The Impact of Development and Growth on CO_2 Emissions

A Case Study for Bangladesh until 2050

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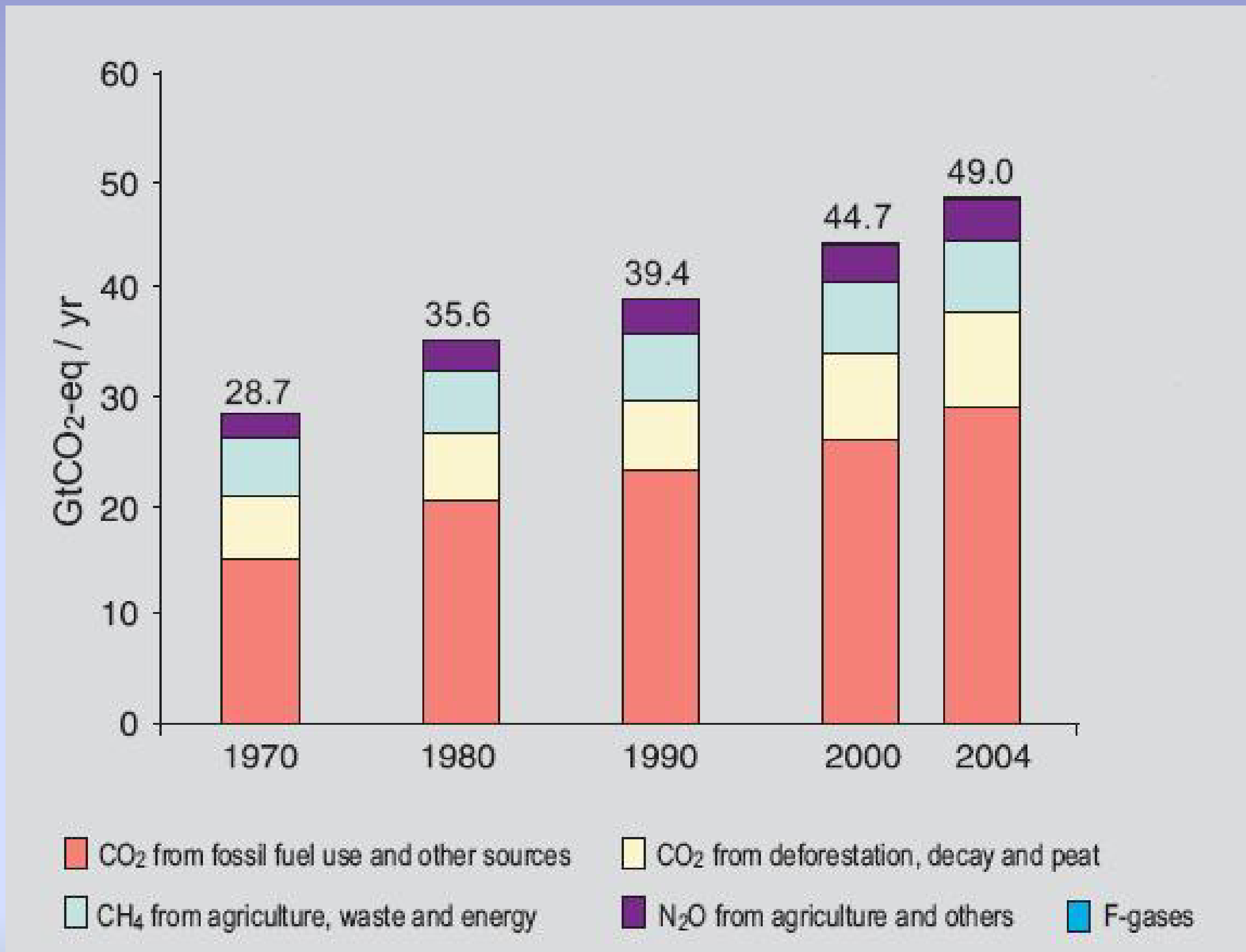
Overview of Presentation

- Introduction and Background
- Methodology
- Results
- Conclusions

Annual Global Anthropogenic GHG Emissions, 1970-2004



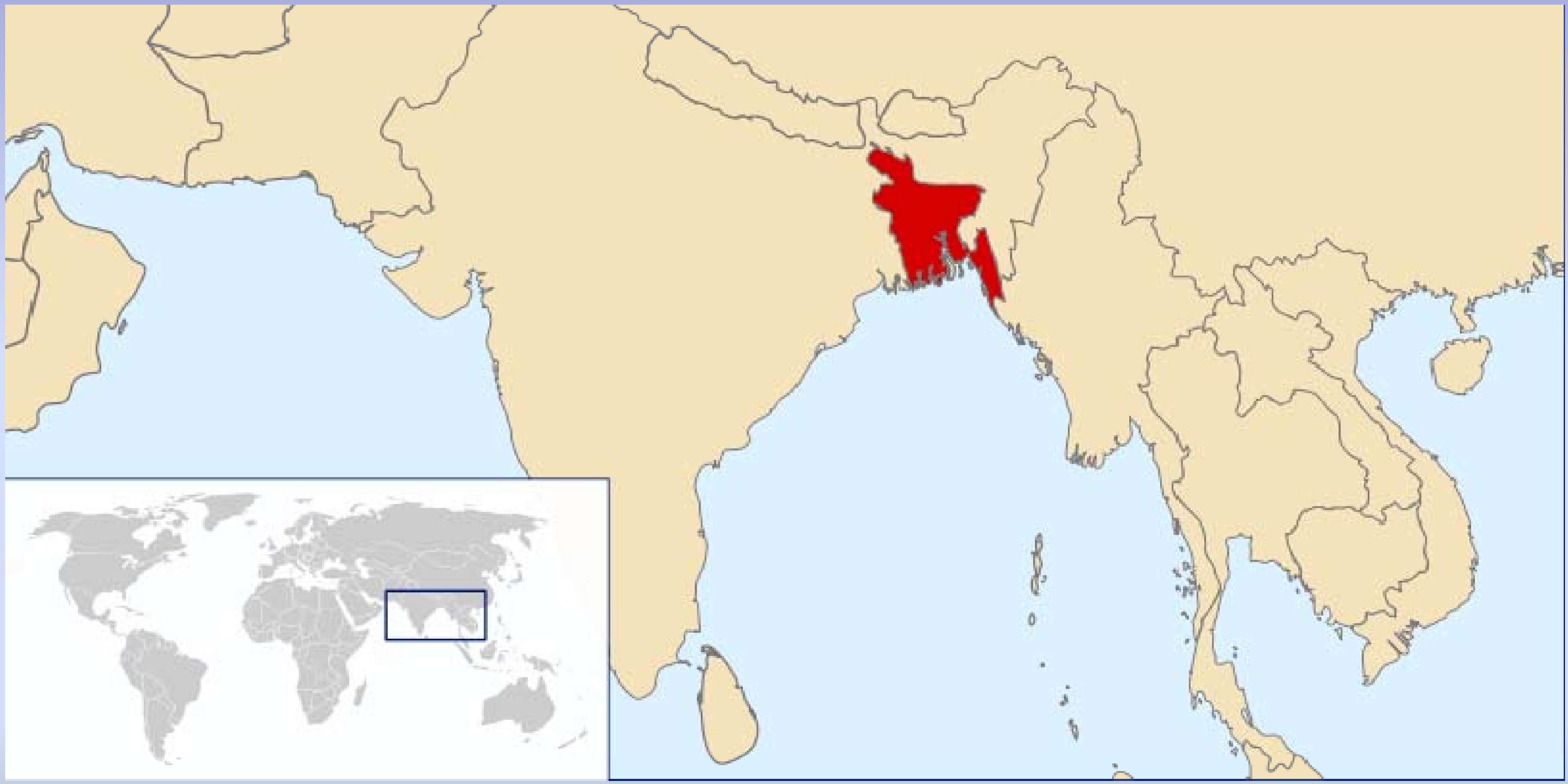
Source: Intergovernmental Panel on Climate Change (IPCC) (2007a) Figure SPM.3.a.

