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**Analysis of  
BP Statistical Review of World Energy  
with respect to  
CO<sub>2</sub>-Emissions**

2<sup>nd</sup> Edition

Joint Working Paper

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## Executive Summary:

This working paper analyses the BP Statistical Review of World Energy with respect to CO<sub>2</sub> emissions from fossil fuel consumption. The focus is put on the classification of Annex-B and non Annex-B countries as defined in the Kyoto protocol.

The method is to convert the fossil fuel consumption with specific emission factors for coal, oil and gas into CO<sub>2</sub> emissions and to analyse the results. Though this method might be criticised as being too simple, the trends and relative changes are reproduced sufficiently accurate.

Main trends are:

- The world CO<sub>2</sub> emissions from fossil fuel consumption in 2000 were higher than in 1999 (about two percent). Since 1990 world CO<sub>2</sub> emissions increased by about 7.5 percent.
- The emissions of Annex-B countries are one percent below the 1990 emissions. This decrease is mainly attributable to the strong emission reductions in the Economies in Transition. The only other countries with reduced emissions are Sweden (- 6.6 %), UK (- 5.3 %), Switzerland (- 1.8 %) and Germany (-13.3 %), where the latter also (but not only) took advantage from the inclusion of the former GDR.
- The emissions of the non Annex-B countries increased by about 24 percent, giving these countries a larger share on total emissions of about 40 percent.
- The largest relative increases come from Thailand (+ 110 %), South Korea (+ 106 %) and Taiwan (+ 92 %)
- The share of coal in primary energy supply decreased in most countries. The strongest decrease took place in China.
- China increased its coal consumption until 1996 heavily, but reduced it since then by almost 30 percent, resulting in 10 percent less coal consumption than 1990.
- The world's largest coal consumer in 1990 was China; in 2000 the world's largest coal consumer were the USA, which also had the largest absolute increase in coal consumption
- Emission trends of many countries seem to be influenced by the Kyoto protocol. Those of China seem to be most influenced. On the other hand, China and India with the high specific CO<sub>2</sub> emission per primary energy unit still have a huge potential for further improvements in energy efficiency.

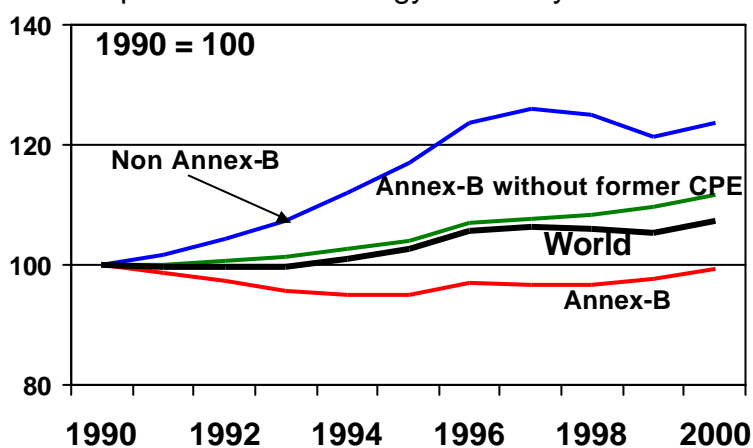


Figure: CO<sub>2</sub> emission trends

# Analysis of BP Statistical Review of World Energy with respect to CO<sub>2</sub>-Emissions

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## **Analysis of BP Statistical Review of World Energy with respect to CO<sub>2</sub>-Emissions**

### **1 Introduction:**

In this paper we analyse the energy consumption of nearly all countries with respect to their CO<sub>2</sub>-emissions. Basic data are taken from the BP Statistical Review of World Energy [1] which are published annually. With simplified emission factors for coal, oil and gas the energy consumption is converted into direct CO<sub>2</sub>-emissions due to combustion of fossil fuels. Although the derived results do not take into account country specific differences in fuel quality and preparation, the resulting trends should give confident results – even when the absolute emission figures are not correctly represented.

Main emphasis is put on the difference of Annex - B countries (industrialised countries) and non Annex - B countries as defined by the Kyoto protocol. Existing trends in energy consumption patterns are exhibited and shown to explain the changing patterns of CO<sub>2</sub>-emissions.

Finally, several countries are explained explicitly to demonstrate the regional and country specific choices which lead to the different emission patterns. Most prominent are the United States of America and China. Both countries represent the largest emitter in each category (Annex B, resp. Non Annex B), and surprisingly, in recent years both countries developed differently from most projections. Whereas the United States of America continue to rise coal consumption, and total emissions, China's economy already has started to reduce its energy consumption, most notably by reducing its coal consumption.

### **2 LBST-Methodology:**

The applied method of one separate emission factor for coal, oil and gas consumption, neglecting country and sector specific deviations, might be criticized as oversimplifying the situation. To give a feeling on that effect, first we compare the baseline emissions which are reported in the national communications by each Annex-B country with these simplified results. The overall emissions coincide within about 6 %. But for the individual countries large deviations occur by as much as 35 % in the worst case (Netherlands). Most large emitters are represented accurately to about 10 %. Therefore, some caution must be taken in applying the absolute values (e.g. for comparison to different statistics). However, we believe that relative annual changes, which are mainly due to relative changes of the energy supply situation might be represented sufficiently accurate. At least the major trends are given correctly.

The IPCC (Intergovernmental Panel on Climate Change) recommends the following specific emission factors for combustion of fossil fuels:

Oil:	20 Mg carbon per TJ	=	264 g CO <sub>2</sub> /kWh
Natural Gas	15.3 Mg carbon per TJ	=	202 g CO <sub>2</sub> /kWh
Lignite	28.5 Mg carbon per TJ	=	381 g CO <sub>2</sub> /kWh
Bituminous	25.8 Mg carbon per TJ	=	340 g CO <sub>2</sub> /kWh.

Since the basic data are given in Mtoe (Megaton of oil equivalent), we used a conversion factor of 11.6 MWh/Mtoe. Applied to all energy carriers, this factor doesn't influence the relative changes.

