GROWTH AND CO_2 EMISSIONS: HOW DOES INDIA COMPARE TO OTHER COUNTRIES?

Background paper

India – Strategies for Low Carbon Growth

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Acknowledgement

This report was produced as a background paper for the study *India: Strategies for Low Carbon Growth*. The team that has worked on this paper comprises the following World Bank staff and consultants: Robert Bacon, Soma Bhattacharya, Richard Damania, Masami Kojima, Kseniya Lvovsky, and Suphachol Suphachasalai. Valuable comments were received from Dan Biller, Kirk Hamilton, Kwawu Mensan Gaba, and Gary Stuggins. Kseniya Lvovsky is the Team Leader for the study, Karin Kemper and Salman Zaheer are responsible Sector Managers, and Isabel Guerrero is the Country Director for India.

Abbreviations and Acronyms

Btu	British thermal units
CO_2	carbon dioxide
EIA	Energy Information Administration
GDP	gross domestic product
GHG	greenhouse gas
GoI	Government of India
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goal
MER	market exchange rate
PPP	purchasing power parity

Executive Summary

This paper has been prepared as part of the *India Low Carbon Growth Strategy* study in response to a request from the Government of India to complement an analysis of India's growth scenarios with a comparative assessment of India's performance with respect to carbon dioxide (CO_2) emissions from fossil fuel combustion in the international context.

As a major economy and the second most populous nation in the world, India's CO_2 emissions from fossil fuel combustion rank high. Its CO_2 emissions will continue to grow for some time, as in all those developing countries which need to increase the currently low levels of per capita energy use to support growth, reach the Millennium Development Goals and eventually provide modern living standards to all their citizens.

The key question therefore is what India, as a member of the global community which is to collectively address the global challenge of climate change, can be expected to do—and what it has been already doing—to grow and meet is energy needs in a "low carbon" manner compared to reasonable international benchmarks. It is in this context that this paper assesses India's CO_2 performance over a 10-year period and compares it with that of other developed and developing economies. Specifically, it analyzes in detail data from 1994 to 2004 for 70 countries using a decomposition technique, and complements this analysis with a review of available future projections (from recent studies by reputed international research groups) to 2030 or 2050.

The main findings are as follows:

- By two measures—CO_2 emissions per capita and CO_2 emissions per unit of gross domestic product (GDP) based on purchasing power parity—**India emerges as a relatively low carbon economy** by global comparison.
- **India has also been offsetting its CO_2 emissions in line with the performance of the global economy**. Offsetting is defined in this paper as the combined effect on changes in CO_2 emissions of reduced energy intensity, lower carbon intensity of fossil fuels, and fuel substitution away from fossil fuels, relative to the effect of growth in GDP and population in a particular country.
- **India has managed to improve both the level of offsetting of CO_2 emissions and CO_2 emissions intensity of its economy over the period 1999–2004 compared to 1994–1999**, when its economic growth accelerated and against the backdrop of increasing CO_2 intensity of the global economy. The decline in CO_2 emission intensity in India occurred from a relatively low initial level.
- Most of the available projections undertaken by reputed independent international organizations indicate that **India's CO_2 intensity per unit of GDP is likely to continue to decline through 2030–2050.** In this context, international financial institutions such as the World Bank can make an important contribution by supporting, strengthening, and accelerating the implementation of government policies and programs that reduce CO_2 intensity as the economy continues to grow at a rapid pace, and by bringing concessional financing as needed.
- Given large variations in CO_2 performance across countries and large swings in this performance across time periods, as observed by the analysis reported in this paper, **further in-depth work is necessary to better understand the key determinants of India's CO_2 intensity** and policies that would be effective in keeping the CO_2 emissions intensity low.

Background

India is a large, fast growing economy with a significant share of coal in its primary energy mix. As a consequence of the size of its economy and population, India's CO_2 emissions from fossil fuel combustion[1]—at about 1.1 billion ton in 2004—rank high. Together with other major economies, India features prominently in climate change discussions. The combustion of fossil fuels is the largest single contributor to CO_2 and total greenhouse gas (GHG) emissions, responsible for changing global climate. CO_2 emissions from consumption of fossil fuels constitute more than half of total GHG emissions in many countries, India among them. In India's case, CO_2 emissions from fossil fuel combustion constituted 54 percent of total GHG emissions in 2000 (World Resources Institute 2007). Of all major sources of GHGs, CO_2 from fuel combustion has grown the most rapidly since 1970. Furthermore, the recent Fourth Assessment report by the Intergovernmental Panel on Climate Change (IPCC) shows that the long-observed trend in declining global fossil-fuel-derived CO_2 emission intensity per unit of GDP has reversed around 2000, implying that, with rapid economic growth, global CO_2 emissions are growing faster than at any time since 1970 (IPCC 2007).

Accelerating and maintaining the high rate of economic growth is the key to poverty reduction in India (where the largest number of the world poor still live) and achieving the Millennium Development Goals (MDGs). The energy needs to support this growth are vast. India is the only major economy with half of rural population, or roughly 400 million people, with no electricity access. India's CO_2 emissions will continue to grow for some time, as in all those developing countries that need to increase the currently low per capita levels of energy use to support growth, reach the MDGs and eventually provide modern living standards to all their citizens. The Government of India (GoI) estimates that meeting the MDGs (without improving energy services to urban and commercial customers and supporting economic growth) alone will imply an increase of about 18 percent in energy use from the current level and an additional 133 million metric tons of CO_2 emissions per year, or 12 percent increase from the 2004 level.[2]

The key question therefore is what India, as a member of the global community which is to collectively address the global challenge of climate change, can be expected to do—and what it has been already doing—to grow and meet its energy needs in a "low carbon" manner. A related question is how to define a "low carbon economy" or a "low carbon economic growth" in a particular country relative to reasonable international benchmarks. It is in this context that this paper assesses India's CO_2 performance over time relative to other developed and developing economies. It analyzes in detail the past trends using data from the period 1994–2004 for 70 countries and complements this analysis with a review of available future projections to 2050.

Learning from past trends: decomposing CO_2 emissions for 1994–2004

The growth of CO_2 emissions over time has shown substantial variation across countries. In order to better appreciate individual countries' position in a debate over an international framework and to provide focus on the factors that are amenable to policy interventions, it is important to understand (i) the comparative performance of different countries, and (ii) the key determinants of this

[1] This paper considers CO_2 emissions from fossil fuel combustion only. It excludes other GHG emissions from fossil fuel use, such as methane escape or venting during natural gas operations.
[2] Presentation by Dr. Prodipto Ghosh.

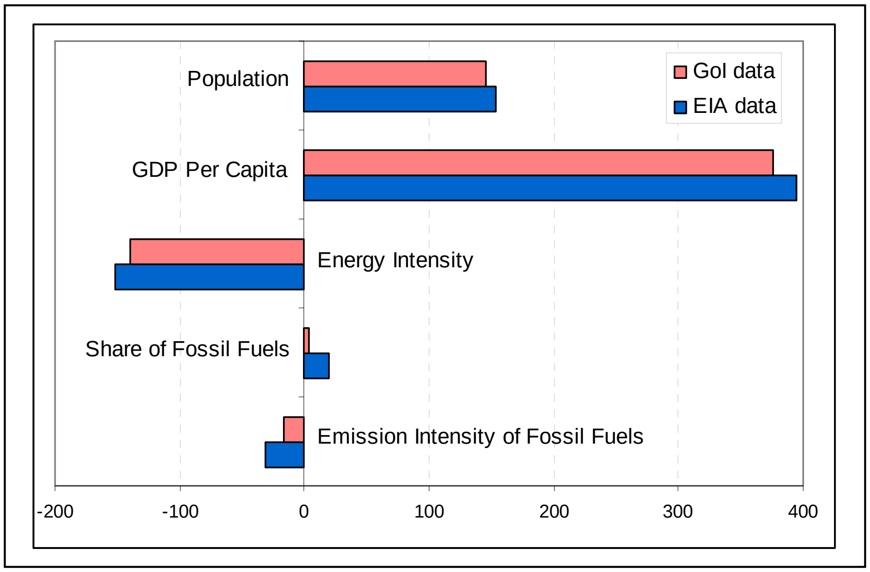
performance and its variations. The principal tool for describing the relationship between the growth of emissions and changes in various related factors is termed "decomposition analysis." It attempts to assess the changes in emissions resulting from its proximate determinants—factors such as GDP (economic activity), size of population, fuel mix and efficiency of fuel use. Numerous studies have applied this technique to fossil fuel emissions of CO_2, most of which concentrate on high income countries, with one or two large developing countries also being covered. This paper draws on a recent more comprehensive assessment by the World Bank which provides fuller details (Bacon *et al* 2007).

At the outset a number of important caveats are in order. First, the analysis excludes the use of biomass, for which there is no comparable international data available. For the same reason, non-CO_2 GHGs are not considered. Second, the focus is only on CO_2 from fossil fuel use. There are significant CO_2 emissions from other sources (particularly from forestry and land use changes), but again they are not examined in this paper because a comprehensive database is not available. These issues are briefly addressed later in the paper. Third, the size of an economy has an important impact on emission performance. Typically, all other things being equal, a larger economy can be expected to emit higher emissions than a smaller economy. Hence, in evaluating a country's CO_2 performance, it is necessary to assess the contribution of GDP. This raises questions about whether the appropriate way to measure GDP is at purchasing power parity (PPP) or market exchange rates (MER).

Using market exchange rates to compare countries can be misleading because these reflect mainly: (a) trade flows on goods exchanged in international markets, (b) currency flows on capital accounts, and (c) country exchange rate policies, which may widely depart from the long-run stationary "equilibrium exchange rate" if the country adopts either fixed or floating pegs. In most developing countries a larger proportion of output is not traded, so GDP measured at exchange rates could be expected to understate the true levels of output and production. The PPP methods seek to correct for these deficiencies; it is an improvement for making comparisons of GDP, but there remain numerous imperfections. A key problem is that the numbers are sensitive to the basket of goods used to make adjustments. Some argue that, for energy decomposition, the basket should be based on energy-intensive goods. Conversely, other commentators suggest that a representative consumption bundle remains more appropriate since it provides a more accurate reflection of the energy intensity of consumption and economic activity in a country. In view of the lack of consensus and the uncertainties, many of the results are presented with comparisons of GDP at both PPP and MER. It is beyond the scope of this short paper to provide alternative measures of GDP, or resolve these long-standing debates in macroeconomics.

The definitions of the variables presented in this study and sources of all data are in Annex 1. In order to have a common database for all the 70 countries, data from the U.S. Energy Information Administration (EIA) were used. In addition, for India, an assessment of India's performance over time using official data from GoI sources and the data from the U.S. EIA employed in the rest of this note has been undertaken and reported in Annex 2. Figure 1 suggests that differences between the EIA and GoI data are not large and the five variables calculated show the same qualitative trends. As such, using the common EIA data base is unlikely to introduce significant distortions for India in making global comparisons. While Government data may be presumed more accurate, the use of information from a common data set, derived using a common methodology and definitions, is necessary to generate global comparisons. Accordingly the most recent EIA data is used for comparative analysis with countries ranked by various measures of emissions including total CO_2 fossil fuel emissions; emissions per capita; and emissions per unit of GDP.

Figure 1: Decomposition of the Change in CO2 Emissions for India in 1994–2004 (million metric tons of CO_2)



The period 1994 to 2004 was chosen to permit wide coverage of countries (data coverage is not as full for earlier years) while focusing on the most recent data available for a sufficiently lengthy period to identify important changes in the relationship between emissions and the various factors used.

The technique of decomposition analysis

It is instructive to begin with a brief overview of the decomposition techniques. Full details are in the companion report (Bacon *et al*, *op cit*). The decomposition of fossil fuel CO_2 emissions into related factors dates back to a series of studies undertaken in the 1980s, mainly at industry level for a single industrialized country. Kaya (1990) was influential in proposing an identity around which a decomposition of emissions related to four factors could be based. This has subsequently been expanded as follows. Letting E = the amount of CO_2 emissions from the consumption of fossil fuel, FEC = the amount of fossil fuel consumption, TEC = the total primary energy consumption, and POP = population, emissions in country i can be expressed by the identity

$$E_i \equiv \frac{E_i}{FEC_i} \times \frac{FEC_i}{TEC_i} \times \frac{TEC_i}{GDP_i} \times \frac{GDP_i}{POP_i} \times POP_i \qquad (1)$$

which is abbreviated in this note (followed by subscript $_{\text{eff}}$ as shown below) as

$$\equiv C_i S_i I_i G_i P_i \qquad (2)$$

The change in a country's emissions (ΔE_i) between a base year 0 and an end year T can be decomposed into the effects of (i) the change in C (the emissions per unit of fossil fuel, termed the coefficient effect, C_{eff}) ; (ii) the change in S (the share of fossil fuels in total energy, termed the substitution effect, S_{eff}); (iii) the change in E (the energy intensity effect, I_{eff}); the change in GDP per capita (G_{eff}); and (v) the change in population (P_{eff}). This is illustrated in equation (3) below.

$$\Delta E_i \equiv E_i(T) - E_i(0) \equiv C_{eff} + S_{eff} + L_{eff} + G_{eff} + P_{eff} \tag{3}$$

The effects, in turn, can be calculated from the following formula using a logarithmic mean Divisia index[3]:

$$C_{eff} = \left[E_i(T) - E_i(0)\right] \cdot \frac{\ln[C_i(T)/C_i(0)]}{\ln[E_i(T)/E_i(0)]} \tag{4}$$

Other effects ($S_{eff}, I_{eff}, G_{eff}, P_{eff}$) can also be derived from similar formulae. With data on all the variables for a common base year and terminal year, the decomposition of the change in emissions can be calculated according to equation (4).