Introduction and Background

- **This paper provides a variety of alternative projections for Bangladesh's future CO_2 emissions.**

- **The main determinants for Bangladesh's future CO_2 emissions are:**
  - **population growth,**
  - **growth of income per capita,**
  - **changes in the level of modernization/agglomeration,**
  - **changes in energy efficiency/intensity, and**
  - **changes in carbon intensity.**

Bangladesh serves as an interesting case study



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

Introduction and Background

- **Bangladesh's 160 million people represent about 2.4 percent of the world's population.**
- **Bangladesh emitted about one tenth of a percent (0.14 %) of the world's CO_2 emissions in 2006.**

- **The reason for Bangladesh's low CO_2 emissions is Bangladesh's low energy consumption (which is related to Bangladesh's low income).**
  - **Bangladesh's share in world electricity consumption is 0.13 percent.**
  - **Bangladesh's share in world GDP is 0.17 percent.**
  - **Bangladesh's income per capita was US$470 in 2007.**

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)

Bangladesh has — relative to its income level — typical energy indicators

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 authors based on data provided in Table 20.2 of *World Energy Outlook 2007*

Introduction and Background

- **Bangladesh is in the midst of resolving a serious energy crisis.**
  - **Only 38.5 percent of Bangladesh's population had access to electricity in 2006.**
  - **However, the demand for electricity surpasses that of supply by a large margin, leading to extensive load-shedding.**
  - **The decade-long electricity shortage has become worse in recent years as no new reliable electricity generation was added during 2002-2006.**

Methodology

- **Most of the early environmental impact literature concentrated on the so-called IPAT equation.**
- **It calculated the environmental impact (I) based on a simple multiplicative contribution of**
  - **population (P)**
  - **affluence (A)**
  - **technology (T)**
- **That is: 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.**

Methodology

- **More recent research by Chertow (2001) and York, Rosa and Dietz (2003) suggests that:**
  - **the assumption of a simple multiplicative relationship among the main factors is not optimal**
  - **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 (in addition to population and wealth).**
  - **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.**

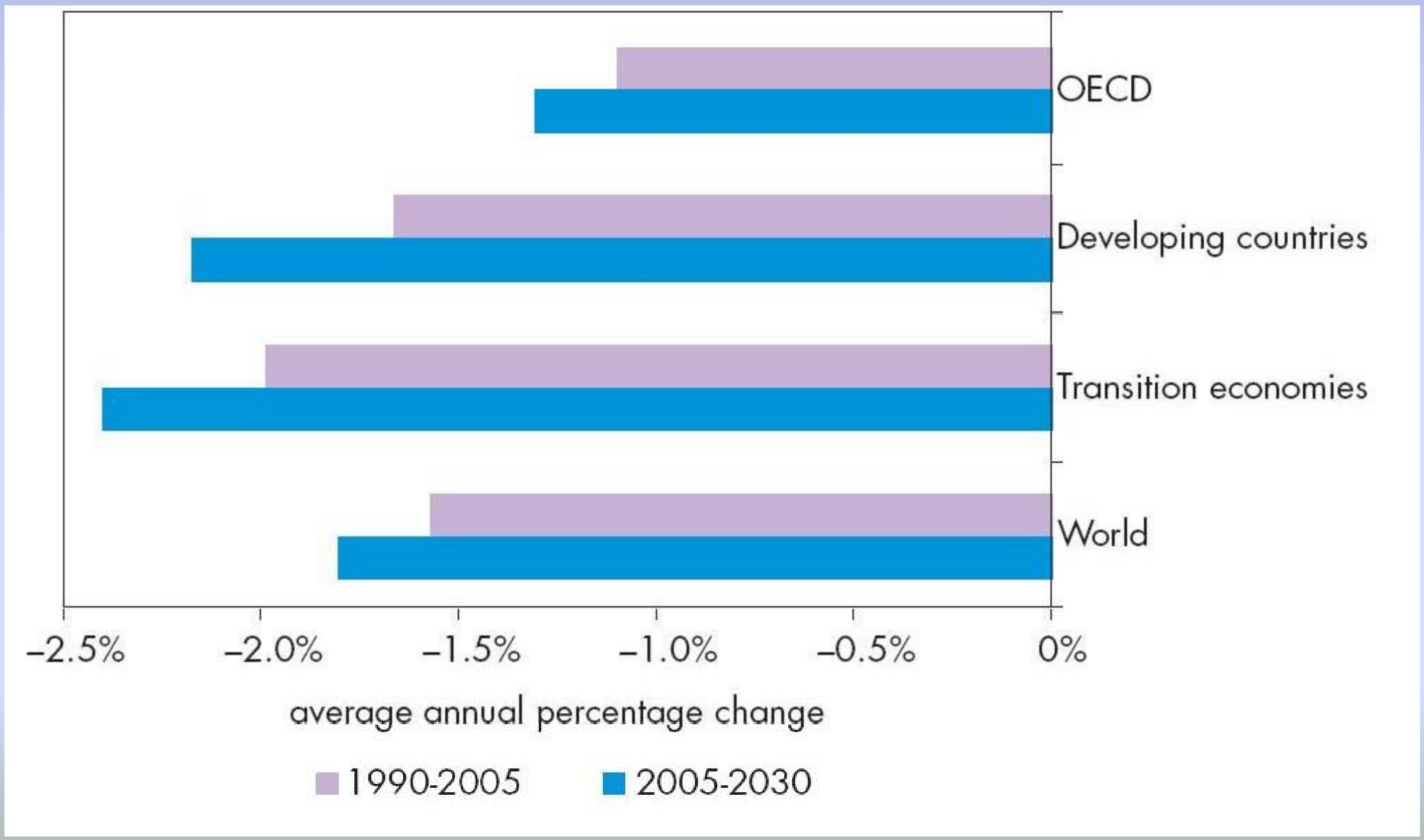
Methodology: Projections on Population and GDP Growth

