Scanning for Global Greenhouse Gas Emission Reduction Targets and their Distributions

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March 2012

A working paper for the project ICPIA "Coping with Complexity in the Evolving international Climate Policy Institutional Architecture" funded by the Austrian "Klima- und Energiefonds" and carried out within the research programme "ACRP".

Abstract

If dangerous and irreversible climatic events are to be avoided, global average temperature should not increase by more than 2 °C above pre-industrial levels. In order to achieve such a global target, a mitigation pathway has to limit global emissions to about 50 percent below 1990 levels by 2050. We want to investigate in this paper the radical change of the energy system that would be needed for entering the pathway for halving emission levels by applying a global analytical tool. A comprehensive data base with a global coverage including socio-economic data as well as data on energy and emissions has been set up. By dividing the word into six countries and regions which account for two thirds of global emissions and a region for the rest of the world we investigate in an analytical framework the key drivers and parameters of the energy system which refer to population dynamics, economic activity, energy and carbon intensity. Based on assumptions about the diffusion and convergence of these key parameters we derive implications for long-term emission reduction targets.

Keywords: greenhouse gas emission reduction targets, effort sharing, structural indicators

JEL codes: Q54, Q58

1 Motivation

Targets for greenhouse gas emissions continue to be the cornerstone of climate policy despite the considerable shift of its global architecture from a Kyoto to a Copenhagen style regime. The majority of the world's countries are committed to limiting greenhouse gas emissions targets that limit global warming to 2 °C and there are a number of proposals how this temperature target translates into emission targets. Meinshausen et al. (2009) estimate that halving global emissions by 2050 compared to 1990 levels still leaves a 12 to 45 percent probability of exceeding a 2 °C target. UNEP (2011) states that emissions would have to peak before 2020 and afterwards to decline with more than 2 percent per year in order to maintain the chance of meeting the 2 °C target. In a roadmap for 2050 the European Commission suggested in March 2011a reduction target for the EU between 80 and 95 percent.

We want to investigate in this paper the radical change of the energy system that would be needed for entering the pathway for halving emission levels by applying a global analytical tool. A comprehensive data base with a global coverage including socio-economic data as well as data on energy and emissions has been set up. By dividing the word into six countries and regions which account for two thirds of global emissions and a region for the rest of the world we investigate in an analytical framework the key drivers and parameters of the energy system which refer to population dynamics, economic activity, energy and carbon intensity. Based on assumptions about the diffusion and convergence of these key parameters we derive implications for long-term emission reduction targets.

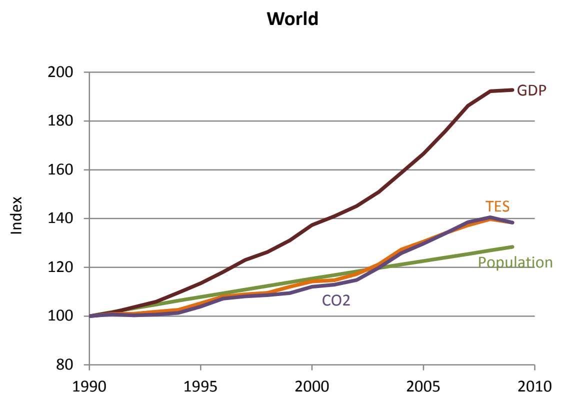
2 Identifying structures and dynamics of the global energy system

It goes without saying, that the global energy system is undergoing rapid changes. We will gather in this section evidence of these changes both on a global and on a regional scale. In addition we want to grasp a first impression about the drivers of these changes. Population and economic activity, measured by gross domestic product (GDP), are considered as the key causalities for energy demand which in turn determines via the carbon intensity of the energy mix the CO_2 emissions.

2.1 The global perspective

We obtain from Figure 2-1a first impression about the key indicators GDP (at constant 2000 prices and purchasing power parity), TES (total energy supply), CO_2 (carbon dioxide emissions), and population which have all expanded since 1990 with different dynamics. Remarkable is the nearly linear population path, the almost doubling of global GDP which is leveling off after a pronounced exponential growth and a similar path for energy. CO_2 emissions follow an almost identical path as total energy supply which is evidence of almost unchanged carbon intensity over the past two decades.

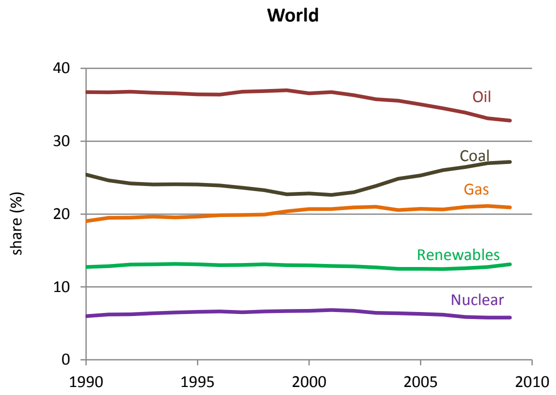
Figure 2-1: Key global indicators



Source: Own analyses based on IEA and UN databases

The composition of global total energy supply (TES) is visible in Figure 2-2. The steady decline of the share of oil since 2000 is overcompensated by a rapid increase of the share of coal. Slightly upward movements can be observed for natural gas and recently for renewables. There is a slight decline in the share of nuclear.

Figure 2-2: Composition of global energy supply



Source: Own analyses based on IEA databases

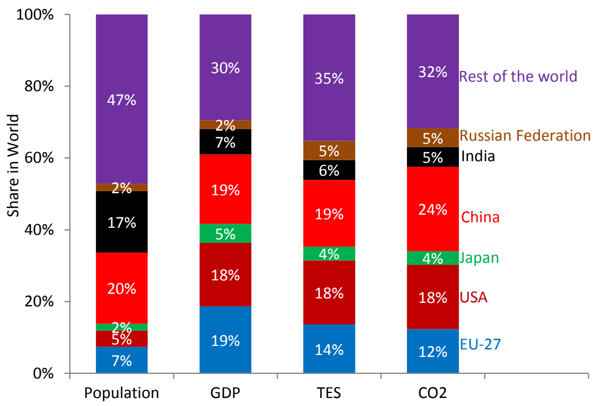
2.2 The regional perspective

We obtain valuable insights into the regional differences of population dynamics, economic activity, energy supply and CO_2 emissions by splitting the world into seven regions or countries, namely

- EU-27,
- USA,
- Japan,
- China,
- India,
- Russian Federation, and
- Rest of the World

The wide differences in the regional distribution of population, GDP, total energy supply and CO_2 emissions can be seen in Figure 2-3 and the accompanying Table 2-1. The USA, e.g. has shares in the global total of 5 percent for population and uniform 18 percent for GDP, total energy supply and CO_2. The corresponding numbers for the EU are 7 percent for population, 19 percent for GDP, 14 percent for energy, and 12 percent for emissions. Compared with the USA this reveals for the EU a lower GDP per capita but also considerable lower energy and emissions intensities.

