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Environment and European enlargement:

Air emissions

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Foreword

This study is the first in a series of analyses that will assess the impact of EU enlargement on the environment. Particular consideration will be given to the 10 CEE (Central and Eastern European) countries seeking accession to the EU ('accession countries'). Given, however, the transnational nature of air pollution, other CEE countries have also been included in the study.

Commissioner Ritt Bjerregaard has repeatedly stated that 'enlargement may be one of the ultimate tests for the EU's environment', and the Commission Services (DG XI) stipulated as early as 1996 that the accession countries should progressively be included in future EU environmental assessments. So far, however, the only serious attempts to do so were those undertaken by the EEA in 1995 ('The Dobris Report') and in 1998 ('The Second Assessment'). These studies, produced for the Conference of European Environment Ministers and for the Environment for Europe Programme, sought to assess environmental trends in all CEE countries and to gauge various ways in which they might impact on the European environment.

In this study, the analysis is based on the 'what if?' concept: given that long-term prospective analysis is, by nature, uncertain, and all the more so when it concerns transition economies experiencing rapid change, this study seeks to quantify and contrast a number of different options. The results are of interest to decision-makers and the general public alike, since, by knowing what may happen in the future, citizens are better equipped to make informed choices.

The study finds that while the economic recession experienced by many accession countries in the early 1990s had a positive impact on the environment as regards air pollution, namely emissions of CO_2, SO_2, No_x and VOCs, many of them are at present in a phase of rapid economic development which will bring consumption levels in line with current western levels. As such, the study suggests that the necessary reduction in emissions, particularly those of CO_2, can only be achieved through structural changes. Emphasis should therefore be placed on reducing energy and carbon intensities by allocating resources to technological developments and greater fuel diversification (renewable, co-generated sources of energy etc.). In addition, planning methods in these countries should be adapted in order to develop more efficient production processes and to establish integrated resource management and demand-side management methods. In short, more sustainable development means achieving a higher quality of life without a corresponding increase in the consumption of natural resources and, in particular, of energy.

Improvements in power generation systems will also reduce other emissions such as SO_2 thereby bringing down the cost of complying with current and forthcoming EU legislation in this area. However, while increased energy efficiency will also impact positively on the reduction of No_x emissions, the expected growth in the transport sector is likely to cancel out these gains. As such, the overall costs of reducing No_x emissions are likely to remain high if a more sustainable growth plan for the transport sector is not developed.

Overall, the accession countries, like certain other eastern European countries, now have the option of simultaneously implementing fundamental environmental and economic reforms, thereby taking advantage of the synergies that may exist between the two. However, there is a danger that resources and financial aid will focus primarily on 'end-of-pipe' abatement measures (which could amount to over 7 billion ECU annually) while ignoring the potential (both in environmental and economic terms) of a more integrated approach.

However, as indicated, there is certainly scope for putting into place structural and systemic measures which could reduce the cost of complying with environmental legislation while improving overall economic performance. Target sectors are transport, energy and manufacturing. Improving the sustainability of these sectors would not only reduce the cost of complying with air pollution standards, but would also foster innovation and increase efficiency, thereby rendering economies more competitive. This is the real challenge facing not only these fast growing economies, but also the EU in general.

I would like to close by taking this opportunity to thank Teresa Ribeiro as Project Manager, and Keimpe Wieringa as Advisor, for their professionalism and determination to bring this project to a successful conclusion. Many thanks also to those that produced the basic material and report, in particular to Janusz Cofala and Markus Amann from IIASA and to Bernard Laponche from ICE for their contributions. Future generations may also have good reason to thank them.

Domingo Jiménez-Beltrán

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Executive summary

Introduction

This study explores changes in major air pollutant emissions over the medium term (1995-2010), both at the global level (CO_2) and the local or regional level (SO_2, NO_x, ozone). It examines the impact of these on acidification, eutrophication and ground-level ozone in Europe, that is, from the Atlantic to the Ural Mountains. The study covers the Central and Eastern European (CEE) countries and concentrates, in particular, on those in the pro-cess of joining the European Union (also known as 'the accession countries').

The nature and levels of air pollutant emissions are closely related to the energy systems of each country, on both the production and consumption side. Emission trends depend on the type of energy produced, transformed and consumed, not just in terms of quantity, but also in terms of quality. They also depend, therefore, on the type of energy sources and products, and on the emission standards and environmental regulations of each country.

The method: environment and energy scenarios

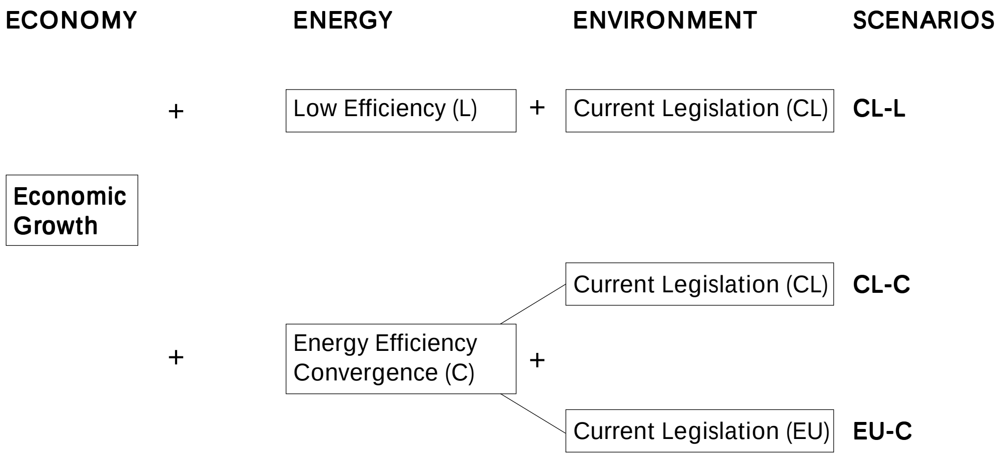
The method used to explore future possibilities is the 'what if?' approach. It is impossible to predict the future, but it can be useful for decision-makers to have a picture of what outcomes are possible and how these will depend on the different options and assumptions made regarding the nature of changing air pollutant emissions. Therefore, the study outlines several scenarios and quantifies the resulting emissions for each, in order to point to environmental outcomes that might reasonably be envisaged in the future.

Environment

For emission standards, the study sets out two scenarios:

a) In the 'Current Legislation' (CL) scenario, the study simulates the effects of implementing the emissions and fuel standards currently in force in each

Figure 1 **The scenarios**



country. The effects of legally-binding emissions ceilings have also been included.

This scenario assumes that the various regulations are fully implemented, which is not always the case at present.

b) In the 'European Union' (EU) scenario, the study evaluates the effects of the CEE countries adopting the legislation on stationary and mobile pollution sources currently in force in the European Union.

This assumption can be qualified as 'optimistic', since it implies not only the reinforcement of current legislation but also, as above, the fact that this improved legislation is fully implemented.

Energy

To explore the evolution of energy systems, the study contrasts two global indicators and their development, namely, energy intensity (ratio of energy consumption over GDP) and energy consumption per capita.

Two basic scenarios are studied:

a) The 'Low Efficiency' (L) scenario assumes that present trends in energy intensity will continue and that there will be no significant change in values over the entire period (1995-2010). This would be due to stagnation in economic restructuring and to little or no progress being made in improving energy efficiency.

Hopefully, such a scenario would have a low probability of actually occurring, but it is useful for comparison, both from the point of view of energy consumption and in terms of related environmental impact.

b) The 'Energy Efficiency Convergence' (C) scenario assumes that, as the process of reform and the re-building of national economies progresses, energy consumption patterns and energy efficiency in the CEE countries would begin to align with those of the European Union countries.

Economy

It is extremely difficult for any country to make predictions, but it is impossible for the CEE countries, most of which are still facing deep economic crisis, to predict economic growth or the pace of the economic restructuring process. In addition, this study does not delve into the different assumptions behind one of the basic indicators of economic growth: GDP per capita. A single set of GDP data for each country has been selected, based on national and international forecasts.

The RAINS model

In order to link atmospheric emissions and environmental impact to changing energy and economic systems, the study uses the Regional Air Pollution Information and Simulation (RAINS) model developed at the International Institute for Applied System Analysis (IIASA, Luxembourg, Austria).

The RAINS model focuses on acidification and eutrophication (SO_2 and NOx emissions), tropospheric ozone and CO_2 emissions (climatic change factors) and as such, provides a consistent framework for analysing emission reduction strategies. RAINS includes modules which cover emission generation (with databases on current and future economic activities, energy consumption levels, fuel characteristics, etc.), emission control options and costs, atmospheric dispersion of pollutants and environmental sensitivities (critical loads).

The restructuring process

In the early 1990s, almost all CEE countries embarked upon profound economic reforms aimed at making the transition from centrally-planned to market economies. In many areas, these reforms also included changes to environmental or related legislation. National environmental action plans were set up in several countries. An increasing number of countries began to incorporate international standards into their national legislation, such as including the obligations laid out in various protocols to the Convention on Long-range Transboundary Air Pollution. In preparation for possible accession to the European Union, portions of the EU environmental standards are being adopted as part of national legislation in CEE countries.

