Scenarios of World Anthropogenic Emissions of Air Pollutants and Methane up to 2030

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1 Introduction

Global warming is influenced not only by the emissions of direct greenhouse gases, but also – in the indirect way - by the emissions of air pollutants. While NO_x, CO, and non-methane VOC contribute to global ozone formation, emissions of sulphur dioxide form aerosols, which have important cooling effect. Methane is the second most important greenhouse gas, and accounts for ca. 20% of the direct radiative forcing from greenhouse gases.

This paper describes two scenarios of global emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and methane (CH_4). The "current legislation" (CLE) scenario reflects the current perspectives of individual countries on economic development and takes into account the anticipated effects of presently decided emission control legislation. The "maximum technically feasible reduction" (MFR) scenario outlines the scope for emission reduction offered by a full implementation of the best available emission control technologies. These scenarios were used for the assessment of the effect of emissions of air pollutants and methane on tropospheric ozone and radiative forcing (Dentener et al., 2004). Currently the same data set is used for additional simulations within the IPCC-AR4 /ACCENT project (compare http://www2.nilu.no/farcry_accent/).

The analysis was done for national energy scenarios, as compiled for the needs of the integrated assessment of regional air pollution. Among the factors that determine the future evolution of emissions from anthropogenic sources, the changes in the volumes of emission generating activities (activity rates) due to economic development and changes in the unit emissions (emission factors) due to applied emission control measures are most relevant. For this analysis we used a global version of the Regional Air Pollution Information and Simulation (RAINS) model (Amann et al., 1999) to systematically compile country- and sector-specific information for all countries and regions of the world up to the year 2030. Essentially, the RAINS model combines national perspectives on sectoral economic development with emission factors that describe the technical features of the emission sources, considering their change over time resulting from country- and sector-specific emission control legislation. Emissions of pollutants are calculated as a product of activity level, uncontrolled emission factor, removal efficiency of control technology applied in a given sector, and implementation level of that technology in a given emission scenario.

To derive global assessment, we used the European (Amann *et al.*, 2004) and Asian (RAINS-Asia, 2001, Cofala *et al.*, 2004, Klimont et al., 2001) implementations of the RAINS model and complemented them with country-specific data for North America, the countries of the former Soviet Union, Latin America, Africa and Australia. In total, we prepared estimates for the period 1990 – 2030 for 75 countries or country groups. Detailed emissions by scenario and country are available from the IIASA web page:

http://www.iiasa.ac.at/rains/global_emiss/global_emiss.html

Main assumptions about the development of emission generating activities and data sources are discussed in Section 2. Section 3 presents the assumptions on emission factors and control techniques used in our scenarios. Next section presents the resulting emissions and compares them with the assessment done within the SRES study (Nakicenovic et al., 2000). Finally, Section 5 summarizes main findings and formulates conclusions.

2 Projections of activity levels

For all countries and regions included in our analysis, we collected to the possible extent the present national perspectives on future sectoral economic and energy development up to the year 2030. We distinguished fuel consumption by economic sector and fuel type, transport activities, production levels by industrial sectors. To assess the emissions from agriculture we used available projections of livestock farming.

In particular, in RAINS we use estimates of fuel consumption for the following economic sectors:

Power plants
Industry
Domestic (residential-commercial sector)
Road transport
Off-road mobile sources.

The RAINS model takes into account 22 fuel types in this analysis. Transport sources are divided into several vehicle categories. In the road sector we include cars and light duty trucks, heavy-duty trucks, motorcycles and mopeds. Emissions are assessed separately for vehicles with spark ignition and compression ignition (diesel) engines. In the off-road sector we include sources like rail, inland waterways, agricultural tractors and machines, construction machinery etc. Besides, the emissions are estimated for more than 20 industrial processes in energy production sector, iron and steel, metal production, chemical industry and other. Also emissions from waste treatment and disposal are estimated by the model.

Sources relevant for CH_4 emissions include:

Livestock farming (enteric fermentation and manure management for six types of animals)
Rice cultivation
Waste (solid waste and wastewater)
Production and distribution of fuels in the coal, gas and oil sectors

National projections used in our study reflect national governmental expectations and probably in many cases also merely policy ambitions. Thus there is no guarantee for international consistency, e.g., in the volumes of exports and imports or in the underlying assumptions on the development of oil prices. However, the value of this set of projections is that it reflects bottom-up expectations on economic development as seen today by the individual countries.

For Europe our analysis uses the baseline projections for the enlarged EU of 25 countries from the European Commission's study on energy and transport trends to 2030 (EC, 2003). For the non-EU countries we used national projections as compiled for the environmental outlooks study of the European Environment Agency (EEA, 2002). Projection for Russia is based on official national energy strategy developed by the Russian Ministry of Industry and Energy (MTE, 2003). It has been converted to the RAINS format and extended till 2030 by Popov, 2003. Projections for Asia have been extracted from the RAINS-Asia database (Cofala et al., 2004, Boudri et al., 2002), which combines national economic projections from 22 Asian countries, distinguishing 39 provinces (or mega-cities) in China and 20 states/mega-cities in India. To derive projections for the other world regions, we adjusted the national energy consumption and industrial production levels as reported by the International Energy Agency (IEA, 2002) and the UN commodity statistics (UN, 2003) for the year 2000 following the trends of future economic and energy development from the IPCC SRES B2 scenario, as calculated with the MESSAGE model (Riahi and Roehl, 2000, Nakicenovic, 2000). Since the official energy statistics of many developing countries do not include total biomass fuel consumption, biomass use data for Latin America and Africa was taken from Riahi and Roehl, 2000.