- **Population: We use the United Nations (2004) population projections for our benchmark population projections**
  - **Bangladesh's population is projected to reach 254.6 million in 2050**
- **GDP growth: We use the recent projections by Hawksworth and Cookson (2008) for our benchmark scenario**
  - **7 percent annual real GDP growth rate in US$ terms = 5.1 percent annual real GDP growth in purchasing power parity (PPP) terms**
- **We also use two alternative scenarios, which takes into account that population growth and GDP growth are in the long run not independent from each other:**
  - **High-GDP-growth scenario: 250 million population and real GDP growth rate of 6.0 percent in PPP terms**
  - **low GDP-growth scenario: 259.2 million population and real GDP growth rate of 4.2 percent in PPP terms**

Methodology: Gains in Energy Efficiency

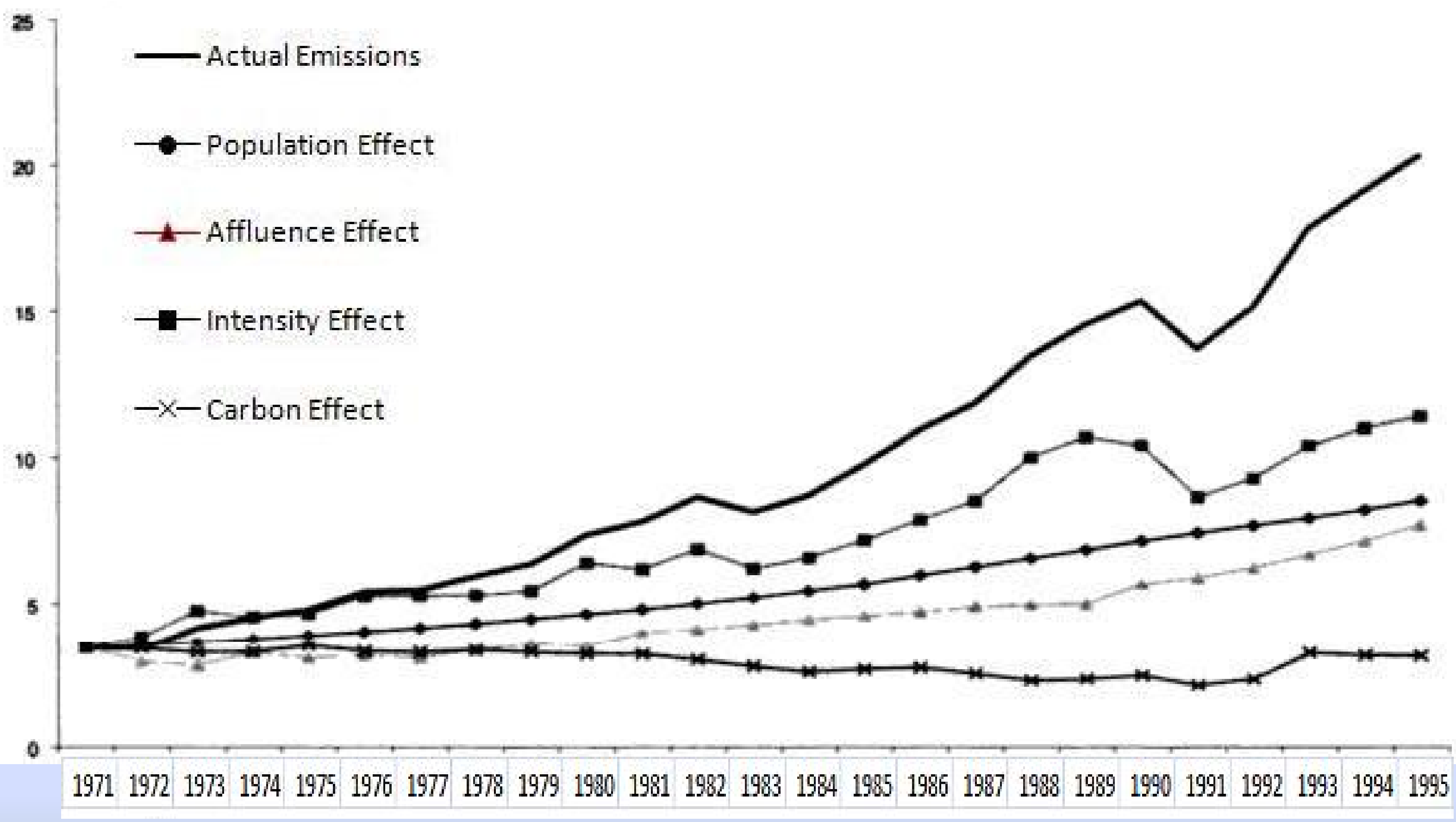
Past and Future Progress in Primary Energy Intensity

(without adopting new policies to improve energy efficiency)



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

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



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

Methodology: Gains in Energy Efficiency

- There are two main factors determining Bangladesh's future energy efficiency:
  - rapidly increasing access to electricity, which is likely to increase Bangladesh's energy intensity; and
  - new policies, which are supposed to decrease the energy intensity (Bangladesh's new National Energy Policy addresses energy efficiency, but actual progress is slow).