We chose the following emission factors:

Oil:	260 g CO <sub>2</sub> /kWh,
Natural Gas:	195 gCO <sub>2</sub> /kWh,
Coal:	330 gCO <sub>2</sub> /kWh

Even with these (with respect to the IPCC recommendation) reduced factors our results are in average 5 percent above those reported in the National Communications by Annex-I countries. This difference was not investigated in more detail. A major reason for the difference might be that non energetic use of fossil fuels consumption is not separated in these statistics. Non energetic use usually does not result in direct CO<sub>2</sub>-emissions.

### 3 The Emissions of the Negotiating Parties of the Kyoto Protocol

Our calculations give total CO<sub>2</sub> emissions from combustion of fossil fuels of about 22 Gt in the base year 1990. Two thirds of these emissions are attributable to the Annex-B countries (for a list of these countries see below). Total emissions increased by about 7.5 % until 2000. The Emissions of the Annex-B countries reduced slightly by 1 %, where the emissions of the non Annex-I countries increased by more than 20 %.

#### Global CO<sub>2</sub>-Emissions from fossil fuel combustion: Annex-B vs. Non Annex-B countries

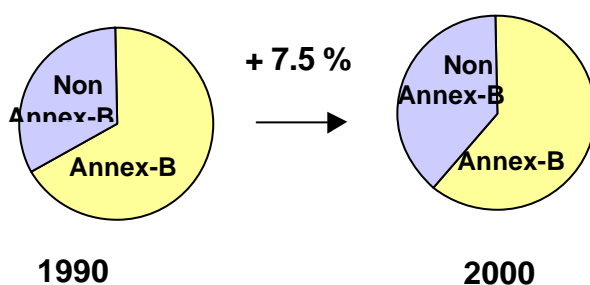


Figure 1: Share of Annex - B countries and non Annex - B countries on the world carbon emissions from fossil fuel combustion.

#### 3.1 Emissions of Annex – B Countries:

The following table 1 lists the Annex-B countries and their CO<sub>2</sub>-emissions from fossil fuel combustion.

The first row after the country's name shows the baseline 1990 emissions as reported to the UN-FCCC. To compare our results, the second row gives the 1990 emissions as derived from BP world energy statistics from fossil fuel consumption with the above explained emission factors for oil, gas and coal consumption. The

third row exhibits the percentage deviation of the calculated figure from the reported baseline emission. The fourth row gives the 2000 emissions calculated with the same method. Therefore, these figures should show the relative difference to the 1990 - figures sufficiently accurate. The last row gives the percentage change of 2000 emissions with respect to the 1990 figures.

Table 1: CO<sub>2</sub>-Emissions from fossil fuel combustion of Annex-B countries (in Gg)

	1990 Emission UNFCCC	1990 from BP-Energy Statistics (LBST-method)	Deviation BP over UNFCCC	2000 from BP Energy Statistics (LBST-method)	Change 2000 over 1990
Australia	262,623	283,800	+ 8.1 %	338,700	19 %
Austria	46,620	58,100	+ 24.6 %	62,200	7 %
Belgium/Luxemb	118,052	136,100	+ 15.3 %	158,100	16 %
Bulgaria	76,484	72,600	- 5.1 %	46,300	- 36 %
Canada	412,000	453,500	+ 10.1 %	520,800	15 %
Czech Republic	160,073	164,700	+ 2.9 %	115,100	- 30 %
Denmark	50,898	54,200	+ 6.5 %	56,600	4 %
Estonia	37,184	n.a.	--	n.a.	--
Finland	53,900	51,000	- 5.4 %	52,800	3 %
France	364,315	402,500	+ 10.5 %	420,900	5 %
Germany	986,832	1,002,000	+ 1.5 %	868,400	- 13 %
Greece	77,256	78,200	+ 1.2 %	95,100	22 %
Hungary	68,105	69,200	+ 1.6 %	54,800	- 21 %
Iceland	1,674	2,200	+ 31.4 %	3,100	41 %
Ireland	29,038	26,000	- 10.5 %	39,200	51 %
Italy	400,047	424,700	+ 6.1 %	455,100	7 %
Japan	1,052,964	1,142,300	+ 8.5 %	1,298,300	14 %
Latvia	24,209	n.a.	--	n.a.	--
Liechtenstein	208	n.a.	--	n.a.	--
Lithuania	37,332	n.a.	--	n.a.	--
Monaco	106	n.a.	--	n.a.	--
Netherlands	157,530	212,000	+ 34.6 %	234,300	10 %
New Zealand	22,240	28,400	+ 27.7 %	34,700	25 %
Norway	26,403	34,000	+ 28.8 %	38,900	14 %
Poland	371,433	374,800	+ 1 %	303,300	- 19 %
Portugal	43,281	44,200	+ 2.1 %	72,100	63 %
Romania	165,382	163,800	- 1 %	92,000	- 44 %
Slovakia	56,585	53,500	- 6 %	38,000	- 29 %
Slovenia	13,294	n.a.	--	n.a.	--
Spain	207,592	230,900	+ 11.2 %	328,500	42 %
Sweden	51,328	59,200	+ 15.4 %	55,300	- 7 %
Russian Federation	2,298,900	2,299,700	+/- 0	1,563,000	- 32 %
Switzerland	40,330	43,400	+ 7.6 %	42,600	- 2 %
Ukraine	672,075	736,500	+ 9.6 %	319,200	- 57 %
United Kingdom	558,091	605,200	+ 8.4 %	573,100	- 5 %
United States of America	4,928,900	5,304,200	+ 7.6 %	6,198,000	17 %
Total	13,873,284	14,611,000	+ 5.3 %	14,478,500	- 0.9 %

In total, the Annex-B countries reduced their emissions over the period by 0.9%. But these reductions are almost completely due to the restructuring of the former centrally planning economies, the so called economies in transition. Without these states the total CO<sub>2</sub> emissions of Annex-B countries are 10,676,000 Gg in 1990 compared to 11,947,000 Gg in 2000. This corresponds to an increase of 12 %. Besides the economies in transition, the only decreasing emissions are seen for Germany (including former GDR – 13.3 %), Sweden (-6.6 %), Switzerland (-2 %) and UK (-5 %).