Agricultural scenarios necessary to estimate methane emissions originate to a large extent from the existing RAINS databases. Missing information (for countries not covered up-to-now with RAINS) was taken from FAO (2002), Nakicenovic et al. (2000), Houghton et al. (1997a, b) and UN Population Division (2000).

Compilation of national expectations of the development of energy demand within the next 30 years results in an increase of world CO_2 energy-related emissions of about 4.4 PgC/yr, which lies between the B2 marker scenario (MESSAGE – 3.3 PgC/yr) and more coal –intensive alternative scenarios from the same family (B2-AIM, B2C- Maria, B2High-MiniCAM – 4.8 – 4.9 PgC/yr – compare Nakicenovic et al., 2000).

It needs to be stressed that our study did not assess emissions from biomass burning, form air traffic as well as from international sea traffic. For the needs of global atmospheric modeling these emissions were taken from other studies (for details see Dentener et al., 2004).

3 Derivation of emission factors

As mentioned above, the RAINS model calculates emissions as a product of activity levels and emission factors. Emission factors for NO_x distinguishing the removal efficiencies of individual control technologies have been taken from the RAINS database (Cofala *et al.*, 2000; Cofala and Syri, 1998a), which has been extensively reviewed by European and Asian experts from academia, governments and industry. For Europe, North America, Russia and Southeast Asia we used country-specific emission factors that reflect the national characteristics of the emission sources (e.g., fuel quality, fleet composition, maintenance levels, etc.), and we applied general default factors for the other countries. CO emission factors were derived from the IPCC guidelines (IPCC, 1997). In addition, some factors (e.g., for wood burning in the domestic sector, US-specific factors for mobile sources) were taken from the EPA database as used for the US emission trends report (EPA, 2001). In case of SO_2, the emission factors depend on quality of fuel burned (i.e., sulfur content, calorific value, and sulfur retained in ash) and types and removal efficiencies of control technologies applied to mitigate the emissions. Similarly as for NOx, information on control technologies has been taken from the RAINS database (Cofala and Syri, 1998b). Important parameters determining emissions from coal burning (e.g., sulfur content, calorific value, existing emission control equipment, etc.) for countries for which information was not available from national sources have been taken from the IEA Coal Research directory of world coal fired power plants (IEA CR, 1997).

Emission factors for methane have been compiled from the literature (with the IPCC recommended emission factors (Houghton et al. 1997a, Houghton et al. 1997b) as a starting point) and adapted to country-specific circumstances. In addition, other information like the EDGAR 3.2 database (RIVM, 2002) was used to validate and, if results seemed implausible, to adjust emission factors. Details are available from Höglund-Isaksson and Mechler, 2004, Mechler 2003.

For the future evolution of emission factors, we consider the country-, sector- and technology-specific impacts of emission control measures that are imposed by present legislation (the "current legislation" – CLE scenario). The RAINS model contains reviewed databases on the technical features of the most important emission control technologies that are presently available. For instance, to control NO_x emissions from stationary sources several primary (combustion modification) measures as well as secondary measures (e.g., selective catalytic reduction – SCR) are available. Sulfur emissions can be controlled by using fuels with lower S content or through flue gases desulfurization. Emissions from mobile sources may be reduced through engine modifications or implementation of catalysts and filters. Measures applied on mobile sources simultaneously reduce several pollutants (NOx, hydrocarbons, CO, fine particles).

Examples of emission control options for methane are: modified diet for livestock with improved feed conversion efficiency, manure management, alternative rice strains, as well as several technologies for waste treatment (e.g., paper recycling, CH_4 recovery from landfills), and reduction of methane emissions from energy production, transmission and distribution (recovery of coal bed methane, better utilization of waste gases, minimization of gas leakages etc.). Details can be found in the cited above literature.

For this study, we compiled for all countries the state of national legislation on emission controls as of the end of 2002 and its evolution in the coming years as laid down in the present national legislations. While there is well-documented information for most industrialized countries available, information for many developing countries is sparser. However, a wealth of relevant information on new legislation became recently available, especially on emission standards for the transport sector in Asia and Latin America (Weaver and Walsh, 1996, Bertelsen and Walsh, 2000, CAI, 2004). For Europe and North America, we consider international and national fuel quality and emission standards as currently in force. In addition, we assume for the European countries enforcement of technical standards required by the Gothenburg Protocol to the Convention on Long-range Transboundary Air Pollution. Country-specific information for South-east Asia was collected in the context of the RAINS-Asia II project (RAINS-Asia, 2001, Boudri, 2002) and updated with recent information on mobile sources from CAI, 2004. For other countries and world regions, information for stationary sources was taken from the emission standards handbook (Mc Conville, 1997).