The change in emissions will reflect changes in the five factors because of the nature of the identity linking them. To interpret these links, it is necessary to consider the circumstances under which the factors that can be directly influenced by emissions related policies will change.

The carbon emissions per unit of total fossil fuel consumption (C_{eff}) will rise if there is a relative shift to higher emitting fuels (for example, the share of coal rising relative to the share of gas). This could occur even if the total quantity of fossil fuels consumed in energy terms stayed constant.

The ratio of fossil fuels consumed to total energy consumed (S_{eff}) will rise if the share of non-fossil fuels (hydro, nuclear and renewable energy) declines relative to the share of fossil fuels consumed. The energy intensity of the economy (I_{eff}) will decrease if the use of energy increases more slowly than the level of GDP. This can occur for two main reasons. Firstly, if the sector structure of GDP changes towards sectors that are less energy intensive, without any other changes, the average use of energy in total GDP would fall. Secondly, if energy efficiency increased in one or more sectors, without any structural shifts, the overall energy intensity would decline. The aggregate form of decomposition analysis used in this paper does not distinguish between these two effects.

The exclusion of use of biomass fuel outside the power sector limits the generality of analysis, especially because its use varies greatly among countries. However, its omission is unlikely to have a large effect on the current level of total CO_2 emissions because the use of biomass is generally, but not always, carbon neutral. Including biomass consumption outside the power sector would produce an increase in measured energy intensity and decrease the share of fossil fuels in total energy use relative to what is reported in this paper. The differences between the results obtained with and without full inclusion of biomass would obviously depend on the amount of biomass consumed outside the power sector. In the future, if households and small establishments switch from biomass, commercial or otherwise, to fossil fuels and electricity—and households are most certain to do so with increasing income—fossil fuel intensity and CO_2 emissions may both rise more than what might be projected based on the past trends.

[3] For small changes in the factors, this formula shares the total change in emissions by the ratio of the growth rate of each factor to the growth rate of emissions.

Emissions levels and decomposition of emissions changes between 1994 and 2004

This section begins with a description of the level of emissions in each country, measured as total emissions, emissions per unit of GDP and emissions per capita. These demonstrate the nuanced nature of the problem, suggesting that total emissions represent but one criterion that should guide policy focus. This is followed by the decomposition of changes in emissions between 1994 and 2004, and then a breakdown of the decomposition into two sub-periods, 1994–1999, and 1999–2004.

a. <u>The level of emissions</u>

Table 1 shows the level of CO_2 emissions from fossil fuel combustion in 2004 for countries ranked by total emissions. The absolute and percentage changes with respect to emissions in 1994 are also shown.

Several features are immediately apparent:

1. India ranks fifth, but the difference between the top two countries (United States and China) and the rest is much more substantial than the difference between India and any other lower ranking country, suggesting that greater care is needed in grouping the countries.
2. The majority of countries with the highest level of emissions in 2004 are high-income countries, but large developing economies—Brazil, China, India, Indonesia, Iran, Mexico South Africa, and Ukraine—also are in the top 20.
3. A notable group of countries that appear in the top 30 emitters are large oil producers, some of which have small populations or relatively low per capita incomes.
4. Fifteen countries experienced absolute decreases in emissions during the period, and these include several former Soviet Union and eastern European countries, whose economies underwent major transformations of the economy during the period.
5. The percentage growth of emissions between 1994 and 2004 showed considerable variation among countries. Some large economies saw their total emissions remain essentially the same (the Russian Federation, Germany, and the United Kingdom) while other large and several medium-size economies experienced substantial growth in emissions. The latter included China and India, but also countries as different as Bangladesh, Chile, Egypt, the Islamic Republic of Iran, Malaysia, Saudi Arabia, Spain, Thailand, Turkey, and Vietnam.

Table 1: CO_2 emissions in 2004 (in million metric tons)

Country	Rank	Emissions in 2004	Increase since 1994	% increase since 1994	Country	Rank	Emissions in 2004	Increase since 1994	% increase since 1994
United States	1	5912	674	13	Greece	36	106	22	26
China	2	4707	1911	68	Romania	37	95	-21	-18
Russian Fed.	3	1685	-5	0	Nigeria	38	94	-1	-1
Japan	4	1262	174	16	Algeria	39	77	-7	-8
India	5	1113	384	53	Philippines	40	75	22	42
Germany	6	862	-5	-1	Austria	41	70	13	23
Canada	7	588	95	19	Israel	42	66	18	38
United Kingdom	8	580	12	2	Portugal	43	63	17	38
Korea, Rep. of	9	497	143	40	Chile	44	62	26	70
Italy	10	485	85	21	Finland	45	61	4	7
South Africa	11	430	86	25	Sweden	46	59	0	0
France	12	406	46	13	Vietnam	47	57	30	108
Iran, Islamic Rep. of	13	402	153	62	Hungary	48	56	-2	-4
Australia	14	386	107	38	Denmark	49	56	-9	-13
Mexico	15	385	52	15	Belarus	50	55	-10	-16
Saudi Arabia	16	365	127	53	Colombia	51	55	2	4
Ukraine	17	364	-76	-17	Syrian Arab Rep.	52	53	12	29
Spain	18	362	128	55	Norway	53	51	15	43
Brazil	19	337	69	26	Bulgaria	54	47	-3	-7
Indonesia	20	308	99	48	Switzerland	55	45	3	6
Poland	21	288	-32	-10	Ireland	56	42	13	46
Netherlands	22	267	46	21	Slovak Rep.	57	38	-2	-5
Thailand	23	219	92	72	Bangladesh	58	38	19	97
Turkey	24	212	73	53	New Zealand	59	38	7	22
Kazakhstan	25	172	18	12	Azerbaijan	60	37	-9	-20
Malaysia	26	154	65	73	Trinidad and Tobago	61	33	11	50
Belgium	27	148	20	16	Morocco	62	29	2	7
Egypt, Arab Rep. of	28	147	50	51	Peru	63	27	4	19
Venezuela, R. B. de	29	143	24	20	Oman	64	23	8	56
Argentina	30	142	27	23	Bahrain	65	23	7	44
United Arab Emirates	31	141	47	51	Ecuador	66	23	5	27
Singapore	32	129	48	60	Croatia	67	22	4	23
Uzbekistan	33	121	23	24	Tunisia	68	21	5	30
Czech Rep.	34	112	-7	-6	Dominican Rep.	69	20	11	107
Pakistan	35	106	22	26	Angola	70	20	12	169

Source: EIA 2007 and World Bank calculations.
Note: These numbers are taken from a table posted on the EIA Web site before September 18, 2007. The revised figures for 2004 posted on September 18 differ slightly from those shown in this table.

To place the country data on the emissions of CO_2 from the use of fossil fuels in the wider context of total GHG emissions, data measured in million tons of CO_2 equivalent in 2000 are available from the Climate Analysis Indicators Tools database (World Resources Institute 2007). The data on total GHG emissions includes the six main gases—CO_2, methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6)—from all sources including land use changes and international bunkers. Although the derivation of CO_2 emissions from fossil fuel combustion may not be exactly the same as that used by the EIA, and 2000 is the most recent year currently available for the range of countries in this study, the ratio of CO_2

emissions from fossil fuelcombustion to total GHG emissions (shown in Table 2) indicates the relative importance of fossil fuels globally and in specific countries.

Table 2: Ratio of fossil fuel CO2 emissions to total GHG emissions in 2000

Country	% CO_2 from fossil fuel combustion to total GHG emissions	Country	% CO_2 from fossil fuel combustion to total GHG emissions
Indonesia	9.3	Oman	66.3
Peru	10.3	Iran	66.5
Malaysia	12.5	Greece	66.8
Angola	13.6	Sweden	68.5
Brazil	13.8	Croatia	68.5
Nigeria	19.1	Denmark	68.9
Ecuador	19.2	South Africa	69.4
Colombia	21.4	Syria	69.7
Bangladesh	23.4	Canada	69.7
Philippines	30.4	Spain	70.0
Pakistan	30.5	Romania	70.1
Singapore	31.5	Belgium	70.2
Venezuela	35.6	France	70.7
New Zealand	38.8	Kazakhstan	71.6
Argentina	39.1	Bulgaria	71.8
Morocco	47.0	Israel	72.0
Thailand	48.8	Hungary	73.1
Tunisia	51.8	Saudi Arabia	73.4
Vietnam	52.0	Azerbaijan	74.2
Chile	53.1	Slovak Republic	75.4
India	**53.7**	Russia	75.8
Turkey	53.8	Trinidad and Tobago	75.9
United Arab Emirates	55.4	Switzerland	76.6
Egypt	57.2	United Kingdom	76.9
Mexico	58.5	Finland	77.1
Dominican Republic	59.0	Portugal	77.2
Ukraine	59.5	Italy	77.8
China	59.5	Austria	78.5
Algeria	60.9	Poland	78.6
Ireland	61.4	Korea, Republic of	79.0
Uzbekistan	63.6	Germany	80.1
Norway	64.4	Czech Republic	82.3
Belarus	64.6	Bahrain	82.5
Netherlands	64.9	Japan	83.3
Australia	65.2	United States	86.8

Source: World Resources Institute 2007.

The ratiovaries substantially across countries. It is more than 50 percent for 53 of the countries—including India—and rises to more than 80 percent for 8 countries. For certain countries, such as Indonesia and Brazil, where other sources of GHG emissions are predominant, policies to reduce total emissions need to focus more intensively on non-fossil fuel sources. In India, the share of fossil fuel CO_2 emissions is more than 50 percent but significantly lower than in the Russian Federation and most high-income countries. This suggests that a strategy for controlling the GHG intensity of growth in India might need to include activities and programs outside energy production and use.

A different perspective is provided by tabulating CO_2 emissions per unit of GDP, which is typically referred to as emissions intensity. The data in Table 3 indicate that the ranking of countries according to emissions per unit of GDP at PPP is quite different from that for total emissions[4]. Particularly, Japan, India, and Mexico move a long way down the list, with the United States and China moving to the mid-range. Higher- and lower-income countries are scattered throughout the table, suggesting that there is little evidence of a systematic relationship between emissions per unit of GDP and the level of GDP.

Table 3: Emissions per unit of GDP and GDP per capita in 2004

Country	E/G PPP	E/G MER	GDP pc PPP	GDP pc MER	Country	E/G PPP	E/G MER	GDP pc PPP	GDP Pc MER
Uzbekistan	2686	7204	1712	639	Israel	437	548	22950	18319
Trinidad & Tobago	2054	2938	12181	8516	Croatia	437	973	10890	4891
Kazakhstan	1785	6309	6504	1840	Indonesia	431	1564	3245	894
Bahrain	1749	2292	18148	13852	New Zealand	423	614	22423	15425
UAE	1488	1470	22135	22405	Turkey	422	923	6951	3175
Ukraine	1300	8254	5949	937	Finland	418	465	28078	25239
Russia	1298	5124	9018	2285	Germany	403	442	25905	23627
Azerbaijan	1240	4683	3551	940	Mexico	402	624	9061	5847
Saudi Arabia	1204	1698	12661	8977	Algeria	392	1161	6058	2046
Singapore	1202	1227	25209	24689	Chile	378	707	10168	5436
Venezuela	995	1188	5457	4568	Hungary	366	1017	15228	5474
South Africa	972	2821	9362	3226	Japan	364	259	27080	38041
Belarus	877	3308	6425	1704	India	362	1887	2831	542
Iran	867	3163	6738	1847	Spain	357	552	23782	15372
Syria	861	2484	3304	1145	Denmark	350	334	29338	30685
Bulgaria	799	3101	7577	1953	Pakistan	349	1235	1969	556
Nigeria	762	1663	959	439	Dominican Rep.	341	948	6786	2442
Angola	719	1594	1772	799	Portugal	332	548	18278	11096
Australia	690	848	28049	22846	United Kingdom	331	364	29406	26741
Oman	663	1027	13881	8961	Italy	326	428	25641	19527
China	661	2745	5441	1311	Argentina	316	495	11750	7486
Malaysia	658	1437	9374	4296	Ireland	314	359	33102	28981
Czech Rep.	638	1758	17233	6251	Norway	307	283	36234	39302
Poland	632	1497	11797	4983	Tunisia	290	897	7170	2322
Canada	631	747	29164	24618	Austria	288	340	29675	25087
Netherlands	569	670	28918	24560	Vietnam	274	1394	2520	496
Romania	569	2030	7688	2154	France	249	287	26989	23456
United States	552	552	36234	36234	Brazil	247	514	7406	3564
Korea, Rep. of	546	810	19108	12879	Morocco	243	727	3875	1297
Egypt	541	1286	3747	1577	Sweden	232	224	28226	29219
Slovak Rep.	536	1589	13282	4479	Philippines	207	836	4431	1094
Belgium	499	599	28437	23681	Colombia	196	586	6275	2099
Greece	476	774	20077	12354	Switzerland	194	177	31958	35060
Ecuador	463	1154	3740	1501	Peru	194	445	5122	2227
Thailand	460	1457	7453	2356	Bangladesh	155	655	1756	416