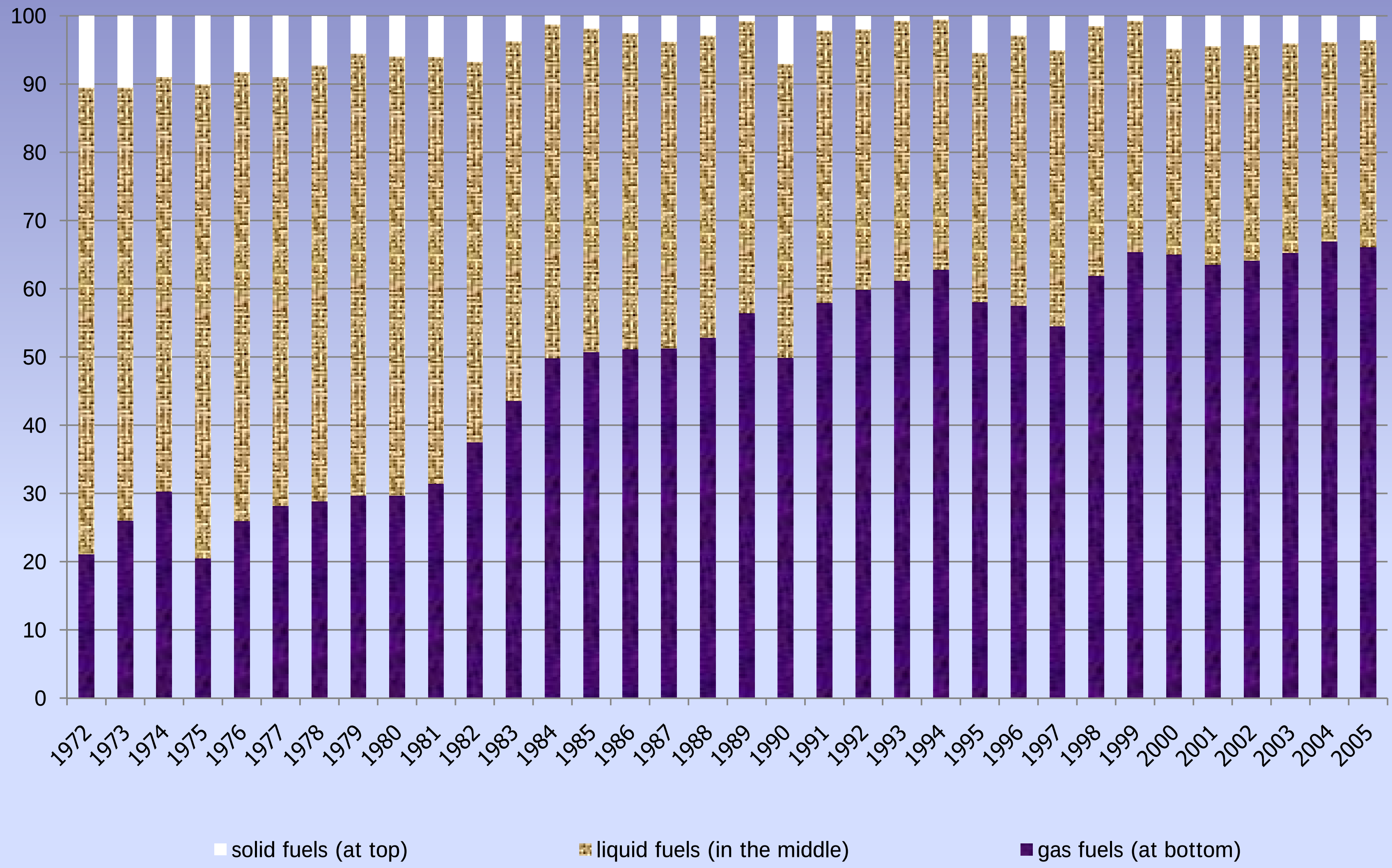
Methodology: Gains in Energy Efficiency

- Given the significant uncertainties related to Bangladesh's future energy efficiencies, we will use the following three alternative energy efficiency scenarios:
  - ***Projections A*** assume that there are no improvements and no deteriorations in Bangladesh's energy efficiency/intensity.
  - ***Projections B*** assume that the improvements in Bangladesh's energy efficiency will approach the current energy efficiency level of the European Union (EU).
  - ***Projections C*** assume 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.

Methodology: Changes in Carbon Intensity

- There are three main factors determining Bangladesh's future carbon intensity:
  - The reduction of the currently extensive load-shedding will reduce the carbon intensity as the generators used during load-shedding are more carbon intensive.
  - The net effect from increasing access to electricity on carbon intensity is uncertain.
  - The likely increase in using coal for future electricity generation will increase Bangladesh's carbon intensity.

Figure 8: Percentage Shares of CO_2 Emissions from Gas, Liquid, and Solid Fuels



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

Methodology: Changes in Carbon Intensity

- 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 CO_2 emission, we keep Bangladesh's carbon intensity constant for our analysis.

