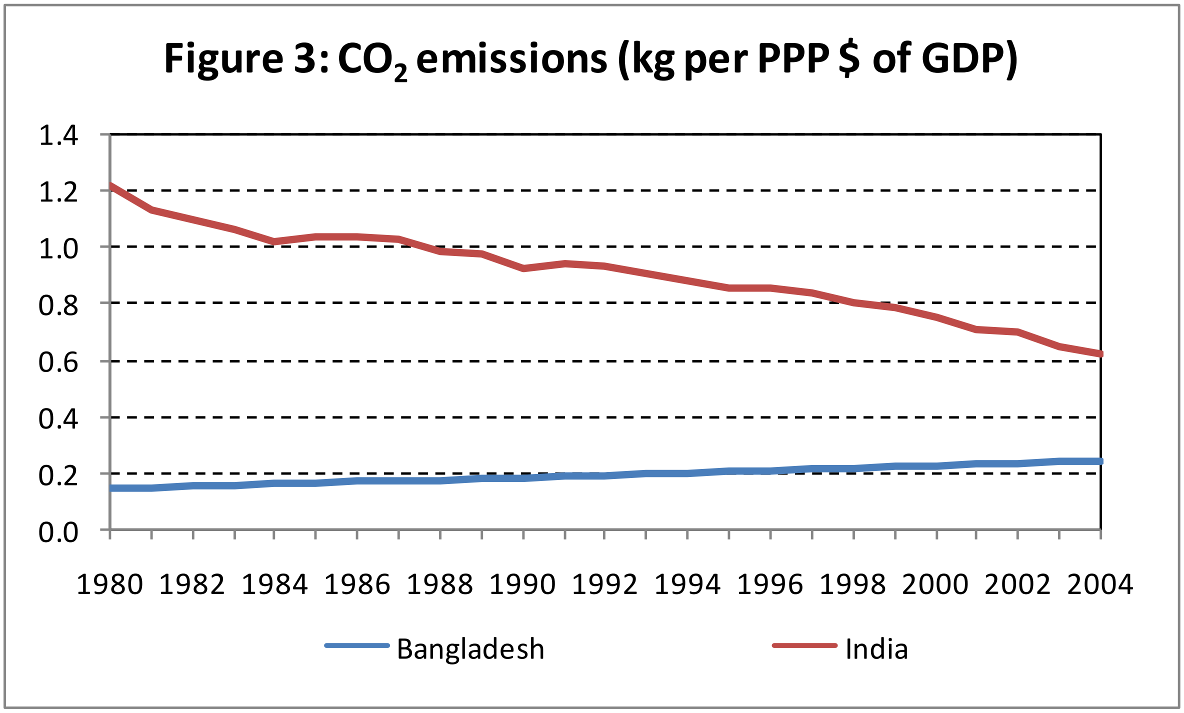
Country	**Clean cooking fuel index**	***Rank***	**Electricity access index**	***Rank***	**Electricity generation per capita index**	***Rank***	**Energy Development Index (EDI)**	***Rank***
Tanzania	0.00	*16*	0.00	*16*	0.00	*16*	0.00	*16*
Bangladesh	0.10	*14*	0.25	*14*	0.02	*15*	0.12	*15*
Ghana	0.01	*15*	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	*11*	0.52	*8*	0.10	*7*	0.30	*8*
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*
Brazil	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 author based on data provided in Table 20.2 of *World Energy Outlook 2007*

Finally, 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. Clearly, reflecting a combination of energy efficiency/intensity and carbon intensity, the long term trend of CO_2 emission per GDP is far from linear.

[10] See World Bank (2008a), p. 24 and GTZ (2005), Table 2, showing that 90 percent of Bangladesh's 3,700 MW public electricity generation of 2004 was gas based and that another captive 1000 MW are 95 percent gas based.

[11] To construct the Energy Development Index (EDI), a separate index was created 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.



Source: World Bank (2008b) *World Development Indicators 2008*, and calculations by author.