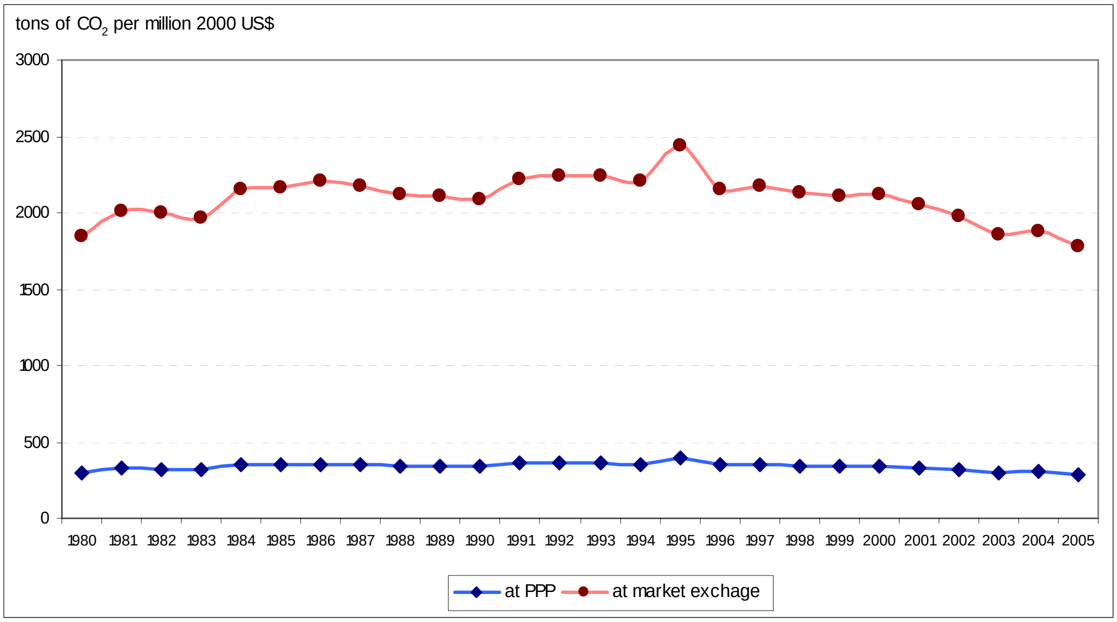
Source: World Bank calculations.

E/G ≡ emissions in metric tones per million US$ of GDP; GDP pc ≡ GDP per capita; GDP pc PPP ≡ GDP per capita measured at purchasing power parity in 2000 US$; GDP pc MER ≡ GDP per capita measured in 2000 US$ at market exchange rates;.

[4] The emissions intensity for 1994 and 1999 are provided in Annex 4.

It is evident from Table 3 that country rankings based on emissions intensity vary depending on whether MER or PPP is used to measure GDP. However, *trends* in emissions intensity are not affected by the choice of MER or PPP. To illustrate this point, Figure 2 compares the trends of India's emissions intensity using GDP measured at MER and PPP from 1980 to 2005. The intensities calculated with GDP at MER are 5.2 times higher than those calculated with GDP at PPP, which simply reflects a constant ratio between the two measures of GDP in India. For both measures, the intensities have been declining slightly since 1994.

Figure 2: India's emissions intensity trend, 1980–2005

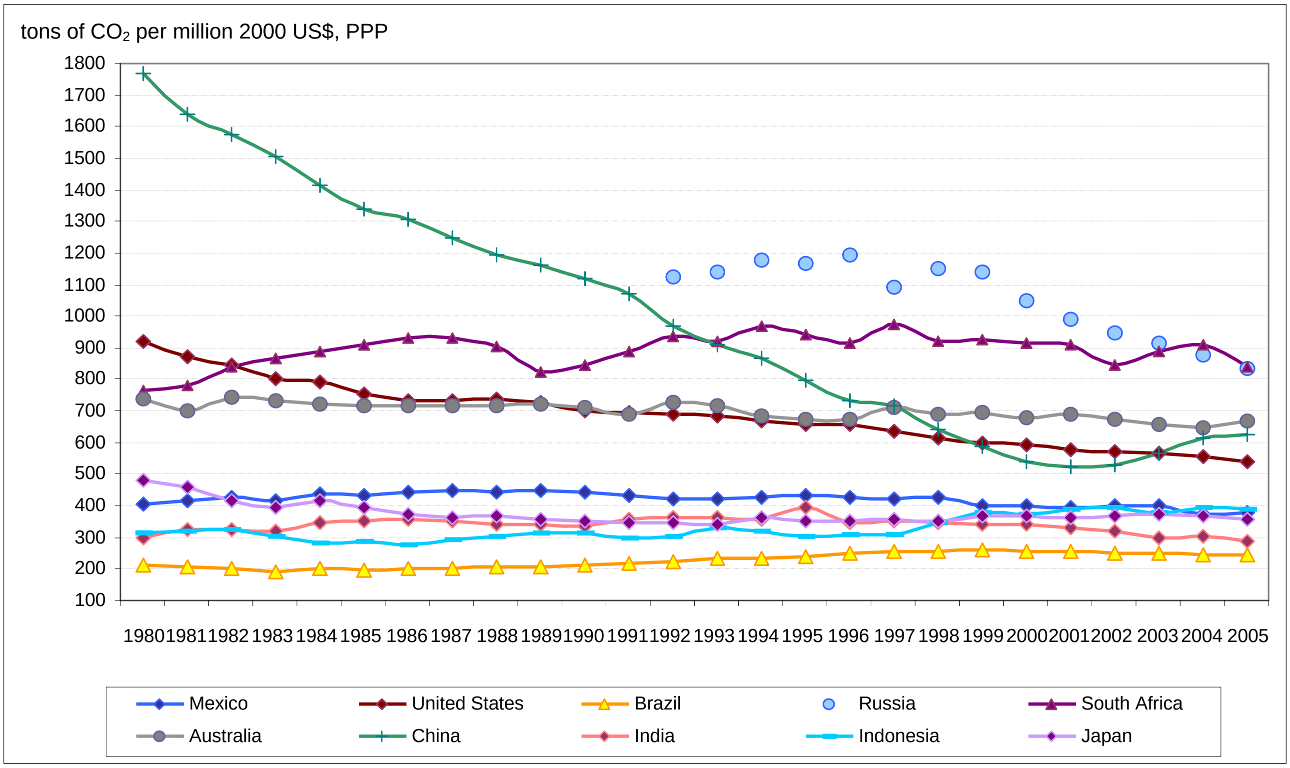


Source: World Bank calculations based on EIA's International Energy Annual 2005

Figure 3, which is based on GDP at PPP, shows that India's CO_2 intensity has been relatively low compared to other large economies over the same period. It has been much lower than those of the United States, Russian Federation, China, South Africa, and Australia, and close to that of Japan. If the emissions from land-use change and forestry had been included in Figure 3, Indonesia's and Brazil's levels would be significantly higher, making India the least emission intensive country in the group of countries considered.[5]

[5] Emissions from land-use change and forestry account for 80 percent and 90 percent of Brazil's and Indonesia's total emissions respectively; these emissions are negligible for India.

Figure 3: CO_2 intensity: India and comparators, 1980–2005



Source: World Bank calculations based on EIA's International Energy Annual 2005

Table 4 shows emissions per capita for each country in the list and GDP per capita, with countries ranked by emissions per capita. Higher-income countries are found predominantly in the top half of the rankings, and lower-income countries in the bottom half. In addition to income, population size matters: a group of low population countries rises in the ranking, while populous nations such as China, India and Indonesia fall markedly in the rankings. The global Gini coefficient for emissions per capita, where all individuals within a country are assumed to share emissions equally, is 0.53. This is almost identical to the measure of inequality of per capita incomes for the same group of countries.

Table 4: Emissions per capita (tons per person) and GDP per capita (2000 US$ PPP) in 2004

Country	Emissions per capita	GDP per capita	Country	Emissions per capita	GDP per capita
UAE	32.94	22135	Malaysia	6.17	9374
Bahrain	31.75	18148	Portugal	6.08	18278
Singapore	30.30	25209	Bulgaria	6.06	7577
Trinidad & Tobago	25.02	12181	Iran	5.84	6738
United States	20.01	36234	Belarus	5.64	6425
Australia	19.36	28049	Hungary	5.57	15228
Canada	18.40	29164	Venezuela	5.43	5457
Netherlands	16.45	28918	Croatia	4.76	10890
Saudi Arabia	15.24	12661	Uzbekistan	4.60	1712
Belgium	14.20	28437	Azerbaijan	4.40	3551
Finland	11.74	28078	Romania	4.37	7688
Russia	11.71	9018	Chile	3.84	10168
Kazakhstan	11.61	6504	Argentina	3.71	11750
Norway	11.12	36234	Mexico	3.65	9061
Czech Rep.	10.99	17233	China	3.60	5441
Germany	10.43	25905	Thailand	3.43	7453
Korea, Rep. of	10.43	19108	Turkey	2.93	6951
Ireland	10.41	33102	Syria	2.85	3304
Denmark	10.26	29338	Algeria	2.38	6058
Israel	10.04	22950	Dominican Rep.	2.32	6786
Japan	9.87	27080	Tunisia	2.08	7170
United Kingdom	9.75	29406	Egypt	2.03	3747
Greece	9.56	20077	Brazil	1.83	7406
New Zealand	9.47	22423	Ecuador	1.73	3740
Oman	9.20	13881	Indonesia	1.40	3245
South Africa	9.10	9362	Angola	1.27	1772
Austria	8.54	29675	Colombia	1.23	6275
Spain	8.49	23782	**India**	**1.02**	**2831**
Italy	8.36	25641	Peru	0.99	5122
Ukraine	7.74	5949	Morocco	0.94	3875
Poland	7.46	11797	Philippines	0.92	4431
Slovak Rep.	7.12	13282	Nigeria	0.73	959
France	6.73	26989	Vietnam	0.69	2520
Sweden	6.56	28226	Pakistan	0.69	1969
Switzerland	6.20	31958	Bangladesh	0.27	1756

Source: World Bank calculations.

b. <u>The decomposition of emissions between 1994 and 2004</u>

The decomposition of the change in CO_2 emissions between 1994 and 2004 is presented in Table 5, where countries are ranked by decreasing GDP per capita. The decomposition is based on GDP measured in PPP and, as mentioned above, the results are identical for virtually all countries when GDP in MER is used. The table also includes the decomposition for the aggregate of the 70 countries; this can be taken as a close approximation of the decomposition for the global economy.

Table 5: Decomposition of the change in CO2 emissions between 1994 and 2004 (million metric tons)