All these countries were struck simultaneously by a sharp decline in industrial production. In 1995, the average GDP per capita (at purchase power parity) of the CEE countries was 66% of 1990 figures (32% of the GDP per capita of the European Union). These ratios vary less dramatically for the accession countries where there was an average decrease of only 11% between 1990 and 1995; and GDP per capita in 1995 was 39% that of European Union.

One of the main obstacles to economic renewal is that energy systems in the CEE countries are very poor. The legacy of the centrally-planned economy, the strong expansion of highly energy-intensive industries and the extensive exploitation of natural resources, quite apart from the costs involved, led to a situation where the energy system became both a burden for the economy, and generated considerable environmental damage. The CEE countries, with very few exceptions, have high pollutant emissions in relation to GDP and in per capita terms.

Energy intensity in the CEE countries has been quite high compared to those of European Union countries. In 1990, primary energy intensity (the ratio of primary energy consumption to GDP expressed in purchase power parity) was about three times higher on average for the CEE countries than for the European Union (EU-15). Over the 1990 - 1995 period, energy and electricity consumption decreased by about one third in CEE. This decline was mainly due to the economic crisis and to the ensuing industrial collapse. However, energy consumption declined at a slightly lower rate than GDP, leading to an increase in energy and electricity intensity.

Nevertheless, and in some accession countries in particular, the economic reforms launched and the measures undertaken to improve energy efficiency have had important effects on economic performance and on the industrial structure. This has lead to changes in energy consumption patterns which should lead to improved energy intensity ratios over the medium term and to global reduction of air pollutant emissions.

The scenarios

Economic assumptions

Average annual GDP growth per capita in each country for the period 1995-2010 varies from a low of 2.1% to a high of 4.2%, with an average of 3.5% for the CEE countries and 3.4 % for the accession countries. This can be compared to the 2.1% figure for the European Union projected in the 'Conventional wisdom' scenario drawn up by DG XVII of the European Commission in 1996.

This assumption of GDP growth can be considered to be fairly conservative here, given that the average GDP per capita for the CEE countries in 2010 would only be about 39% that of the EU -15. It is important to bear this in mind when analysing

Table 1 **GDP per capita (1990 ECU ppp[1])**

Regions	1990	1995	1995 - 2010 growth rate (%)	2010
Average CEE	5,407	3,580	3.5 %	5,997
Accession countries	**4,883**	**4,350**	**3.4 %**	**7,150**
EU - 15	10,392	11,309	2.1 %	15,462

1 ppp: purchase power parity

Total GDP figures for each country and group of countries are obtained by multiplying the GDP per capita by the total population.

Population (millions) **Table 2**

Regions	1990	1995	2010
CEE	299.5	297.2	296.5
Accession countries	**106.0**	**105.0**	**106.0**
EU - 15	365.1	371.5	386.7

Sectoral energy and electricity intensities **Table 3**

Regions	Industry Energy Intensity 1990 2010 (1990=100) MJ/ ECU			Industry Electricity Intensity 1990 2010 (1990=100) kWh/ECU			Freight and Collective Transport Energy Intensity 1990 2010 1990=100) MJ/ ECU		
		L	C		L	C		L	C
CEE	9.80	80	50	0.38	95	68	1.92	84	58
Accession countries	**7.81**	**66**	**45**	**0.34**	**76**	**59**	**1.92**	**69**	**50**
EU -15	2.84	74	74	0.18	89	89	0.76	84	84

Per capita energy and electricity consumption **Table 4**

Regions	Domestic Energy cons./c. 1990 2010 (1990=100) GJ			Domestic Electricity cons./c. 1990 2010 (1990=100) kWh			Car transport Energy cons./c. 1990 2010 (1990=100) GJ		
		L	C		L	C		L	C
CEE	34.1	104	103	1246	124	170	3.6	155	331
Accession countries	**28.9**	**120**	**120**	**1249**	**147**	**182**	**4.2**	**156**	**306**
EU -15	31.1	112	112	2210	122	122	15.2	121	121

the energy and environmental consequences of economic change.

Energy consumption assumption

Four scenarios reflecting ‘Energy Efficiency Convergence’ have been studied. They differ in terms of the degree and nature of convergence and also depend on the assumptions made about the selected energy consumption indicators: energy intensity in the industrial sector, energy consumption per capita in the domestic sector, energy consumption per capita in car transport, energy intensity in other transport (mostly freight transport), electricity intensity in industry and electricity consumption per capita in the domestic sector.

Qualitatively speaking, ‘convergence’ is based on two ideas. On the one hand, since energy intensity in the industrial sector of the CEE countries is considerably higher than in the EU, convergence presumes a decline of these levels of intensity. On the other hand, per capita energy consumption in the residential, commercial, and passenger transport sectors is present-

Table 5 **Air pollutant emissions in CEE**

	1990	1995 1990=100	2010 (1990=100) CL-L	 CL-C	 EU-C
Primary energy cons. per capita	153 GJ (1)	72	95	82	82
Energy intensity	28.3 MJ(2)/ECU	109	24.3	20.9	20.9
CO_2	2970 Mt(3)		89	74	74
SO_2	20.3 Mt		46	31	30
NO_x	8.3 Mt		81	88	57

(1) GJ: giga-joule (10^9 joule) - 1 toe=44,8 GJ
(2) MJ: mega-joule (10^6 joule)
(3) Mt: million tonnes

Table 6 **Air pollutant emissions in accession countries**

	1990	1995 1990=100	2010 (1990=100) CL-L	 CL-C	 EU-C
Primary energy cons. per capita	129 GJ	85	106	96	96
Energy intensity	26.5 MJ/ECU	95	72	66	66
CO_2	987 Mt		99	87	87
SO_2	10.8 Mt		38	32	31.5
NO_x	3.8 Mt		63	63	44

ly lower in the CEE countries than in the EU. Economic development should provide greater material welfare to the population in these countries and this would most likely lead to an increase in household energy consumption.

Scenario C is ‘partial convergence’. As opposed to B (business as usual), this scenario is based on the assumption that the gap in sectoral energy intensity levels between a CEE country and the EU average declines at the same rate as the gap in per capita GDP. (For countries in which the GDP per capita is too low, it has been assumed that energy intensities would improve by 50 % by the year 2010.) In this scenario, the change in energy consumption per capita in the domestic sector is moderate; the per capita energy consumption for car transport will double or triple in comparison to the 1990 level.

Energy consumption and atmospheric emissions

As in figure 1, three scenarios have been studied. The same GDP growth rate is used here in conjunction with certain assumptions that are made regarding changing energy efficiency and emission standards:

- scenario CL-L combines ‘current legislation’ and ‘low efficiency’,
- scenario CL-C combines ‘current legislation’ and ‘partial convergence’,
- scenario EU-C combines ‘EU legislation’ and ‘partial convergence’.

The results obtained using the RAINS model for energy consumption, energy intensity and air pollutant emissions are presented in tables 5 and 6, for the CEE area as a whole and for the accession countries.

CO_2 emissions

Tables 5 and 6 show that, by applying these assumptions to emission controls, CO_2 emissions remain unchanged. They are directly linked to the energy system (from production to consumption) both in terms of the quantity of energy used, and the nature of energy products.

a) CEE countries

Compared to 1990, both energy 'pathways' lead to a decrease in primary energy consumption in the CEE and thus, to a decrease in CO_2 emissions.

In scenario L ('low efficiency'), the drop in energy consumption is mainly linked to consumption decreases during the early 90s. In scenario C ('partial convergence'), there is a sharper decrease due to progress in energy efficiency and a changing fuel mixture (more natural gas, less coal).

b) Accession countries

In the accession countries, the drop in energy consumption between 1990 and 1995 was less pronounced. Scenario L shows primary energy consumption increasing by 6% in 2010 in contrast to 1990, with associated CO_2 emissions at about the same level (- 1%), attributable to changes in the fuel mixture. Scenario C results in primary energy consumption being reduced by only 4% between 1990 and 2010, with a 13 % decrease in CO_2 emissions.

SO_2 emissions

SO_2 emissions will depend on the energy scenario chosen and on emission control assumptions.

Nevertheless, even the CL-L scenario brings emissions down far below their 1990 levels (by more than 50%) and this is true both for the CEE countries as a whole and for the accession countries. This is partly due to changes in fuel use, notably for electricity generation (less coal, more natural gas) but it is also due to the emission controls already required by national legislation in many countries, as well as emission ceilings and new plant standards required by the Second Sulphur Protocol.

The 'partial convergence' energy scenario C would lead, in CL-C as well as EU-C, to a further decrease in SO_2 emissions (30% of the 1990 level). A comparison between CL-C and EU-C shows that the application of current EU emission standards would not have a significant effect on SO_2 emissions.

These results do not mean, however, that nothing needs to be done, since these scenarios assume that legislation is fully implemented.