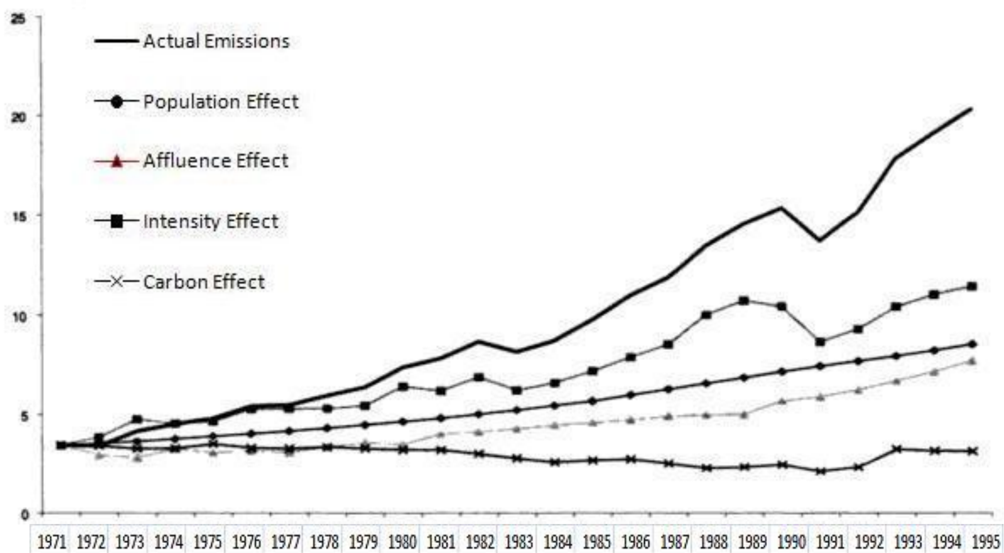
III. Methodology

There are many complex factors that influence the CO_2 emissions of any country, and especially of a fast growing low-income country like Bangladesh. Based on the latest IPCC synthesis report (IPCC, 2007b, 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 many 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.

Most of the early environmental impact literature concentrated on the so-called IPAT equation.[12] 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 for Bangladesh, see Figure 4.

[12] See Ehrlich and Holdren (1971) and Commoner (1972) for some of the earliest contributions.

Figure 4: Decomposition of the Changes in Bangladesh's CO_2 emissions *(in Mt)*, 1971-1995



Source: Ravindranath and Sathaye (2002), Figure 3.3a, p. 46.

More recent research 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.[13] York, Rosa and Dietz (2003) have also suggested that population has a proportional effect (unitary elasticity) on CO_2 emissions, while affluence monotonically increases CO_2 emissions. They also show that indicators of modernization (urbanization and industrialization) are important determinants for CO_2 emissions, which are only partly accounted for by the level of GDP per capita (affluence). The impact of urbanization and industrialization on CO_2 emission can also be approximated by population density as a factor of agglomeration.[14] Hence, we will use population density as an additional indicator when projecting Bangladesh's CO_2 emissions. While even a decomposition of CO_2 emissions based on historical data is far from perfect (mostly due to unreliable and inconsistent data), any projection of future CO_2 emissions is even more complex and subject to various assumptions and uncertainties. The following paragraphs provide some details on the assumptions used in this study, whereby we base the long-term projections for Bangladesh's CO_2 emissions on (i) growth rates of population, GDP per capita (affluence), and population density (agglomeration), (ii) gains in energy efficiency, and (iii) changes in the carbon intensity.

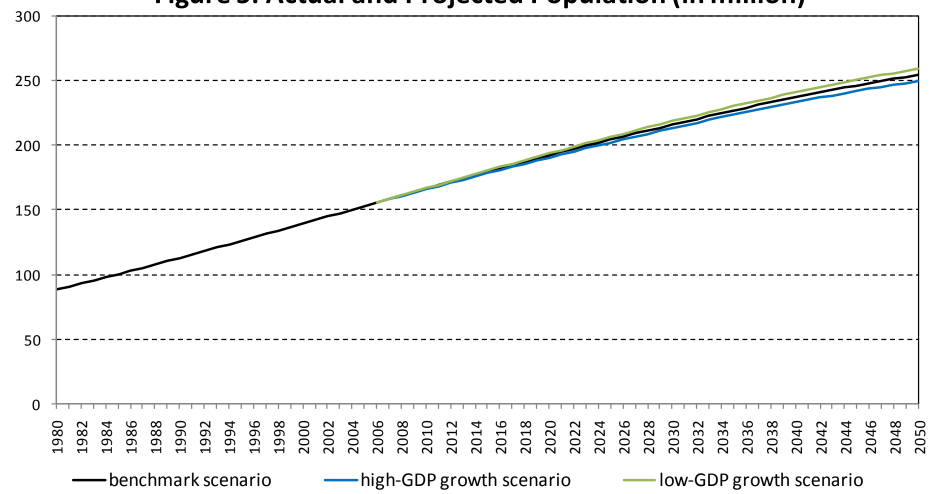
[13] See Chertow (2001) and York, Rosa and Dietz (2003) for details.