Figure 2-3: Regional distribution of population, GDP, total energy supply and CO_2 emissions



Source: Own analyses based on IEA and UN databases

Table 2-1: Regional distribution of population, GDP, total energy supply (TES), and CO_2 emissions

2009	Population	GDP	TES	CO2
EU-27	7%	19%	14%	12%
USA	5%	18%	18%	18%
Japan	2%	5%	4%	4%
China	20%	19%	19%	24%
India	17%	7%	6%	5%
Russian Federation	2%	2%	5%	5%
Rest of the World	47%	30%	35%	32%
World	6,761	64,244	12,274	28,999
	Mill persons	Bill 2000 USD PPP	Mill to oe	Mill to CO2

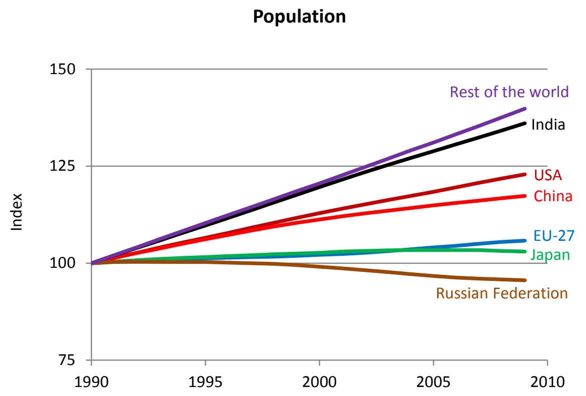
Source: Own analyses based on IEA and UN databases

The regional dynamics of the key indicators population, GDP, total energy supply, and CO_2 emissions can be seen from Figure 2-4 to Figure 2-7 together with Table 7-9 to Table 7-12 in the appendix that reveal the following emerging evidence for the past two decades:

- China could increase its GDP about 530 percent, accompanied by an increase of energy of about 160 percent but an increase of emissions of about 210 percent with a population increase of only 17 percent.
- India could about triple its GDP accompanied by an increase of energy of about 110 percent and of emissions of about 170 percent with a population increase of to 36 percent.
- The USA could increase its GDP by about 60 percent together with an increase of energy of 13 percent and of emissions of 7 percent with a population growth of 23 percent.

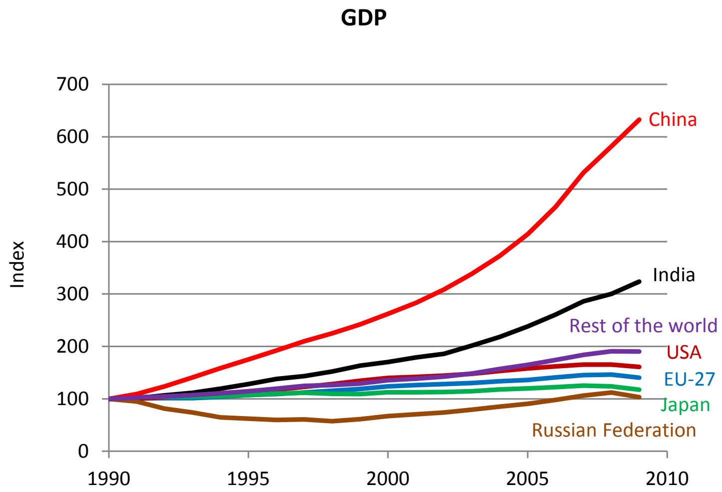
- The EU exhibits a 40 percent growth of GDP with stagnating energy and a decline in emissions of 12 percent together with a 6 percent increase of population.
- Japan shows only a 17 percent increase of GDP together with an increase of 7 percent of energy and of 3 percent of emissions.
- The Russion Federation is facing a GDP and population decline of about 4 percent compared to 1990 levels together with a sharp decline of energy by 26 percent and emissions by 30 percent.
- The Rest of the World expanded GDP by 90 percent together with energy by 57 percent and emissions by 53 percent with a population growth of 40 percent.

Figure 2-4: Regional dynamics of population



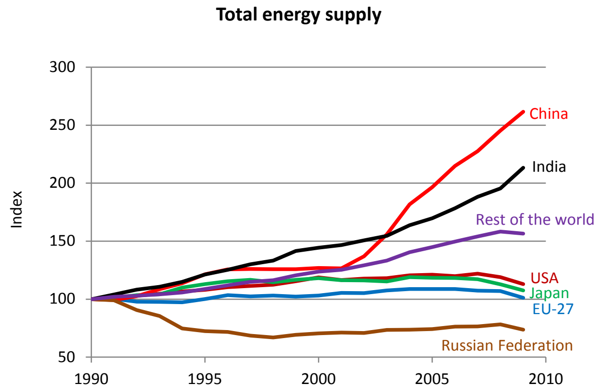
Source: Own analyses based on UN databases

Figure 2-5: Regional dynamics of gross domestic product (GDP)



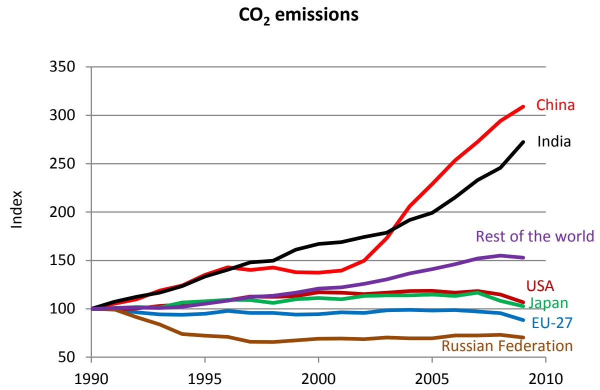
Source: Own analyses based on IEA databases

Figure 2-6: Regional dynamics of total energy supply (TES)



Source: Own analyses based on IEA databases

Figure 2-7: Regional dynamics of CO_2 emissions



Source: Own analyses based on IEA databases

3 Searching for relevant indicators for greenhouse gas reduction targets

Suggestions for emission reduction targets are often based on single indicators as emissions per person, per GDP or per energy used. These single criteria indicators are sometimes weighted to obtain multi-criteria indicators.

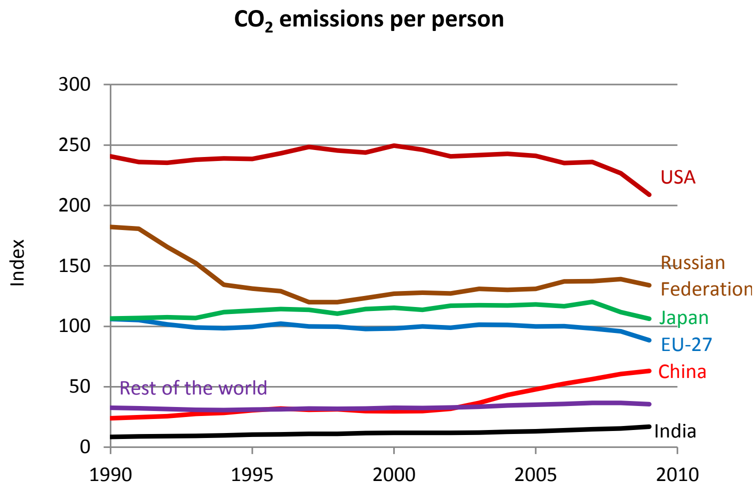
In contrast to using single and weighted multiple indicators we suggest a more integrated approach by identifying a set of structural indicators based on the demand and supply structure of the energy system and related emissions.

3.1 Single criteria indicators

Indicators for emission reductions which are based on a single criterion are popular, because they seem to convey obvious messages as the amount of emissions per person or the amount of emissions per unit of GDP.

In Figure 3-1we obtain insights about the regional disparities of greenhouse gas emissions per person. These indices can be easily compared since they are normalized on the EU value for 2005 which is set to 100. Obviously the USA has emissions per person which are more than twice above the EU levels but rapidly declining. In contrast this indicator has been strikingly increasing for China over the last decade and to a lesser extent for India.