NOx emissions

The situation is different for NOx emissions: in this case both the energy and environment scenarios are important.

a) CEE countries

The CL-L scenario indicates a 19 % decrease compared to 1990. However if we take the 'partial convergence' energy scenario C, and assume that there is no change in environmental standards, as per scenario CL-C, emissions would be 9% higher in 2010 compared to CL-L. This can be explained by the following: convergence scenarios assume a strong decrease in energy intensity but, at the same time, a strong increase in the use of cars - hence, higher energy consumption in the transport sector, accompanied by high levels of SO_2 emissions.

If countries come into line with EU emissions standards, this would reduce NOx emissions by 30% in 2010, compared to CL-L. Most of these improvements would be achieved in the transport sector.

b) Accession countries

As far as NOx emissions are concerned, there are also differences between accession countries and other CEE countries. Some accession countries have already adopted stricter emission standards for mobile sources. Thus, the CL-C scenario, even with higher energy consumption in car transportation, would not increase total NOx emissions in these countries. In addition, car emission increases are partly compensated for by lower emissions from industry and freight transport given the lower levels of energy intensity in these two sectors.

Ozone

In order to estimate the effects of these scenarios on ozone levels, it would have been necessary to calculate the emissions of non-methane volatile organic compounds (VOCs). It was not possible, however, to perform these detailed calculations within the time-frame of this study. Preliminary estimates show that VOC emissions in the CEE countries (in the CL-L scenario) are likely to be situated at approximately their 1990 levels. In the EU-C scenario, these emissions would decrease by about 40 %.

Emission abatement costs
CO_2

There is no abatement cost for the reduction of CO_2 emissions. This reduction is a direct result of improvements in energy efficiency (lower energy intensity) and changes in energy sources and products used. These energy efficiency convergence scenarios assume that all the operations undertaken to improve energy efficiency are technically feasible and economically justifiable (ie., the cost of saving energy is less than the cost of supplying it). The gains in CO_2 emissions, therefore, constitute a benefit without cost.

The RAINS model methodology and data

In calculating the costs of SO_2 and NOx emission controls, the RAINS model uses a limited list of characteristic emission abatement options for each area of application (i.e. the emission source categories seen in the model). It extrapolates the current experience to future years, taking into account the most important circumstances and specificities of each country and situation while modifying the applicability and costs of the techniques used.

For each of the available emission abatement options, RAINS estimates the specific costs of reductions, taking into account operating and investment-related costs. Investments are annualised over the technical lifetime of the pollution abatement equipment. A discount factor of four percent is applied. The databases on emission abatement costs have been built upon real operational experience as documented in a number of national studies as well as in the reports of international organisations which assess different emission abatement options

Data on SO_2 control techniques and costs were reviewed during the negotiations of the Second Sulphur Protocol to the Convention on Long-range Transboundary Air Pollution (CLRTAP). For any given energy scenario, RAINS works on the assumption that reducing SO_2 emissions involves choosing options based on low-sulphur fuel, fuel desulfurisation, combustion modification and fuel gas desulfurisation.

The RAINS model includes two categories of options for abating emissions from stationary sources: primary measures (combustion modifications, low NOx burners) and secondary measures (selective catalytic and non-catalytic reduction). For mobile sources (cars, trucks, buses, off-road mobile sources and machinery), RAINS simulates the effects of implementing technical measures, such as using catalytic converters and combustion modifications, that allow for reduction of engine emissions down to the levels prescribed by mobile sources emission standards. Data for mobile sources have been taken from various reports developed within the Auto/Oil programme (European Commission, 1996) and from other national and international sources.

Emission abatement costs

Emission abatement of SO_2 and NOx for the three scenarios described above are shown in Table 7.

a) Changing the energy pathway from ‘low efficiency’ to ‘partial convergence’ and maintaining the ‘current legislation’ on emissions would decrease costs for SO_2 emission abatement measures but in-

Emission control costs (billion ECU per year) **Table 7**

Total CEE	CL-L	CL-C	EU-C
SO_2	3.6	2.9	3.4
NO_x	1.9	2.3	14.0
Total	**5.5**	**5.2**	**17.4**

Accession countries	CL-L	CL-C	EU-C
SO_2	2.0	1.7	1.8
NO_x	1.5	2.3	5.7
Total	**3.5**	**4.0**	**7.5**

crease NOx abatement costs (comparison between CL-C and CL-L).

The decrease in emission abatement costs for SO_2 results in the opposite trend (due to lower coal consumption) leading to the rise in NOx emission abatement costs, mainly for the transport sector.

For the CEE countries as a whole, the net effect would be a slight decrease in abatement costs (by 5%) while there would be an increase of 14% for the accession countries. This means that for the non-accession CEE countries there is a decrease of about 40% (all NOx abatement costs in CL-C are limited to the accession countries).

b) This general trend also holds if the national emission regulations are brought in line with current EU standards. For both the CEE and accession countries, SO_2 emissions abatement costs are lower in EU-C than in CL-L, but slightly higher in EU-C than in CL-L. The cost of NOx emission abatement measures in transport would increase dramatically with the introduction of EU standards: sixfold increases for the CEE countries as a whole, and increases of 2.5 times for the accession countries.

1. Introduction

The economies of countries in Central and Eastern Europe (CEE) have historically been characterised by high emissions of air pollutants, both when expressed in relation to their gross national product (GDP) as well as when expressed in per capita terms. Per unit of GDP, CEE countries released in 1990 about nine times more emissions of sulphur dioxide (SO_2) and about five times more nitrogen oxides (NO_x) than the average country in the European Union (EU), if GDP is measured in market exchange rates. Expressed on a per capita basis, SO_2 emissions in the CEE countries were double those in the EU countries.

At the beginning of the 1990s, however, the countries in the CEE region initiated profound economic reforms aimed at a transition from central planning to market economies. These reforms have had important effects on the economic performance and the structure of the industry, resulting in changed energy consumption patterns and improved energy intensities. In many cases these reforms also altered the environmental legislation. National environmental action plans have been initiated in several countries. An increasing number of countries have started to incorporate international environmental standards into their national legislation, such as the obligations of the various protocols of the Convention on Long-Range Transboundary Air Pollution. In preparing for possible accession to the European Union, CEE countries are integrating EU environmental standards into national legislation.

It can be expected that in the long-run, the ongoing reforms will lead to significant changes in the economic structures, the legislative systems and the life styles of people in the CEE countries. In turn, these transformations will have profound impacts on the volumes and structures of energy demand. Combined with the new environmental standards, it would perhaps not be unreasonable to expect a significant decline in emissions of air pollutants as a side effect of the economic transition process.

Despite the (autonomous) improvements anticipated from the ongoing reform process, the question remains: to what extent would an accelerated move towards the present energy and environmental standards of the European Union result in environmental benefits not only for the countries in the CEE region, but also for the other European countries?

1.1. Scope and overall approach of the study

This study aims to quantify the possible environmental improvements resulting from the ongoing economic transition process in the CEE countries, and attempts to assess the additional gains to be made by an accelerated harmonisation of the energy and emission standards with the current EU legislation . The analysis is restricted to changes in energy intensity, the emissions of major air pollutants (SO_2, NO_x, NH_3, VOC, and CO2) and the resulting impacts on acidification, eutrophication and ground-level ozone.

At the present time it is not possible to accurately predict the future pace of the economic restructuring process in the CEE region, which is, however, an obvious input assumption to the analysis. To overcome this difficulty, the study constructs, as a first step, a range of alternative scenarios of the 'what-if' type. These hypothetical scenarios do not attempt to forecast the future, but try to explore, for a possible range of economic input assumptions, the resulting impacts on energy consumption and environmental conditions. In a second step, these resulting changes are compared with the input assumptions, and general trends are identified. This analysis is thereby able to derive conclusions about the overall potential for environmental improvements offered by the transformation process. Since the scope of the analysis is mainly oriented toward the identification of the potential magnitude of an environmental improvement, aspects of political feasibility and the possible pace of implementation have been excluded from the terms of reference for this study.

To create a benchmark for the comparison of the effects of a faster harmonisation with the EU standards, a baseline scenario is constructed assuming the continuation of the present economic trends and the enforcement of the currently applicable national environmental legislation (including the obligations of international agreements). This reference scenario is based on the projected development of the overall economies and energy systems, as communicated by the national governments to the United Nations Economic Commission for Europe (UN/ECE) and reported in the UN energy data base (UN/ECE, 1996). For the EU countries, the 'Conventional Wisdom' energy scenario developed by DG-XVII has been used for comparison (DG XVII, 1996).

In order to explore the potential offered by an accelerated application of the EU standards, two alternative energy scenarios are constructed, based on the assumption that energy intensities and consumption patterns in the CEE region approach values typical for countries belonging to the European Union. Due to the uncertainties about the possible speed of transformation, the analysis explores the impacts of an improvement in energy efficiency/intensity (i) for the case of full convergence towards the levels presently observed in the EU, and (ii) for a 'halfway' approach towards the EU standards.