At a first glance, it looks like that for the UK clear political signals showed a strong change of energy consumption patterns which resulted in reduced CO<sub>2</sub> emissions. (e.g. steadily increasing CO<sub>2</sub> -Taxes on gasoline and a strong switch to natural gas in the power sector). In Germany, the contribution of lignite decreased dramatically. For the first half of the nineties, the restructuring of the former German Democratic Republic may have contributed substantially to this decrease. But at least for the last few years further decreases are attributable to other effects.

The following figure 2 shows the ranking of Annex-B countries according to their 1990 baseline emissions, based on national communications.

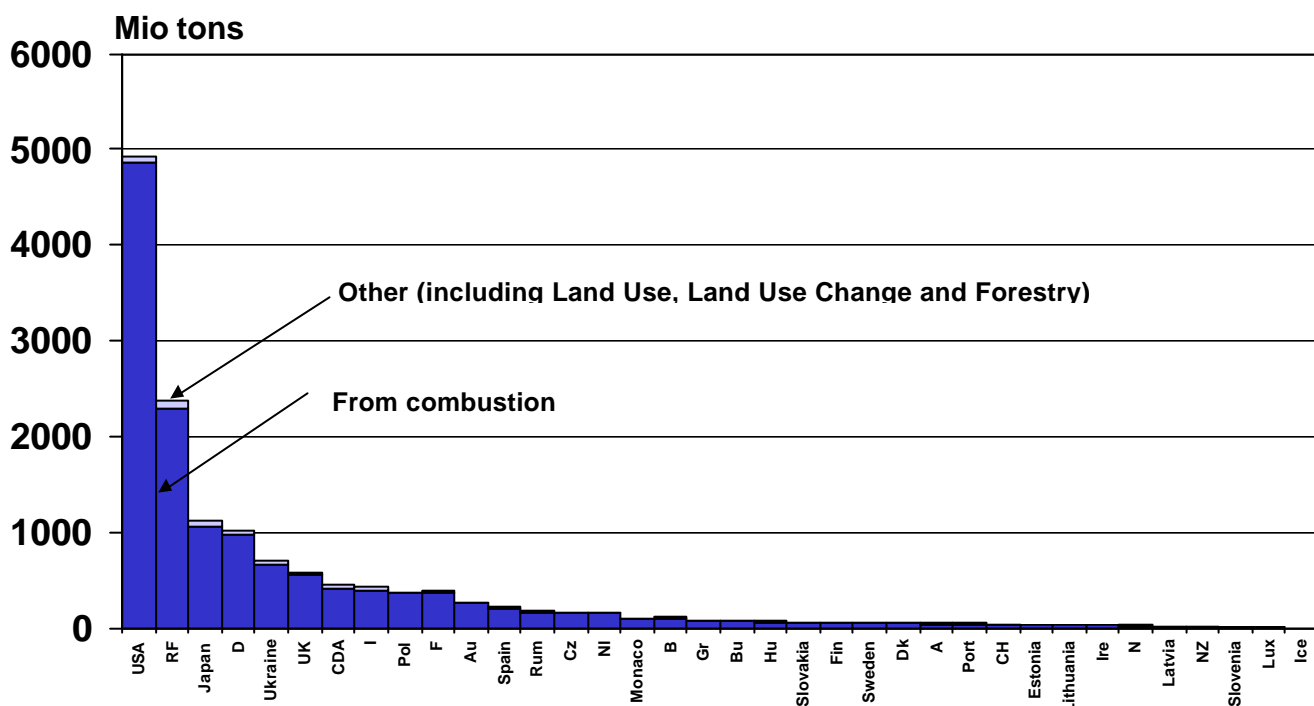


Figure 2: Ranking of Annex-B countries according to their 1990 CO<sub>2</sub> – emissions. Note that in extension to table 1 also the emissions and sinks (LULUCF) other than from combustion are included. The data are taken from UNFCCC [2]

Note that the four largest emitting countries USA, RF (= Russian Federation), Japan and Germany covered two thirds of the Annex-B emissions in 1990. (In both calculations, with UNFCCC figures and with BP energy data). In 2000 this share increased slightly to 68.6 percent.

### 3.2 Emissions of Non Annex-B Countries Using the LBST method:

Table 2 lists the non Annex-B countries and their CO<sub>2</sub>-emissions from fossil fuel combustion. These figures are derived from fossil fuel combustion applying the above specified emissions factors for oil, gas and coal.

Table 2: CO<sub>2</sub>-emissions of non Annex – B countries. The emissions are calculated with the above described LBST-method (in Tg)

Country	1990 Emission	2000 Emission	Change
Algeria	62.5	76.3	22 %
Argentina	100.4	130.7	30 %
Azerbaijan	58.1	33.4	- 43 %
Bangladesh	16.6	31.8	91 %
Belarus	107.4	49.7	- 54 %
Brazil	220.2	320.5	46 %
Chile	32.5	60.7	87 %
China	2405	2573	7 %
China-Hongkong	40.1	48.4	20 %
Colombia	50.4	52.1	3 %
Ecuador	12.9	19.8	54 %
Egypt	88.6	118.9	34 %
India	606.5	970.8	60 %
Indonesia	145.9	254.7	75 %
Iran	192.4	303.9	58 %
Kazakhstan	244.3	123.8	- 49 %
Kuwait	29.3	43.6	49 %
Malaysia	59.6	110.9	86 %
Mexico	273.7	350.0	28 %
Pakistan	63.2	105.8	68 %
Peru	18.9	23.9	27 %
Philippines	38.5	67.1	74 %
Saudi Arabia	222.7	283.9	28 %
Singapore	61.2	90.9	49 %
South Africa	323.0	381.4	18 %
South Korea	249.5	514.0	106 %
Taiwan	127.5	244.7	92 %
Thailand	84.4	177.5	110 %
Turkey	158.8	227.9	43 %
Turkmenistan	34.7	40.0	15 %
UAE	72.7	111.0	53 %
Uzbekistan	128.8	128.0	- 0.6 %
Venezuela	101.0	124.7	23 %
other			
<b>Total</b>	<b>7549.0</b>	<b>9351.0</b>	<b>23.9 %</b>

In total , the emissions rose over the ten year period by 24 percent with strongest increases in Thailand (110 %), South Korea (106 %), and Taiwan (92 %).