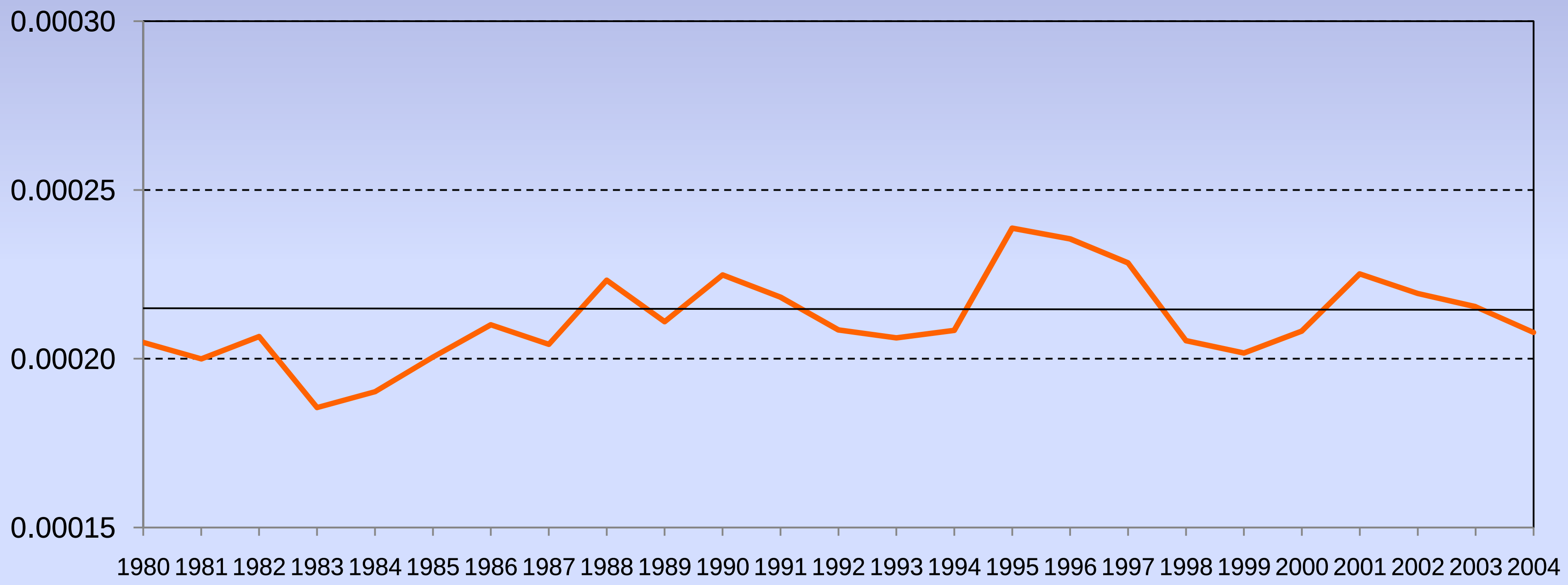
Methodology: How to put it all together

- 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.
- Hence, we divide the CO_2 emission by population, GDP per capita, and population density.
- We define this as Bangladesh's CO_2 base emission:

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

Methodology: How to put it all together

Figure 9a: CO_2 Base Emissions, 1980-2004

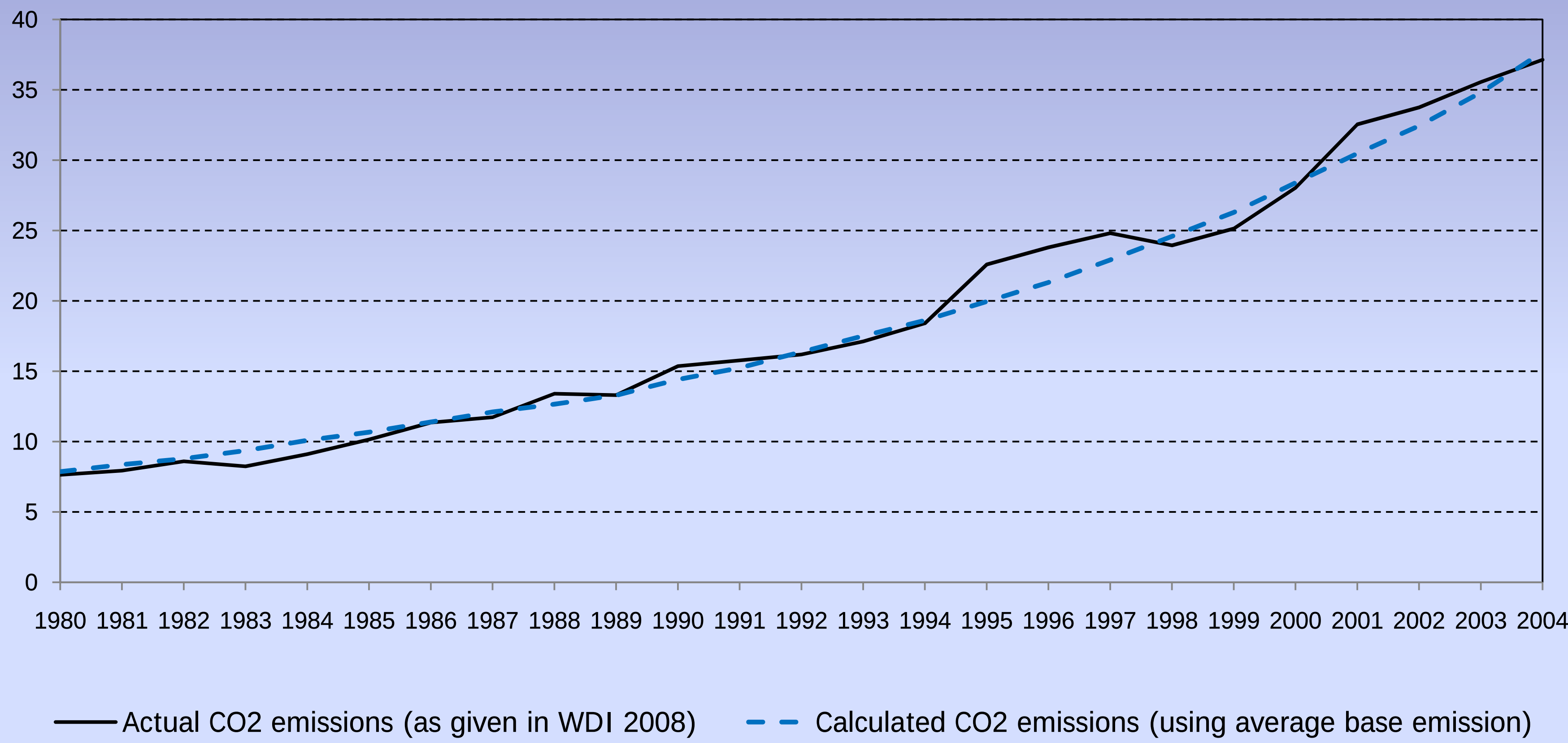


Source: Calculations by the authors based on *World Development Indicators 2008*.