For obvious reasons, these two alternative scenarios of energy development do not make any assumptions about the driving forces of the harmonisation process. These transformations might either be caused by a rapid development of the overall economies (i.e. they will achieve economic structures comparable to that of the EU countries) or by concerted actions targeted at the improvement of the efficiency and environmental performance of the energy infrastructures.

If the overall structure of the economies in the CEE countries approaches those of the EU countries, it might not be unreasonable to assume that the energy intensities (including energy use per person) will also gradually move toward the levels currently observed in the EU countries. Whereas this means a reduction in energy intensities for the industrial sector, transportation (and to a certain degree also for domestic use), harmonisation would imply an increase in energy intensity in the CEE countries compared to the present levels. Given this tendency, it is certainly worthwhile to analysing the impacts of concerted actions that would specifically target energy improvements in the industrial sector, but do not encourage higher energy use by private consumers in the CEE region. Consequently, the study also develops variants of the energy convergence scenarios taking into account this issue.

Energy consumption has a strong impact on the emissions of major air pollutants; but emission control legislation also plays an important role in determining the ultimate emission levels. In order to identify the potential role of emission control legislation, the study analyses the emissions resulting from the energy scenarios outlined above along two variants: the reference case assumes the continuation of current environmental policies both in the CEE region and in the European Union; alternatively, a case is explored in which the CEE countries would also apply the current environmental legislation of the EU to their territories.

Chapter 2 of this paper briefly outlines the basic approach adopted for this study. Chapter 3 analyses the observed impacts of the first phase of the economic reform process (1990–1994) on the level and structure of energy demand in the CEE countries. Assuming a convergence of the sectoral energy intensities towards the average levels of the EU countries, Chapter 4 develops an alternative 'Energy Efficiency Convergence' scenario. Chapter 5 explores the emissions and the environmental impacts of such a scenario and analyses its strength against variations of some important input assumptions. Chapter 6 interprets the scenario results and identifies the main trends associated with the convergence of CEE energy systems towards EU standards. Chapter 7 draws conclusions from the analysis.

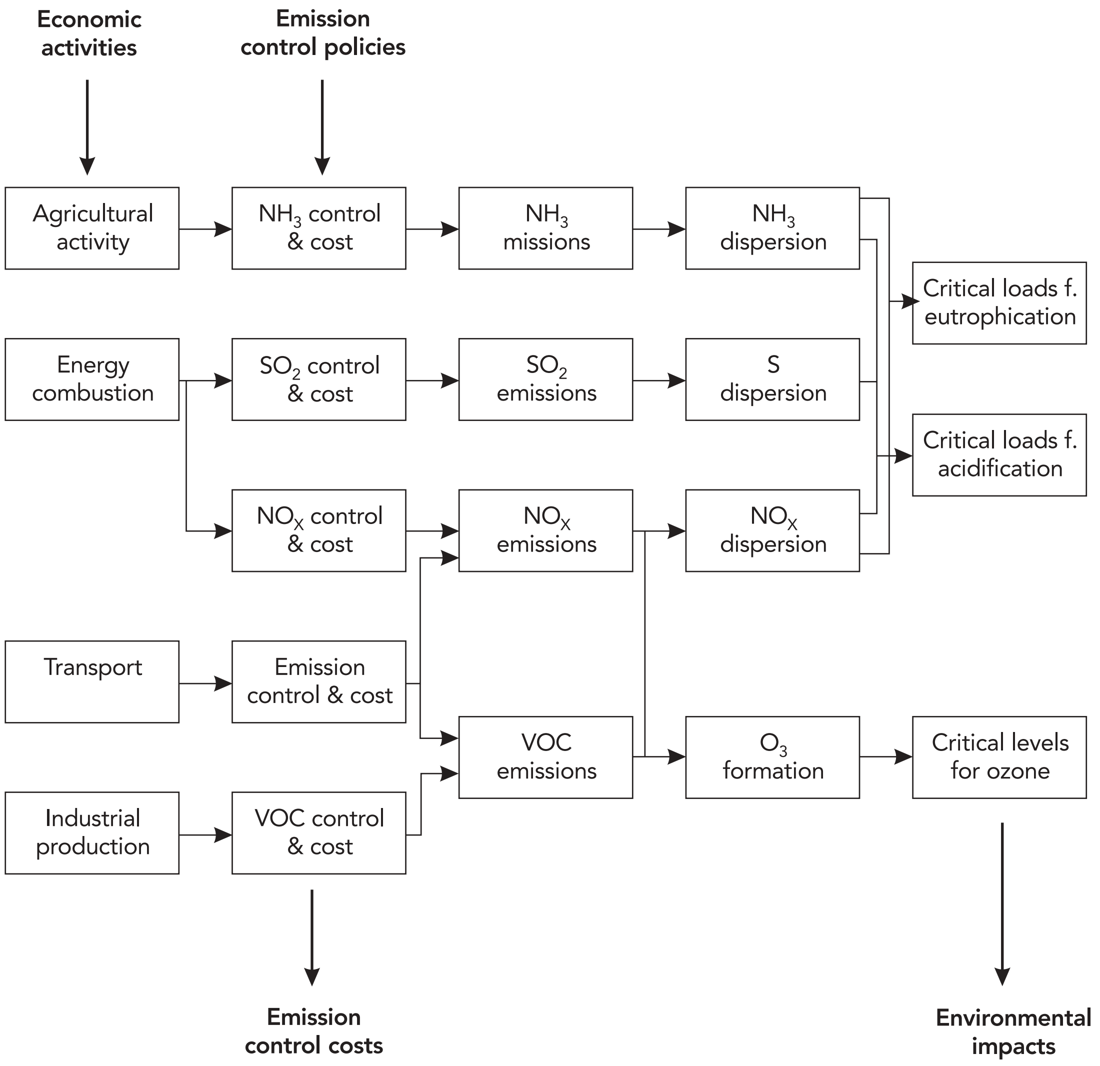
2. Integrated assessment of air pollution control strategies

In order to link the changes caused by the economic reform process to environmental impacts, this study uses the Regional Air Pollution INformation and Simulation (RAINS) model developed at the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria). The RAINS model provides a consistent framework for the analysis of emission reduction strategies, focusing on acidification, eutrophication and tropospheric ozone. RAINS comprises modules for emission generation (with databases on current and future economic activities, energy consumption levels, fuel characteristics, etc.), for emission control options and costs, for atmospheric dispersion of pollutants and for environmental sensitivities (i.e. databases on critical loads). To create a consistent and comprehensive picture of the options for simultaneously addressing the three environmental problems (acidification, eutrophication and tropospheric ozone), the model considers emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3) and volatile organic compounds (VOC). Figure 2.1 outlines the interaction of the various sub-modules of RAINS. A more detailed description of the RAINS model can be found in Annex 1.

The RAINS model can be operated in the ‘scenario analysis’ mode, i.e. following the pathways of emissions from their sources to their environmental impacts. In this case, the model provides estimates of regional costs and environmental benefits of alternative emission control strategies. Alternatively, a (linear programming) ‘optimisation mode’ is available for the acidification part to identify cost-optimal allocations of emission reductions to achieve specified deposition targets. The latter mode of The RAINS model was used extensively during the negotiation process of the Second Sulphur Protocol under the Convention on Long-Range Transboundary Air Pollution for elaborating effect-based emission control strategies. A non-linear optimisation module for tropospheric ozone has also been recently completed.

The RAINS model uses projections of future energy consumption as an extraneous input. For most of the analyses carried out up to now with this model, the energy scenarios were extracted from other databases or studies. This study, however, attempts to derive a rough estimate of future energy consumption patterns, based on a range of assumptions about the pace of the economic reform process in the CEE countries. The methodology for constructing these forecasts is described in Section 4.

Structure of the RAINS model **Figure 2.1**



3. The economic reform process and the energy structure – an analysis of the early phase

The reform process of the CEE countries, which started in 1990, caused drastic changes to the national economies. This economic restructuring had extraordinary impacts on the energy sector. As presented in Table 3.1, between 1990 and 1994 energy consumption in all CEE countries decreased dramatically. For instance, by 1994 gross energy consumption declined by 34% from 46 EJ to 30 EJ, and electricity consumption by about 30%, from 1085 TWh to 750 TWh (Table 3.2).

There are at least three important factors contributing to this steep decline in energy consumption in the CEE countries:

- a deep economic recession caused by the transformation from a command to a market economy with tight monetary, fiscal and wage policies;
- large increases in energy prices;
- the collapse of the Soviet Union and of the Council of Mutual Economic Assistance (CMEA).