[14] 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 could also be used as economic agglomeration at the country level that contributes to a country's CO_2 emission.

III.1. Population Growth

We first use the United Nations (2004) population projections for 2050 for our benchmark population projections. However, when making longer-term projections for CO_2 emissions for poor countries, it is important to recognize that future population growth is dependent on the income per capita level, which is determined by GDP growth. Keeping everything else constant, we know that a higher income per capita has the tendency to lower population growth, while lower income per capita tends to slow down the demographic trend of lower fertility rates. Hence, we use 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.

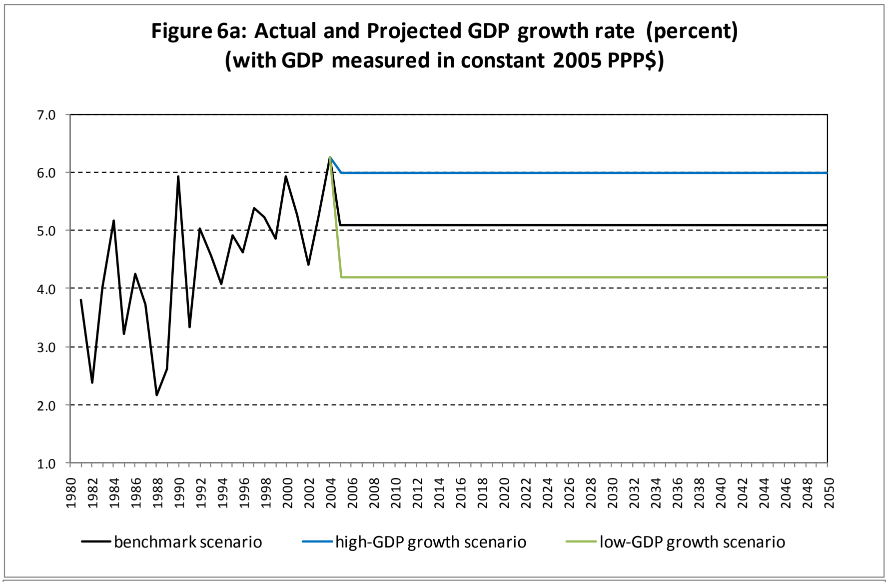
Figure 5: Actual and Projected Population (in million)

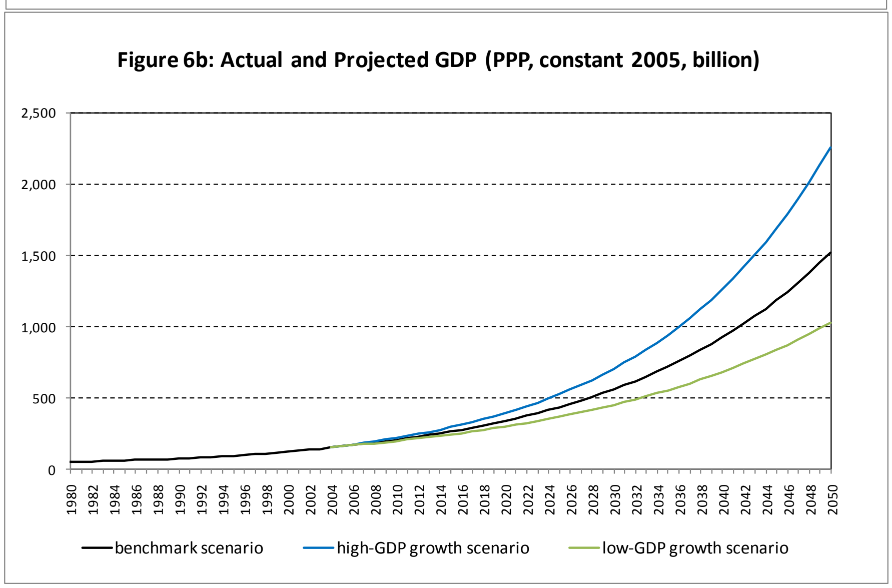


Source: World Bank (2008b) *World Development Indicators 2008* database (providing the actual data), the United Nations (2004) projections for the benchmark scenario, and calculations by the author based on the assumptions described above.