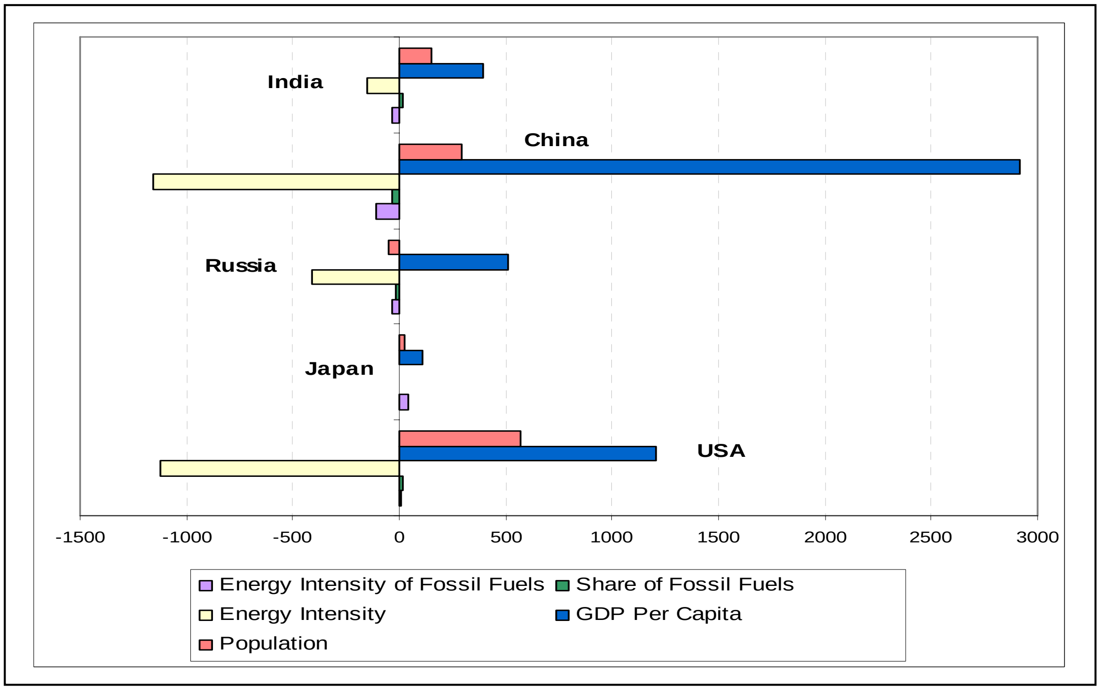
Country	Ceff	Seff	Ieff	Geff	Peff	ΔE	2004 GDP per capita (2000 US$, PPP)
Norway	-2.4	11.6	-6.7	10.3	2.6	15.4	36234
USA	6.1	14.6	-1126.1	1210.7	569.0	674.5	36234
Ireland	-0.9	-0.2	-12.3	22.3	4.6	13.4	33102
Switzerland	-0.2	1.3	-4.4	4.2	1.6	2.6	31958
Austria	0.2	2.0	-3.1	12.5	1.3	13.0	29675
United Kingdom	-25.5	8.3	-133.7	143.7	19.6	12.4	29406
Denmark	-1.3	-6.2	-13.5	10.1	2.3	-8.6	29338
Canada	-9.4	38.6	-109.9	124.1	52.2	95.5	29164
Netherlands	11.1	-2.9	-21.1	46.0	13.3	46.4	28918
Belgium	-6.8	-0.2	-2.5	25.6	4.0	20.1	28437
Sweden	-1.1	-2.3	-13.3	15.2	1.5	-0.1	28226
Finland	-1.2	-2.5	-13.3	19.3	1.7	4.0	28078
Australia	6.3	3.3	-22.0	80.7	38.8	107.2	28049
Japan	41.8	-0.4	0.6	106.1	26.0	174.1	27080
France	-2.5	-4.1	-32.0	69.9	15.0	46.3	26989
Germany	-22.2	-23.7	-84.7	111.6	14.1	-4.9	25905
Italy	-6.6	3.2	20.0	61.6	6.5	84.8	25641
Singapore	-4.1	0.0	-0.5	28.6	24.4	48.4	25209
Spain	-4.9	8.7	22.3	82.3	20.2	128.5	23782
Israel	-1.6	0.2	0.7	5.3	13.5	18.1	22950
New Zealand	1.7	1.3	-7.2	7.7	3.4	6.9	22423
UAE	-4.6	0.0	-21.6	2.0	71.7	47.4	22135
Greece	-2.9	-1.8	-8.1	30.3	4.7	22.2	20077
Korea, Rep. of.	-11.0	-21.9	-28.0	175.9	27.9	142.8	19108
Portugal	-1.1	1.3	2.6	12.4	2.3	17.4	18278
Bahrain	-0.3	0.0	-1.7	4.4	4.5	7.0	18148
Czech Rep.	-6.9	-6.1	-23.2	30.3	-1.2	-7.1	17233
Hungary	-4.1	0.0	-20.0	23.2	-1.2	-2.1	15228
Oman	-0.3	0.0	2.0	3.1	3.4	8.3	13881
Slovak Rep.	-2.8	-1.4	-14.5	16.1	0.4	-2.2	13282
Saudi Arabia	-6.6	0.0	70.9	-18.7	81.2	126.8	12661
Trinidad & Tobago	-6.3	0.0	1.5	14.7	1.0	10.9	12181
Poland	-20.0	1.0	-148.0	134.8	0.2	-31.9	11797
Argentina	-4.6	2.8	14.4	0.0	14.1	26.6	11750
Croatia	0.8	0.5	-5.5	8.7	-0.5	4.0	10890
Chile	-3.5	3.4	3.7	15.8	6.2	25.6	10168
Malaysia	-5.2	2.7	8.6	31.9	26.8	64.9	9374
South Africa	-0.3	-1.0	-30.1	62.2	55.0	85.8	9362
Mexico	-9.5	-4.0	-28.9	40.1	54.1	51.7	9061
Russia	-34.5	-17.7	-414.3	514.2	-52.4	-4.6	9018
Romania	0.3	-7.8	-39.3	30.4	-4.9	-21.3	7688
Bulgaria	-2.4	-1.6	-8.0	12.1	-3.6	-3.4	7577
Thailand	-9.7	-0.8	49.7	35.7	16.8	91.8	7453
Brazil	-27.2	2.0	22.3	27.6	43.9	68.6	7406
Tunisia	-1.3	-0.1	-2.5	6.4	2.2	4.9	7170
Turkey	-8.4	2.1	9.7	41.9	27.7	73.0	6951
Dominican Rep.	0.3	-0.2	3.2	5.1	2.1	10.5	6786

Country	Ceff	Seff	Ieff	Geff	Peff	ΔE	2004 GDP per capita (2000 US$, PPP)
Iran	-27.3	1.3	35.2	107.5	36.6	153.1	6738
Kazakhstan	3.3	2.9	-59.9	84.3	-12.8	17.8	6504
Belarus	-3.8	-0.1	-34.6	31.0	-2.8	-10.3	6425
Colombia	-2.1	-0.5	-7.1	2.3	9.3	1.9	6275
Algeria	-6.7	-0.3	-30.4	18.2	12.4	-6.9	6058
Ukraine	-11.3	-16.6	-93.0	84.0	-38.8	-75.7	5949
Venezuela	2.2	-0.2	8.9	-12.3	25.4	24.1	5457
China	-108.3	-35.8	-1155.4	2917.7	293.0	1911.2	5441
Peru	-0.1	-1.7	-2.6	4.6	4.1	4.3	5122
Philippines	-0.3	-1.2	-2.1	13.2	12.5	22.0	4431
Morocco	-0.9	-0.9	-4.6	3.9	4.4	1.9	3875
Egypt	-11.4	2.6	5.8	29.8	22.9	49.7	3747
Ecuador	0.6	0.2	-1.4	2.3	3.1	4.7	3740
Azerbaijan	-1.7	-1.1	-31.4	21.8	3.4	-9.0	3551
Syria	-1.2	0.7	-2.3	2.6	12.0	11.9	3304
Indonesia	-1.6	-3.3	30.1	40.6	33.6	99.4	3245
India	**-31.7**	**20.0**	**-152.4**	**394.4**	**153.2**	**383.6**	**2831**
Vietnam	-5.9	1.4	5.5	22.9	5.9	29.8	2520
Pakistan	-3.7	1.0	-10.4	13.3	21.7	22.0	1969
Angola	5.4	0.2	-2.2	5.7	3.3	12.4	1772
Bangladesh	0.2	0.2	4.2	8.5	5.5	18.7	1756
Uzbekistan	-3.9	1.2	-14.7	24.1	16.7	23.3	1712
Nigeria	-29.8	-0.5	-6.6	13.3	22.7	-1.0	959
Aggregate	**-156.4**	**150.4**	**-3389.3**	**5735.0**	**2664.6**	**5004.3**	**9099**

Source: World Bank calculations.
Note: See the discussion of equation (3) for definitions of the decomposition factors.

The aggregation of countries can be misleading for drawing conclusions for any particular country. To complement and draw additional observations, Figure 4 summarizes the decomposition of the five largest contributors to CO_2 emissions. First, it is important to observe that Japan's population grew slowly and its economy stagnated through much of this period. Hence GDP and population had a minimal impact on emissions. The Russian Federation too experienced sharp structural breaks and economic dislocation in this period, so growth-related emissions are negligible. Hence comparing these two countries with India, with its rapid growth, are somewhat less informative when it concerns the impact of growth. Of the remaining economies in the figure, the effects of India's growth and population on CO_2 emissions are lower. Regarding the intensity coefficient, the situation is reversed: India and Japan had much lower energy intensity per GDP_{PPP} than the other three countries during the decade, so their performance is not directly comparable. India performed better on the intensity coefficient than Japan, and, as Table 5 shows, better than Mexico and Brazil—two large developing economies that also have relatively low CO_2 intensity based on GDP_{PPP}.

Figure 4: Decomposition for select countries for 1994–2004 (million metric tons of CO_2)



Source: World Bank calculations.

"Offsetting" CO_2 emissions

Another useful way to summarize the decomposition analysis is to compare the effects from income and population growth, which are virtually always positive,[6] and are outside direct interventions that might have been expected to moderate emissions, and the three other factors that had the potential through policy interventions to reduce emissions. To this end an "offsetting" coefficient is defined:

Offsetting coefficient = – [sum of changes from emissions per unit of fossil fuel, fossil fuel consumption relative to total energy consumption, and energy intensity of GDP] / [changes from GDP per capita and population]

$$= -\left(\frac{C_{eff} + S_{eff} + I_{eff}}{G_{eff} + P_{eff}}\right) \qquad (5)$$

A score of 100 percent indicates that the total increase in emissions attributed to GDP per capita growth and population growth was exactly offset by improvements in the three other factors. A negative score indicates that emissions increased faster than would have been accounted for by the growth of GDP and population. For the aggregate of 70 countries, 40 percent of the potential growth in emissions from GDP and population growth was offset by the three factors. For individual countries, the offsetting coefficients, ranked by size of coefficient, are shown in Table 6.

[6] The exceptions are Saudi Arabia where per capita income fell during the period, and the Russian Federation and other countries in the former Soviet Union and Eastern Europe where changed political boundaries led to falls in population.

Table 6: Offsetting coefficients for decomposition of emissions, 1994–2004

Country	Offsetting coefficient	Country	Offsetting coefficient
Ukraine	267.4	Belgium	32.0
Romania	183.6	Trinidad and Tobago	30.4
Denmark	169.1	**India**	**30.0**
Bulgaria	140.3	Korea, Rep. of	29.9
Belarus	136.4	South Africa	26.8
Azerbaijan	135.5	Netherlands	21.7
Czech Republic	124.4	Bahrain	21.5
Poland	123.7	Syria	19.0
Algeria	122.6	Philippines	14.2
Slovak Rep.	113.5	Ecuador	12.4
Hungary	109.5	Australia	10.3
Germany	103.9	Singapore	8.8
Nigeria	102.7	Austria	6.0
Russia	101.0	Egypt	5.7
Sweden	100.4	Brazil	4.0
United Kingdom	92.4	Israel	3.5
Colombia	83.6	Vietnam	-3.3
Finland	80.7	Turkey	-4.9
Morocco	77.3	Iran	-6.3
Kazakhstan	75.0	Malaysia	-10.5
United States	62.1	Chile	-16.2
Switzerland	56.7	Portugal	-18.6
Croatia	51.5	Norway	-19.5
Peru	50.6	Italy	-24.4
Ireland	50.2	Spain	-25.4
Canada	45.8	Oman	-26.9
France	45.5	Japan	-31.9
Mexico	45.1	Bangladesh	-33.2
Tunisia	43.8	Indonesia	-33.9
Uzbekistan	42.8	Angola	-38.6
China	40.5	Dominican Republic	-45.6
New Zealand	37.9	Thailand	-74.6
Pakistan	37.1	Venezuela	-83.8
Greece	36.5	Argentina	-89.8
United Arab Emirates	35.7	Saudi Arabia	-102.8

Source: World Bank calculations.

The range of offsetting experienced during the period was wide. Fifteen countries more than fully offset the potential increase in emissions from income and population growth. Many of those included the economies of Eastern Europe and Central Asia whose economies collapsed in the early 1990s and then experienced economic transformation. Nineteen countries experienced negative offsetting, with growth in CO_2 emissions higher than growth in GDP and population. This group included a mix of countries but also many oil producing economies and some high-income countries. Looking across the list of countries as a whole, it is noticeable that the offsetting coefficient is not correlated with income levels. India lies in the middle range, suggesting that its offsetting performance is broadly in line with the global average, but there could be scope for accelerating the pace of offsetting by emulating the more successful economies in this respect.

The changing pattern of performance between 1994 and 2004

Many economies experienced structural changes during the decade analyzed. In addition, the increasing price of oil and other fossil fuels, as well as heightened awareness of global warming, may have led more recently to intensification of policies to slow the growth of emissions. By splitting the data into two sub-periods of equal duration, some shifts in behavior may be detected. The offsetting coefficient and changes in emissions for the two sub-periods, ranked by the magnitude of offsetting coefficients for the whole period, are shown in Table 7. Figure 5 shows countries from the top half of the list ranked by the level of CO_2 emissions as shown in Table 1 that experienced the highest overall growth in emissions in 1994–2004, with emission growth differentiated between two sub-periods. The detailed tables for the decompositions during the two sub-periods are given in Annex 3.