In addition to the “current legislation” (CLE) scenario, we estimated the theoretical scope for emission controls offered by full application of all presently available technical emission control measures (the “maximum technically feasible reduction” - MFR scenario). Considering this calculation as a theoretical analysis of the long-term reduction potential, we did not take account of practical limitations on the penetration of most advanced emission control measures imposed by the gradual turnover of existing capital stock especially in the short run, and we did not estimate the obviously high costs of such a theoretical emission control strategy. On the other hand, we did not consider in this scenario the potential for emission reductions offered by structural changes, such as increased energy efficiency measures, fuel substitution, more efficient production technologies or reduced transport demand. Earlier studies have shown that the emission reduction potential of such measures is considerable and that some of them could be even cost-effective (e.g., Rentz et al., 1994, Van Vuuren et al., 2005).

4 Emission scenarios

With these data sources, we were able to reproduce national emission estimates for the year 2000 with quite high accuracy. For SO_2 and NO_x, estimates for most industrialized countries do not differ by more than five to ten percent, although there are somewhat larger differences to inventories for some developing countries that have been published by different sources (e.g., EDGAR - RIVM, 2002). Discrepancies between our CH_4 estimates and data reported to UNFCCC are typically in a range of 10 to 20 percent. However, for many countries the UNFCCC estimates are missing or are incomplete. On a regional level the RAINS assessment is consistent with other estimates (EDGAR, SRES). The differences between RAINS CO estimates and national inventories are for majority of countries within the same range as for methane. RAINS CO estimates of total world anthropogenic emissions (without biomass burning) are nine percent lower than EDGAR, which is mainly due to lower RAINS assessment for Europe, as well as lower numbers for Asia and Russia. The differences are caused by different assessment of the emissions from coal and wood burning in small stoves, as well as different assumptions about the effect of catalytic converters on the emissions of mobile sources. The latter factor was particularly important for Europe. The SRES estimates are about 15 percent lower than RAINS, which indicates still existing uncertainties of emission factors for the mentioned above categories of sources.

4.1 Sulfur dioxide

With the data and assumptions described above we estimated the future development of SO_2 emissions. The results for individual world regions are shown in Table 4.1. According to the RAINS estimates, the world emissions of SO_2 in 1990 were about 122 million tons. In 2000 the emissions were about 20 percent lower, which was mainly due to strict controls implemented in Western Europe, but also due to economic restructuring in Central and Eastern Europe and in Russia and Newly Independent States. Under the Baseline assumptions, the world emissions decrease to about 97 million tons in 2010 and then increase again to 105 million tons by 2030. Implementation of the best available control technology (the MFR scenario) reduces the emissions to about 20 percent of the 1990 level.

Future development of emissions is strongly region-dependent. In five regions (Pacific OECD, Russia and Newly Independent States, Middle East and North Africa, Central and Eastern Europe, and Western Europe) the emissions decrease by 40 to even more than 60 percent. The decrease in North and Latin America is modest (5 – 14 percent). The emissions from the Centrally Planned Asia and China stabilize at a level close to 2000 emissions. However, if policy targets from the recently announced pollution control plans in China materialize, the resulting emissions might importantly decrease. National projections anticipate a high increase of the consumption of coal in many countries of South and Pacific Asia. Since simultaneously the SO_2 emission control legislation in those countries is rather liberal, the SO_2 emissions are likely to increase. This is particularly dramatic in South Asia, where the current policies might cause a factor of three increase compared with the current level.

Obviously, the scope for emissions reduction down to the MFR level is strongly depending on the stringency of the already implemented measures and thus differs greatly among countries/world regions. While our calculations show a limited potential in Europe, there remains significant scope in many developing countries.

Figure 4.1 compares our estimates with sulfur emissions for two scenarios included in the SRES report (Nakicenovic et al., 2000). For 1990 the SRES emissions as calculated by the MESSAGE model are quite consistent with our assessment. The difference is less than seven percent. However, for 2000 the SRES emissions are about 20 percent higher. The likely reason for these differences is that SRES simulations did not include the effects of emission controls implemented in many countries in recent years. Also changes in fuel quality and fuel mix due to economic restructuring in China, Central and Eastern Europe (including the former GDR), and in the countries of the former Soviet Union seem not to be fully incorporated into the SRES analysis.

The SRES estimates for projection years depend heavily on the development pathway. Whereas the emissions in 2030 for the B2 scenario are only 5 percent higher than the assessment presented in this study, the emissions for the A2 scenario are 69 percent higher.