III.2. GDP Growth

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$) terms at 7 percent, and the real GDP growth rate in purchasing power parity (PPP) terms at 5.1 percent. This relative high growth rate reflects Bangladesh's accelerating growth rate from 2002-2008, but is far above Bangladesh's historical record (see Figure 6a). The difference between expressing GDP growth rates in US$ and PPP terms is important especially for our purpose as improved 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 6b, the less than one percent differences to the benchmark scenario make quite a difference over the long projection period.





Source: World Bank (2008b) *World Development Indicators 2008* database (providing the actual data), the Hawksworth and Cookson (2008) projections for the benchmark scenario, and calculations by the author based on the assumptions described above.

The combination of population and GDP growth implies that GDP per capita in constant 2005 PPP$ will, at the end of the projection period—in year 2050, reach:

- $5,982 in the benchmark scenario,
- $9,018 in the high-GDP growth and lower-fertility scenario, and
- $3,956 in the low-GDP growth and higher-fertility scenario.

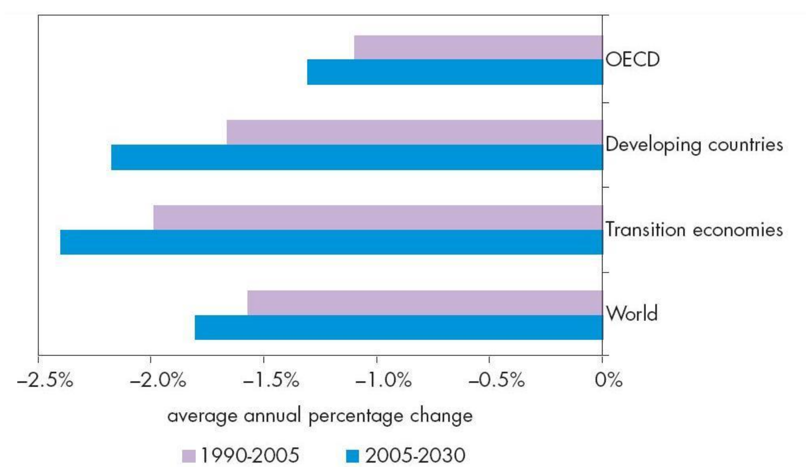
These considerable differences in projected GDP per capita levels are mostly due to the differences in GDP growth projections. For example, applying the lower population growth rate to the benchmark GDP growth scenario would result in a GDP per capita level of $6,092 (in constant 2005 PPP$) in 2050, while applying the higher population growth rate to the benchmark GDP growth scenario would result in a GDP per capita level of $5,876 (in constant 2005 PPP$) in 2050. The relative small impact of different population growth rates are of course due to the much smaller differences among the three alternative population growth projections, which are due to the fact that future population growth rates are much easier to project than future GDP growth rates. Still, these results reflect the reality that future CO_2 emissions depend much more on future GDP growth than on future population growth.

III.3. Gains in Energy Efficiency/Intensity

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 of the issue.

Based on information provided in the *World Energy Outlook (WEO) 2007*, the primary energy intensity has (during 1990-2005) fallen at about 1.5 percent at the global level. 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 7.

Figure 7: Past and Future Progress in Primary Energy Intensity
(without adopting new policies to improve energy efficiency)



Source: *World Energy Outlook 2007*, Figure 15, p. 79.

Furthermore, 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 GTZ supported report states that Bangladesh's new National Energy Policy is compared to the old policy "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."[15]

Another important factor that needs to be taken into account is the—at least currently—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. 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.[16] 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,[17] 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 than 2020 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 energy supply not demand. We will discuss this issue further when examining Bangladesh's future carbon intensity. Given the significant uncertainties related to Bangladesh's future energy efficiencies, we will—for solely illustrative purposes—keep Bangladesh's energy

[15] See Centre for Energy Studies (CES) (2006), p. 5.

[16] A World Bank (2008a, p. 39) report has put the 2007 coverage at 43 percent, while a detailed GTZ (2006, p. 4) study reported coverage to have been 32 percent in 2004. Taking the actual increase in the number of electricity customers from 2004 to 2007 into account (as it is reported in the World Bank report), the 2007 coverage could only have been 37.6 percent. 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. We have therefore calculated the 2006 access rate as an average of the information provided in the GTZ, WEO and World Bank studies.