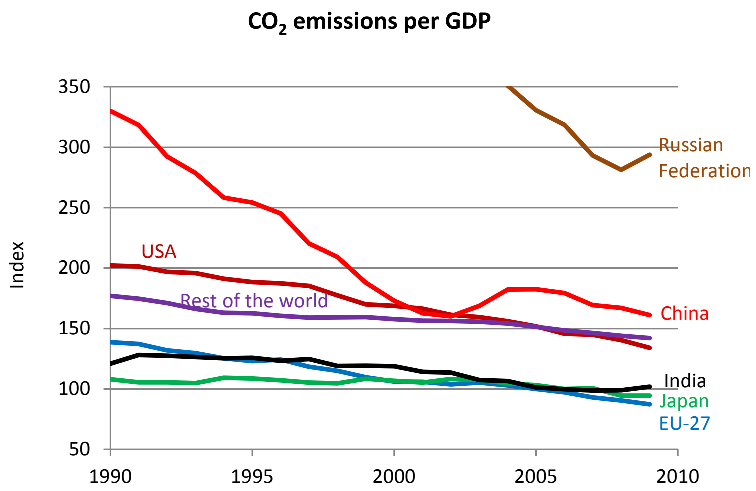
Figure 3-1: Emissions per person



Source: Own analyses based on IEA and UN databases

Another popular single criterion indicator is defined as emissions per unit of GDP as depicted in Figure 3-2 and normalized in the same way as the indicator for emissions per person. Quite different insights emerge from this emission intensity indicator related to economic activity since all regions have been able to improve with respect to this indicator. For China and above all the Russian Federation, however, economic activity is still coupled with a very high emission intensity. To a lesser extent this also holds for the USA and the Rest of the World. The EU has managed to produce one unit of GDP with the lowest emissions.

Figure 3-2: Emissions per GDP



Source: Own analyses based on IEA and UN databases

These two popular single criterion indicators suggest that the information of just one indicator is insufficient since each indicator provides complementary information. Quite often, therefore, single indicators are weighted to a composite index. Because of the arbitrariness involved in the weighting scheme we suggest a set of indicators which are based on a structural model of the energy system.

3.2 Structurally integrated indicators

Starting point of our set of structurally integrated indicators is a basic model which describes the demand and supply structure of the energy system by the following key parameters:

- population (number of persons),
- economic activity (GDP per persons),
- energy intensity (TES per GDP), and
- carbon intensity (CO_2 per TES)
  which results from the shares in TES of
- renewables,
- nuclear, and the
- carbon intensity of fossils (CO_2 per unit of fossils).

The analytical framework for this integrated indicator approach is a basic structural model of the energy system with the following variables:

C CO_2 emissions

P population

Q GDP

E total energy supply (TES)

The following identity is interpreted as the demand for emissions:

(1) $C = P \cdot (Q/P) \cdot (E/Q) \cdot (C/E)$

by defining as structural parameters

(Q/P) economic activity (GDP per person),

(E/Q) energy intensity (TES per GDP), and

(C/E) carbon intensity (CO_2 per TES).

By defining the components of total energy supply as

E_{fos} fossils,

E_{res} renewables,

E_{nuc} nuclear, and

E_{oth} others

we describe the supply side by the energy mix as

(2) $E = E_{fos} + E_{res} + E_{nuc} + E_{oth}$

from which we obtain for the total carbon intensity

(3) $(C/E) = (C/ E_{fos}) \cdot [1 - (E_{res}/E) - (E_{nuc}/E) - (E_{oth}/E)]$

with the supply side parameters

(C/ E_{fos}) carbon intensity of fossils,

(E_{res}/E) share of renewables in TES,

(E_{nuc}/E) share of nuclear in TES, and

(E_{oth}/E) share of others in TES.

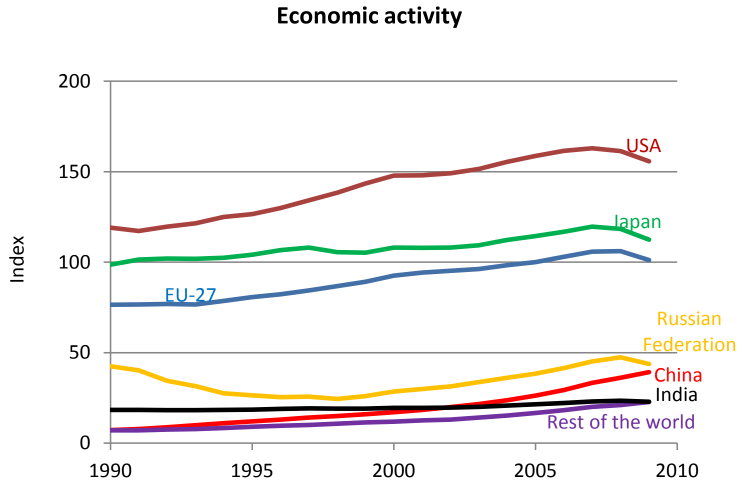
Within this analytical framework CO_2 emissions can be traced according to equation (1) by the impact of

- population (as in Figure 2-4),
- economic activity (as in Figure 3-3),
- energy intensity (as in Source: Own analyses based on IEA and UN databases
- Figure 3-4), and
- carbon intensity (as in Figure 3-5).

This overall carbon intensity in turn is according to equation (3) determined by

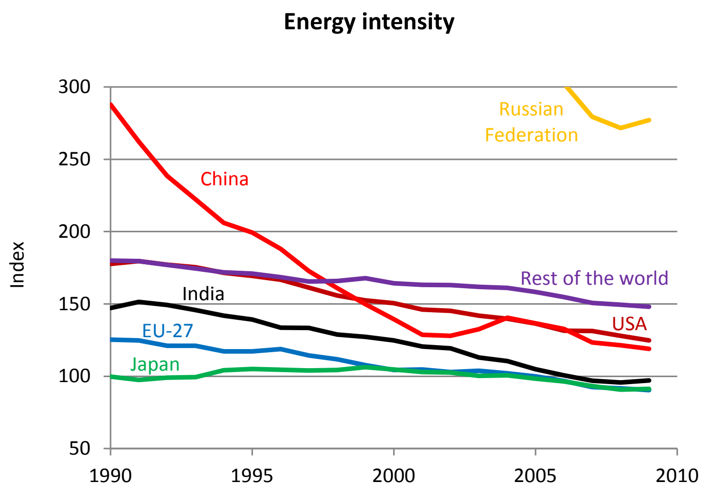
- carbon intensity of fossils,
- share of renewables in TES,
- share of nuclear in TES, and
- share of others in TES.

Figure 3-3: Structural parameter for economic activity



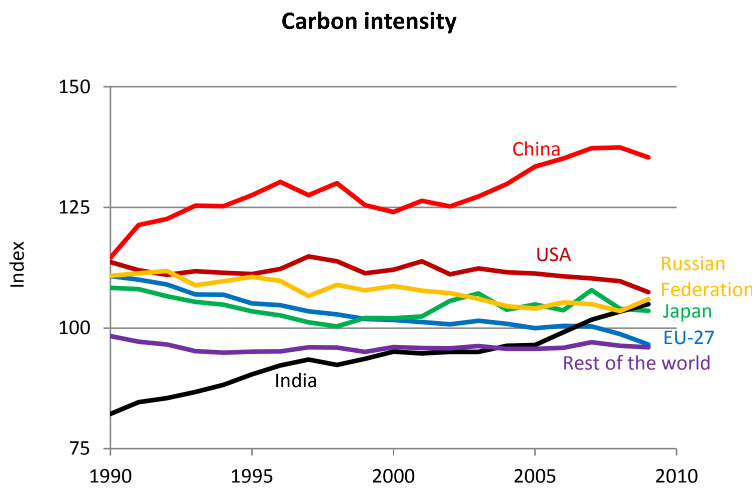
Source: Own analyses based on IEA and UN databases

Figure 3-4: Structural parameter for energy intensity



Source: Own analyses based on IEA databases

Figure 3-5: Structural parameter for carbon intensity



Source: Own analyses based on IEA databases

4 Simulating emissions targets and their distributions

We propose in this section a procedure for finding emission reduction targets and their distribution among countries and regions based on the structural indicator model explained in equation (1) of the previous section by explaining the analytical framework and some simulation results.