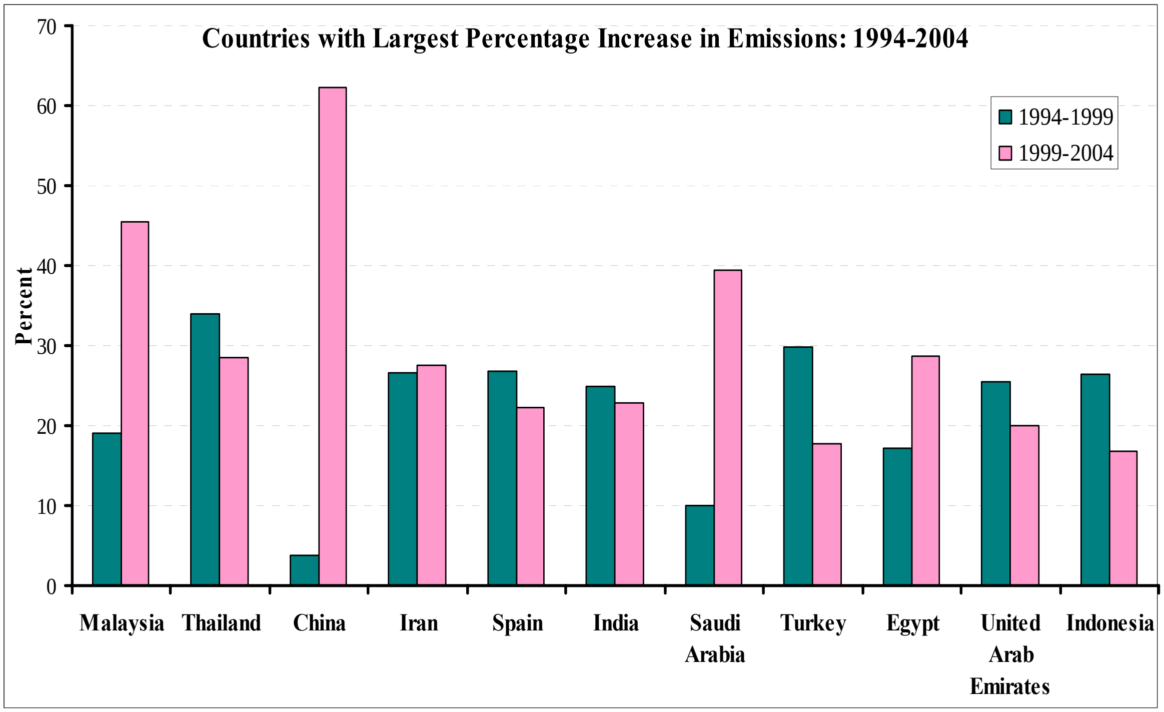
Table 7: Offsetting and changes in emissions, 1994–1999 and 1999–2004

Country	ΔE (94–99)	Offsetting %	ΔE (99–04)	Offsetting %
Ukraine	-115.4*	-6.1	39.7	71.1
Romania	-25.3*	-1461.9	4.0	83.5
Denmark	-7.0	185.2	-1.6*	138.7
Bulgaria	-6.3*	-101.4	2.9	73.6
Belarus	-7.8	191.0	-2.4*	113.1
Azerbaijan	2.8	46.0	-11.8*	155.2
Czech Rep.	-15.9	249.5	8.8	47.5
Poland	4.7	94.9	-36.7*	177.1
Algeria	0.3	97.6	-7.2*	142.7
Slovak Rep.	-2.9	133.4	0.6	91.8
Hungary	-0.9	109.4	-1.2*	109.5
Germany	-35.6	148.5	30.7	38.4
Nigeria	-10.4	194.5	9.5	58.9
Russia	-153.1*	-65.1	148.4	72.2
Sweden	-1.1	111.8	1.0	86.4
United Kingdom	-17.1	120.6	29.5	61.9
Colombia	3.9	-3.3	-1.9*	123.5
Finland	-9.9	188.9	13.9	-83.4
Morocco	3.0	-6.1	-1.1*	118.6
Kazakhstan	-23.3*	-190.9	41.2	44.8
USA	419.2	59.8	255.2	65.5
Switzerland	3.2	-7.4	-0.7*	122.7
Croatia	2.3	40.3	1.7	62.2
Peru	3.4	22.4	0.9	79.7
Ireland	9.1	41.4	4.3	64.1
Canada	65.9	30.0	29.5	65.1
France	41.5	9.2	4.8	88.4
Mexico	26.7	43.9	25.0	46.3
Tunisia	3.0	31.3	1.9	57.9
Uzbekistan	5.2	63.6	18.1	30.1
China	105.4	91.5	1805.9	-10.2
New Zealand	3.2	32.8	3.7	42.0
Pakistan	18.4	-18.5	3.6	83.1
Greece	10.8	17.5	11.4	49.0
UAE	23.8	19.3	23.6	48.6
Belgium	10.5	32.2	9.6	31.7

Country	**ΔE (94–99)**	**Offsetting %**	**ΔE (99–04)**	**Offsetting %**
Trinidad & Tobago	4.5	15.0	6.4	39.8
India	**205.6**	**21.4**	**178.0**	**39.4**
Korea, Rep. of	72.2	15.8	70.6	41.7
South Africa	24.7	45.4	61.1	13.4
Netherlands	15.8	61.5	30.6	-88.5
Bahrain	4.4	-24.2	2.6	55.1
Syria	9.4	-45.3	2.4	72.3
Philippines	16.0	-47.2	6.0	63.2
Ecuador	1.6	-128.7	3.2	34.7
Australia	71.8	-7.9	35.4	36.1
Singapore	22.8	14.2	25.6	1.8
Austria	6.7	14.8	6.3	-6.9
Egypt	16.8	35.5	32.9	-32.9
Brazil	65.5	-100.1	3.1	92.9
Israel	11.4	-0.6	6.7	10.9
Vietnam	13.4	-9.2	16.4	2.8
Turkey	41.3	-35.7	31.8	23.0
Iran	66.1	-35.3	87.0	11.9
Malaysia	16.9	28.3	48.0	-47.6
Chile	22.5	-84.6	3.0	74.4
Portugal	16.8	-52.6	0.6	85.3
Norway	7.9	-4.0	7.5	-46.9
Italy	36.7	-0.7	48.1	-55.2
Spain	62.5	-32.4	66.0	-18.1
Oman	5.4	-91.3	2.9	29.2
Japan	61.4	-44.2	112.7	-25.5
Bangladesh	7.5	-34.6	11.2	-31.9
Indonesia	55.1	-248.1	44.3	30.5
Angola	6.1	-59.3	6.3	-15.1
Dominican Rep	4.4	-8.9	6.1	-125.4
Thailand	43.2	-355.2	48.6	-1.6
Venezuela	13.7	-174.6	10.4	-24.2
Argentina	23.5	-73.8	3.1	-704.4
Saudi Arabia	23.7	-61.7	103.1	-118.6

Source: World Bank calculations.

Figure 5: Countries with largest percentage increase in emissions, 1994–2004



Source: World Bank calculations.
Note: The figure includes only those countries that are in the top half of the emitters listed in Table 1.

A striking feature is a very different performance by many countries in the two-sub-periods. More than 40 percent of the countries decreased their offsetting during the second sub-period. Six countries moved from partial positive offsetting in the first sub-period to negative offsetting in the second sub-period, indicating that the policy-related factors had ameliorated the effects of growth earlier, but added to it in the latter period. This group includes Austria, China, Colombia, Egypt, Malaysia, and the Netherlands. The remaining countries improved or maintained their offsetting coefficient, with seventeen countries moving from negative to positive offsetting.

While experiencing high economic growth, India almost doubled its offsetting between the two sub-periods and reduced both growth in CO_2 emissions and CO_2 emissions intensity of GDP, suggesting that the country was on a lower carbon growth trajectory. Among other countries with large absolute emissions, the United States experienced growth in emissions but offset a substantial fraction of the effects of income growth during both sub-periods. China experienced little growth in emissions in the first sub-period—partly thanks to high offsetting—but in the second sub-period experienced a very large growth in emissions, when the effects of very rapid growth were slightly compounded by negative offsetting. Japan experienced modest increases in emissions during both sub-periods, partly related to negative offsetting in both. The Russian Federation experienced a substantial drop in emissions during the first sub-period, but then experienced a sizeable growth in emissions during the second sub-period despite a high degree of offsetting.

Relatively few countries, however, performed steadily across both sub-periods. Above all, this has shown that offsetting, rate of growth in CO_2 emissions and trends in CO_2 intensity are prone to significant swings. It suggests that, if a country is motivated by a goal of controlling CO_2 emissions growth, it is important to periodically evaluate and update a set of policies in place.

To investigate the possibility that the findings of this study might have been influenced by the selection of the three years for which calculations were performed—1994, 1999, 2004—alternative calculations were also run for absolute emission levels and energy intensity for the top 20 CO_2 emitters. In the alternative calculations, data from three years centered around the above three years were averaged: averaging over 1993–1995 instead of using data only from 1994, averaging over 1998–2000 instead of taking data from 1999 only, and so on. These calculations were run to check if there might have been anything unusual about 1994, 1999, or 2004. The results are shown in Annex 5. These calculations show that the trends observed hold when data are averaged across three years. All energy intensity figures, for example, were within 10 percent between the two sets of calculations.

Looking to the future

The finding reported above that CO_2 emission trends are often volatile and subject to dramatic changes means that a simple extrapolation of trends cannot be used for forecasting future performance. To gain some understanding of India's performance in the future, a review of several recent studies and models projecting CO_2 emissions in India and other countries has been undertaken and is summarized in Annex 6. These include projections undertaken by the World Bank earlier (but not as part of the *Low Carbon Growth Strategy* study under which this background paper was commissioned), the International Energy Agency (IEA), the GoI's Planning Commission, and those cited by the IPCC's 3rd working group.

In virtually all of the studies and scenarios, India's CO_2 emission intensity declines through 2030 (except for one scenario in one model). This suggests that there is an opportunity for India to remain on a relatively low carbon growth trajectory.[7] The *Low Carbon Growth Strategy* study is developing a bottom-up model to evaluate a range of future scenarios and to help develop, monitor, and refine policies and programs that will maintain low carbon intensity for this rapidly growing economy by international standards.

Conclusions

The key findings on India's CO_2 emissions performance that emerge from an analysis of CO_2 emission trends and drivers for 70 countries between 1994 and 2004, complemented by a limited review of future projections from existing studies, are as follows:

- By two measures—CO_2 emissions per capita and CO_2 emissions per unit of GDP PPP—India emerges as a relatively low carbon economy by global comparison.
- India has also been offsetting its CO_2 emissions in line with the performance of the global economy through a combination of reduced energy intensity and lower carbon intensity of fossil fuels.
- India has managed to improve both the level of offsetting and CO_2 emissions intensity of the economy over the period of 1999–2004 compared to 1994–1999, when its economic growth accelerated and against the backdrop of increasing CO_2 intensity of the global economy.

[7] An analysis of the power sector development plan given in the Government 11th Five Year Plan, reported in a parallel paper being submitted by the World Bank to the GoI, quantifies the CO_2 reducing impact of several specific measures that are already in government programs.

- Most of the available projections undertaken by reputed independent international organizations indicate that India's CO_2 intensity per unit of GDP is likely to continue to decline through 2030-2050**.** In this context, international financial institutions such as the World Bank can make an important contribution by supporting, strengthening, and accelerating the implementation of government policies and programs that reduce CO_2 intensity as the economy continues to grow at a rapid pace, and by bringing concessional financing as needed.
- Given large variations in CO_2 performance across countries and large swings in this performance across time periods, further in-depth work is necessary to better understand the key determinants of India's CO_2 emissions and policies that would be effective in keeping CO_2 intensity low.

Annex 1. Data Sources

Although the data are taken from well established sources, where updating and regular publication are observed, there are clearly possibilities of differences between the common sources and government's statistics. Differences in definition, differences in assumptions about conversion factors to energy equivalents and CO_2 emissions, and lags in publications can all lead to divergences in figures given for the decomposition, as well as in the basic data used. Inferences made about individual country results are limited by the accuracy of the data available.

The specific sources for data for the main variables discussed in this study are detailed below.

The emission of CO_2 from fossil fuel consumption (million metric tons)
The data source for emissions of fossil fuel consumption was the U.S. Department of Energy Web site[8], produced by the Energy Information Administration (EIA). To arrive at the total emissions from all fossil fuels, it is necessary to aggregate the emissions from the three fuels involved (coal, oil, and natural gas) into common units. This is provided by the EIA through a two stage calculation. First, consumption of each fuel measured in physical units is converted into British thermal units (Btu) as a common energy unit that can be aggregated to provide a measure of total fossil fuel consumption[9]. The second step is to derive emissions of CO_2 for each fossil fuel. Different fuels require an individual conversion factor from energy available to emissions produced, and the conversion factor for coal further depends on the quality of coal consumed. Details of these conversion factors are not provided on the EIA Web site. Data in million metric tons of CO_2 emitted are provided for a list of 163 countries for every year in our data period and, from these, the 70 countries with the largest CO_2 emissions in 2004 were selected for further study.

The consumption of fossil fuels (quadrillion Btu)
The EIA Web site provides consumption data for the three fossil fuels measured in Btu, and these are aggregated to provide the total fossil fuel consumption. The ratio of fossil fuel emissions to the consumption of fossil fuels provides the value of C, the emissions per unit of fossil fuel defined in equations (1) and (2).

The consumption of primary commercial energy (quadrillion Btu)
The EIA figures for the consumption of primary commercial energy includes oil, dry gas, coal, net hydro production, net nuclear production, and renewable sources of electricity supplied to the grid (net geothermal, solar, wind, and wood and waste). It does not include biomass or solar consumed outside of the power sector. The ratio of the consumption of fossil fuels to the total consumption of primary energy provides the value of S, the share of fossil fuels in total energy.