[17] See World Bank (2008a), Table 2 (p. 11), which provides the number of total customers and can thus be used to calculate the increase in coverage, taking into account that the total number of potential customers has (due to population growth) also been increasing.

efficiency/intensity constant. Hence, this allows us to clearly see the impact of population growth and GDP growth.

III.4. Changes in Bangladesh's Carbon Intensity

Past and future changes in Bangladesh's carbon intensity are mainly determined by changes in Bangladesh's fuel composition used for electricity generation. 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 highly polluting 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.

What is clear is that the current fuel composition for producing Bangladesh's electricity will not stay at the current level of gas amounting to about 90 percent. 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 a possible 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). 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 climate change. This also explains why there are no specific plans for using the more costly[18] renewable energy at any significant level for the publicly generated electricity, though solar energy is generated at increasing rates by individuals, especially in the rural areas that are not connected to the electricity grid.[19]

Bangladesh's plans to make use of its coal reserves are consistent with increased coal uses in other countries. 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% in 2006 to 29% 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. "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."[20] 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.

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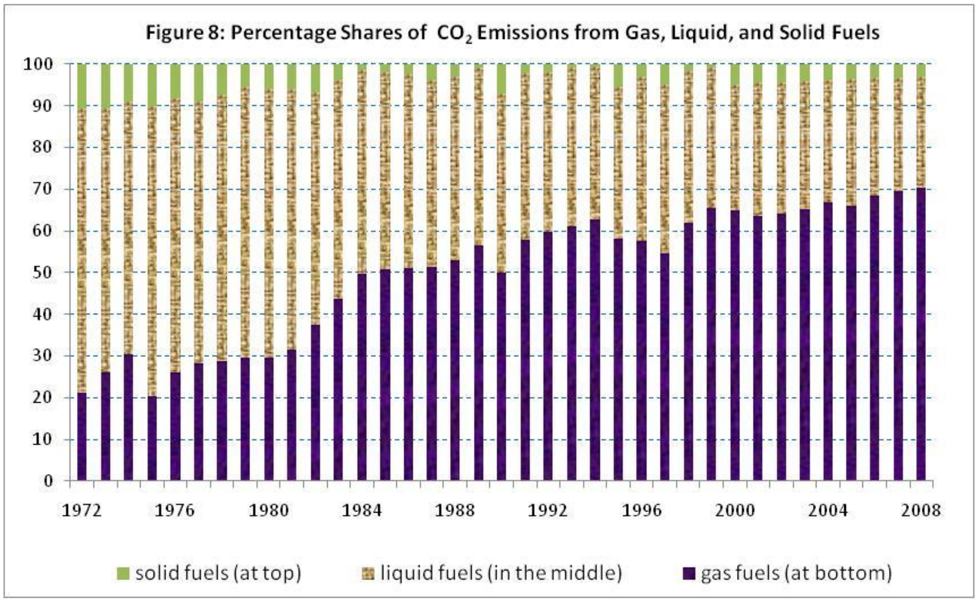
[18] Renewable energy is more costly at current economic prices that do not take into account the various environmental externalities, including the severe costs of climate change.

[19] According to World Bank (2008a), p. 2, over 200,000 solar home systems have been introduced in Bangladesh.

[20] See *WEO 2007*, p. 51.



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

Based on the decomposition of Ravindranath and Sathaye (2002) shown in Figure 4 above, Bangladesh's carbon intensity has declined only 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 8, there are various inconsistencies for specific years. 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 (1997) report.[21] Given the partly inconsistent historical data, the highly uncertain outlook and the fact that this paper focuses on the impact of development and growth on energy use and CO_2 emission, we keep Bangladesh's carbon intensity constant for our analysis.

III. 5. Establishing the Baseline

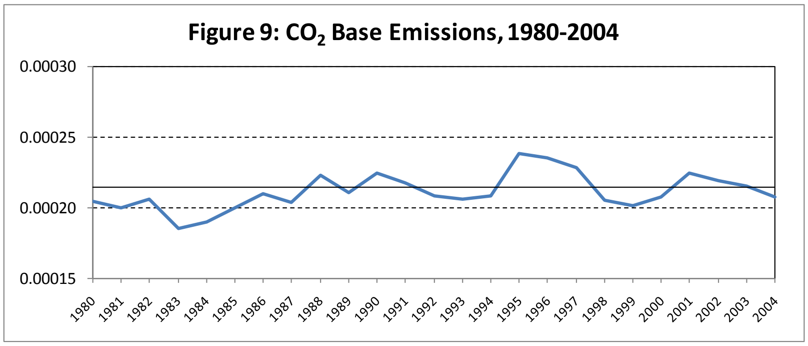
It is useful at this point to look at the historical trend of Bangladesh's CO_2 emission after controlling for population, affluence, and agglomeration (that is, dividing the CO_2 emission by population, GDP per capita, and population density), which we define as Bangladesh's CO_2 base emission:

$$CO_2 \text{ base emission} = \frac{CO_2 \text{ emission}}{\text{Population*GDP per capita (PPP)*Population Density}} \qquad (1)$$

[21] 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.