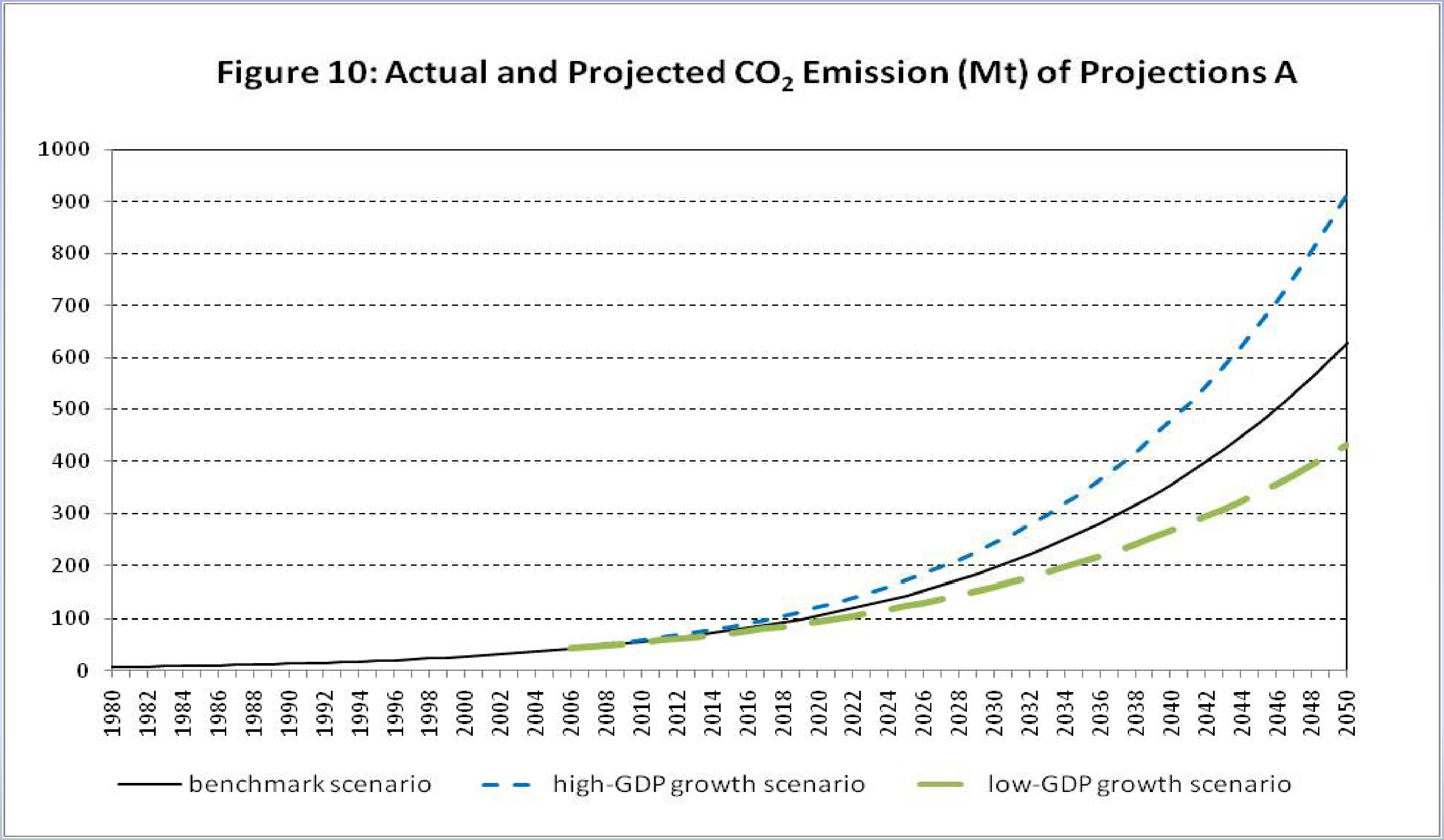
Methodology: How to put it all together

- The historical trend from 1980-2004 of Bangladesh's CO_2 base emission 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 overall 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 CO_2 emission for any level of (i) population, (ii) GDP per capita, and (iii) agglomeration.

Figure 9b: Actual versus Estimated CO_2 Emission (Mt)