Reduced emissions are only seen from those Economies in transition which are not included in Annex-B.

The largest states with emerging economies are China and India. While India's emissions rose by 60 %, Chinas emissions, surprisingly, rose only moderately by about 7 %.

The following figure 3 shows a ranking of non Annex – B countries according to their calculated 1990 emissions (blue or dark bars at left). The green bars give the calculated 1999 emissions, the right bars the calculated 2000 emissions.

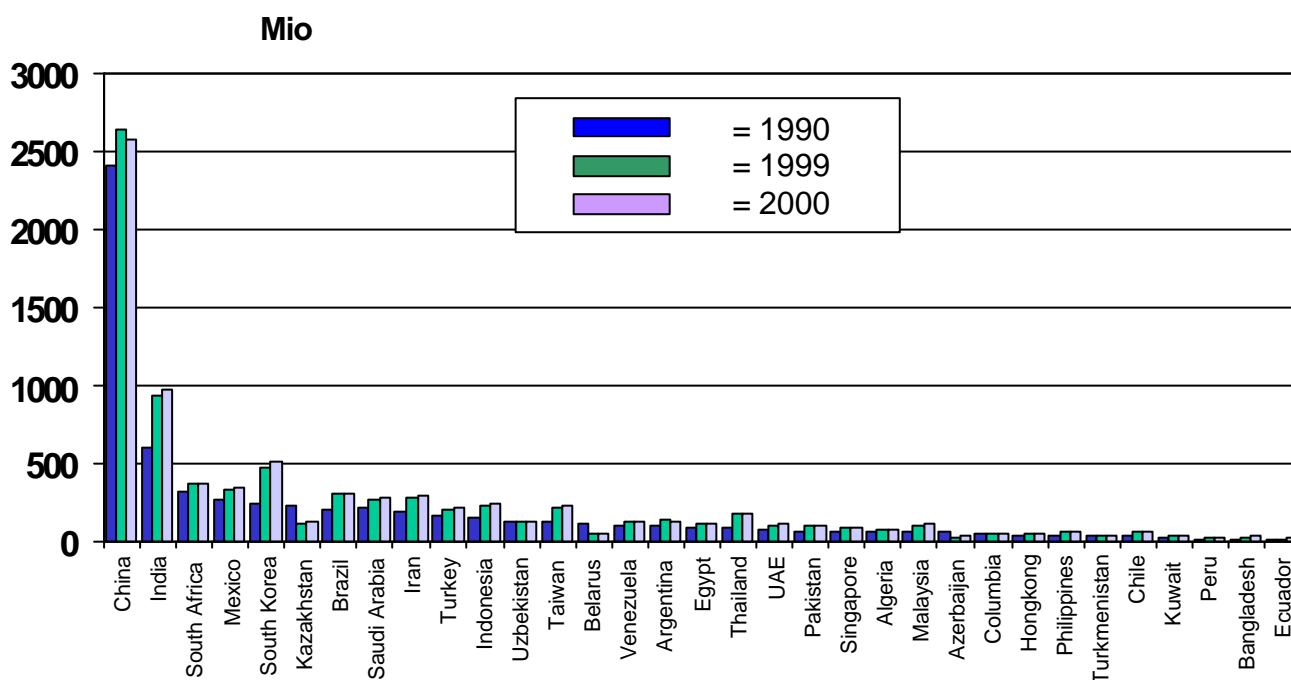


Figure 3: Ranking of non Annex-B countries according to their 1990 emissions. The green bars (middle) show the 1999 emissions, the violet bars (right) the 2000 emissions

South Korea, in 1990 the fifth largest emitter, now is the third largest CO<sub>2</sub> emitting non Annex-B country. The four most emitting countries China, India, South Korea and South Africa, covered in 2000 about half of all non Annex-B emissions.

### 3.3 Emission Changes 1990 to 2000

In figure 4 the countries are listed according to a ranking of their relative emission changes 1990 to 2000. As specified above the emerging markets Thailand, South Korea and Taiwan exhibit the strongest CO<sub>2</sub>-emission increases with more than 90 %. Bangladesh increased its emissions also by about 90 percent, though still at a very moderate absolute level.

The Annex-B countries are marked with red bars. In Europe, the strongest relative increase was in Portugal, Ireland and Iceland with about 40 – 45 percent. Emission reductions happened only in former central planning economies (so called Economies in Transition) and in UK, Switzerland, Sweden and Germany. Germany profits to some extent from the inclusion of the former German Democratic Republic. But, as shown below, its reduction is also due to additional effects.