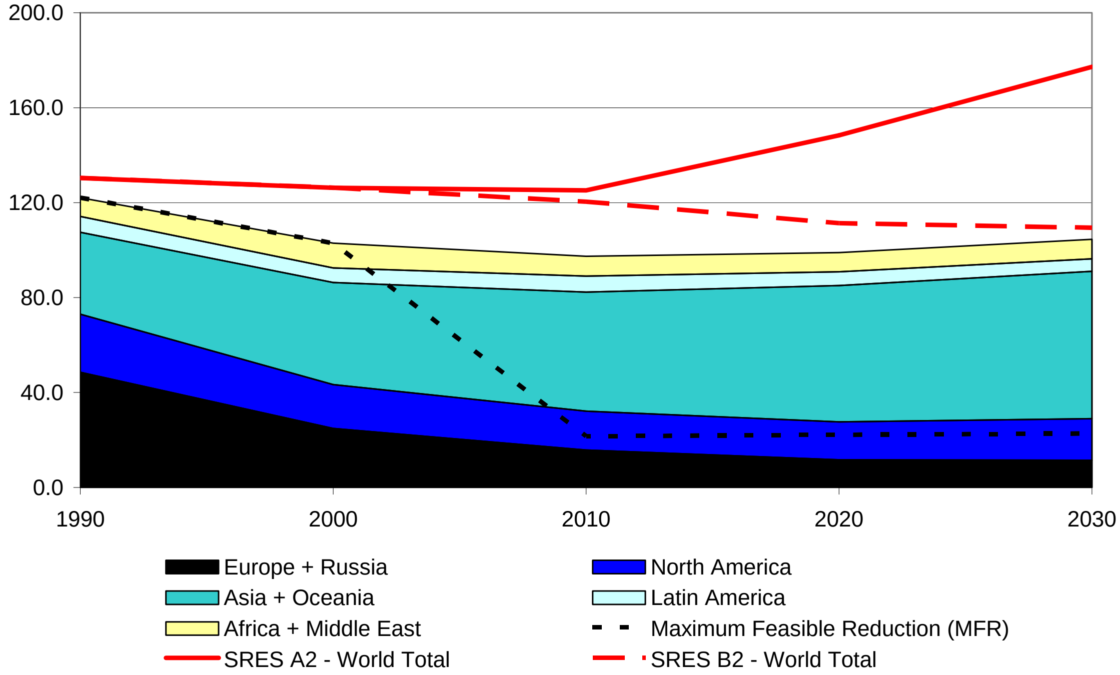

Figure 4.1: Projected development of anthropogenic SO_2 emissions by world region (million tons SO_2). Emissions from biomass burning, international shipping and aircrafts are not included.

Table 4.1: SO_2 emissions by SRES world regions, current legislation and maximum technically feasible reduction scenarios (million tons SO_2). Emissions from biomass burning, international shipping and aircrafts are not included.

			Current legislation (CLE)			Maximum feasible reductions (MFR)		
Region	1990	2000	2010	2020	2030	2010	2020	2030
Sub-Saharan Africa	4.8	5.4	4.9	5.2	5.8	1.3	1.3	1.3
Centrally Planned Asia and China	22.0	28.4	30.9	31.1	29.4	6.7	6.6	6.4
Central and Eastern Europe	11.1	5.9	4.1	2.6	2.3	0.8	0.6	0.6
Latin America and Caribbean	6.7	6.2	6.8	5.8	5.3	1.8	1.8	1.7
Middle East and North Africa	3.1	5.0	3.5	2.8	2.4	0.8	0.7	0.7
North America	24.4	18.5	16.4	15.9	17.5	2.9	3.2	3.3
Newly Independent States	19.5	11.1	7.8	6.0	6.3	1.8	1.7	1.7
Pacific OECD	2.7	2.6	2.8	2.1	1.5	0.6	0.5	0.5
Other Pacific Asia	5.1	4.3	5.4	6.9	8.7	1.5	1.8	2.0
South Asia	4.8	7.6	11.0	17.3	22.5	1.9	2.6	3.3
Western Europe	17.9	7.9	3.8	3.1	2.9	1.4	1.3	1.2
World Total	122.1	102.9	97.4	98.9	104.5	21.5	22.2	22.7
SRES B2 (Message)	130	126	120	111	109	-	-	-
SRES A2 (Message)	130	126	125	148	177	-	-	-

4.2 Nitrogen oxides

The regional development of NO_x emissions for the two scenarios is shown in Table 4.2. Our calculations suggest a strong decline in Europe and stabilization in North America due to present emission control legislation despite the underlying economic growth and the corresponding increase in transport volumes. For Asia, current national expectations anticipate a growth in transport demand by a factor of four to five; however, under the assumption of full implementation of the recently decided pollution control legislation for vehicles, NO_x emissions would not grow till 2030 by more than 60 percent from present days levels. Latin American NO_x emissions are expected to stabilize due to recently imposed control requirements in majority of countries in this region. At the global level, this moderate increase in NO_x emissions from developing countries would be partly offset by the decline in European emissions, so that global anthropogenic NO_x emissions would grow by not more than 13 percent up to the year 2030 (Figure 4.1).