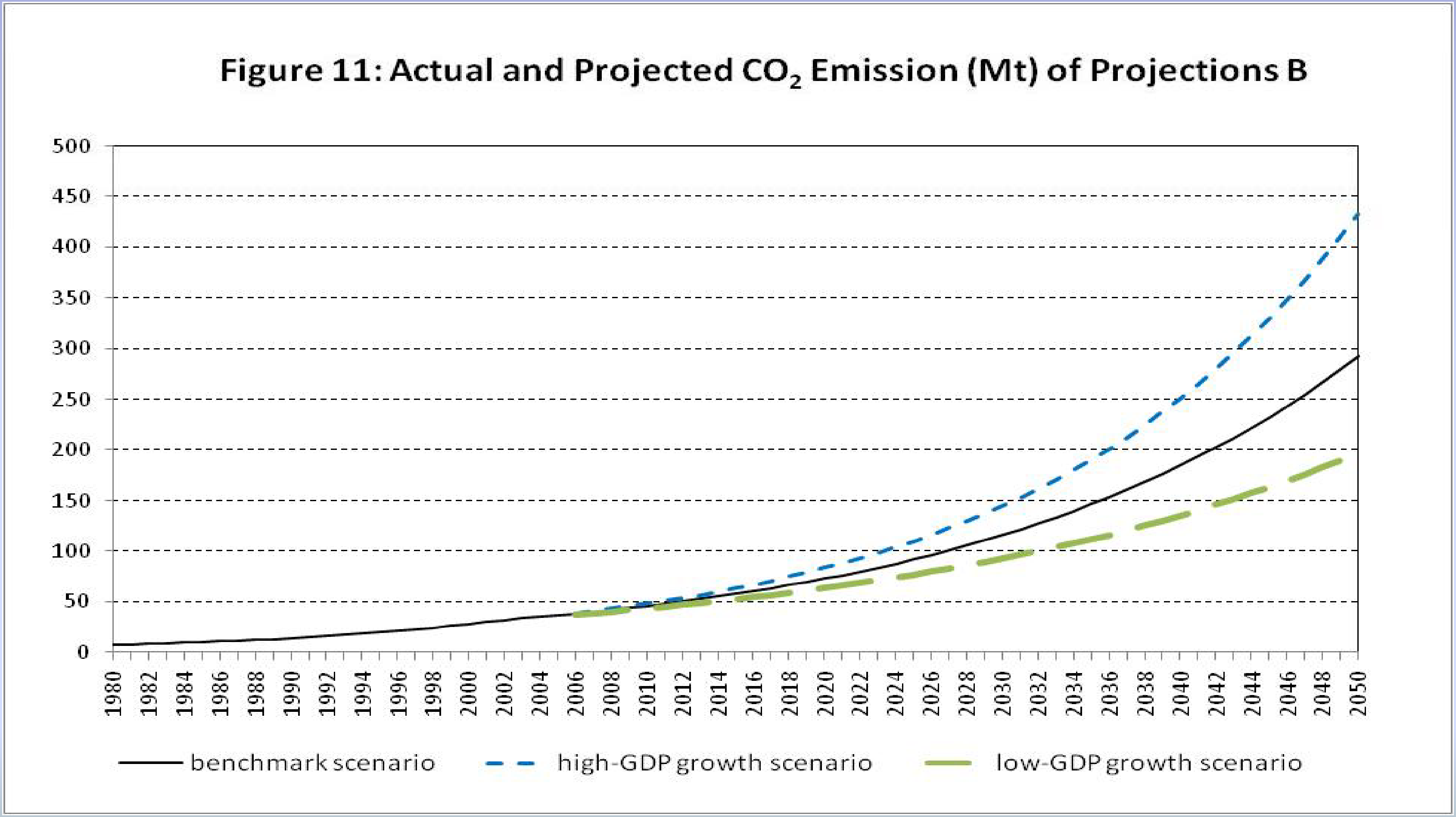
Results: Projections A
(no change in energy efficiency)



Results: Projections A
(no change in energy efficiency)

- The projected 2050 level of the benchmark scenario (628 Mt of CO_2 emissions) is about one tenth of what the U.S. 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 (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 (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.

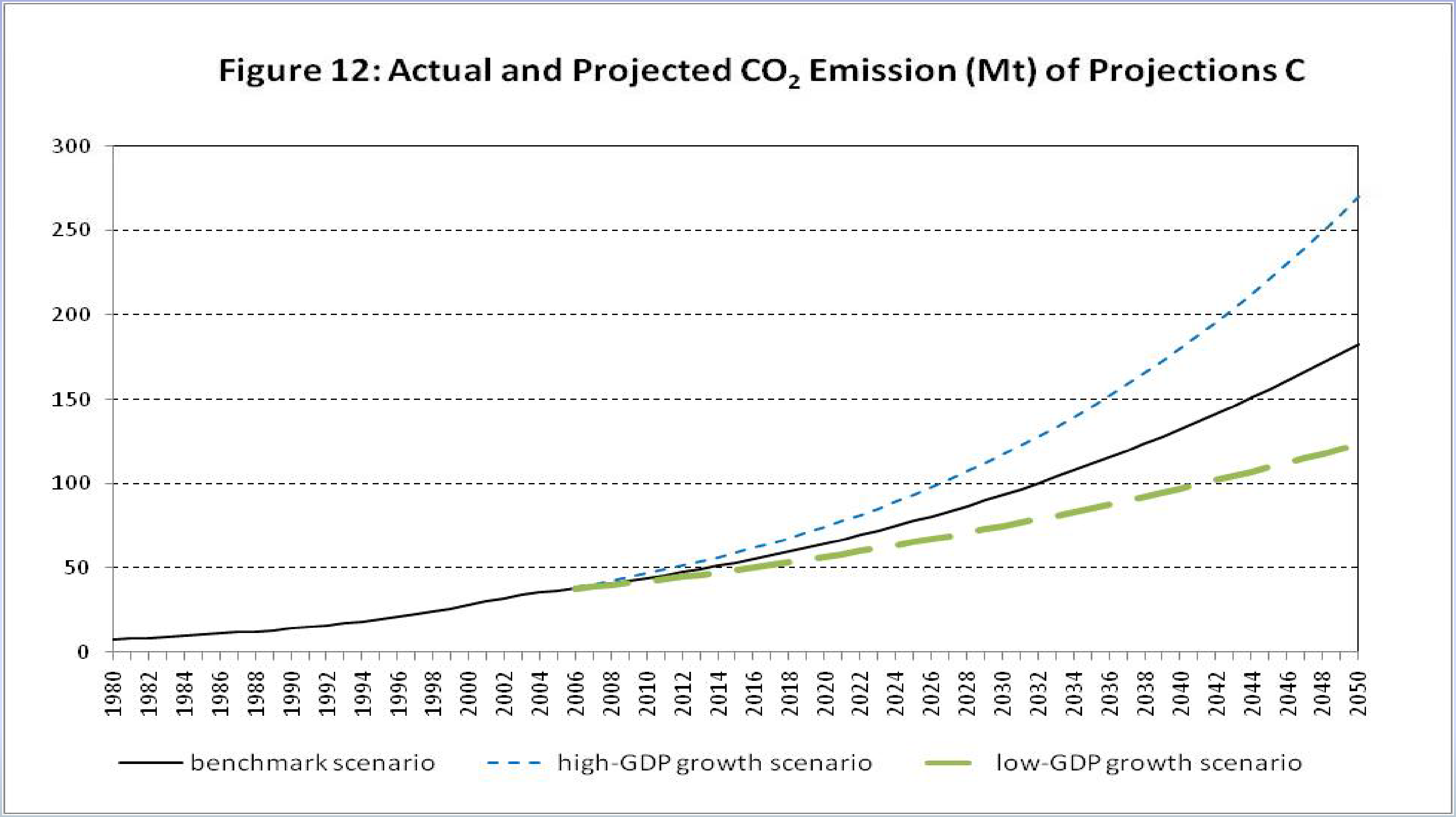
Results: Projections B
(reaching the EU's current energy efficiency in 2050)



Results: Projections B
(reaching the EU's current energy efficiency in 2050)

- 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).