Table 3.1 **Primary energy consumption in the CEE countries, 1990-1995, in PJ (10^{15} Joule)**

[PJ]	1990	1992	1993	1994	1995[a]
Albania	128	93	65	71	106
Belarus	1,762	1,572	1,339	1,037	1,265
Bosnia-H.	311	243	20	27	222
Bulgaria	1,296	829	882	846	966
Croatia	413	303	287	321	325
Czech Republic	1,956	1,773	1,735	1,711	1,714
Estonia	423	275	233	233	337
Hungary	1,109	1,027	1,019	1,022	1,039
Latvia	399	252	226	219	205
Lithuania	677	449	368	332	350
Poland	4,202	4,015	4,062	3,884	4,073
FYR Macedonia	151	129	115	116	124
Rep. of Moldova	392	296	221	201	275
Romania	2,425	1,901	1,819	1,724	1,965
Russia[b]	18,237	12,422	11,589	10,070	10,834
Slovakia	987	775	739	734	823
Slovenia	231	233	242	247	259
Ukraine	9,970	9,356	8,091	6,912	7,209
Yugoslavia	790	649	556	547	579
Total CEE[c]	45,859	36,591	33,608	30,255	32,668
Accession countries[1]	**13,705**	**11,528**	**11,326**	**10,952**	**11,730**
EU-15	**54,357**	**-**	**-**	**-**	**57,128**
Cohesion countries[2]	5,691	-	-	-	6,262

[1] Accession countries: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia.

[2] Cohesion countries: Greece, Ireland, Portugal, and Spain.

Gross electricity consumption in the CEE countries, 1990-1995, in PJ **Table 3.2**

[TWh]	1990	1992	1993	1994	1995[a]
Albania	2.6	2.2	2.7	3.1	2.8
Belarus	41.4	34.0	28.9	27.9	32.0
Bosnia-H.	11.0	12.2	1.5	1.5	8.3
Bulgaria	35.2	27.7	26.2	27.0	26.8
Croatia	13.2	9.4	9.4	9.6	10.9
Czech Republic	49.1	40.8	40.9	41.4	44.1
Estonia	6.8	5.7	4.2	5.0	5.2
Hungary	31.1	28.6	27.4	26.7	27.0
Latvia	8.7	4.7	5.3	5.2	6.3
Lithuania	11.9	9.2	9.0	8.8	8.6
Poland	96.2	85.6	86.6	85.3	87.6
FYR Macedonia	5.1	5.2	5.1	4.8	4.4
Rep. of Moldova	9.7	8.8	7.2	6.5	7.7
Romania	53.0	40.5	36.5	35.0	40.1
Russia[b]	428.3	305.6	285.1	253.8	280.1
Slovakia	21.9	20.7	20.1	19.2	21.8
Slovenia	10.1	8.9	8.9	9.2	9.1
Ukraine	223.5	186.6	169.7	152.2	167.3
Yugoslavia	25.8	29.6	27.9	27.1	21.7
Total CEE[c]	1,084.6	866.1	802.4	749.5	811.8
Accession countries	**324.0**	**272.0**	**265.0**	**263.0**	**277.0**
EU-15	**1,814.0**	**-**	**-**	**-**	**1,964.8**
Cohesion countries	189.2	-	-	-	213.5

Notes to Table 3.1 and Table 3.2:

[a] For the majority of countries, values for 1995 are based on projections. Statistical data was not available on a consistent basis.

[b] IIASA estimates of energy consumption in the European part within the EMEP region.

[c] For calculating totals, linear interpolation of missing data has been used.

3.1. The economic recession

Although the economic performances of countries can only be compared with a certain ambiguity (due to methodological questions about proper exchange rates), all available indicators reveal a deep economic recession for the CEE countries after the year 1990.

Tables 3.3 and 3.4 illustrate this phenomenon by comparing the development of the gross domestic product (GDP) of the CEE countries between 1990 and 1995 on a per capita basis. The tables present the GDP estimates using market exchange rates (MEXR) and purchasing power parities (PPP).

Table 3.3 reveals the low level of the per capita GDP when compared to the EU average. Measured with market exchange rates, in 1990 the average CEE per capita GDP was only about 20% of that of the European Union. Furthermore, in nearly all countries (with the exception of Poland and Slovenia) per capita GDP experienced a further sharp decline after 1990, so that in 1995 the average per capita GDP was only at about 13% of the average EU level.

Table 3.3 Development of the per capita GDP (1990 ECU/capita), using market exchange rates (MEXR)

Country	1990	1991	1992	1993	1994	1995
Albania	772	553	495	544	590	635
Belarus	2,302	2,281	2,067	2,231	1,697	1,528
Bosnia-H.	1,964	-	-	-	-	1,203
Bulgaria	1,079	962	900	911	911	944
Croatia	4,011	3,052	2,093	1,949	2,306	2,691
Czech Republic	3,366	2,886	2,699	2,145	2,740	2,869
Estonia	2,179	1,959	1,698	853	1,227	1,902
Hungary	3,521	3,127	3,056	3,063	3,178	3,254
Latvia	3,457	3,218	2,124	1,812	1,852	1,852
Lithuania	1,990	1,827	1,189	999	1,060	1,045
Poland	1,888	1,839	1,789	1,851	1,940	2,069
FYR Macedonia	1,074	-	-	-	-	684
Rep. of Moldova	1,603	1,314	927	911	625	602
Romania	1,295	1,107	919	903	966	1,038
Russian Fed.	3,462	3,027	2,592	2,374	2,082	2,005
Slovakia	2,253	2,012	1,771	1,685	1,752	1,867
Slovenia	6,833	5,182	4,929	5,001	5,641	7,346
Ukraine	2,251	2,052	1,853	1,598	1,233	1,091
Yugoslavia	2,404	-	-	-	-	1,541
Average CEE[a)]	2,627	2,323	2,058	1,916	1,773	1,761
Accession countries	**2,151**	**1,908**	**1,781**	**1,767**	**1,858**	**1,990**
EU-15	12,688	12,904	13,123	13,347	13,575	13,808
Cohesion countries	**8,890**	**9,078**	**9,132**	**9,088**	**9,312**	**9,524**

[a)] For the calculation of averages, missing data were interpolated.

There are, however, large differences between the CEE countries. Whereas the majority of the countries of the former Soviet Union faced a decline of 40%–50%, Poland and Slovenia managed to achieve an increase compared to 1990. In 1995, countries of the Vysehrad Group (i.e. Poland, Hungary, the Czech Republic and Slovakia), Estonia, Croatia and Slovenia appeared to have started the process of recovery.

Measuring the GDP in market exchange rates might distort the picture about the economic wealth of the population. Alternatively, the GDP could also be calculated using the purchasing power parities (PPP) of individual countries (Table 3.4). Using the PPP concept, the average per capita GDP in CEE countries was, in 1990, only 50% lower than in the EU. Nevertheless, the PPP also reveals the decline between 1990 and 1995, and reduces the average level in the CEE in 1995 to about 33% of the EU countries.

Notes to Table 3.3 and Table 3.4: Sources: IMF 1997, World Bank 1994-1996, EBRD

Development of the per capita GDP (ECU$_{1990}$/capita) using purchasing power parities PPP) **Table 3.4**

Country	1990	1991	1992	1993	1994	1995
Albania	1,720	1,226	1,091	1,194	1,288	1,380
Belarus	5,453	5,375	4,847	4,996	3,936	3,525
Bosnia-H.	1,889	-	-	-	-	962
Bulgaria	4,043	3,579	3,326	2,930	3,323	3,442
Croatia	3,859	3,447	3,035	3,008	3,123	3,134
Czech Republic	8,776	7,482	6,958	6,049	6,984	7,271
Estonia	7,477	6,723	5,828	5,389	5,243	5,102
Hungary	5,615	4,970	4,840	4,835	5,000	5,101
Latvia	7,736	7,165	4,705	3,994	4,061	4,061
Lithuania	4,881	4,456	2,884	2,412	2,545	2,507
Poland	4,197	4,067	3,937	4,052	4,226	4,484
FYR Macedonia	1,974	-	-	-	-	1,232
Rep. of Moldova	4,516	3,679	2,579	2,522	1,718	1,646
Romania	3,120	2,663	2,206	2,286	2,294	2,452
Russian Fed.	7,001	6,097	5,193	4,734	4,132	3,961
Slovakia	6,899	6,127	5,355	5,063	5,232	5,540
Slovenia	7,196	5,903	6,904	7,256	7,861	8,332
Ukraine	4,869	4,419	3,969	3,405	2,616	2,302
Yugoslavia	2,818	-	-	-	-	1,795
Average CEE[a]	5,407	4,811	4,262	3,982	3,645	3,580
Accession countries	**4,883**	**4,336**	**4,028**	**4,058**	**4,150**	**4,350**
EU-15	10,392	-	-	-	-	11,309
Cohesion countries	**9,527**	**-**	**-**	**-**	**-**	**10,180**

[a] For the calculation of averages, missing data were interpolated.

1996, WIIW 1996. These sources do not provide full time series. Consequently, the individual numbers in the report should be treated with care, although they indicate the general trend. An exchange rate of 0.79 ECU/$ (IMF, 1997) was used.

3.2. The increase in energy prices

Until 1990 energy prices in the CEE countries were low. For instance, the average energy price for industry in CEE countries was about 30% to 40% below world market prices (compare Hughes, 1991). This difference was most drastic for coal, whereas prices of petroleum products and natural gas were closer to West European price levels. The heavy reliance of power generation on (under-priced) coal also resulted in artificially low electricity prices.