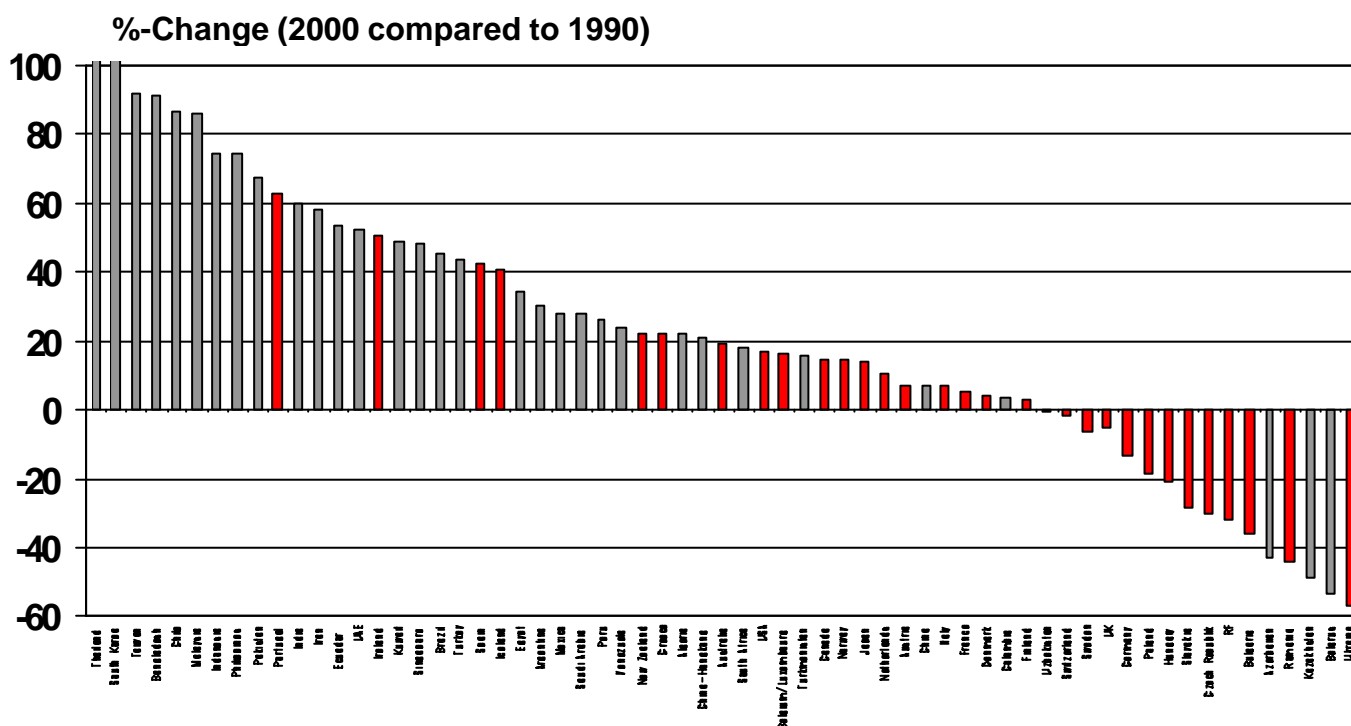


Figure 4: Relativ changes of CO<sub>2</sub> emissions in 2000 with respect to 1990 emissions. Annex – B countries are marked with red or dark bars

### 3.4 Development of CO<sub>2</sub> Emissions

Figure 5 shows the time development of the CO<sub>2</sub>-emissions. The thick line shows the development of the worlds CO<sub>2</sub> – emissions from fossil fuel consumption according to LBST-method.

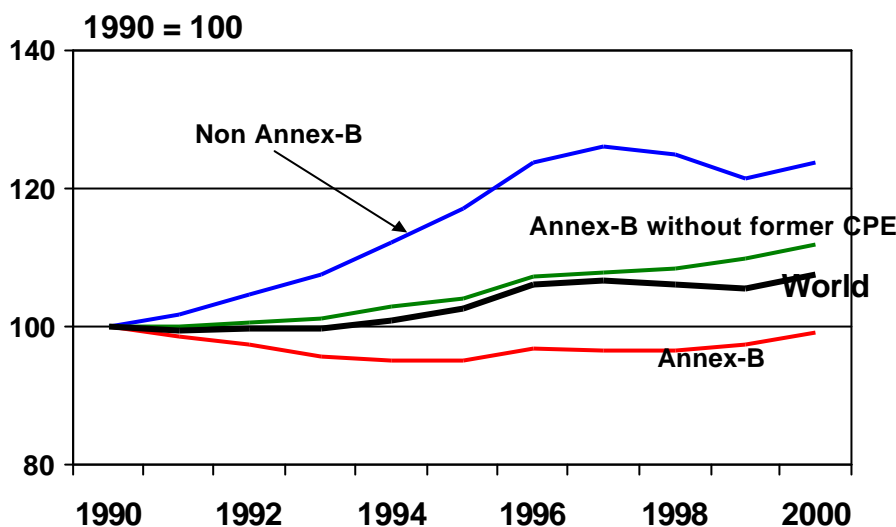


Figure 5: Development of CO<sub>2</sub> emissions from fossil fuel consumption. The thick line gives the world total emissions. The various thin lines show the emissions from Annex-B and non Annex-B countries as marked in the figure.

The 7.5 percent increase in world CO<sub>2</sub> emissions results from a very inhomogeneous time history: In the first period until about 1994 the emissions were almost constant. This is composed of a strong increase of emissions from non-Annex-B countries and a decrease in Annex-B countries. Further splitting the emissions from Annex-B countries into those from OECD countries and formerly centrally planning countries (CPE or economies in transition) exhibits that the decrease of Annex-B countries' emissions was almost totally attributable to former CPE's. The emissions from OECD countries rose also over this period.

Between 1994 and 1996 global emissions rose by about 3 percent per year. This is due to an increase of emissions in both, Annex-B and non Annex-B countries.

Between 1996 and 1999 global CO<sub>2</sub> emissions slightly reduced. Since emissions from Annex-B countries remained constant over that period, this reduction is almost completely due to a reduction of the emissions in non Annex-B countries. In addition, neglecting the economies in transition exhibits that the emissions in the rest of the Annex-B countries (mainly the OECD countries) still increased over the last years.

Analysing this behaviour further shows that the decrease in global CO<sub>2</sub>-emissions since 1996 is almost completely due to reduced CO<sub>2</sub> emissions from China. However, in 2000 the increases in India outweigh the still ongoing decrease of China's emissions. This is shown in figure 6.

The Economies in Transition started to increase their energy consumption and CO<sub>2</sub>-emissions in the late 90ies, but still at a lower rate than expected by most observers. Australia, Japan and the United States of America increased their emissions steadily over the nineties by about 15-20 percent each ignoring their aim adopted in the Climate Convention to return to their 1990 levels in 2000. This increase is twice the world average.

The European Union kept its emissions almost constant. This was mainly due to reductions in Germany (which profited from the inclusion of the former GDR) and in the UK. Germany, which is also explicitly listed in the figure, shows a steady decrease of emissions even over the last few years, indicating that the former GDR contributed only partly to that emission reduction. Other effects are also responsible for that as, e.g., a steady shift from coal to less carbon intensive fuels.