The level of GDP (2000 US$ at purchasing power parity)
Data on the level of GDP is taken from the *World Development Indicators* (World Bank various years). The data chosen was in constant 2000 US dollars, valued according to PPP. Data valued at market exchange rates (MER) in constant US dollars was also investigated. In virtually every case, data valued at MER showed the same percentage increase between 1994 and 2004 as the data in PPP. This indicated that for each country, the ratio between MER-based and PPP-based figures was constant throughout this period because of the lack of updating of the PPP calculations. The ranking

[8] http://www.eia.doe.gov/emeu/international/contents.html
[9] For coal, which comes in various qualities ranging from lignite to hard coal, the conversion factor depends strongly on the type and quality of the coal consumed and can be a source of differences among various estimates of emissions.

of countries by energy intensity (energy consumption per unit of GDP) does change markedly when the calculation is shifted from PPP to MER, but this does not affect the decomposition analysis which focuses on changes in emission during the period. The ratio of total energy consumption to GDP (coefficient I in equation 2) provides the measure of energy intensity.

The population of the country (millions)

Data on population is taken from the UN Population Fund and is based on extrapolations from the most recent census data available. The ratio of GDP to population (coefficient G in equation 2) provides the measure of GDP per capita.

Annex 2. Comparison of Decomposition of CO_2 emissions in India using EIA and Government of India data

This section provides an assessment of India's CO_2 performance from 1994 to 2004 using both GoI data and information from the EIA in June 2006, which is based on earlier published government sources. GoI data can be taken as the most authoritative currently available. The data from the GoI takes account of the specific quality of the fuels consumed, which is reflected in the thermal content and in the emissions per physical unit. As described in Annex 1, data on GDP at 2000 US dollars in PPP is from the World Development Indicators (WDI; World Bank various years), as the sole source for comparable PPP data, and population data continued to be taken from the UN Population Fund as the most widely used estimate of population between censuses. Data from the two sources is shown so as to illustrate the differences, and provide alternative decompositions.

a. Consumption of fossil fuel data in physical units

	EIA 1994	**GoI 1994**	**EIA 2004**	**GoI 2004**
Petroleum – '000 barrels a day	1413	1412	2450	2419
Dry gas – billion cubic feet	594	612	1088	1185
Coal – million short tons	314	261	478	397

b. Consumption of energy in thermal units (quadrillion British thermal units)

	EIA 1994	**GoI 1994**	**EIA 2004**	**GoI 2004**
Petroleum	2.94	2.88	5.02	4.92
Dry gas	0.68	0.62	1.13	1.26
Coal	5.45	5.05	8.11	7.19
All primary energy including non-fossil fuels	9.97	8.89	15.42	13.84

c. Emission of CO_2 from fossil fuel consumption (million metric tons)

	EIA 1994	**GoI 1994**	**EIA 2004**	**GoI 2004**
Petroleum	193	200	306	342
Dry gas	36	33	64	67
Coal	497	461	741	656
All fossil fuels including gas flaring	729	693	1113	1064

d. Gross Domestic Product in billion 2000 US$ at PPP

	WDI 1994	**WDI 2004**
GDP	323	590

e. Population in millions

	UNFAP 1994	UNFAP 2004
Population	918	1087

The comparison of the EIA data and the recent GoI data exhibit some important differences. EIA data consistently suggest higher fuel consumption, particularly coal, and as a consequence GoI figures suggest that CO_2 emissions in 1994 and in 2004 are about 5 percent lower than those given by the EIA. These differences are also reflected in the decomposition analysis.

Table A2.1 below and Figure 1 in the main text show the results of applying the decomposition formula (equation 4) to the data.

Table A2.1 Decomposition of changes in emissions between 1994 and 2004 (million metric tons)

	Ceff	Seff	Ieff	Geff	Peff	ΔE
EIA data	-31.7	20.0	-152.4	394.4	153.2	383.6
GoI data	-15.9	3.9	-139.1	376.0	146.0	371.0

To interpret these results, note that a positive coefficient indicates that the factor in question has contributed to an *increase in emissions*, whereas a negative sign indicates that the factor has helped to *reduce emissions*. Accordingly in India increases in population (P_{eff}) and per capita GDP (G_{eff}) contribute to higher emissions. This is a direct consequence of an increase in the size of the economy. Likewise the small positive value of S_{eff} suggests a slight shift in the fuel mix towards more CO_2 intensive fossil fuels. Conversely the negative coefficients on I_{eff} and C_{eff} indicate that some of the growth in CO_2 has been offset by improvements in intensity and the emissions per unit of fossil fuel used. These are likely to be a consequence of factors such as changes in economic structure, efficiency and technology. Comparison of EIA and GoI data also suggests that differences appear to be small, and importantly for none of the variables is the sign reversed. The magnitudes of the five factors differ but the main conclusions on the relative importance of the different factors are similar.

Annex 3. Decomposition of Emissions between 1994 and 2004 (million metric tons)

Decomposition of Emissions between 1994 and 1999 (million metric tons)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	ΔE
Norway	0.0	3.3	-3.1	6.3	1.3	7.9
USA	-3.2	-19.2	-601.2	753.6	289.4	419.2
Ireland	-0.6	0.1	-5.8	14.0	1.5	9.1
Switzerland	-0.3	0.9	-0.3	2.0	1.0	3.2
Austria	0.3	-0.3	-1.2	7.2	0.7	6.7
United Kingdom	-26.0	-4.1	-69.5	73.1	9.5	-17.1
Denmark	-5.4	-2.6	-7.3	7.0	1.3	-7.0
Canada	-3.4	31.5	-56.4	69.6	24.6	65.9
Netherlands	7.1	-2.5	-29.8	34.3	6.6	15.8
Belgium	-5.8	-0.9	1.7	13.3	2.2	10.5
Sweden	-0.4	-3.1	-6.6	8.6	0.5	-1.1
Finland	-6.3	-4.8	-10.0	10.3	0.8	-9.9
Australia	4.5	2.3	-1.6	47.3	19.2	71.8
Japan	-10.9	-23.7	53.5	28.0	14.5	61.4
France	-0.5	7.5	-11.2	38.4	7.3	41.5
Germany	-28.1	-13.3	-67.6	63.5	9.9	-35.6
Italy	-10.4	1.0	9.6	33.1	3.3	36.7
Singapore	0.7	0.0	-4.4	12.6	13.9	22.8
Spain	-3.4	10.3	8.4	43.1	4.1	62.5
Israel	-0.4	0.2	0.3	4.1	7.2	11.4
New Zealand	-0.2	1.7	-3.1	3.2	1.5	3.2
UAE	0.3	0.0	-6.0	0.5	29.0	23.8
Greece	-1.6	-1.2	0.5	10.0	3.0	10.8
Korea, Rep. of	-5.8	-16.5	8.8	69.6	16.1	72.2
Portugal	-0.1	4.1	1.8	10.1	0.9	16.8
Bahrain	0.3	0.0	0.6	0.9	2.7	4.4
Czech Rep.	-6.9	-0.3	-19.3	11.2	-0.5	-15.9
Hungary	-2.3	0.3	-8.2	9.8	-0.5	-0.9
Oman	1.2	0.0	1.4	0.6	2.3	5.4
Slovak Rep.	-4.4	0.4	-7.4	8.2	0.4	-2.9
Saudi Arabia	-17.7	0.0	26.7	-19.5	34.1	23.7
Trinidad & Tobago	-1.4	0.0	0.6	4.7	0.5	4.5
Poland	-9.2	0.2	-79.5	92.2	1.0	4.7
Argentina	-2.3	6.4	5.9	5.9	7.6	23.5
Croatia	0.7	-0.3	-1.9	4.4	-0.5	2.3
Chile	-0.5	6.6	4.2	8.8	3.4	22.5
Malaysia	-2.8	0.3	-4.2	11.4	12.1	16.9
South Africa	-0.6	-3.1	-16.9	11.4	33.9	24.7
Mexico	5.2	-10.1	-16.1	19.4	28.2	26.7
Russia	-8.6	-17.3	-34.5	-77.3	-15.4	-153.1
Romania	-0.1	-9.0	-14.6	1.1	-2.8	-25.3
Bulgaria	0.1	-2.7	-0.7	-1.3	-1.9	-6.3
Thailand	-0.8	0.9	33.5	1.5	8.0	43.2
Brazil	-4.7	4.2	33.3	10.3	22.4	65.5
Tunisia	-0.4	0.0	-0.9	3.2	1.2	3.0
Turkey	-3.5	2.9	11.5	16.5	13.9	41.3
Dominican Rep.	-0.1	-0.2	0.6	3.2	0.9	4.4

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	**ΔE**
Iran	-13.2	3.0	27.4	29.8	19.1	66.1
Kazakhstan	2.0	2.1	-19.5	0.1	-8.1	-23.3
Belarus	-1.8	-0.8	-13.8	9.8	-1.2	-7.8
Colombia	-0.9	0.8	0.2	-1.3	5.0	3.9
Algeria	-0.3	-0.3	-13.3	7.6	6.7	0.3
Ukraine	-9.1	-16.1	18.5	-93.0	-15.7	-115.4
Venezuela	1.0	-1.6	9.3	-7.8	12.8	13.7
China	-102.7	-23.9	-1010.1	1111.9	130.2	105.4
Peru	0.2	0.0	-1.2	2.2	2.1	3.4
Philippines	0.7	-2.6	7.0	4.6	6.3	16.0
Morocco	0.1	0.1	0.0	0.5	2.3	3.0
Egypt	-2.5	-1.3	-5.4	16.1	9.9	16.8
Ecuador	0.4	-0.1	0.5	-0.8	1.5	1.6
Azerbaijan	17.3	-0.3	-19.4	2.8	2.4	2.8
Syria	-0.1	0.4	2.6	0.5	6.0	9.4
Indonesia	4.0	-2.9	38.1	-0.2	16.0	55.1
India	-13.7	13.0	-55.2	187.4	74.0	205.6
Vietnam	-3.2	0.7	3.6	9.7	2.6	13.4
Pakistan	-0.1	4.9	-1.9	4.0	11.6	18.4
Angola	4.6	0.2	-2.5	2.6	1.2	6.1
Bangladesh	0.1	0.2	1.6	3.2	2.4	7.5
Uzbekistan	-2.2	1.1	-7.9	6.2	8.1	5.2
Nigeria	-19.0	0.0	-2.5	-0.3	11.3	-10.4

Source: World Bank calculations.

Decomposition of Emissions between 1999 and 2004 (million metric tons)

Country	**Ceff**	**Seff**	**Ieff**	**Geff**	**Peff**	**ΔE**
Norway	-2.7	8.8	-3.7	3.8	1.3	7.5
United States	9.8	35.6	-531.0	457.1	283.7	255.2
Ireland	-0.3	-0.3	-7.0	8.5	3.4	4.3
Switzerland	0.1	0.4	-4.2	2.4	0.6	-0.7
Austria	-0.1	2.5	-2.0	5.3	0.7	6.3
United Kingdom	1.2	12.3	-61.4	67.7	9.7	29.5
Denmark	3.8	-3.4	-6.0	3.0	1.0	-1.6
Canada	-6.3	6.6	-55.3	55.9	28.6	29.5
Netherlands	3.7	-0.2	10.9	9.8	6.5	30.6
Belgium	-0.8	0.8	-4.4	12.2	1.7	9.6
Sweden	-0.7	0.9	-6.5	6.5	0.9	1.0
Finland	5.4	2.7	-1.8	6.9	0.7	13.9
Australia	1.8	1.0	-22.7	34.5	20.8	35.4
Japan	54.7	25.2	-57.0	78.7	11.0	112.7
France	-2.1	-12.3	-21.9	33.0	8.1	4.8
Germany	6.3	-9.9	-15.5	45.9	3.9	30.7
Italy	4.6	2.2	10.3	27.9	3.2	48.1
Singapore	-5.5	0.0	5.0	16.2	9.9	25.6
Spain	-1.2	-3.1	14.5	38.4	17.5	66.0
Israel	-1.2	0.0	0.4	1.0	6.5	6.7
New Zealand	2.0	-0.6	-4.1	4.5	1.9	3.7
UAE	-5.6	0.0	-16.7	1.7	44.2	23.6
Greece	-1.4	-0.5	-9.1	20.8	1.6	11.4
Korea, Republic of	-5.2	-4.3	-41.0	109.8	11.4	70.6
Portugal	-1.2	-3.3	1.0	2.6	1.6	0.6
Bahrain	-0.6	0.0	-2.5	3.9	1.8	2.6
Czech Republic	0.3	-5.4	-2.9	17.3	-0.5	8.8
Hungary	-1.8	-0.3	-11.8	13.4	-0.7	-1.2
Oman	-1.9	0.0	0.7	2.9	1.2	2.9
Slovak Rep.	1.6	-1.8	-6.8	7.6	0.0	0.6
Saudi Arabia	15.1	0.0	40.9	4.7	42.5	103.1
Trinidad & Tobago	-5.2	0.0	0.9	10.2	0.5	6.4
Poland	-11.4	0.8	-73.7	48.4	-0.8	-36.7
Argentina	-2.5	-4.0	9.2	-6.6	7.0	3.1
Croatia	0.1	0.8	-3.7	4.4	0.0	1.7
Chile	-3.9	-4.3	-0.7	8.4	3.5	3.0
Malaysia	-1.9	2.5	14.8	19.5	13.0	48.0
South Africa	0.3	2.4	-12.2	51.6	18.9	61.1
Mexico	-15.5	6.7	-12.8	20.8	25.8	25.0
Russia	-24.3	0.4	-360.8	567.7	-34.6	148.4
Romania	0.3	1.2	-21.6	25.8	-1.8	4.0
Bulgaria	-2.4	1.1	-6.8	12.5	-1.6	2.9
Thailand	-10.1	-2.1	13.0	39.0	8.8	48.6
Brazil	-24.9	-2.5	-12.5	19.2	23.7	3.1
Tunisia	-0.9	-0.1	-1.6	3.3	1.1	1.9
Turkey	-5.2	-1.1	-3.2	27.1	14.2	31.8
Dominican Rep.	0.5	-0.1	2.9	1.4	1.3	6.1
Iran	-13.8	-2.4	4.5	82.2	16.6	87.0
Kazakhstan	0.9	0.4	-34.7	77.8	-3.2	41.2
Belarus	-2.0	0.7	-19.7	20.1	-1.5	-2.4
Colombia	-1.3	-1.3	-7.6	3.7	4.6	-1.9
Algeria	-6.4	-0.1	-17.7	11.0	6.0	-7.2
Ukraine	-1.5	0.3	-96.5	156.4	-19.0	39.7