Energy prices were far below the economic costs. They were determined by the governments and played an important role in the command and control type of economic system. In contrast to Western Europe, private households were granted lower

Table 3.5 **Energy consumption of the CEE countries by fuel, 1990-1995, in PJ**

[PJ]	1990	1992	1993	1994	1995
Solids	12,534	11,594	11,083	9,990	9,892
Liquids	11,872	9,825	8,156	6,836	7,240
Gaseous	18,040	12,414	11,628	10,787	12,929
Nuclear	2,519	1,769	1,788	1,639	1,560
Hydro	967	997	962	1,006	991
Other	2	-8	-10	-4	56
Total	**45,933**	**36,591**	**33,608**	**30,255**	**32,668**
Solids	27%	32%	33%	33%	30%
Liquids	26%	27%	24%	23%	22%
Gaseous	39%	34%	35%	36%	39%
Nuclear	5%	5%	5%	5%	5%
Hydro	2%	3%	3%	3%	3%
Other	1%	-1%	0%	0%	1%

prices for electricity and gas than industry. Consequently, energy prices did not create the right basis for rational decision making. Instead of a market system, countries used a complicated system of central allocation of energy to industrial and household consumers..

Beginning in 1990, a radical energy pricing reform was introduced in all CEE countries, resulting in a substantial increase of real energy prices. At the same time, central allocation was phased out. At the early and intermediate stages of the economic transition process, energy price increases were often systematically eroded by inflation; yet, today's energy prices for industry in the countries that have successfully advanced economic reforms are close to the economic costs.

In spite of substantial increases in real terms, in the majority of countries in the region, prices of network fuels to households do not yet cover the full delivery costs (EBRD, 1996). Thus, these prices will have to be further increased. Obviously, the pace of these price adjustments has to take into account the specific ability of the households to pay.

3.3. The collapse of the Soviet Union and the CMEA

The collapse of the CMEA and the USSR ended the 'soft rouble trade' among the former CMEA member states. The resulting shift to a dollar trading system caused a drastic contraction of the volumes traded among those countries, and also had a profound impact on the trade of energy. For instance, beginning in 1990, energy imports from Russia were paid for in hard currency. Some countries, such as Bulgaria and some independent states of the former USSR, have not been able to finance such imports due to foreign exchange shortages. This has caused a drastic limitation in the consumption of liquid fuels in those countries. Tables 3.5 and 3.6 illustrate this effect by showing for the period 1990-1994, a 40% decline for liquid fuels and natural gas, which were to a large extent imported. Coal consumption, on the other hand, declined by only 25%.

Energy consumption of the accession countries by fuel, 1990-1995, in PJ **Table 3.6**

[PJ]	1990	1992	1993	1994	1995
Solids	6,143	5,797	5,705	5,383	5,446
Liquids	3,357	2,537	2,541	2,519	2,691
Gaseous	3,257	2,303	2,193	2,151	2,685
Nuclear	673	631	633	622	628
Hydro	231	257	261	276	257
Other	45	3	-6	1	23
Total	**13,705**	**11,528**	**11,326**	**10,952**	**11,730**
Solids	45%	51%	51%	48%	47%
Liquids	24%	22%	22%	23%	23%
Gaseous	24%	20%	19%	20%	23%
Nuclear	5%	5%	6%	6%	5%
Hydro	2%	2%	2%	3%	2%
Other	0%	0%	0%	0%	0%

Note: The category “Other” includes the export/import balance of electricity.

Although the statistical material currently available should be treated with care (statistical information for 1995 is still incomplete), energy consumption appears to have increased again in 1995.

3.4. The change in energy intensities

The preceding analysis reveals a severe decline in economic activity accompanied by a steep reduction in energy demand in the CEE countries. It is instructive to explore whether the simultaneous economic reform process also resulted in a shift of the economic and industrial structures towards less energy-intensive production processes.

It is interesting to realise that, with a few exceptions, at least at the beginning of the transformation process, the changes in energy demand and GDP levels resulted in only moderate alterations in energy intensities (Table 3.7). Between 1990-1994, the average level of energy intensity of the GDP (expressed in PPP) remained constant in the CEE countries, while the energy intensity of the economies of the EU countries decreased by 6%. The most dramatic change occurred in the Ukraine (30% increase), which is due to a drop in the GDP level without a proportional drop in energy consumption. Changes in the energy intensities of the economies of other countries were moderate. Despite the preliminary nature of the 1995 statistics, available data suggests that the beginning upward trend in economic performance is accompanied by increased energy intensities.

Consequently, it must be stated that despite the substantial economic reform process in Central and Eastern Europe, there are no comparable improvements in energy intensities . From 1990 to 1995, the gap in energy intensity between the CEE and the EU countries increased further by about 20%. Whereas in 1990 the energy intensities of the CEE countries was 2.4 times above the EU average, in 1995 it is expected to exceed it by a factor of 2.9.

This widening gap can also be observed in Table 3.8 for electricity intensities. For one

Table 3.7 **Energy intensities in the CEE countries, in MJ/(1990 ECU$_{\text{PPP}}$)**

Country	1990	1992	1993	1994	1995
Albania	22.6	25.5	16.1	16.3	22.4
Belarus	31.6	31.9	26.5	26.1	35.6
Bosnia-H.	38.3	-	-	-	53.3
Bulgaria	35.6	28.2	34.4	29.4	32.7
Croatia	23.7	22.3	21.4	23.1	23.4
Czech Republic	21.6	24.7	27.8	23.7	22.8
Estonia	35.9	30.6	28.3	29.4	44.1
Hungary	19.1	20.8	20.8	20.4	20.5
Latvia	19.3	20.6	22.2	21.5	20.4
Lithuania	37.4	42.1	41.3	35.3	37.8
Poland	26.3	26.6	26.0	23.8	23.4
FYR Macedonia	37.4	-	-	-	44.6
Rep. of Moldova	19.9	26.0	19.7	26.1	37.0
Romania	33.5	37.5	34.8	33.1	35.5
Russian Fed.	25.3	23.4	24.0	24.0	27.0
Slovakia	27.2	27.1	27.1	25.9	27.2
Slovenia	16.1	17.0	17.0	16.0	16.0
Ukraine	39.7	45.9	46.4	51.7	61.4
Yugoslavia	27.6	-	-	-	30.1
Average CEE[a]	28.3	28.8	28.3	27.9	30.7
Accession countries	**26.4**	**27.0**	**26.4**	**25.0**	**25.6**
EU-15	12.1	-	-	-	11.3
Cohesion countries	**9.5**	**-**	**-**	**-**	**9.7**

[a] For calculating averages, linear interpolation of missing data has been used.

unit of GDP, electricity use in the EU countries dropped by 3% between 1990 and 1995; yet CEE countries increased their specific electricity use by 3%, so that it is currently about twice the EU level.

To summarise, energy intensities in the CEE countries have not yet improved substantially. In spite of the progress in economic restructuring and much lower absolute consumption levels, the average energy consumption per unit of GDP (expressed in PPP) is still nearly three times higher than the EU average. This difference increases to about six if GDP is measured with market exchange rates (MEXR). Electricity intensities of the CEE economies are on average about two times higher than the EU average and show a tendency to increase further.

Electricity intensities in the CEE countries, in kWh/(1990 ECU_{PPP}) **Table 3.8**

Country	1990	1992	1993	1994	1995
Albania	466.6	594.9	668.3	696.1	599.1
Belarus	743.2	690.2	571.5	702.1	901.6
Bosnia-H.	1,347.8	-	-	-	1,993.4
Bulgaria	968.3	942.9	1,023.4	939.0	907.7
Croatia	757.0	694.1	696.0	689.7	780.9
Czech Republic	543.0	568.4	655.2	573.5	586.2
Estonia	574.3	638.8	507.4	634.1	677.0
Hungary	534.6	579.8	561.5	533.6	533.4
Latvia	420.8	386.3	515.9	510.9	630.9
Lithuania	659.4	859.1	1,008.2	937.2	933.0
Poland	601.1	566.3	554.8	522.4	503.9
FYR Macedonia	1,257.5	-	-	-	1,596.6
Rep. of Moldova	493.5	771.0	645.6	847.6	1,042.3
Romania	731.9	799.1	698.3	671.7	723.4
Russian Fed.	595.0	576.1	591.4	605.2	852.5
Slovakia	604.2	723.9	738.2	678.1	699.6
Slovenia	702.9	648.9	622.5	597.5	564.3
Ukraine	889.1	915.4	972.4	1,138.7	1,426.0
Yugoslavia	901.7	-	-	-	1,129.9
Average CEE[a)]	669.7	680.5	675.9	690.8	761.2
Accession countries	**624.8**	**638.7**	**618.2**	**600.6**	**604.1**
EU-15	402.3	-	-	-	388.9
Cohesion countries	**315.7**	**-**	**-**	**-**	**329.1**

[a)] For calculating averages, linear interpolation of missing data has been used.