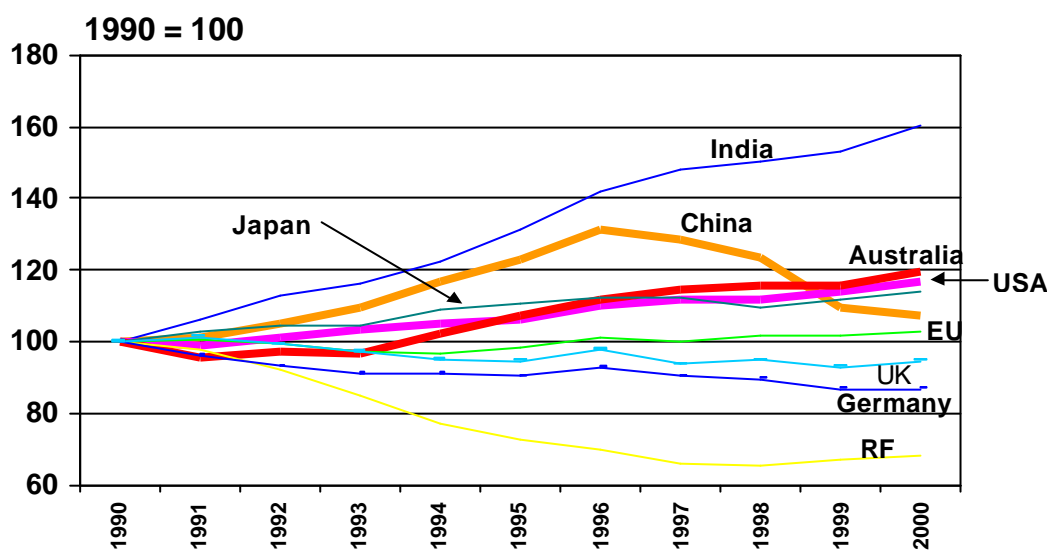


Figure 6: CO<sub>2</sub> emissions from leading Annex-B and non-Annex-B countries

The Russian Federation (RF) had the strongest emission reduction with almost 35 percent. As expected the reduction was strongest within the first few years. Over the last years emissions have already slightly been increasing again.

The most remarkable change with global influence happened in China. In 1996 the CO<sub>2</sub> emissions were at maximum. Now they have been falling the fourth year in a row. In contrast, the second largest non Annex-B emitter, India, still shows a steady emission increase of about 60 percent in total.

From figure 6 it looks like that existing trends changed considerably only in China.

Figure 7 shows that these changes in CO<sub>2</sub> emissions are not only due to a reduction of primary energy consumption but also to a switch from carbon rich to less carbon rich energy sources.

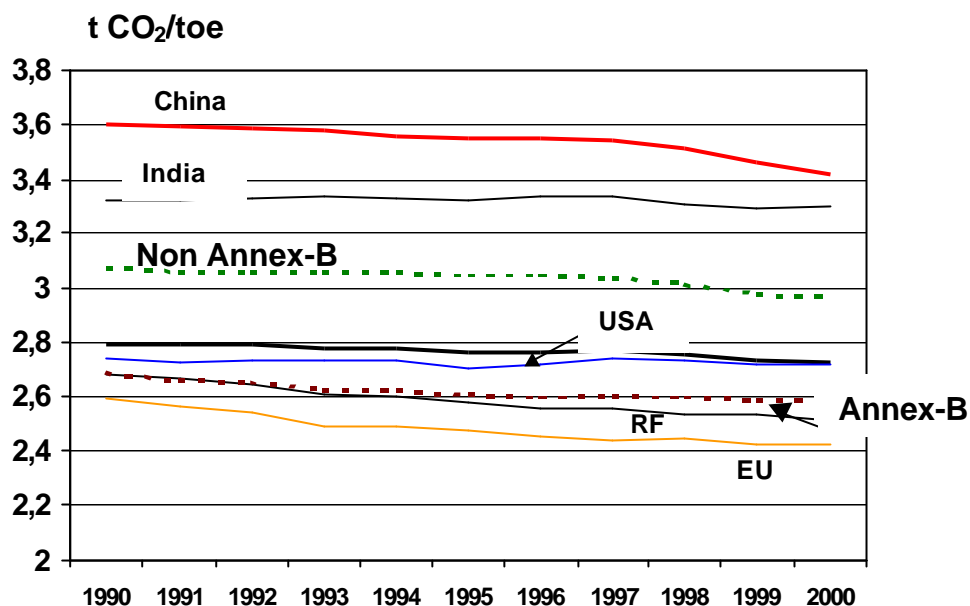


Figure 7: Average CO<sub>2</sub>-emissions per primary energy consumed for various leading countries and regions

On the average, specific carbon emissions per primary energy unit reduced by about three percent. Note, that BP Statistical Review of World Energy includes only the commercially traded energy sources oil, gas, coal, nuclear and hydropower. All forms of renewable energy (except hydro) are excluded from this statistics and not taken care of in this analysis.

Nevertheless, the figure shows that China still has by far the most carbon rich energy economy emitting about 3.4 t carbon dioxide per consumed ton of oil equivalent primary energy. However, over the recent years China started to switch its energy supply to less carbon rich energy sources. This switch together with a similar switch of the EU countries and the RF is responsible for the reduction of the specific carbon emissions per energy unit.

The United States of America is the only investigated country which kept its carbon intensity almost unchanged over the last ten years while nearly all other countries improved their carbon balance. We believe that this behaviour is at least to some extent due to the fact that severe supply constraints of the domestic alternatives gas and oil appeared over the last years which force the USA, to stay on coal consumption. Domestic oil production has decreased for almost 30 years, domestic gas production from large old fields started to decline.

## 4 Primary Energy Consumption

### 4.1 The Share of Fossil Fuels

Figure 8 shows the change of the energy mix in Annex-B and non Annex-B countries. The general trend of a reduction of coal share in the world energy mix increased over the last few years, mainly triggered by the reduction of the coal share in non Annex-B countries. But still, coal share in non Annex-B countries with about 31 % is far above the coal share in Annex-B countries (about 21 %).