Results: Projections C
(reaching the EU's projected 2030 energy efficiency in 2050)

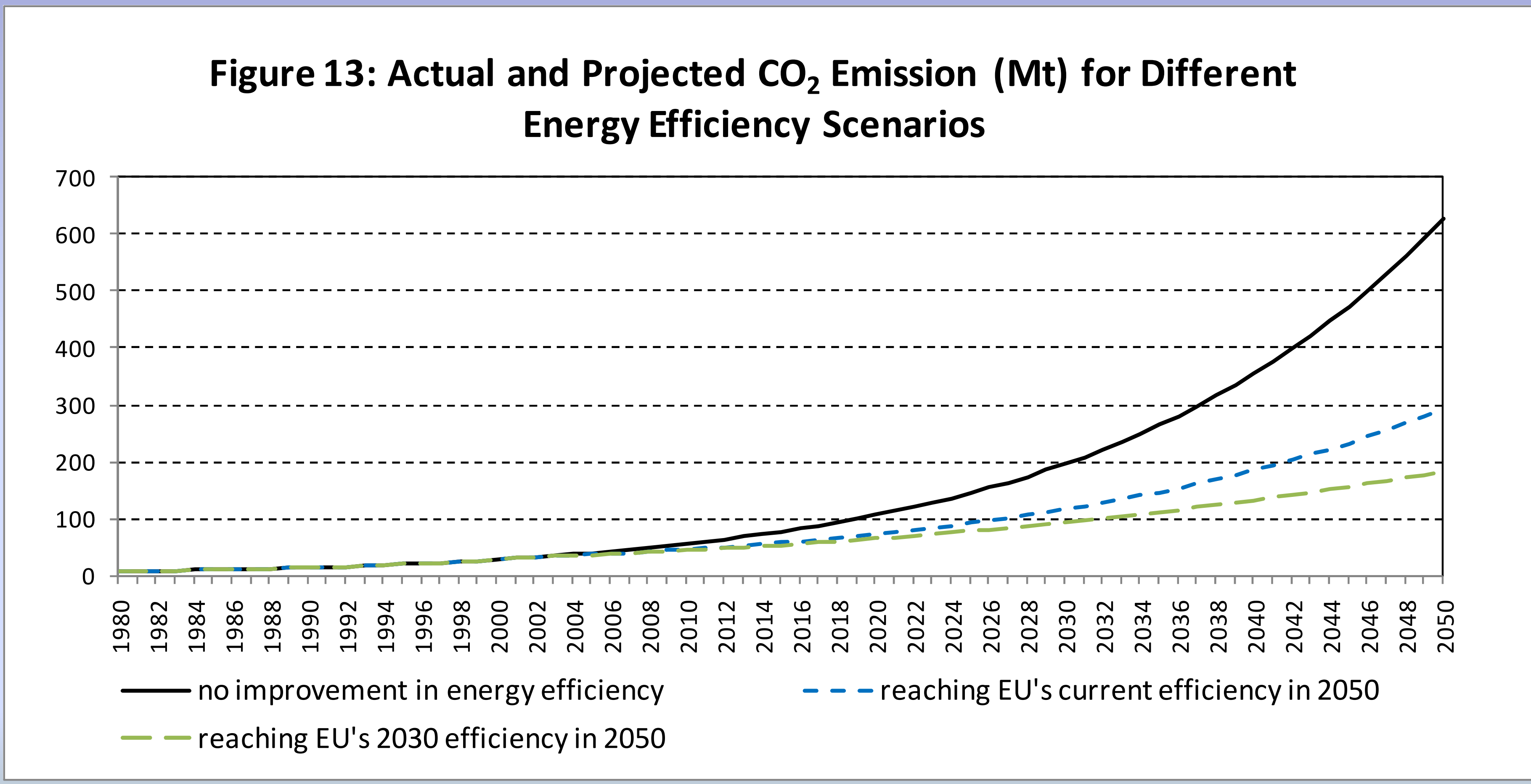


Results: Projections C
(reaching the EU's projected 2030 energy efficiency in 2050)

- The projected 2050 level of the benchmark scenario (183 Mt) would be about 5 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 7 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.

Results: Comparisons

(impact of changes in energy efficiency)



Conclusions

- 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.

Conclusions

- In the benchmark scenario, Bangladesh's GDP per capita would increase from $1,068 in 2005 to $5,982 in 2050. In other words, income per capita would increase nearly six times.
- 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.
- Even if reaching the EU's 2030 energy efficiency in 2050, Bangladesh's 2050 CO_2 emission would still increase nearly seven times the 2005 value.
- Yet, it needs to be stressed that Bangladesh's CO_2 per capita emission would still only be about 1/3 of the world average in the case of no energy efficiency gains and about 15 percent of the world average in the case of reaching the EU's 2030 energy efficiency in 2050.

Conclusions

- Based on per capita CO_2 emissions, countries like Bangladesh have every right to increase their currently marginal share of CO_2 emissions.
- Yet, 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 industrialized countries.
- This is likely to be one of the world's largest equity issue.

Conclusions

- 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. In our example and assumptions:
  - 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 the emissions under the no-energy-efficiency-gains scenario.
  - if reaching the EU's 2030 energy efficiency by 2050, which is ambitious though feasible if there is political will, Bangladesh' increase in CO_2 emissions would be less than one third of emissions under the no-energy-efficiency-gains scenario.

Conclusions

- Finally, comparing the implications of different GDP growth rates, it looks like that lower GDP growth rates are 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, in basically all three energy efficiency scenarios.
- 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, low GDP growth will actually increase CO_2 emissions in the long-run.
- 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.