4.1 Assumptions of the simulation procedure

We simulate in the structural indicator framework the changes in global CO_2 emissions based on a number of assumptions.

(a) CO_2 emissions (C) are determined by a set of linked indicators, namely

P population,

(Q/P) economic activity (GDP per person),

(E/Q) energy intensity (TES per GDP), and

(C/E) carbon intensity (CO_2 per TES).

via the structural relationship equation (1)

$$C = P \cdot (Q/P) \cdot (E/Q) \cdot (C/E)$$

(b) We compare a start year with and end period.

The start year is 2009, the latest available data point. The end period is tentatively 20 years later.

(c) We calculate population for the end period by using UN population predictions for 2030.

(d) For the remaining structural parameters we assume an adjustment process towards aligned global economic structures.

This adjustment process is based on an indicative change target value, c, and an adjustment of the regions and countries by an adjustment factor, d, and is derived from equation (4).

(4) $x_{end,i} = x_{start,i} \cdot c - d \cdot (x_{start,i} \cdot c - 100 \cdot c)$

The rationale for this adjustment mechanism is as follows. In the start year the global value of parameter x is 100 and the individual country/region value of this parameter is $x_{start,i}$ for the i-th country or region. The indicative global target at the end period is $100 \cdot c$. The indicative individual target at the end period is $x_{start,i} \cdot c$. The adjustment factor d (ranging between 0 and 1) determines to what extent the discrepancy between the indicative individual and global target at the end period is adjusted.

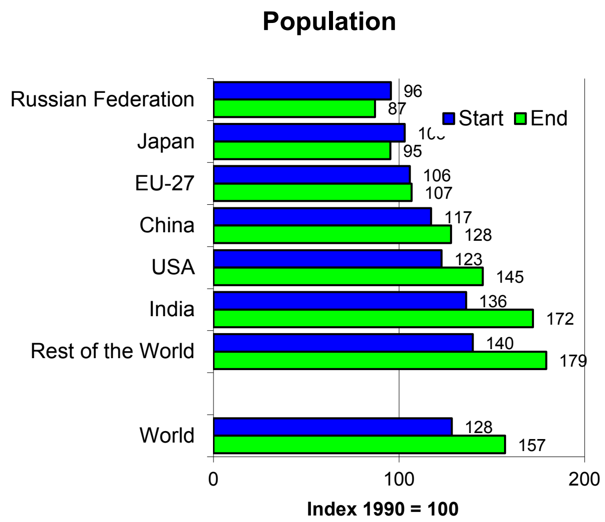
4.2 Simulation results

We demonstrate the usability of this procedure for determining global emission targets and their distribution among regions and countries by a simulation for the seven regions considered.

We aim at obtaining for a tentative end period of 2030 suggestions for a global emission reduction target and a compatible distribution for the seven regions and countries considered.

Starting point is the UN population forecast for the end period 2030. Figure 4-1 indicates this forecast in comparison with the data in the start year 2009. All data are converted into an index with 1990=100. Thus world population in 2009 is 28 percent higher than in 1990 with a forecast of a 57 percent increase by 2030.

Figure 4-1: Forecasting the change of population



Source: Own analyses based on UN data base and population forecast

Next we apply our adjustment mechanism to the structural parameters of our modeling framework. For all parameters we need to define indicative targets and adjustment factors.

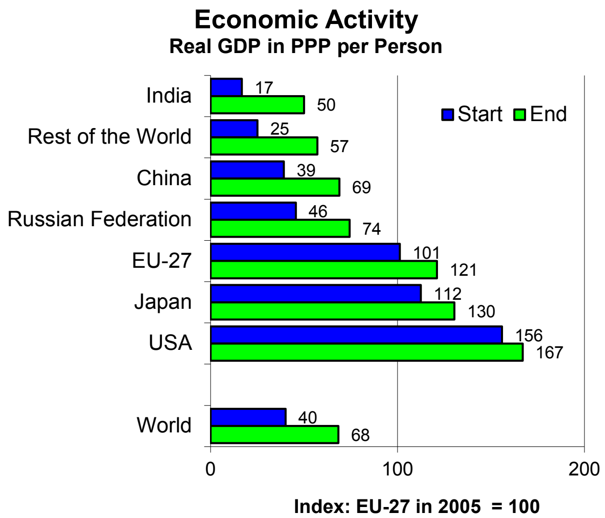
We assume a uniform adjustment of 0.3 or 30 percent for all parameters between the global and individual target value.

For economic activity, defined as GDP per person, we assume an indicative increase of 20 percent over the next two decades. The results of this procedure (i.e. of applying an adjustment factor of 30% and change factor of 20%) can be seen in Figure 4-2. All countries exhibit economic growth until 2030 but with higher rates for the poor countries.

For energy intensity, defined as total energy supply (TES) per GDP, we assume an indicative reduction of 30 percent. The results are illustrated in Figure 4-3. All indicators for parameters are normalized as an index with value 100 for the EU-27 in 2005. This means, e.g., that the EU-27 improved its energy intensity by 2009 by 10 index points to 90 and is expected to reduce this parameter to 66 by the end period in 2030.

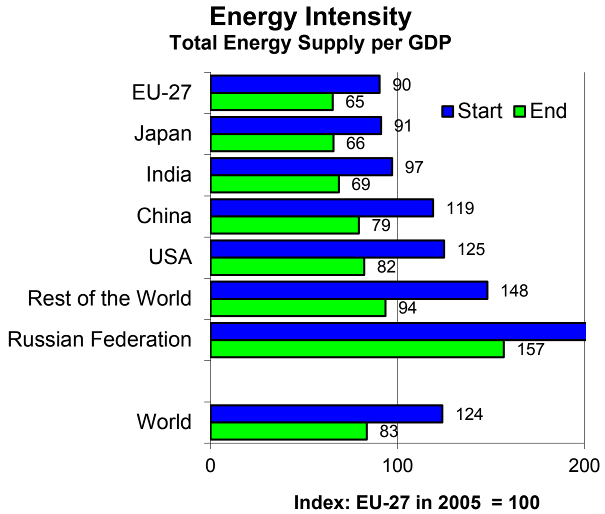
For carbon intensity, defined as CO_2 emissions per total energy supply (TES), we also assume an indicative reduction of 30 percent and obtain the results in Figure 4-4Figure 4-2. Remarkable is the position of China with particular high carbon intensity.