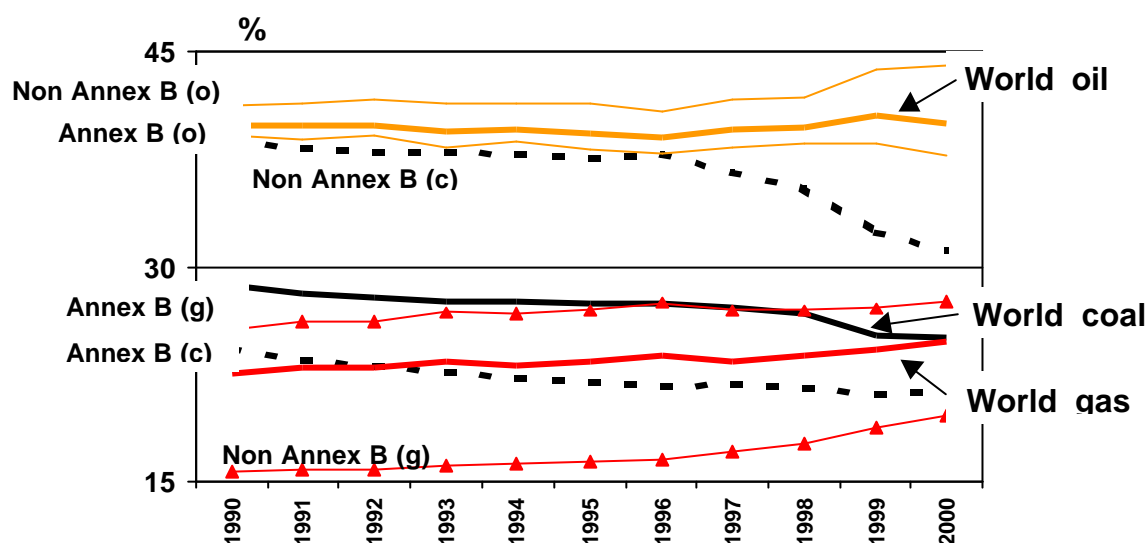


Figure 8: Development of the share of oil, gas and coal on the primary energy mix for the world, the Annex-B and the non-Annex-B countries from 1990 to 2000. Thick lines represent world averages. Broken lines are for coal. The other thin lines are for oil and gas where each pair (Annex-B and non Annex-B) belongs to a thick world average line in between of them.

The share of gas rose slightly over the last ten years in the Annex-B countries from about 25 percent in 1990 to 27 percent in 2000. Though still at a much smaller level the non Annex-B countries increased the share of gas over the last few years from 15.8 percent to 19 percent.

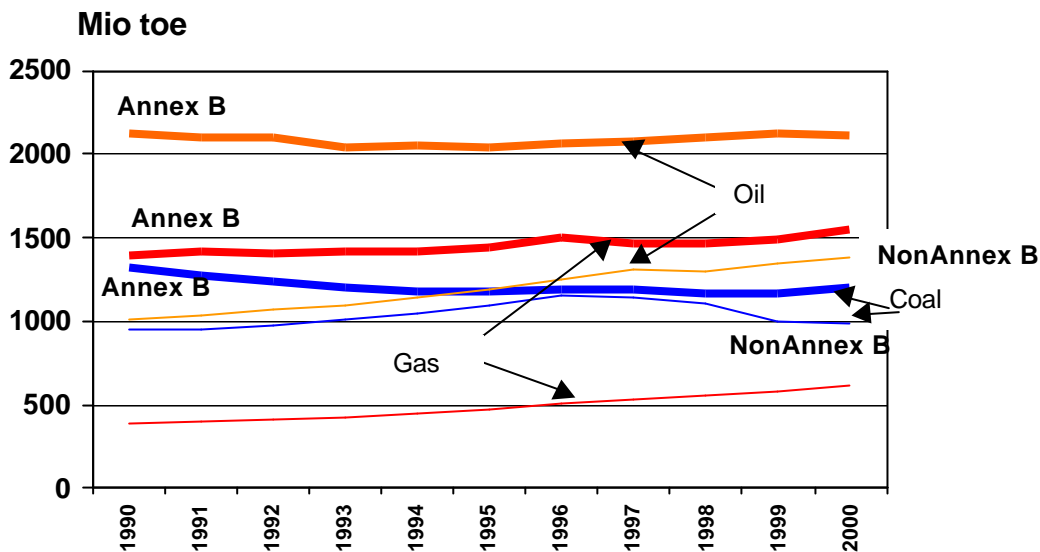


Figure 9: Consumption of oil, gas and coal in Annex-B and non-Annex-B countries. Thick lines represent Annex-B countries, thin lines are for non Annex-B countries

Figure 9 shows the development of the fossil fuel consumption in Annex-B and non Annex-B countries in absolute figures. On the average, the gas consumption rose in Annex-B countries by about 11 %, followed by oil with -0.3 % and coal with -9 %. In non Annex-B countries gas consumption increased by 60 %, oil consumption by 37 % and coal consumption by about 4 %.

## 4.2 Coal Consumption

Since coal has by far the highest specific CO<sub>2</sub> emissions, a reduction in coal consumption shows the strongest effects in reducing carbon dioxide emissions. Figure 10 gives the coal consumption since 1990 for the world, the Annex B and non Annex-B countries and several large consumers.