4. An energy efficiency convergence (EEC) scenario

As outlined in the previous section, the actual development of the last few years has not resulted in significant structural improvements. This study makes an attempt to explore the potential for environmental improvement offered by an economic and legislative reform process. For this purpose a scenario is constructed with the assumption that, progressive success of the reform process will result in energy consumption patterns and energy intensities in the CEE countries approaching those of the European Union.

As a reference for the convergence scenario, the so-called 'Baseline' scenario was used. This scenario is based on the projected development of the overall economies and energy systems as communicated by the national governments of individual countries to the United Nations Economic Commission for Europe (UN/ECE). The official energy scenarios are further called the 'Official Energy Pathways' (OEP'96) and have been taken from the UN/ECE Energy Database (UN/ECE, 1996). Where necessary, missing forecasts have been constructed by IIASA based on a simple energy projection model. The baseline projections are also used for scenario calculations conducted for the negotiations of the Second NO_x Protocol under the Convention on Long-Range Transboundary Air Pollution.

For the countries of the European Union, the 'Conventional Wisdom' scenario of the 'Energy 2020' Study (DG-XVII, 1996) was used.

4.1. Assumptions and scenario design

The construction of the convergence scenario starts from assumptions about economic (Table 4.1) and population (Table 4.2) development. GDP data are expressed in purchasing power parities (PPP) and are the same as assumptions adopted by national sources for the development of the official energy pathways (compare IEA reviews of national energy policies, IEA, 1991-1996). If GDP forecasts were not available for the 'Official Energy Pathway', forecasts collected by the EBRD (EBRD, 1996) were used. The GDP development for the 15 EU countries is derived from the 'Conventional Wisdom' scenario (DG XVII, 1996). For population projections, the forecasts of the United Nations (United Nations, 1995) were used.

The basic assumption of the energy efficiency convergence scenario is that, on a sectoral level, the energy intensities of each country will gradually approach the level of the EU countries.

A comparison of energy intensities on the sectoral level reveals that in the industrial sector of CEE countries, the energy intensity (per unit of GDP) is considerably higher than in EU countries. Consequently, the convergence scenario postulates a decline of energy intensities in the industry of CEE countries. On the other hand, per capita energy consumption in the residential/commercial sector and for passenger transport is presently lower in the CEE countries than in the EU. Economic development bringing higher material welfare to the population in these countries would therefore most likely increase the energy consumption of private households.

It is difficult to accurately predict the pace and the possible extent of a transition towards the energy intensities of the EU countries. Consequently, the study explores a range of transition scenario variants without making any assumptions about the probabilities of the individual projections. Since it would not be realistic to assume that the large structural differences between the energy systems in CEE and EU countries could be entirely eliminated within the next 10 to 15 years, the scenario constructs an interim step in the year 2010 on the way towards complete harmonisation. As shown earlier, substantial diversity among the CEE countries exists both in terms of GDP per capita and in terms of energy intensity, which will definitely influence the speed of transformation.

Assumed development of the GDP per capita for the EEC scenario, 1990 ECU_{ppp} per capita **Table 4.1**

Country	1990	1995	2000	2005	2010	%/year, 2010/1995
Albania	1,720	1,380	1,532	1,725	1,871	2.1%
Belarus	5,453	3,525	4,116	5,166	6,135	3.8%
Bosnia-H.	1,889	962	1,217	1,444	1,725	4.0%
Bulgaria	4,043	3,442	3,969	4,653	5,410	3.1%
Croatia	3,859	3,134	3,691	4,401	5,248	3.5%
Czech Republic	8,776	7,271	9,047	10,359	11,901	3.3%
Estonia	7,477	5,102	5,711	7,506	8,774	3.7%
Hungary	5,615	5,101	6,117	7,259	8,487	3.5%
Latvia	7,736	4,061	4,723	6,038	6,999	3.7%
Lithuania	4,881	2,507	2,909	3,615	4,248	3.6%
Poland	4,197	4,484	5,582	6,385	7,277	3.3%
FYR Macedonia	1,974	1,232	1,430	1,611	1,817	2.6%
Rep. of Moldova	4,516	1,646	1,915	2,325	2,664	3.3%
Romania	3,120	2,452	2,952	3,448	4,090	3.5%
Russian Fed.	7,001	3,961	4,431	5,602	6,720	3.6%
Slovakia	6,899	5,540	6,758	7,591	8,545	2.9%
Slovenia	7,196	8,332	10,434	12,712	15,436	4.2%
Ukraine	4,869	2,302	2,693	3,397	4,073	3.9%
Yugoslavia	2,818	1,795	2,139	2,513	2,924	3.3%
Average CEE	5,407	3,580	4,199	5,094	5,997	3.5%
Accession countries	**4,883**	**4,350**	**5,316**	**6,187**	**7,150**	**3.4%**
EU-15	**10,392**	**11,309**	**12,317**	**13,800**	**15,462**	**2.1%**
Cohesion countries	9,527	10,180	11,590	13,226	15,192	2.7%

In practice, the convergence scenario assumes that in the year 2010 the differences in sectoral energy intensities will diminish to the same degree as the per capita GDP approaches the present average EU level. Expressed differently, it has been assumed that the present gap in sectoral energy intensity between a CEE country and the EU average will close at the same rate as the gap of the per capita GDP (for the purpose of this analysis the PPP concept has been used).

There are, however, some CEE countries for which the economic projections listed in Table 4.1 would not bring the per capita GDP above 50% of the present EU average. For these cases, it has been assumed that energy intensities would improve by 50% by the year 2010. A detailed description of the procedure for deriving the energy scenarios is provided in Annex 2.

It must be re-emphasised that this scenario is not intended to provide a realistic projection of energy demand in the year 2010. Currently, it is impossible to accurately predict the speed of the transition process and the effects of various types of constraints on this process. This scenario therefore has to be considered simply as one plausible and consistent projection for exploring the effects of changes in the energy consumption structure on pollu-

Table 4.2 Population development in Europe, 1990–2010, million people

Country	1990	1995	2000	2005	2010	%/a, 2010/1995
Albania	3.3	3.4	3.6	3.8	4.1	1.1%
Belarus	10.2	10.1	10.1	10.0	10.0	0.0%
Bosnia-H.	4.3	4.3	4.3	4.4	4.4	0.1%
Bulgaria	9.0	8.6	8.6	8.4	8.2	-0.3%
Croatia	4.5	4.4	4.4	4.4	4.4	-0.1%
Czech Republic	10.3	10.3	10.3	10.4	10.4	0.1%
Estonia	1.6	1.5	1.5	1.5	1.5	-0.2%
Hungary	10.4	9.9	9.9	9.8	9.7	-0.2%
Latvia	2.7	2.5	2.5	2.4	2.4	-0.2%
Lithuania	3.7	3.7	3.7	3.7	3.7	0.1%
Poland	38.1	38.8	38.8	39.3	39.9	0.2%
FYR Macedonia	2.0	2.2	2.2	2.3	2.4	0.5%
Rep. of Moldova	4.4	4.5	4.5	4.6	4.8	0.4%
Romania	23.2	22.6	22.6	22.4	22.3	-0.1%
Russia*	102.8	101.2	101.2	100.2	99.5	-0.1%
Slovakia	5.3	5.5	5.5	5.6	5.7	0.3%
Slovenia	2.0	1.9	1.9	1.9	1.9	-0.1%
Ukraine	51.6	51.0	51.0	50.5	50.1	-0.1%
Yugoslavia	10.2	10.7	10.7	10.9	11.1	0.2%
CEE	299.5	297.2	297.4	296.6	296.5	0.0%
Accession countries	**106**	**105**	**105**	**105**	**106**	**0.0%**
EU-15	**365.1**	**371.5**	**376.8**	**381.2**	**386.7**	**0.3%**
Cohesion countries	62.9	63.7	63.8	63.9	63.5	0.0%

* Only the European part of Russia.

tion loads and emission abatement strategies. The effects of modifying some input assumptions are discussed in Section 4.3.

4.2. The ‘energy efficiency convergence’ scenario: Results

The assumptions about the gradual improvement of the sectoral energy intensities of the CEE countries have been discussed above. The algorithm described in Annex 2, prescribes for the year 2010 an average decrease in industrial energy intensities by 37%, compared to the 2010 projection in the baseline scenario, or a 50% improvement compared to 1990. Still, the average energy intensity will be twice as high as the EU level, and significant differences remain among individual CEE countries. Changes in the domestic and residential sector are moderate. The largest difference, however, occurs for passenger transport. Compared with the baseline scenario for 2010, per capita energy consumption will double, or triple if related to the year 1990. On the other hand, even after such a sharp increase, the per capita consumption will reach only two thirds of the EU level (Table 4.3).