Country	**Ceff**	**Seff**	**Ieff**	**Geff**	**Peff**	**ΔE**
Venezuela	1.2	1.6	-0.8	-4.4	12.8	10.4
China	24.4	-5.1	148.2	1510.9	127.4	1805.9
Peru	-0.4	-1.9	-1.4	2.5	2.1	0.9
Philippines	-1.2	1.7	-10.8	9.5	6.7	6.0
Morocco	-1.0	-1.1	-4.9	3.6	2.2	-1.1
Egypt	-9.2	4.4	13.0	12.3	12.5	32.9
Ecuador	0.1	0.3	-2.1	3.4	1.5	3.2
Azerbaijan	-17.4	-0.9	-14.9	20.0	1.4	-11.8
Syria	-1.2	0.3	-5.5	2.4	6.5	2.4
Indonesia	-6.7	-0.2	-12.5	45.6	18.2	44.3
India	-18.7	6.5	-103.4	212.6	81.0	178.0
Vietnam	-2.5	0.7	1.3	13.5	3.4	16.4
Pakistan	-3.9	-4.4	-9.3	10.2	11.0	3.6
Angola	-0.3	0.0	1.1	3.2	2.3	6.3
Bangladesh	0.0	0.0	2.6	5.4	3.1	11.2
Uzbekistan	-1.6	0.0	-6.2	17.8	8.1	18.1
Nigeria	-9.3	-0.5	-3.8	12.9	10.2	9.5

Source: World Bank calculations.

Annex 4. Emissions Intensity in 1994, 1999, and 2004

Region/Country	Carbon Emissions intensity (tonnes/constant 2000 US$, million)			Carbon Emissions intensity (tonnes/constant 2000 PPP$, million)		
	1994	1999	2004	1994	1999	2004
Algeria	1851	1569	1161	625	530	392
Angola	1211	1516	1594	546	684	719
Argentina	449	486	495	286	309	316
Australia	880	895	848	717	729	690
Austria	345	338	340	292	286	288
Azerbaijan	10766	10233	4683	2850	2709	1240
Bahrain	2535	2659	2292	1935	2030	1749
Bangladesh	553	602	655	131	142	155
Belarus	6264	4796	3308	1661	1272	877
Belgium	642	618	599	535	515	499
Brazil	519	579	514	250	278	247
Bulgaria	3958	3701	3101	1020	954	799
Canada	868	823	747	733	694	631
Chile	657	819	707	351	438	378
China	3911	2624	2745	943	632	661
Colombia	701	703	586	235	235	196
Croatia	1208	1112	973	543	499	437
Czech Republic	2403	1893	1758	872	687	638
Denmark	475	369	334	497	386	350
Dominican Republic	755	778	948	272	280	341
Ecuador	1193	1251	1154	479	502	463
Egypt	1319	1208	1286	555	509	541
Finland	619	414	465	556	372	418
France	318	314	287	276	273	249
Germany	514	452	442	468	412	403
Greece	886	864	774	545	531	476
Hungary	1547	1298	1017	556	466	366
India	2261	2113	1887	433	405	362
Indonesia	1417	1675	1564	390	461	431
Iran	3074	3269	3163	843	896	867
Ireland	526	434	359	460	380	314
Israel	554	555	548	442	443	437
Italy	412	412	428	314	314	326
Japan	250	254	259	351	357	364
Kazakhstan	8764	7871	6309	2480	2227	1785
Korea, Republic of	936	904	810	631	609	546
Malaysia	1364	1273	1437	625	583	658
Mexico	702	661	624	453	426	402
Morocco	913	918	727	305	307	243
Netherlands	706	633	670	600	537	569
New Zealand	694	662	614	477	455	423
Nigeria	2460	1937	1663	1126	887	762
Norway	267	269	283	290	292	307
Oman	935	1084	1027	604	700	663
Pakistan	1416	1460	1235	400	412	349

Region/Country	Carbon Emissions intensity (tonnes/constant 2000 US$, million)			Carbon Emissions intensity (tonnes/constant 2000 PPP$, million)		
	1994	1999	2004	1994	1999	2004
Peru	530	510	445	231	222	194
Philippines	886	965	836	219	238	207
Poland	2596	1972	1497	1097	833	632
Portugal	521	579	548	316	352	332
Romania	3164	2517	2030	887	705	569
Russia	6756	6508	5124	1712	1649	1298
Saudi Arabia	1438	1458	1698	970	1006	1204
Singapore	1284	1232	1227	1257	1207	1202
Slovak Rep.	2551	1909	1589	860	644	536
South Africa	3061	2889	2821	1055	995	972
Spain	505	535	552	326	346	357
Sweden	298	250	224	308	259	232
Switzerland	191	192	177	210	211	194
Syria	2637	2812	2484	914	975	861
Thailand	1155	1451	1457	365	459	460
Trinidad and Tobago	3513	3398	2938	2456	2376	2054
Tunisia	1104	1020	897	357	330	290
Turkey	905	969	923	413	443	422
Ukraine	11165	10970	8254	1759	1728	1300
United Arab Emirates	1845	1748	1470	1867	1769	1488
United Kingdom	474	397	364	431	361	331
United States	674	601	552	674	601	552
Uzbekistan	8460	7727	7204	3155	2881	2686
Venezuela	1092	1171	1188	914	980	995
Vietnam	1361	1407	1394	268	277	274

Annex 5. Averaged Emissions and Intensities of Top 20 Emitters during 1993-95, 1998-00, and 2003-05

	1993-1995	1998-2000	2003-2005	1993-1995	1998-2000	2003-2005	1993-1995	1998-2000	2003-2005
	Average CO2 emissions (million tons of CO2)			Average CO2 intensity at MER (tons of CO2 per million $ GDP)			Average CO2 intensity at PPP (tons of CO2 per million $ GDP)		
United States	5,226	5,686	5,902	676	605	553	676	605	553
China	2,743	2,938	4,686	3,865	2,657	2,715	931	640	654
Russia	1,742	1,540	1,664	6,741	6,456	5,077	1,707	1,635	1,286
Japan	1,063	1,145	1,235	244	251	254	348	358	363
India	758	949	1,108	2,339	2,164	1,872	448	415	359
Germany	876	848	859	520	459	441	467	411	395
Canada	494	556	624	876	820	793	740	692	669
United Kingdom	567	555	573	477	399	362	435	364	330
Korea, Rep. of	350	412	489	923	875	798	622	590	538
Italy	412	440	468	424	413	414	315	307	308
South Africa	335	373	424	2,979	2,905	2,769	1,026	1,001	954
France	364	402	411	322	314	292	266	260	242
Iran	249	309	413	3,040	3,172	3,252	833	869	891
Australia	281	346	388	887	888	849	676	676	647
Mexico	323	370	390	703	673	634	450	431	406
Saudi Arabia	235	270	381	1,420	1,472	1,761	953	988	1,181
Ukraine	440	325	346	10,715	10,798	8,106	1,687	1,700	1,276
Spain	244	302	371	527	546	565	346	358	371
Brazil	268	332	352	481	530	496	249	275	257
Indonesia	207	258	339	1,402	1,615	1,716	386	445	472

Annex 6. A Summary of Recent Projections of India's CO_2 Intensity vis-à-vis Other Countries

Table A6.1: Summary of Projections

	2020	2030	2050	2020	2030	2050		
	CO_2 emissions[1] (billion tons)			Ratio of CO_2 intensity to its base year			Brief Scenario Description	% Real GDP Growth Assumptions
World Bank (2007), Dancing with Giants – used IMACLIM-R model (CIRED, France), a general equilibrium model with sub-sector detail on energy-producing, energy-transforming, and key energy-using sectors. CO_2 emissions are from fossil fuel combustion only. Base year for calculating the ratio of intensity is 2005.								
Business as Usual (BAU)							Present trends continue (continued heavy reliance on fossil fuels)	
India	1.80	3.10†	5.72	0.85	0.82†	0.80		5.4 (2005-20); 4.2 (2020-50)
China	7.19	9.20†	13.24	0.79	0.66†	0.55		6.8 (2005-20); 3.2 (2020-50)
Supply & Demand side scenario							Efficiency improvements and fuel-switching measures[2]	
India	1.29	2.06†	3.62	0.63	0.55†	0.51		5.2 (2005-20); 4.2 (2020-50)
China	5.23	6.13†	7.93	0.59	0.45†	0.34		6.7 (2005-20); 3.2 (2020-50)
BAU – High Growth							Heavy reliance on fossil fuels, plus optimistic growth	
India	2.57	5.62†	11.73	0.86*	1.18†	1.40*		7.0-8.0 (next decade or two from now), drop to 3-4 by 2050
China	8.07	11.37†	17.97	0.64*	0.56†	0.51*		7.5-9.0 (next decade or two from now), drop to 3-4 by 2050
International Energy Agency (2007), World Energy Outlook – used its World Energy Model, a bottom-up, partial equilibrium model with detailed representation of end-use sectors. The latest version has disaggregated regional models for China, rural-urban model in Indian residential sector, and is also integrated into a general equilibrium model (IMACLIM-R, in collaboration with CIRED, France). CO_2 emissions are from fossil fuel combustion only. Base year for calculating the ratio of intensity is 2005								
Reference							Includes policies and measures already enacted by mid-2007 (not all are fully implemented); No new policies; Heavy reliance on fossil fuels	
India	2.31 (1.80)‡	3.31	…	0.73 (0.78)‡	0.62	…		7.2 (2005-15); 5.8 (2015-30)
China	9.57 (8.63)‡	11.45	…	0.73 (0.81)‡	0.57	…		7.7 (2005-15); 4.3 (2015-30)
Alternative Policy							Full implementation of adopted policies and of those formulated for future plans and currently under consideration[3]	
India	1.88 (1.61)‡	2.42	…	0.57 (0.63)‡	0.45	…		7.2 (2005-15); 5.8 (2015-30)
China	8.35 (8.09)‡	8.88	…	0.62 (0.76)‡	0.35	…		7.7 (2005-15); 4.3 (2015-30)
High Growth							Policy assumptions match those of Reference scenario; higher growth	
India	2.57 (1.90)‡	3.90	…	0.72 (0.83)‡	0.52	…		8.3 (2005-15); 7.5 (2015-30)

	2020	2030	2050	2020	2030	2050		
	CO_2 emissions[1] (billion tons)			**Ratio of CO_2 intensity to its base year**			**Brief Scenario Description**	**% Real GDP Growth Assumptions**
China	10.09 (9.50)[‡]	14.10	…	0.74 (0.79)[‡]	0.64	…		9.0 (2005-15); 6.0 (2015-30)
Energy Information Administration, US Department of Energy (2007), International Energy Outlook – used SAGE, a variant of MARKAL developed at the US EIA. CO_2 emissions are from fossil fuel combustion only. Base year for calculating the ratio of intensity is 2004.								
Reference							Only GDP growth rates are available in the report	
India	1.72	2.16	…	0.60	0.46	…		6.0 (2004-20); 4.8 (2020-30)
China	8.80	11.24	…	0.60	0.47	…		7.0 (2004-20); 5.0 (2020-30)
US	6.94	7.95	…	0.73	0.64	….		2.9 (2004-20); 2.8 (2020-30)
Japan	1.29	1.31	…	0.82	0.78	…		1.4 (2004-20); 0.6 (2020-30)
Brazil	0.50	0.60	…	0.87	0.75	…		3.4 (2004-20); 3.2 (2020-30)
High Growth							Only GDP growth rates are available in the report	
India	1.82	2.40	…	0.59	0.46	…		6.4 (2004-20); 5.3 (2020-30)
China	9.34	12.50	…	0.60	0.46	…		7.5 (2004-20); 5.5 (2020-30)
US	7.32	8.71	…	0.72	0.61	…		3.4 (2004-20); 3.3 (2020-30)
Japan	1.36	1.44	…	0.81	0.76	…		1.8 (2004-20); 1.1 (2020-30)
Brazil	0.54	0.68	…	0.87	0.76	…		3.8 (2004-20); 3.7 (2020-30)
Planning Commission, Government of India (2006), Integrated Energy Policy Report – used a bottom-up energy model with detailed end-use sectors developed in conjunction with the Observer Research Foundation. CO_2 emissions are from fossil fuel combustion only. Base fiscal year for calculating the ratio of intensity is 2006-07.								
India	…	5.50[∝]	…	…	0.73[∝]	…	Coal-based development	8.0 (2006-31)
	…	3.70[∝]	…	…	0.57[∝]	…	Best scenario[4]	8.0 (2006-31)
Projections used in the Working Group III of IPCC (2007)'s 4th Assessment report – There are several models used for the report. Below include only a set of widely-cited models. Base year for calculating the ratio of intensity is 2000 for all models.								
Mini-CAM – a partial equilibrium energy and land-use model, developed at Joint Global Change Research Institute, University of Maryland. CO_2 emissions are from fossil fuel combustion and cement manufacture.								
India	2.43	3.53	5.26	0.62	0.46	0.27	Reference/BAU	7.0 (2000-2010); 6.3 (2010-30); 4.6 (2030-50)
US	7.33	7.73	8.44	0.77	0.70	0.60		2.4 (2000-2010); 1.7 (2010-30); 1.2 (2030-50)
AIM – a soft-linked bottom-up energy and land-use, and top-down model developed at National Institute of Environmental Studies, Japan. CO_2 emissions are from fossil fuel combustion only.								
India	1.81	2.31	2.74	0.76	0.65	0.41	Reference/BAU	4.7 (2000-2010); 4.0 (2010-30); 3.2 (2030-50)
China	4.71	5.22	6.27	0.50	0.38	0.26		5.3 (2000-2010); 4.1 (2010-30); 2.8 (2030-50)
US	6.15	6.93	8.52	0.84	0.84	0.84		1.4 (2000-2010); 1.4 (2010-30);