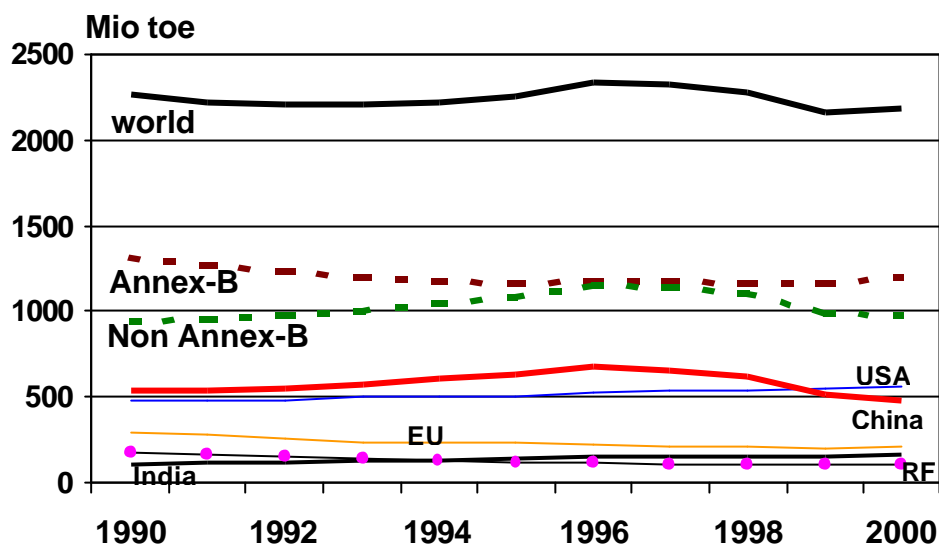


Figure 10: Coal consumption for world, Annex-B and non Annex-B countries. Also shown is the development for various leading countries and regions.

World coal consumption reduced slightly since 1990 by about 4 percent. The disaggregation in Annex-B and non Annex-B countries shows that consumption decreased in the first half of the nineties in the Annex-B countries and was almost constant for the second half of the period.

This decrease is partly due to a decrease of the total energy consumption in the Economies in Transition. But even the European Union reduced its coal consumption by about 30 percent. The main increase of coal consumption happened in the USA with about 17 percent, which transformed to the world's largest coal consumer in 1999 (even in front of China – which was in 1990 the largest coal consumer). This trend continued in 2000.

The non Annex-B countries increased their coal consumption until 1996 by about 24 percent. But since 1996 the consumption has reduced considerably, resulting in a slight increase of 4 percent since 1990.

The second largest non Annex-B consumer, India, increased its consumption by about 54 percent. However, China, in 1990 the world's largest consumer, reduced the coal consumption since 1990 by about 10 percent, nearly outweighing the increases of all other countries. Moreover, China still increased the coal consumption in 1996 to a maximum. With the change of the energy policy and the reduction of subsidies for coal supply, the efficiency increased considerably, reducing the coal consumption within four years since 1996 by about 30 percent.

It might be worth mentioning that China reduced the coal consumption below the level of the United States of America. The USA increased their consumption with 82 Mtoe even more than India 57 Mtoe).

Figure 11 shows the share of coal in the energy consumption of the individual regions. Worldwide, the coal share reduced from close to 30 percent in 1990 to 25 percent. This reduction is mainly due to the non Annex-B countries where even India with the large absolute increase reduced the share of coal consumption. Even more pronounced is the reduction in China as already mentioned. Also the European Union reduced the coal share. The United States of America kept the coal share nearly constant over the last ten years, as well as Japan. In Japan it remained by about 18 percent, though the absolute coal consumption increased by about 20 percent.

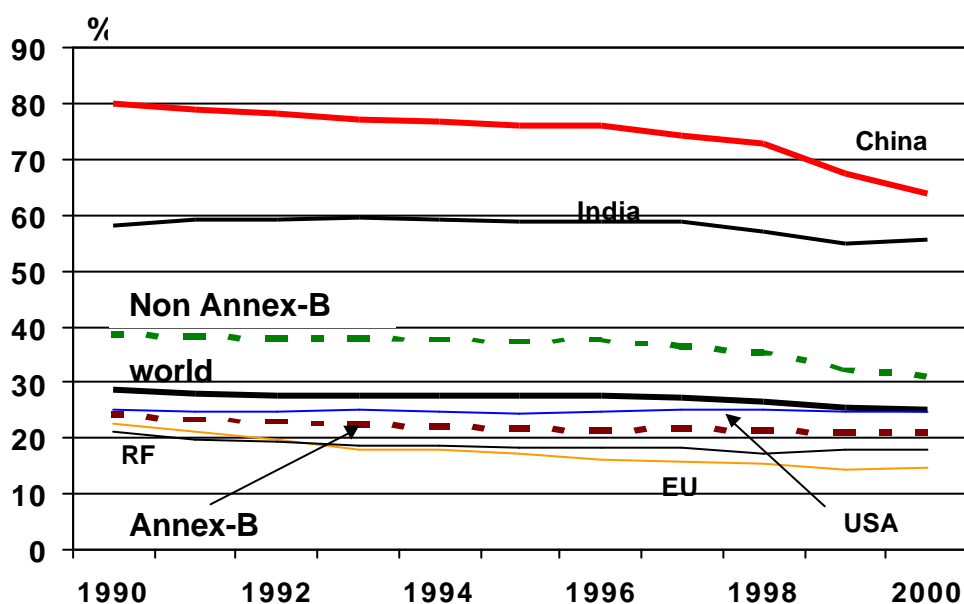


Figure 11: Share of coal consumption in primary energy use in the world, in Annex-B, non Annex-B countries and several leading countries and regions.

## 5 References

- 1 BP Statistical Review of World Energy (see at <http://www.bp.com>)
- 2 CO<sub>2</sub> emissions of Annex-I countries (see at <http://www.unfccc.de> )

## 6 Abbreviations:

CPE	Centrally planning economies (Former CPE are identical to EIT)
EIT	Economies in Transition
EU	European Union
FCCC	Framework Convention on Climate Change
GDR	Former German Democratic Republic (since 1990 part of Germany)
Gg	Gigagramm (identical to kt = kiloton)
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
Mtoe	Million tons of oil equivalent
RF	Russian Federation
Tg	Teragramm
UAE	United Arab Emirates
UK	United Kingdom
USA	United States of America

## 7 Appendix:

Fossil fuel consumption 1990 – 2000 according to BP Statistical Review of World Energy and calculated CO<sub>2</sub> emissions based on these statistics and the emission factors discussed in the text.