Figure 4-2: Simulating the change of economic activity



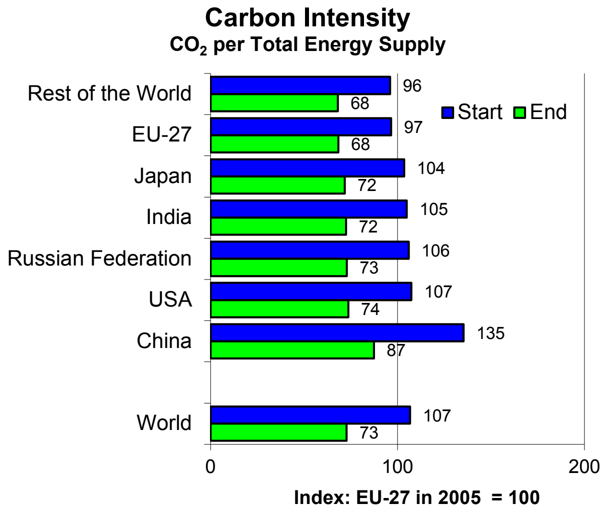
Source: Own analyses based on IEA and UN databases

Figure 4-3: *Simulating the change of energy intensity*



Source: Own analyses based on IEA databases

Figure 4-4: *Simulating the change of carbon intensity*



Source: Own analyses based on IEA databases

The final result of our simulation of a global CO_2 emission reduction target and the distribution of this target among the seven countries and regions can be seen in Figure 4-5 and in Table 4-1. Based on our assumption about rather ambitious reductions of energy and carbon intensities but also additional economic activity in particular for the poor regions we realize that global emissions might only peak around 2030. Deep emission cuts will be required from the industrialized countries but also from China which, however, will be partly set of by still rising emissions in India and the Rest of the World.

Further insight in the causes of these results are obtained from Table 4-2 which breaks down the CO_2 reductions for countries and regions into five components, namely the impact of

the changes from 2005 until the start period 2009,

the expected population changes,

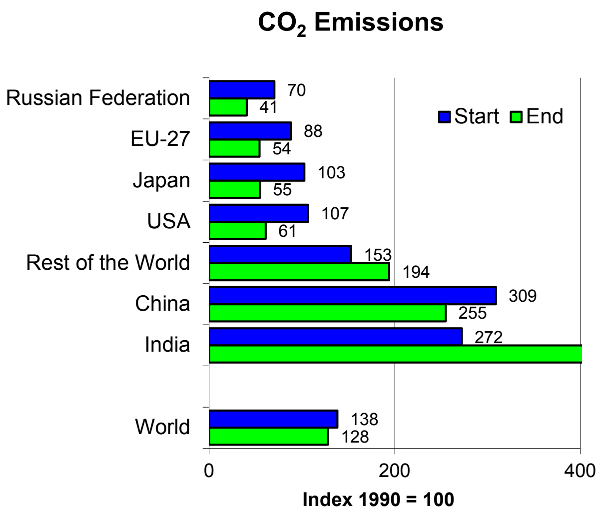
the changes in economic activity,

the changes in energy intensity, and

the changes in carbon intensity.

Thus the expected change of global emissions of -1.2 percent compared to 2005 by the end period can be partitioned into results from realized changes until 2009 of +6.7 percent, from the impact of changes in population of 14.9 percent, from the increase of economic activity of 97.3 percent, from energy intensity of -75.3 percent, and from carbon intensity of -44.7 percent.

Figure 4-5: Targets for CO_2 emission reductions



Source: Own analyses based on IEA and UN databases

Table 4-1: Targets for CO_2 emission reductions

	CO2 Index Start	End	CO2 %-Change from 1990	from 2005
EU-27	88.3	54.4	-45.6	-44.6
USA	106.7	60.9	-39.1	-48.6
Japan	102.7	55.0	-45.0	-52.0
China	308.9	255.0	155.0	11.4
India	272.3	504.0	404.0	153.0
Russian Federation	70.3	40.6	-59.4	-41.6
Rest of the World	152.9	193.9	93.9	37.5
World	138.3	128.2	28.2	-1.2

Source: Own analyses based on IEA and UN databases

Table 4-2: Partition of the targets for CO_2 emission reductions

	Start CO2	CO2 Difference %-Change from 2005 POP	GDP / POP	TES / GDP	CO2 / TES	End CO2
EU-27	-10.1	0.9	17.8	-30.1	-22.9	-44.6
USA	-10.0	16.3	7.6	-38.9	-23.6	-48.6
Japan	-10.5	-6.7	13.3	-26.9	-21.3	-52.0
China	34.9	12.3	111.8	-86.4	-61.3	11.4
India	36.7	36.3	345.9	-152.3	-113.6	153.0
Russian Federation	1.1	-9.0	57.9	-65.1	-26.4	-41.6
Rest of the World	8.3	26.5	172.1	-113.0	-56.5	37.5
World	6.7	14.9	97.3	-75.3	-44.7	-1.2

Source: Own analyses based on IEA and UN databases

5 Conclusions

In several respects the results obtained from our procedure for identifying global emission targets and their distributions among countries and regions seem to be surprising and sobering.

First, despite rather strong assumptions about the reduction of energy and carbon intensities global CO_2 emissions might decline only around 2030 and not before 2020 as recommended with respect to a 2 °C global warming target.

Second, the future dynamics of CO_2 emissions will greatly vary. Rest of the World, but above all India, might still strongly expand their emissions. China's emissions might start declining soon and the industrialized countries need to contribute with deep emission cuts in order to stabilize global emissions.

Third, the main drivers for rising CO_2 emissions remain population growth in India and the Rest of the World and the increase of economic activity in the poorer regions of the world.

Fourth, these results were obtained by postulating rather ambitious technological changes with respect to energy and carbon intensities, thus indicating the need for a rapid dissemination, diffusion and implementation of the corresponding technologies.

6 Literature

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7 Appendix: Key energy indicators

Table 7-1: World

World (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	25.4	22.8	25.3	26.0	26.4	27.0	27.2
Oil and oil products	36.7	36.6	35.0	34.5	33.9	33.1	32.8
Natural gas	19.0	20.7	20.7	20.6	21.0	21.1	20.9
Renewables	12.8	13.0	12.5	12.5	12.6	12.7	13.1
Nuclear	6.0	6.7	6.3	6.2	5.9	5.8	5.8
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	28.3	29.8	31.3	31.4	31.1	31.3	31.3
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	28.7	26.5	26.8	27.4	27.7	27.9	27.3
Transport	25.1	27.7	27.8	27.8	27.8	27.5	27.3
Other	38.6	37.1	36.4	35.8	35.5	35.8	36.4
Non-energy use	7.5	8.7	9.1	9.0	9.1	8.8	8.9

World	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	33,340.6	45,799.1	55,547.2	58,677.7	62,111.5	64,095.3	64,244.4
%-change	*2.6*	*4.8*	*5.0*	*5.6*	*5.9*	*3.2*	*0.2*
%-change trend	*2.6*	*3.2*	*3.5*	*3.7*	*4.0*	*3.9*	*3.5*
Population (mill)	5,266.9	6,075.5	6,455.4	6,531.2	6,607.2	6,684.0	6,760.8
%-change	*1.5*	*1.3*	*1.1*	*1.2*	*1.2*	*1.2*	*1.1*
%-change trend	*1.5*	*1.4*	*1.4*	*1.3*	*1.3*	*1.3*	*1.3*
Total primary energy supply (ktoe)	8,782,276	10,031,854	11,466,610	11,777,216	12,052,953	12,273,672	12,149,845
%-change	*1.0*	*2.0*	*2.6*	*2.7*	*2.3*	*1.8*	*-1.0*
%-change trend	*1.0*	*1.3*	*1.9*	*2.0*	*2.1*	*2.0*	*1.7*
CO2 (mill to)	20,966.3	23,492.9	27,188.3	28,095.9	29,047.9	29,454.0	28,999.4
%-change	*0.8*	*2.4*	*3.1*	*3.3*	*3.4*	*1.4*	*-1.5*
%-change trend	*0.8*	*1.1*	*1.9*	*2.1*	*2.2*	*2.1*	*1.8*
GDP / Population ($ 1.000)	6,330	7,538	8,605	8,984	9,401	9,589	9,503
Energy / GDP (kgoe / 1 mill $)	263,411	219,040	206,430	200,710	194,053	191,491	189,119
Energy / Population (kgoe)	1,667	1,651	1,776	1,803	1,824	1,836	1,797
CO2 / Population (kg CO2)	3,981	3,867	4,212	4,302	4,396	4,407	4,289