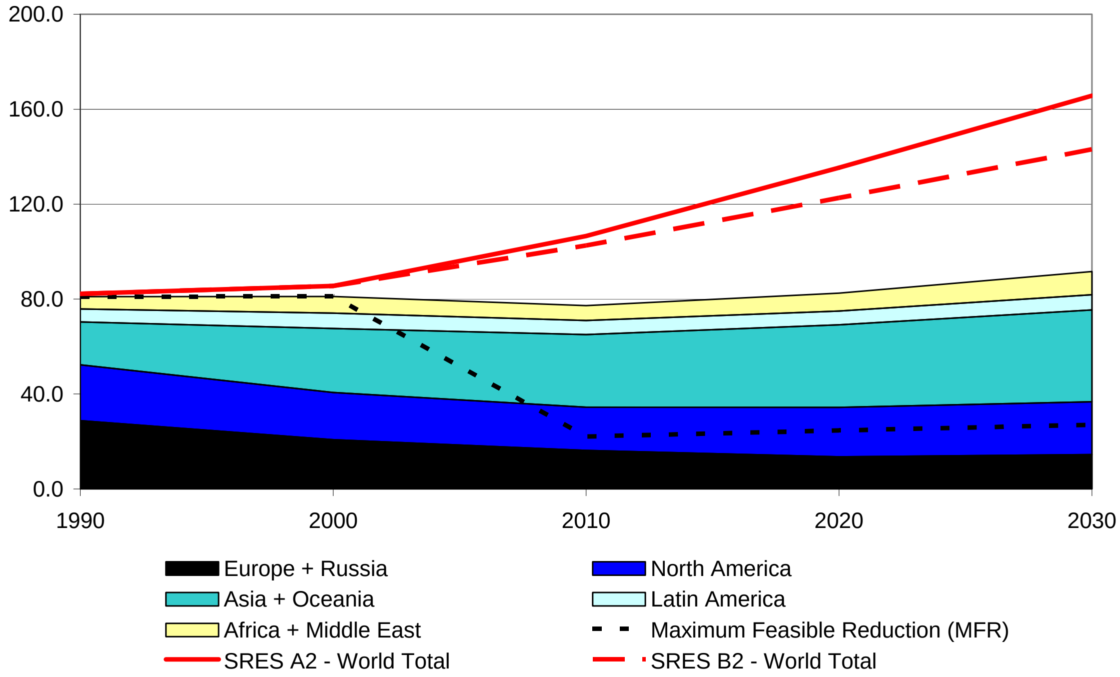

Figure 4.2: Projected development of anthropogenic NO_x emissions by world region (million tons NO_2). Emissions from biomass burning, international shipping and aircrafts are not included.

This estimated increase is significantly lower than projections from earlier studies, including the global emission scenarios published in the IPCC SRES report (Nakicenovic, 2000). While SRES estimates for the year 2000 are approximately six percent higher than our assessment, for 2030 the SRES scenarios suggest global anthropogenic NO_x to increase between 65 and 90 percent. With comparable rates of growth in the vehicle stock, the difference can be explained by different assumptions about pollution control legislation in our modeling exercise compared with SRES. The SRES scenarios do not include legislation in developing countries, which was introduced after finalization of the runs. This refers first of all to the legislation on mobile sources (catalytic converters, engine modifications), which became mandatory in many countries in Asia, Latin America, Eastern Europe and Russia. Besides, SRES simulations for the OECD countries include control measures as in force in mid-1990's, without further changes. In our scenarios we included recently decided stricter legislation in Europe (e.g., EURO IV/V standards on cars and trucks, Large Combustion Plant Directive, IPPC Directive for industrial sources), as well as current reduction plans in North America. Without inclusion of those control measures (both in the OECD and in the developing countries) the 2030 emissions would have been 50 percent higher than 2000 emissions. Approximately half of this difference results from implementation of controls in the developing world and reforming economies, the balance is due to phasing-in more stringent measures in the OECD countries. Remaining difference to the marker B2 scenario (MESSAGE) can be explained by different assumptions about activity levels.

Despite the control measures imposed by recent legislation, full application of present best available technology could lead to significant further reductions in global NO_x emissions. According to our calculations, the emissions decrease by approximately 70 percent in 2030 compared with the CLE case. The MFR scenario includes emission controls for vehicles and off-road sources up to the EURO-IV/ EURO-V standard, for large stationary sources the application of selective catalytic reduction (SCR) and for small stationary boilers the use of low-NO_x burners. Similarly as for SO_2, the scope for further reductions depends on the stringency of the "current legislation" measures and thus differs greatly over countries/country groups.

Table 4.2: NO_x emissions by SRES world regions, current legislation and maximum technically feasible reduction scenarios (million tons NO_2). Emissions from biomass burning, international shipping and aircrafts are not included.