The historical trend from 1980-2004 of Bangladesh's CO_2 base emission (see Figure 9), 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 seems to indicate that during the last 25 years, the combined impacts of energy efficiency and carbon intensity did overall not affect Bangladesh's CO_2 emission. In other words, population, affluence, and agglomeration have been the key determinants for 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 project the total CO_2 emission of Bangladesh for any level of i) population and ii) GDP per capita. All what is needed is to multiply Bangladesh's CO_2 base emission by the population, GDP per capita, and population density.



Source: Calculations by the author based on World Bank (2008b) *World Development Indicators 2008*.

IV. Results

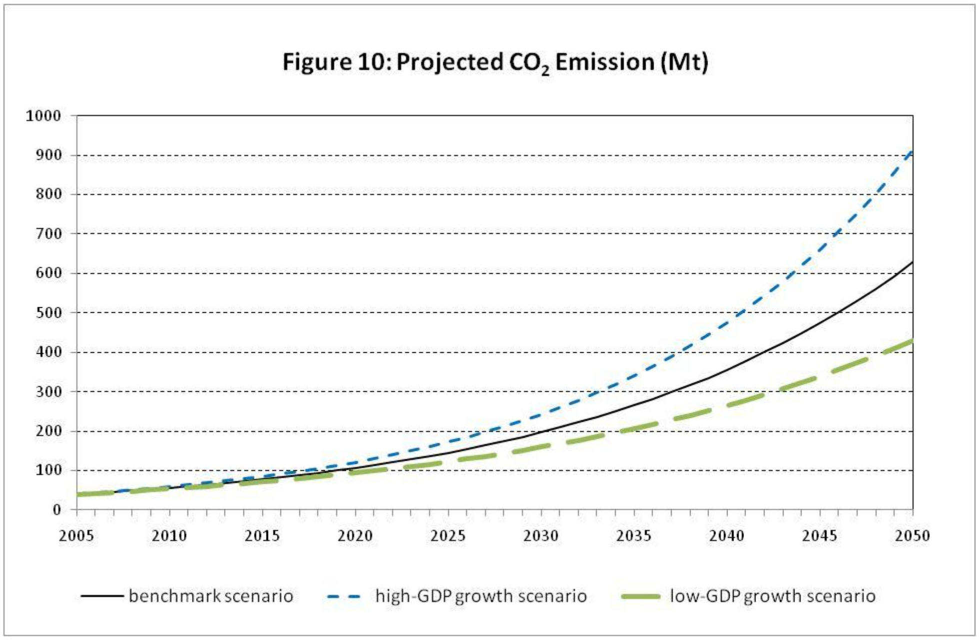
Figure 10 provides Bangladesh's CO_2 emissions for the benchmark, high-growth, and low-growth scenarios and the assumptions that there will be no improvements (and no deteriorations) in Bangladesh's energy efficiency/intensity. As expected, the projections show sharp increases in CO_2 emissions due to a sharply increasing energy demand by the growing and more affluent population.

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;[22]
- the projected 2050 level of the high-growth scenario (913 Mt of CO_2 emissions) is about 16 percent of what the United States is currently emitting.
- the projected 2050 level of the low growth scenario (431 Mt of CO_2 emissions) is less than 5 percent of what the United States is currently emitting.

[22] 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.

All of our projections imply far higher emission levels than what Azad, Nashreen and Sultana (2006) projected based on the 1977-1995 emission trend (293 Mt of CO_2 emission in 2070). This is mostly due to our far higher assumptions for Bangladesh's GDP growth. The average 1977-1995 GDP growth rate (in constant US$) was only 3.9 percent, hence about 3 percent below our benchmark scenario. As we have seen in Figure 6b, a difference of a couple of percentage points in GDP growth rates has huge long term implications.