Source: Own analyses based on IEA and UN databases

Table 7-2: *European Union*

EU-27 (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	27.8	19.0	17.8	18.3	18.7	17.4	16.1
Oil and oil products	36.7	36.7	35.5	35.2	34.5	34.6	34.7
Natural gas	18.0	23.4	25.1	24.6	24.6	25.2	25.1
Renewables	4.3	5.8	6.5	7.0	7.7	8.2	9.2
Nuclear	12.7	14.6	14.6	14.5	13.9	14.0	14.1
Electricity	0.2	0.1	0.1	0.0	0.1	0.1	0.1
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.2	0.4	0.4	0.4	0.5	0.5	0.6
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	31.3	30.6	30.3	30.4	30.8	30.3	30.3
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	30.3	26.2	25.1	24.6	25.1	24.3	22.1
Transport	22.9	26.0	26.1	26.7	27.5	27.0	27.9
Other	38.1	38.4	39.7	39.7	38.0	39.4	41.3
Non-energy use	8.7	9.4	9.1	9.0	9.5	9.2	8.8

EU-27	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	8,566.4	10,591.9	11,667.3	12,065.3	12,445.5	12,537.8	12,007.6
%-change	*1.4*	*3.9*	*2.1*	*3.4*	*3.2*	*0.7*	*-4.2*
%-change trend	*1.4*	*2.1*	*2.0*	*2.2*	*2.3*	*2.1*	*1.5*
Population (mill)	472.9	482.9	492.1	494.1	496.4	498.7	500.4
%-change	*0.2*	*0.2*	*0.5*	*0.4*	*0.5*	*0.5*	*0.3*
%-change trend	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
Total primary energy supply (ktoe)	1,636,250	1,685,513	1,779,442	1,779,114	1,757,170	1,751,287	1,655,792
%-change	*0.0*	*0.7*	*0.1*	*0.0*	*-1.2*	*-0.3*	*-5.5*
%-change trend	*0.0*	*0.3*	*0.6*	*0.5*	*0.3*	*0.3*	*-0.3*
CO2 (mill to)	4,051.9	3,831.2	3,978.9	3,996.2	3,941.9	3,868.3	3,576.8
%-change	*-1.0*	*0.5*	*-0.8*	*0.4*	*-1.4*	*-1.9*	*-7.5*
%-change trend	*-1.0*	*-0.6*	*-0.1*	*0.0*	*-0.2*	*-0.3*	*-1.1*
GDP / Population ($ 1.000)	18,114	21,933	23,707	24,418	25,069	25,141	23,998
Energy / GDP (kgoe / 1 mill $)	191,009	159,133	152,515	147,457	141,189	139,680	137,895
Energy / Population (kgoe)	3,460	3,490	3,616	3,601	3,540	3,512	3,309
CO2 / Population (kg CO2)	8,568	7,933	8,085	8,087	7,940	7,757	7,148

Source: Own analyses based on IEA and UN databases

Table 7-3: United States

USA (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	24.0	23.5	24.1	24.0	23.7	24.0	22.4
Oil and oil products	39.5	38.3	40.1	39.8	38.7	37.2	37.0
Natural gas	22.9	24.1	21.9	21.9	23.2	23.8	24.7
Renewables	5.0	4.5	4.5	4.8	4.7	5.1	5.4
Nuclear	8.3	9.1	9.1	9.3	9.3	9.6	10.0
Electricity	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.2	0.4	0.2	0.3	0.3	0.2	0.3
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	32.5	32.0	32.3	31.9	32.3	32.4	32.4
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	21.9	21.5	18.2	19.2	18.8	19.0	17.7
Transport	37.7	38.0	39.7	40.0	39.8	39.1	39.5
Other	31.2	30.6	32.0	30.8	31.7	32.8	33.9
Non-energy use	9.2	9.9	10.2	10.0	9.7	9.0	8.9

USA	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	7,064.0	9,898.8	11,150.4	11,448.5	11,670.9	11,668.5	11,357.1
%-change	*2.5*	*4.2*	*3.1*	*2.7*	*1.9*	*0.0*	*-2.7*
%-change trend	*2.5*	*3.3*	*3.0*	*3.0*	*2.9*	*2.6*	*2.0*
Population (mill)	250.2	282.4	296.2	299.1	302.0	304.8	307.5
%-change	*1.3*	*1.1*	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*
%-change trend	*1.3*	*1.2*	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*
Total primary energy supply (ktoe)	1,914,996	2,273,332	2,318,861	2,296,686	2,337,014	2,277,034	2,162,915
%-change	*1.5*	*2.8*	*0.5*	*-1.0*	*1.8*	*-2.6*	*-5.0*
%-change trend	*1.5*	*1.7*	*1.2*	*1.0*	*1.1*	*0.7*	*0.1*
CO2 (mill to)	4,868.7	5,698.2	5,771.7	5,684.9	5,762.7	5,586.8	5,195.0
%-change	*1.1*	*3.5*	*0.2*	*-1.5*	*1.4*	*-3.1*	*-7.0*
%-change trend	*1.1*	*1.5*	*1.0*	*0.8*	*0.8*	*0.4*	*-0.3*
GDP / Population ($ 1.000)	28,236	35,050	37,641	38,283	38,641	38,279	36,936
Energy / GDP (kgoe / 1 mill $)	271,093	229,657	207,963	200,610	200,244	195,145	190,447
Energy / Population (kgoe)	7,654	8,049	7,828	7,680	7,738	7,470	7,034
CO2 / Population (kg CO2)	19,461	20,176	19,484	19,010	19,080	18,328	16,895

Source: Own analyses based on IEA and UN databases

Table 7-4: Japan

Japan (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	17.4	18.7	21.1	21.4	22.6	22.9	21.5
Oil and oil products	57.0	49.2	46.7	44.9	44.6	43.1	42.5
Natural gas	10.1	12.7	13.6	14.9	16.1	16.9	17.1
Renewables	3.5	3.2	3.2	3.4	3.2	3.3	3.3
Nuclear	12.0	16.2	15.3	15.2	13.3	13.6	15.4
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.0	0.1	0.2	0.2	0.2	0.2	0.2
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	31.7	33.5	33.3	33.5	33.6	35.6	33.6
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	34.3	28.9	28.0	28.4	28.5	27.2	26.2
Transport	23.9	25.5	24.3	24.1	23.7	24.4	24.3
Other	30.3	33.6	35.4	35.3	35.5	36.9	36.8
Non-energy use	11.5	12.0	12.2	12.3	12.3	11.5	12.8

Japan	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	2,890.1	3,250.3	3,467.6	3,538.3	3,622.0	3,579.6	3,392.9
%-change	*1.4*	*2.9*	*1.9*	*2.0*	*2.4*	*-1.2*	*-5.2*
%-change trend	*1.4*	*1.2*	*1.3*	*1.4*	*1.5*	*1.2*	*0.6*
Population (mill)	123.6	126.9	127.8	127.8	127.8	127.5	127.3
%-change	*0.3*	*0.2*	*0.0*	*0.0*	*0.0*	*-0.2*	*-0.1*
%-change trend	*0.3*	*0.3*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*
Total primary energy supply (ktoe)	439,315	518,946	520,515	519,778	515,171	495,549	471,992
%-change	*2.5*	*1.3*	*-0.4*	*-0.1*	*-0.9*	*-3.8*	*-4.8*
%-change trend	*2.5*	*1.9*	*1.2*	*1.0*	*0.9*	*0.4*	*-0.1*
CO2 (mill to)	1,064.4	1,184.0	1,220.7	1,205.0	1,242.3	1,152.6	1,092.9
%-change	*1.5*	*1.3*	*0.7*	*-1.3*	*3.1*	*-7.2*	*-5.2*
%-change trend	*1.5*	*1.2*	*1.0*	*0.8*	*1.0*	*0.2*	*-0.4*
GDP / Population ($ 1.000)	23,381	25,607	27,140	27,693	28,347	28,073	26,646
Energy / GDP (kgoe / 1 mill $)	152,006	159,662	150,107	146,899	142,236	138,436	139,113
Energy / Population (kgoe)	3,554	4,088	4,074	4,068	4,032	3,886	3,707
CO2 / Population (kg CO2)	8,611	9,328	9,554	9,431	9,723	9,039	8,583