			Current legislation (CLE)			Maximum feasible reductions (MFR)		
Region	1990	2000	2010	2020	2030	2010	2020	2030
Sub-Saharan Africa	2.6	3.7	3.7	4.8	6.7	1.1	1.2	1.4
Centrally Planned Asia and China	7.8	12.3	13.8	15.0	16.2	3.7	4.2	4.5
Central and Eastern Europe	3.5	2.8	2.0	1.7	1.8	0.6	0.6	0.7
Latin America and Caribbean	5.5	6.4	6.0	5.8	6.3	1.3	1.5	1.7
Middle East and North Africa	2.6	3.3	2.6	2.8	3.1	0.7	0.8	0.8
North America	23.4	19.9	18.3	20.8	22.2	5.7	6.3	6.8
Newly Independent States	11.2	7.2	6.7	5.9	6.7	1.5	1.6	1.8
Pacific OECD	3.7	3.7	3.4	3.2	2.8	1.2	1.1	1.0
Other Pacific Asia	3.5	5.6	5.8	6.9	8.2	1.6	2.0	2.4
South Asia	3.1	5.4	7.6	9.7	11.6	1.9	2.4	2.9
Western Europe	14.1	10.8	7.5	6.0	6.1	2.8	3.0	3.1
World Total	81.0	81.1	77.3	82.5	91.6	22.1	24.7	27.1
SRES B2 (Message)	82	86	103	123	143	-	-	-
SRES A2 (Message)	82	86	107	135	166	-	-	-

4.3 Carbon monoxide

For CO emissions, our analysis suggests for most world regions a reduction in the coming three decades. The highest decline (by 55 percent) occurs in Latin America, which is mainly due to a switch from fuel wood to other energy carriers in the residential sector. The only region with increasing emissions is Africa (plus ten percent). This leads to a global decrease of anthropogenic CO emissions of 16 percent, despite increased economic activities (Table 4.3 and Figure 4.3). This decoupling between economic growth and emissions is caused by the declining combustion of coal and fuel wood in households in small stoves and the penetration of three-way catalysts that reduce CO emissions from vehicles by typically between 80 and 90 percent. Without these presently decided pollution control measures for vehicles, global CO emissions would grow in our calculations by approximately 45 percent up to 2030, which is close to the lower range identified in the SRES scenarios.

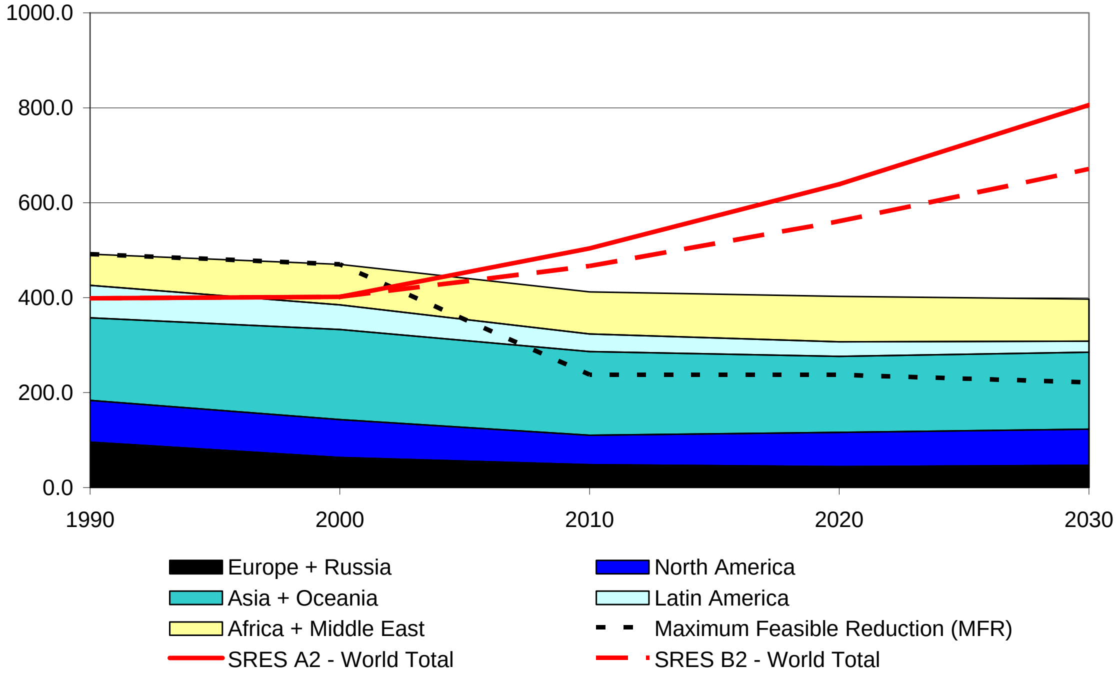

Figure 4.3: Projected development of CO emissions by world region (million tons CO). Emissions from biomass burning, international shipping and aircrafts are not included.

The maximum technically feasible reduction (MFR) scenario assumes full implementation of EURO IV/Euro V emission control standards for mobile sources, as well as good housekeeping measures on stationary combustion sources. However, this scenario does not consider possible reductions in energy demand (e.g., through energy efficiency measures) nor the potential offered by substitution of solid fuels by less polluting forms of energy. Based on these assumptions, the analysis suggests for 2030 a maximum reduction of CO emissions of 53 percent compared to the year 2000.