	2020	2030	2050	2020	2030	2050		
	CO_2 emissions[1] (billion tons)			Ratio of CO_2 intensity to its base year			Brief Scenario Description	% Real GDP Growth Assumptions
								1.1 (2030-50)
Japan	1.12	1.13	1.34	0.78	0.75	0.83		0.7 (2000-2010); 0.6 (2010-30); 0.3 (2030-50)
MERGE – a Computable General Equilibrium model with detailed representation in power sector, developed by A. Manne (Stanford) and R. Richels (EPRI, US). CO_2 emissions are from fossil fuel combustion only.								
India	1.55	1.98	3.00	0.59	0.48	0.30	Reference/BAU	5.5 (2000-2010); 4.8 (2010-30); 4.3 (2030-50)
China	4.55	5.50	8.38	0.59	0.45	0.29		5.1 (2000-2010); 4.7 (2010-30); 4.3 (2030-50)
US	7.04	6.86	7.86	0.76	0.64	0.57		2.4 (2000-2010); 1.9 (2010-30); 1.3 (2030-50)
Japan	1.22	1.24	1.45	0.82	0.73	0.67		1.5 (2000-2010); 1.2 (2010-30); 1.1 (2030-50)
POLES – a top-down, partial equilibrium energy model that is disaggregated into sectors. Key developer is Patrick Criqui (Institute of Energy Policy and Economics, France). CO_2 emissions are from fossil fuel combustion and cement manufacture.								
India	3.17	4.32		0.93	0.90		Reference/BAU	4.8 (2000-30)
China	8.16	10.16		0.75	0.65			4.6 (2000-30)
US	6.89	7.37		0.77	0.69			2.0 (2000-30)
Japan	1.24	1.28		0.78	0.69			1.5 (2000-30)
Brazil	0.78	0.97		0.99	0.97			2.9 (2000-30)

Notes:

† The data for 2030 do not exist and these are from linear interpolation between 2020 and 2050 data.

* No exact information on growth path towards 2050. CO_2 intensities were calculated based on midpoints of the given ranges of average annual growth rates: 7.5% during 2005-20, then 3.5% during 2020-50 (India); 8.25% during 2005-20, then 3.5% during 2020-50 (China).

‡ 2020 data are linearly interpolated between 2015 and 2030 for comparison across studies. The original 2015 figures are in parentheses.

∝ The figures given are for the fiscal year 2031–32.

[1] CO_2 emissions from fossil fuel combustion in 2005 (Gt): India (1.17), China (5.32), US (5.96), Japan (1.23), and Brazil (0.36).

[2] *Demand side scenario* includes additional actions geared toward improving end-use efficiency/energy saving, over and above the energy efficiency improvements already incorporated in the BAU. The additional improvements are (i) a 25 percent improvement in overall energy efficiency in the "composite" sector (including both "pure efficiency" and structural change in the economy with an increase in the share of services in GDP), relative to the base case; (ii) an additional 1.1 percent efficiency gain annually in residential/household energy-using equipment, leading to an eventual 60 percent improvement over the base case; and (iii) a 50 percent improvement in the fuel efficiency of cars by 2050, compared with the base case. *Supply side scenario* includes a higher share of hydroelectric and nuclear power in both China and India than under the BAU cases, which already incorporate some expansion of non-fossil fuels sectors. The additional improvements include (i) a 20 percent increase in hydroelectric capacity, relative to the base case; (ii) a 30 percent increase in the share of nuclear power in new investments for power generation; (iii) the share of biofuels is increased progressively to 10 percent of the total amount of fuels produced by India and China. The shares of wind and solar energy increase significantly from a very low base but not enough to offset the reduction in the use of traditional biomass; and (iv) energy efficiency is increased by 15 percent in the use of coal for industry and by 8 percent in the use of coal for electricity generation in the new capital stock installed after 2005.

[3]IEA (2007)'s measures included in Alternative Policy Scenario for India and China are provided in Table A6.2.
[4]GoI's Planning Commission's best scenario, provided in Table A6.3.

Some observations:

I. India's CO_2 intensity is expected to further decline in most of the studies and scenarios. The only exception is when India grows rapidly without new measures in World Bank (2007)'s BAU – high growth scenario. The recent policy developments were not included in the analysis. This is possibly why IEA (2007)'s high growth – with BAU policies – scenario that takes into account recent policies up to mid-2007 arrived at the opposite trend of intensity.

II. In World Bank (2007) and IEA (2007), the lowest CO_2 intensity shows – for both India and China – when the most aggressive policies were included. It would be interesting to see what happens to intensity when high growth and aggressive policies are assumed simultaneously, the scenario which none of these studies have looked at.

III. EIA's International Energy Outlook 2007: CO_2 intensities will fall over time in India, China, the United States, Japan, and Brazil, and will only slightly vary across growth scenarios. CO_2 emissions do not include those from land-use change and forestry, so Brazil's figure did not capture a substantial proportion (~80%) of its emissions.

IV. Several models were used for the Working Group III of the latest IPCC report. But, most of them adopted very low GDP growth rates and the base year was in 2000 (recent policies and measures enacted between 2000 and 2007 were not there).

Table A6.2: IEA World Energy Outlook 2007 (see footnote 4 in Table A6.1)

Alternative Policy Scenario for India includes:

Policy/measure	Assumption
Power Sector	
Integrated Energy Policy recommendation to increase coal plant efficiency from 30.5% to 39%	Two percentage points higher efficiency for new plant compared to Reference Scenario
Development of IGCC programme	More R&D, IGCC becomes available in 2020
Renovation of electricity networks, Accelerated Power Development and Reform Programme (APDRP)	Six percentage point decline in losses compared to Reference Scenario in 2030
R&M (renovation and modernisation) programme of power stations	One percentage point efficiency improvement of existing coal-fired power stations
Greater use of hydropower	Approach economic potential (150 GW) by 2030
New and Renewable Energy Policy Statement 2005 - Draft II, Rural Electricity Supply Technology (REST) Mission, Remote Village Electrification Programme (RVE)	Faster deployment of renewable technologies through incentives
Expand use of nuclear	25 GW by 2030
Industry Sector	
National Steel Policy - aims to reduce costs and improve efficiency and productivity in the iron and steel sector	Efficiency improves by 15% over Reference Scenario
Greater use of CHP	Increased use of biomass potential in CHP
Higher efficiency processes in energy-intensive industries, particularly cement	Reduction in energy intensity of cement industry of 3% per year
Energy Conservation Act 2001	Stricter enforcement; increased efficiency of motors 15%

Transport Sector	
Fuel economy standards for LDVs	10% increase over all vehicles compared with Reference Scenario
Vehicle emissions standards -- Following the European Vehicle Emissions Standards	Impact on pollution and CO2 emissions, secondary impact on fuel consumption
Biofuels -- 5% ethanol blended petrol extended nation-wide in 2006, although subject to availability.	Ethanol share in gasoline increases to 10% in 2012. Biodiesel blending in diesel starts in 2009, increasing to 5% by 2015 and 8% share by 2018.
CNG -- All commercial vehicles in Delhi, Mumbai and Kolcata run on CNG	Doubling of CNG vehicles compared with Reference Scenario
Construction of highways, ring-roads, overpasses, bus lanes and suburban and underground rail systems	5% increase in buses compared with Reference Scenario in 2030 resulting in 15% less use of cars and two- wheelers
Residential and Services Sector	
Set minimum requirements for the energy-efficient design and construction for commercial buildings or complexes with electricity load of 500 kW or capacity of 600 kVA or more	Greater building stock efficiency improvements
Energy efficiency labelling	50% of all light bulbs are CFLs in 2030; average appliance efficiency is 30% in 2030
Improved cookstoves (chulhas) -- in rural and semi-urban households	1 200 million improved cookstoves by 2030, scale up of the pilot programmes
Biogas -- Promote family type biogas units for recycling of cattle dung to harness its fuel value without destroying manure value	120 lakh biogas plants by 2030
Construction of solar water heating system, solar air heating/ steam generating systems for community cooking	Increased penetration of solar water heaters

Source: IEA (2007)

Alternative Policy Scenario for China includes:

Policy/measure	Assumption
Power Sector	
Renewable Energy Law: National targets, priority connection, tariffs, renewable energy fund	Greater effort to reach targets
Nuclear power: Target for 2020 to have 40 GW in place and 18 GW under construction	Greater effort to reach targets
Clean coal technologies: More R&D, production of larger, more efficient units	Increased efficiency
Measures to increase efficiency of existing plants	Retirement of 50 GW in the period 2005-2030 and increase in efficiency of existing stock
Industry Sector	
Reduce industrial production compared to the services sector	The 11th Five-Year Plan sets the value added, by 2010, in the services sector as a share of GDP 3 percentage points higher than in 2005. By 2020, value added in services accounts for more than 50% of GDP.
Increase industry energy efficiency by closing inefficient, small-scale plants in energy-intensive industries	For cement production, 250 million tons of capacity will be eliminated; for iron ore production, 100 million tons of capacity; and for steel production, 55 million tonnes of capacity, all by 2010.
Taxes	Increases in export taxes for energy-intensive products and decreases in, or elimination of, export credits for steel products.
Top 1000 Enterprises Energy Conservation Program	To manage energy use at the top energy-consuming 1008 industrial firms and utilities through energy auditing, reporting, formulating of goals, incentives and investments.
China Medium and Long Term Energy Conservation Plan	Energy efficiency reduction targets for energy-intensive industries, including iron and steel, cement, ammonia and ethylene, by 2010 and 2020. 2010 targets are consistent with the 11th Five-Year Plan.

Transport Sector	
Fuel economy standards for LDVs	Cars in 2030 40% more efficient than current models. Regulation extended to trucks
Vehicle taxation	Sales taxes for cars, SUVs, medium buses ranging from 3 to 20% of sale price proportional to engine size
Scrappage	Not-for-revenue passenger vehicles to be scrapped after 10/15 years For-revenues passenger vehicles to be scrapped after 8/10 years (or 500 000 km) Trucks to be scrapped when they reach 10 years (or 400 000 km)
Public transport and fuel taxes	Decrease in private cars and trucks use of 5% in 2030 compared to Reference Scenario
Alternative Fuels	Support of CNG subsidise on the natural gas refueling station set up and land allocation Biofuels – subsidies for ethanol and biodiesel production. Indicative targets of ethanol consumption of 10 million tons by 2020 and 2 million tons by 2020 Targets met in 2020, strengthened and prolonged to 2030
Residential and Services Sector	
Minimum efficiency performance standards set for refrigerators, air-conditioners and colour TVs.	All standards met, strengthened and extended to other appliances
Energy efficiency mandatory labelling for refrigerators, air conditioners and clothes washers.	Labelling standards implemented and extended to other products
Building codes: National target to reduce energy consumption in new buildings by 50% by 2010 compared to efficiency of 1980's buildings. Standards for three major climate zones already in place.	Standards met and prolonged

Source: IEA (2007)

Table A6.3: Planning Commission (2006) best scenario (see footnote 5 in Table A6.1)

Measures	Description
Forced hydro	Development of the entire (150 GW) domestic hydro potential (from 32 GW now) by 2031
Coal power plant efficiency	Thermal efficiency of future coal power plants increased to 38-40% from 36% for the present 500 MW super critical boilers
Higher freight share of railways	Increased railways freight share from 32% to 50%
Maximize nuclear	Accelerated development of nuclear capacity to 63 GW
Scale-up renewables	Wind power to 30 GW Solar power to 10 GW Biomass power to 50 GW 10 Mt of bio-diesel and 5 Mt of ethanol
Vehicle efficiency and public transport	Fuel efficiency of all motorized vehicles increased by 50% Public transport
Forced natural gas	16% of electricity generation from gas
Demand side management	Reduce electricity demand by 15%

Source: Planning Commission (2006)

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