Source: Own analyses based on IEA and UN databases

Table 7-5: *China*

China (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	61.2	57.1	64.1	65.1	65.4	66.4	67.2
Oil and oil products	12.8	20.1	18.6	18.4	18.0	17.2	16.8
Natural gas	1.5	1.9	2.3	2.6	3.0	3.2	3.3
Renewables	24.5	20.5	14.2	13.3	12.8	12.3	11.9
Nuclear	0.0	0.4	0.8	0.8	0.8	0.8	0.8
Electricity	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	23.2	29.8	35.6	36.6	36.0	35.2	36.5
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	36.3	38.2	43.9	45.1	46.1	47.7	47.4
Transport	5.6	10.7	11.3	11.5	11.6	11.4	11.2
Other	51.7	44.3	37.1	35.7	34.6	33.3	33.2
Non-energy use	6.5	6.8	7.8	7.7	7.7	7.6	8.1

China	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	1,964.9	5,150.2	8,138.2	9,159.6	10,442.3	11,427.1	12,433.9
%-change	*11.9*	*8.4*	*11.2*	*12.6*	*14.0*	*9.4*	*8.8*
%-change trend	*11.9*	*10.4*	*10.1*	*10.4*	*10.8*	*10.6*	*10.4*
Population (mill)	1,140.9	1,269.3	1,310.5	1,317.9	1,324.8	1,331.6	1,338.5
%-change	*1.2*	*0.8*	*0.6*	*0.6*	*0.5*	*0.5*	*0.5*
%-change trend	*1.2*	*1.1*	*0.9*	*0.9*	*0.8*	*0.8*	*0.8*
Total primary energy supply (ktoe)	862,956	1,094,871	1,696,389	1,853,975	1,963,992	2,117,483	2,257,101
%-change	*4.0*	*0.8*	*8.2*	*9.3*	*5.9*	*7.8*	*6.6*
%-change trend	*4.0*	*2.8*	*5.6*	*6.0*	*6.0*	*6.2*	*6.2*
CO2 (mill to)	2,211.3	3,037.3	5,062.4	5,603.0	6,028.4	6,506.8	6,831.6
%-change	*6.2*	*-0.3*	*11.2*	*10.7*	*7.6*	*7.9*	*5.0*
%-change trend	*6.2*	*3.8*	*6.9*	*7.3*	*7.3*	*7.4*	*7.2*
GDP / Population ($ 1.000)	1,722	4,058	6,210	6,950	7,882	8,581	9,290
Energy / GDP (kgoe / 1 mill $)	439,194	212,586	208,447	202,408	188,080	185,303	181,528
Energy / Population (kgoe)	756	863	1,294	1,407	1,482	1,590	1,686
CO2 / Population (kg CO2)	1,938	2,393	3,863	4,251	4,550	4,886	5,104

Source: Own analyses based on IEA and UN databases

Table 7-6: India

India (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	32.6	35.3	38.6	39.4	40.6	41.7	42.2
Oil and oil products	19.4	24.7	23.5	23.5	23.5	23.6	23.6
Natural gas	3.3	5.0	5.9	5.9	6.0	5.7	7.2
Renewables	44.1	34.0	31.1	30.2	29.0	28.2	26.1
Nuclear	0.5	1.0	0.8	0.9	0.7	0.6	0.7
Electricity	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	20.5	30.3	33.4	33.1	33.9	33.9	33.5
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	27.9	27.3	29.4	30.1	30.0	30.7	30.3
Transport	10.8	10.0	9.7	10.2	10.7	11.4	11.5
Other	56.7	53.6	52.0	50.3	49.5	48.9	49.6
Non-energy use	4.6	9.0	8.9	9.5	9.9	8.9	8.7

India	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	1,411.9	2,402.0	3,363.6	3,681.0	4,035.6	4,242.2	4,567.0
%-change	*5.1*	*4.0*	*9.3*	*9.4*	*9.6*	*5.1*	*7.7*
%-change trend	*5.1*	*5.4*	*6.2*	*6.5*	*6.8*	*6.7*	*6.8*
Population (mill)	849.5	849.5	849.5	849.5	849.5	849.5	849.5
%-change	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
%-change trend	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Total primary energy supply (ktoe)	316,743	457,214	537,909	565,000	596,557	619,024	675,830
%-change	*3.9*	*2.0*	*3.7*	*5.0*	*5.6*	*3.8*	*9.2*
%-change trend	*3.9*	*3.8*	*3.7*	*3.8*	*4.0*	*4.0*	*4.5*
CO2 (mill to)	582.3	972.5	1,160.4	1,252.0	1,357.2	1,431.3	1,585.8
%-change	*5.9*	*3.6*	*3.9*	*7.9*	*8.4*	*5.5*	*10.8*
%-change trend	*5.9*	*5.4*	*4.8*	*5.1*	*5.4*	*5.4*	*5.9*
GDP / Population ($ 1.000)	1,662	2,828	3,959	4,333	4,750	4,994	5,376
Energy / GDP (kgoe / 1 mill $)	224,338	190,346	159,921	153,492	147,823	145,921	147,982
Energy / Population (kgoe)	373	538	633	665	702	729	796
CO2 / Population (kg CO2)	685	1,145	1,366	1,474	1,598	1,685	1,867

Source: Own analyses based on IEA and UN databases

Table 7-7: Russian Federation

Russian Federation (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	21.7	19.4	17.3	17.3	16.5	17.0	14.7
Oil and oil products	30.0	20.4	19.8	19.9	19.7	20.8	21.3
Natural gas	41.8	51.5	53.6	53.5	54.4	53.2	54.1
Renewables	3.0	2.9	2.9	2.8	2.9	2.6	2.8
Nuclear	3.6	5.6	6.0	6.1	6.3	6.2	6.6
Electricity	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.0	0.5	0.5	0.6	0.4	0.4	0.5
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	28.9	32.4	36.7	36.6	36.3	36.8	34.6
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	33.4	30.7	29.9	30.4	29.4	28.8	29.4
Transport	18.5	17.8	21.5	21.5	21.6	22.4	21.2
Other	41.6	42.8	37.8	37.6	38.0	38.0	37.0
Non-energy use	6.4	8.7	10.7	10.5	11.0	10.9	12.3