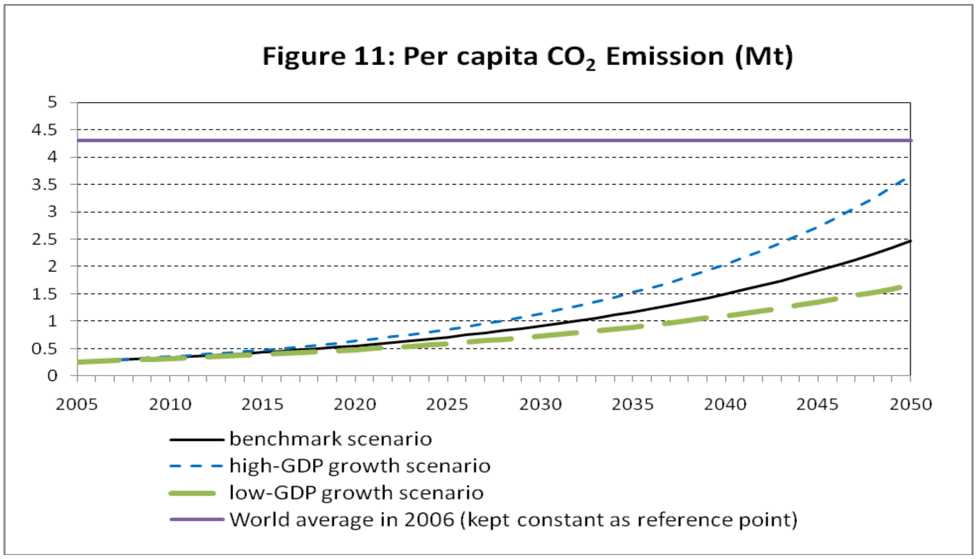


Source: Calculations by the author.

V. Conclusions

In 2050, the world will be a very different animal. As is reflected in Hawksworth and Cookson (2008), there is broad agreement that China's GDP will have surpassed that of the United States and that India's GDP will be close to that of the United States. While Bangladesh's GDP will still be relatively small share of world GDP, Bangladesh is expected to be an upper-middle income country with the seventh largest population. Based on extrapolations of the *WEO 2007* projections, the world's CO_2 emissions of 2050 will have more than doubled under the reference scenario and increased more than 50 percent under a relatively ambitious alternative (more energy-efficient) scenario. Hence, the *WEO 2007*'s alternative scenario is not ambitious enough to stabilize the CO_2 levels in the atmosphere, despite assuming that the CO_2 emissions of the industrialized countries would peak before 2010.

Assuming that Bangladesh's GDP will grow at an average of 5.1 percent per year (in 2005 PPP terms) and that its population will reach 254.6 million in 2050 (our benchmark scenario), Bangladesh's GDP per capita (in constant 2005 PPP terms) would increase from $1,068 in 2005 to $5,982 in 2050. In other words, income per capita would increase nearly six times the 2005 value. However, assuming that there will be no improvements in Bangladesh's energy efficiency and no change in Bangladesh's carbon intensity, the nearly six fold increase in income per capita comes with a nearly 15 times increase in Bangladesh's CO_2 emission. Yet, as Figure 11 shows, it needs to be stressed that Bangladesh's CO_2 per capita emission would still be considerably below the current world average.



Source: Calculations by the author.

Based on per capita CO_2 emissions, countries like Bangladesh have every right to increase their currently marginal share of CO_2 emissions. On the other hand, the projected large growth rates of developing countries' CO_2 emissions will make it very difficult for the world to stabilize its total CO_2 emission. Stabilizing the world's CO_2 emissions would either require sharper decreases in the industrialized countries or decreases in the CO_2 emissions of developing countries that have per capita emissions below those of the industrialized countries. As has been recognized by now, this is likely to be one of the world's largest equity issue for the coming years.[23] 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. There is a huge potential for far lower increases in these countries' CO_2 emissions by increasing these countries' energy efficiency.

Finally, looking at the implications of different GDP growth rates on Bangladesh's CO_2 emissions, it may look like that slightly lower growth rates will be helpful to stabilize the world's CO_2 emissions. Our projections have shown that just one percentage point lower GDP growth implies about 30 percent less CO_2 emissions by 2050. However, this clearly is the wrong interpretation 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, the long-term impact of low GDP growth on CO_2 emissions is actually worse. 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.

[23] For example, see Huq and Toulmin (2006).

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