Table 4.3: CO emissions by SRES world regions, current legislation and maximum technically feasible reduction scenarios (million tons CO). Emissions from biomass burning, international shipping and aircrafts are not included.

			Current legislation (CLE)			Maximum feasible reductions (MFR)		
Region	1990	2000	2010	2020	2030	2010	2020	2030
Sub-Saharan Africa	54.6	73.8	82.5	89.0	81.4	52.7	54.7	45.3
Centrally Planned Asia and China	75.0	85.1	80.2	69.1	69.1	47.4	44.9	44.8
Central and Eastern Europe	7.9	7.6	6.0	5.9	6.3	3.6	4.0	4.2
Latin America and Caribbean	68.6	51.6	36.9	30.8	23.1	22.3	19.3	13.2
Middle East and North Africa	10.7	12.0	6.3	6.5	7.3	2.9	3.4	3.8
North America	88.2	80.0	62.3	72.0	75.9	23.9	28.1	25.4
Newly Independent States	33.2	20.6	19.5	18.1	20.0	8.9	10.0	10.8
Pacific OECD	10.1	9.6	8.3	8.0	7.4	4.5	4.4	4.1
Other Pacific Asia	29.1	36.1	30.5	27.5	29.4	18.0	17.3	19.1
South Asia	59.5	59.0	57.2	55.9	56.4	38.4	35.8	34.7
Western Europe	54.7	35.2	22.6	20.0	20.6	15.4	15.9	16.4
World Total	491.7	470.4	412.2	402.9	397.0	237.9	237.6	221.6
SRES B2 (Message)	399	402	467	561	671	-	-	-
SRES A2 (Message)	399	402	504	639	806	-	-	-

4.4 Methane

For methane, our analysis suggests for the "current legislation" case a continued increase of global anthropogenic CH_4 emissions, leading to 35 percent higher emissions in 2030 than in 2000 (Figure 4.4 and Table 4.4). Overall, emissions from all sectors are expected to grow due to increased economic activities and absence of wide-spread emission control measures. In contrast to the emissions of non-greenhouse gases NO_x and CO, the calculated growth in CH_4 emissions is well within the range spanned by the SRES greenhouse gas scenarios.

A wide range of technical measures is presently available to reduce methane emissions. Such measures include the treatment of manure to generate biogas, measures affecting enteric fermentation, diversion of waste disposal, controlling waste disposal sites, reduction in distribution losses of natural gas, gas recovery in coal mines as well as during oil and gas extraction, alternative rice strains, etc. (Höglund-Isaksson and Mechler, 2004, USEPA, 1999, Hendricks et al., 1998). If all these "maximum technically feasible reductions" were applied to the full extent, global CH_4 emissions would stabilize up to 2030, though at considerable costs.

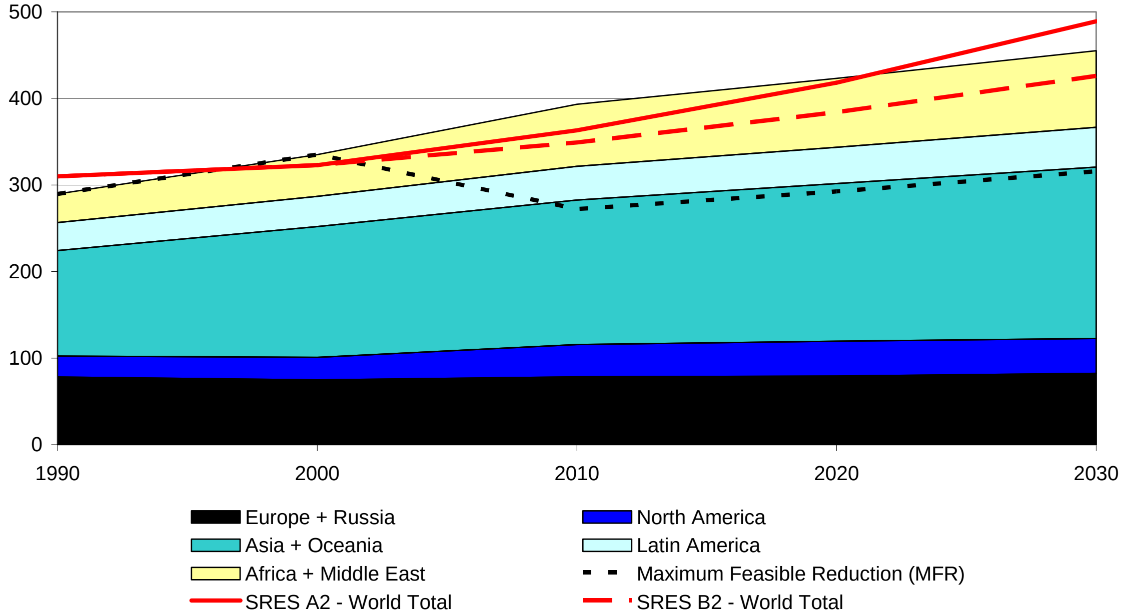

Figure 4.4: Projected development of CH_4 emissions by world region (million tons CH_4)