Russian Federation	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	1,485.0	998.6	1,344.7	1,454.3	1,578.4	1,661.2	1,530.2
%-change	*-9.0*	*10.0*	*6.4*	*8.2*	*8.5*	*5.2*	*-7.9*
%-change trend	*-9.0*	*-4.3*	*0.0*	*0.8*	*1.6*	*2.0*	*1.0*
Population (mill)	147.7	147.7	147.7	147.7	147.7	147.7	147.7
%-change	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
%-change trend	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Total primary energy supply (ktoe)	879,193	619,265	651,712	670,673	672,591	688,483	646,915
%-change	*-6.2*	*1.7*	*0.7*	*2.9*	*0.3*	*2.4*	*-6.0*
%-change trend	*-6.2*	*-3.8*	*-1.8*	*-1.3*	*-1.2*	*-0.8*	*-1.3*
CO2 (mill to)	2,178.8	1,505.5	1,516.2	1,579.8	1,578.5	1,593.4	1,532.6
%-change	*-6.2*	*2.6*	*0.2*	*4.2*	*-0.1*	*0.9*	*-3.8*
%-change trend	*-6.2*	*-3.9*	*-2.2*	*-1.6*	*-1.4*	*-1.2*	*-1.5*
GDP / Population ($ 1.000)	10,056	6,762	9,106	9,848	10,689	11,249	10,362
Energy / GDP (kgoe / 1 mill $)	592,065	620,127	484,663	461,162	426,114	414,454	422,779
Energy / Population (kgoe)	5,954	4,194	4,413	4,542	4,555	4,662	4,381
CO2 / Population (kg CO2)	14,754	10,195	10,267	10,698	10,690	10,790	10,379

Source: Own analyses based on IEA and UN databases

Table 7-8: Rest of the World

Rest of the World (%-share)	1990	2000	2005	2006	2007	2008	2009
Coal and coal products	27.8	19.0	17.8	18.3	18.7	17.4	16.1
Oil and oil products	36.7	36.7	35.5	35.2	34.5	34.6	34.7
Natural gas	18.0	23.4	25.1	24.6	24.6	25.2	25.1
Renewables	4.3	5.8	6.5	7.0	7.7	8.2	9.2
Nuclear	12.7	14.6	14.6	14.5	13.9	14.0	14.1
Electricity	0.2	0.1	0.1	0.0	0.1	0.1	0.1
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste non-renewable	0.2	0.4	0.4	0.4	0.5	0.5	0.6
Total primary energy supply	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Losses	31.3	30.6	30.3	30.4	30.8	30.3	30.3
Total final consumption	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Industry	30.3	26.2	25.1	24.6	25.1	24.3	22.1
Transport	22.9	26.0	26.1	26.7	27.5	27.0	27.9
Other	38.1	38.4	39.7	39.7	38.0	39.4	41.3
Non-energy use	8.7	9.4	9.1	9.0	9.5	9.2	8.8

Rest of the World	1990	2000	2005	2006	2007	2008	2009
GDP (bill 2000 USD PPP)	8,566.4	10,591.9	11,667.3	12,065.3	12,445.5	12,537.8	12,007.6
%-change	*1.4*	*3.9*	*2.1*	*3.4*	*3.2*	*0.7*	*-4.2*
%-change trend	*1.4*	*2.1*	*2.0*	*2.2*	*2.3*	*2.1*	*1.5*
Population (mill)	472.9	482.9	492.1	494.1	496.4	498.7	500.4
%-change	*0.2*	*0.2*	*0.5*	*0.4*	*0.5*	*0.5*	*0.3*
%-change trend	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
Total primary energy supply (ktoe)	1,636,250	1,685,513	1,779,442	1,779,114	1,757,170	1,751,287	1,655,792
%-change	*0.0*	*0.7*	*0.1*	*0.0*	*-1.2*	*-0.3*	*-5.5*
%-change trend	*0.0*	*0.3*	*0.6*	*0.5*	*0.3*	*0.3*	*-0.3*
CO2 (mill to)	4,051.9	3,831.2	3,978.9	3,996.2	3,941.9	3,868.3	3,576.8
%-change	*-1.0*	*0.5*	*-0.8*	*0.4*	*-1.4*	*-1.9*	*-7.5*
%-change trend	*-1.0*	*-0.6*	*-0.1*	*0.0*	*-0.2*	*-0.3*	*-1.1*
GDP / Population ($ 1.000)	18,114	21,933	23,707	24,418	25,069	25,141	23,998
Energy / GDP (kgoe / 1 mill $)	191,009	159,133	152,515	147,457	141,189	139,680	137,895
Energy / Population (kgoe)	3,460	3,490	3,616	3,601	3,540	3,512	3,309
CO2 / Population (kg CO2)	8,568	7,933	8,085	8,087	7,940	7,757	7,148

Source: Own analyses based on IEA and UN databases

Table 7-9: Population

POP (Index 1990 = 100)	1990	2000	2005	2006	2007	2008	2009
EU-27	100.0	102.1	104.1	104.5	105.0	105.5	105.8
USA	100.0	112.9	118.4	119.5	120.7	121.8	122.9
Japan	100.0	102.7	103.4	103.4	103.4	103.2	103.0
China	100.0	111.3	114.9	115.5	116.1	116.7	117.3
India	100.0	119.6	128.8	130.6	132.4	134.2	136.1
Russian Federation	100.0	99.1	96.7	96.3	96.0	95.8	95.6
Rest of the World	100.0	120.6	131.1	133.2	135.4	137.6	139.8
World	100.0	115.4	122.6	124.0	125.4	126.9	128.4

Source: Own analyses based on IEA and UN databases

Table 7-10: Gross Domestic Product (GDP) at 2000 USD Purchasing Power Parity

GDP (index 1990 = 100)	1990	2000	2005	2006	2007	2008	2009
EU-27	100.0	123.6	136.2	140.8	145.3	146.4	140.2
USA	100.0	140.1	157.8	162.1	165.2	165.2	160.8
Japan	100.0	112.5	120.0	122.4	125.3	123.9	117.4
China	100.0	262.1	414.2	466.2	531.5	581.6	632.8
India	100.0	170.1	238.2	260.7	285.8	300.5	323.5
Russian Federation	100.0	67.2	90.6	97.9	106.3	111.9	103.0
Rest of the World	100.0	135.6	164.8	174.0	183.9	190.6	190.3
World	100.0	137.4	166.6	176.0	186.3	192.2	192.7

Source: Own analyses based on IEA and UN databases

Table 7-11: Total Energy Supply (TES)

TES (index 1990 = 100)	1990	2000	2005	2006	2007	2008	2009
EU-27	100.0	103.0	108.8	108.7	107.4	107.0	101.2
USA	100.0	118.7	121.1	119.9	122.0	118.9	112.9
Japan	100.0	118.1	118.5	118.3	117.3	112.8	107.4
China	100.0	126.9	196.6	214.8	227.6	245.4	261.6
India	100.0	144.3	169.8	178.4	188.3	195.4	213.4
Russian Federation	100.0	70.4	74.1	76.3	76.5	78.3	73.6
Rest of the World	100.0	123.8	145.0	149.7	154.1	158.3	156.6
World	100.0	114.2	130.6	134.1	137.2	139.8	138.3

Source: Own analyses based on IEA and UN databases

Table 7-12: CO_2 Emissions

CO2 (index 1990 = 100)	1990	2000	2005	2006	2007	2008	2009
EU-27	100.0	94.6	98.2	98.6	97.3	95.5	88.3
USA	100.0	117.0	118.5	116.8	118.4	114.7	106.7
Japan	100.0	111.2	114.7	113.2	116.7	108.3	102.7
China	100.0	137.4	228.9	253.4	272.6	294.3	308.9
India	100.0	167.0	199.3	215.0	233.1	245.8	272.3
Russian Federation	100.0	69.1	69.6	72.5	72.5	73.1	70.3
Rest of the World	100.0	120.9	141.1	146.0	152.1	155.0	152.9
World	100.0	112.1	129.7	134.0	138.5	140.5	138.3

Source: Own analyses based on IEA and UN databases