Table 4.4: CH_4 emissions by SRES world regions, current legislation and maximum technically feasible reduction scenarios (million tons CH_4)

			Current legislation (CLE)			Maximum feasible reductions (MFR)		
Region	1990	2000	2010	2020	2030	2010	2020	2030
Africa and Middle East	33.1	48.2	71.6	79.4	88.3	51.1	56.0	62.0
Centrally Planned Asia and China	47.1	62.3	72.0	76.4	80.3	46.1	49.3	52.5
Latin America and Caribbean	32.5	34.9	39.0	42.0	46.0	30.1	32.1	35.1
North America	24.3	26.0	37.5	40.1	40.4	25.9	27.3	27.8
Newly Independent States	45.8	43.8	46.4	46.5	48.6	33.6	34.2	36.4
Pacific Asia+ Oceania	8.7	10.0	10.7	10.5	10.4	7.9	7.9	7.9
Other Pacific Asia	19.0	22.7	25.4	29.6	34.7	17.6	20.4	23.8
South Asia	46.9	56.1	58.7	65.8	72.4	39.5	44.2	48.4
Western Europe	23.6	22.9	22.5	23.0	23.5	15.1	15.5	15.8
World Total	289.7	335.0	393.0	423.1	454.9	272.3	292.6	315.9
SRES B2 (Message)	310	323	349	384	426	-	-	-
SRES A2 (Message)	310	323	363	418	489	-	-	-

5 Discussion and conclusions

In this report we present a set of global emission projections for SO_2, NO_x, CO, and CH_4. These projections are based on present national expectations on economic development, taking into account the impacts of present emission control legislation (the "current legislation" - CLE scenario). Our analysis focuses on the next decades up to 2030, which is of immediate relevance for today's policy decisions.

According to our analysis, global SO_2 emissions decreased in 1990's by about 20 percent. Current energy and air pollution control policies cause a further five percent decrease till 2010 – 2020. However, in the third decade of the 21st century the emissions might start to increase again, unless stricter controls are enforced in some world regions, first of all in Southeast Asia. Also implementation of political targets to reduce air pollution in China might result in substantial reductions of SO_2 emissions compared with the estimates from our paper.

While the compiled growth rates in economic development and particularly in transport demand are largely consistent with the assumptions of other global assessments, new national legislation on mobile sources that has been adopted after the year 2000 in many developing countries in Asia and Latin America leads to substantially lower growth rates in emissions of NO_x and CO from the transport sector compared to earlier studies. Overall, these recent changes in developing countries make strong increases of global emissions of these pollutants unlikely to occur in the coming decades. Based on our assessment, global NO_x emissions are calculated to increase by approximately 13 percent in 2030 compared to 2000. Wide-spread application of emission controls for vehicles and a switch from coal and fuel wood use in small stoves to cleaner fuels in the residential sector should decrease CO emissions in most world regions (minus 16 percent for world total). Methane emissions, assuming implementation of present emission control legislation, are computed to increase by 35 percent up to 2030.

Obviously, there is some uncertainty about the actual implementation of this new legislation in developing countries, especially in the near future. However, considering the capacities provided by progressing economic and institutional development and technological advance over the next few decades (e.g., in on-board diagnostics for cars) and given the pressure from the strong public concern on local air quality in many developing countries (compare e.g., Cifuentes et al., 2001, CAI, 2004, He et al., 2003), it does not seem unreasonable to assume wide-spread compliance with these regulations in the year 2030.

Implementation of the best available control technology (the MFR scenario) makes it possible to further reduce the emissions. Compared with 2000 levels, the achievable reductions are: 77 percent for SO_2, 67 percent for NO_x , 53 percent for CO, and six percent for CH_4.

Within this study, only limited validation of data was possible. More work is needed to verify the presented estimates. In spite of rather high uncertainties of the estimates for individual countries, the scenario seems to properly illustrate the possible changes in the emissions within the next 20-30 years.

Since in our study we concentrated on the assessment of national emissions, we did not include the emissions from international shipping and air traffic. Also anthropogenic emissions from biomass burning (deforestation, savannah and agricultural waste burning, and forest fires) were not included. In the future the analysis with the RAINS model should also cover these emission sources.

Finally, due to lack of data, our analysis did not include non-methane volatile organic compounds (NMVOC). This was mainly due to missing information about sources not related to fuel production and consumption (use of paints and solvents, processes in chemical industry etc.). For tropospheric ozone calculations (Dentener et al., 2004) we assumed that the NMVOC follow the same pathway as the emissions of CO. Such an assumption provides a good approximation for energy- and transport- related emissions. For countries for which VOC estimates were available from the RAINS model (about 40 percent of the total number of countries covered in this study) the correlation between changes in CO and VOC emissions was quite high. Anyway, more detailed analysis is necessary in the future, when data on other (non-energy) anthropogenic sources for the remaining countries will become available.

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