The assumptions made for this scenario and the implied improvements in energy intensities are that total energy consump-

Table 4.3 Comparison of specific energy consumption in the energy convergence (EEC-B) with the baseline (OEP'96) scenario

	Industry, MJ/ECU GDP			Domestic, GJ/capita			Car transport, GJ/capita			Other transport, MJ/ECU GDP		
Country	1990	2010		1990	2010		1990	2010		1990	2010	
		Baseline	EEC-B		Baseline	EEC-B		Baseline	EEC-B		Baseline	EEC-B
Albania	7.06	5.46	3.78	7.99	7.54	21.17	0.29	2.36	10.37	1.93	2.22	1.43
Belarus	10.06	7.73	4.91	49.26	44.95	39.87	3.54	6.58	12.48	2.49	1.67	1.15
Bosnia-H.	12.39	11.21	6.65	7.92	9.15	21.97	2.70	2.99	10.68	2.11	2.33	1.48
Bulgaria	13.54	10.35	6.22	17.02	22.74	28.77	4.65	6.79	12.58	3.22	2.46	1.55
Croatia	6.20	3.70	2.89	24.13	29.21	32.00	5.83	8.18	13.28	1.29	1.20	0.92
Czech Republic	5.82	3.73	2.47	47.25	41.06	36.24	6.11	7.48	15.86	1.47	0.93	0.70
Estonia	7.63	7.06	4.24	53.57	58.95	45.24	6.51	13.96	16.46	2.03	1.61	1.06
Hungary	4.28	2.38	2.22	34.83	48.27	40.87	5.33	9.87	14.54	1.22	1.21	0.89
Latvia	5.37	5.28	3.69	53.16	50.09	42.44	5.70	8.92	13.64	3.00	3.63	2.13
Lithuania	6.64	5.73	3.91	41.20	45.55	40.17	5.66	7.25	12.81	3.35	3.97	2.30
Poland	6.54	3.84	2.97	29.75	38.06	36.43	3.65	6.35	12.36	1.64	1.03	0.83
FYR Macedonia	13.51	11.05	6.57	8.73	7.87	21.33	3.15	3.11	10.74	1.97	1.88	1.26
Rep. of Moldova	5.13	6.35	4.22	31.64	24.50	29.65	1.98	2.09	10.23	1.18	1.68	1.16
Romania	13.63	11.16	6.63	13.75	20.29	27.54	2.25	3.03	10.70	2.00	1.63	1.13
Russian Federation	9.20	8.39	5.24	39.92	38.73	36.76	3.49	5.07	11.72	1.94	1.75	1.19
Slovakia	9.93	6.25	3.95	37.59	35.91	35.30	4.50	7.76	13.63	1.73	1.50	1.02
Slovenia	4.87	2.09	2.09	20.10	22.45	34.77	12.11	15.33	18.37	1.01	0.51	0.51
Ukraine	16.26	16.89	9.49	41.26	42.46	38.63	2.94	4.35	11.36	2.08	2.22	1.43
Yugoslavia	8.22	6.49	4.29	7.87	7.27	21.03	3.95	4.12	11.25	1.33	1.25	0.94
Average CEE	9.80	7.86	4.93	34.10	35.50	35.09	3.63	5.41	12.03	1.92	1.61	1.11
Accession countries	**7.81**	**5.14**	**3.52**	**28.92**	**34.78**	**34.64**	**4.20**	**6.55**	**12.85**	**1.84**	**1.33**	**0.96**
EU-15	**2.84**	**2.09**	**2.09**	**31.07**	**34.79**	**34.79**	**15.18**	**18.37**	**18.37**	**0.76**	**0.64**	**0.64**
Cohesion countries	2.39	1.86	1.86	13.90	20.85	20.85	12.01	18.47	18.47	0.98	0.82	0.82

Table 4.4 **Comparison of specific electricity consumption in the Energy Efficiency Convergence (EEC-B) with the Baseline scenario (OEP'96)**

Country	Industry, kWh/ECU GDP 1990	2010 Baseline	2010 EEC-B	Domestic, kWh/capita 1990	2010 Baseline	2010 EEC-B	Transport, kWh/capita 1990	2010 Baseline	2010 EEC-B
Albania	0.29	0.24	0.20	253	267	1,483	42	85	160
Belarus	0.42	0.38	0.27	1,469	1,552	2,126	272	287	261
Bosnia-H.	0.71	0.72	0.44	1,172	1,150	1,925	31	38	136
Bulgaria	0.51	0.45	0.30	1,699	2,236	2,468	145	181	208
Croatia	0.33	0.25	0.20	1,537	1,734	2,217	92	80	157
Czech Republic	0.29	0.22	0.17	1,941	2,927	2,752	278	257	246
Estonia	0.25	0.24	0.19	2,333	3,019	2,838	123	144	189
Hungary	0.25	0.17	0.16	1,501	2,726	2,711	107	157	196
Latvia	0.19	0.22	0.19	1,654	1,904	2,302	156	163	199
Lithuania	0.33	0.28	0.22	1,520	2,102	2,401	82	81	158
Poland	0.27	0.21	0.18	1,232	1,824	2,262	169	233	234
FYR Macedonia	0.73	0.63	0.39	1,010	963	1,832	41	23	129
Rep. of Moldova	0.23	0.33	0.24	1,146	1,036	1,868	64	69	152
Romania	0.53	0.44	0.30	515	656	1,678	105	106	170
Russian Fed	0.34	0.37	0.26	1,246	1,475	2,088	515	561	398
Slovakia	0.42	0.36	0.25	1,011	1,840	2,315	273	245	240
Slovenia	0.42	0.20	0.16	1,944	2,171	2,699	58	61	148
Ukraine	0.57	0.70	0.43	1,274	1,358	2,029	258	250	242
Yugoslavia	0.47	0.40	0.28	1,159	1,130	1,915	52	61	148
Average CEE	0.38	0.36	0.26	1,246	1,545	2,123	291	313	274
Accession countries	**0.34**	**0.26**	**0.20**	**1,249**	**1,836**	**2,269**	**157**	**187**	**211**
EU-15	**0.18**	**0.16**	**0.16**	**2,210**	**2,700**	**2,700**	**109**	**234**	**234**
Cohesion countries	0.15	0.13	0.13	1,475	2,191	2,191	66	303	303

tion in the CEE region shrinks by 14% compared to the baseline. On a sectoral basis, industrial energy use declines by 32%, energy use in the domestic/residential sector remains constant, and energy use for freight transport decreases by about 20%. Energy demand for passenger transport, however, would be about one third higher than in the baseline scenario, and about 40% higher if compared to the year 1990 (Table 4.4).

The structural changes implied by the transition also cause significant shifts in the fuel composition (compare Tables 4.5, 4.6 and 4.7). Most important is the drastic decline of the share of solid fuels, which diminishes from 27% in 1990 to 14% in 2010. This is compensated for by the growing importance of natural gas (from 47% to 51%) and of liquid fuels (from 22% to 25%). Industry would consume only 36% instead of 45% of total fuel, but transport would grow from 10% to 16%. It is interesting to note that total electricity consumption is only 5 % lower, because the decrease in the industry is, to a large extent, offset by the increase in the domestic

Energy consumption by fuel and by sector in the CEE countries in the year in 1990, in PJ **Table 4.5**

Fuel/Sector	Industry [1]	Domestic	Transport [2]	Power plants	Sum
Brown coal/lignite	136	437	0	2,857	3,430
Hard coal	816	1,913	17	3,546	6,291
Derived coal (Coke, briquettes)	1,559	192	4	14	1,769
Other solid fuels (wood, waste)	144	743	1	155	1,044
Heavy fuel oil	2,694	440	10	3,721	6,865
Medium distillates (gas oil)	456	236	2,185	143	3,020
Light fractions (gasoline, naphtha, LPG)	232	108	1,636	11	1,986
Natural gas and derived gases	7,139	2,105	2	8,794	18,040
Renewables	0	0	0	0	0
Hydropower	0	0	0	967	967
Nuclear	0	0	0	2,519	2,519
Electricity[3]	3,145	1,343	314	-4,874	-72
District heat[3]	5,906	2,696	46	-8,649	0
Total	**22,227**	**10,214**	**4,214**	**9,203**	**45,858**

Energy consumption by fuel and by sector in the CEE countries for the Baseline scenario in the year in 2010, in PJ **Table 4.6**

Fuel/Sector	Industry [1]	Domestic	Transport [2]	Power plants	Sum
Brown coal/lignite	78	194	0	2,361	2,633
Hard coal	515	1,366	0	3,111	4,993
Derived coal (Coke, briquettes)	1,089	114	0	13	1,216
Other solid fuels (wood, waste)	179	600	0	172	951
Heavy fuel oil	1,924	327	10	1,638	3,899
Medium distillates (gas oil)	421	422	2,530	171	3,545
Light fractions (gasoline, naphtha, LPG)	214	121	1,556	11	1,902
Natural gas and derived gases	7,106	2,924	1	10,132	20,164
Renewables	1	3	0	0	4
Hydro	0	0	0	1,079	1,079
Nuclear	0	0	0	2,825	2,825
Electricity[3]	3,248	1,650	334	-5,208	25
District heat[3]	4,781	2,803	30	-7,615	0
Total	**19,557**	**10,525**	**4,463**	**8,691**	**43,235**

Notes:

[1] 'Industry' includes manufacturing industry, conversion other than power plant, consumption by energy producing industries, losses in transport and distribution, and non-energy use.

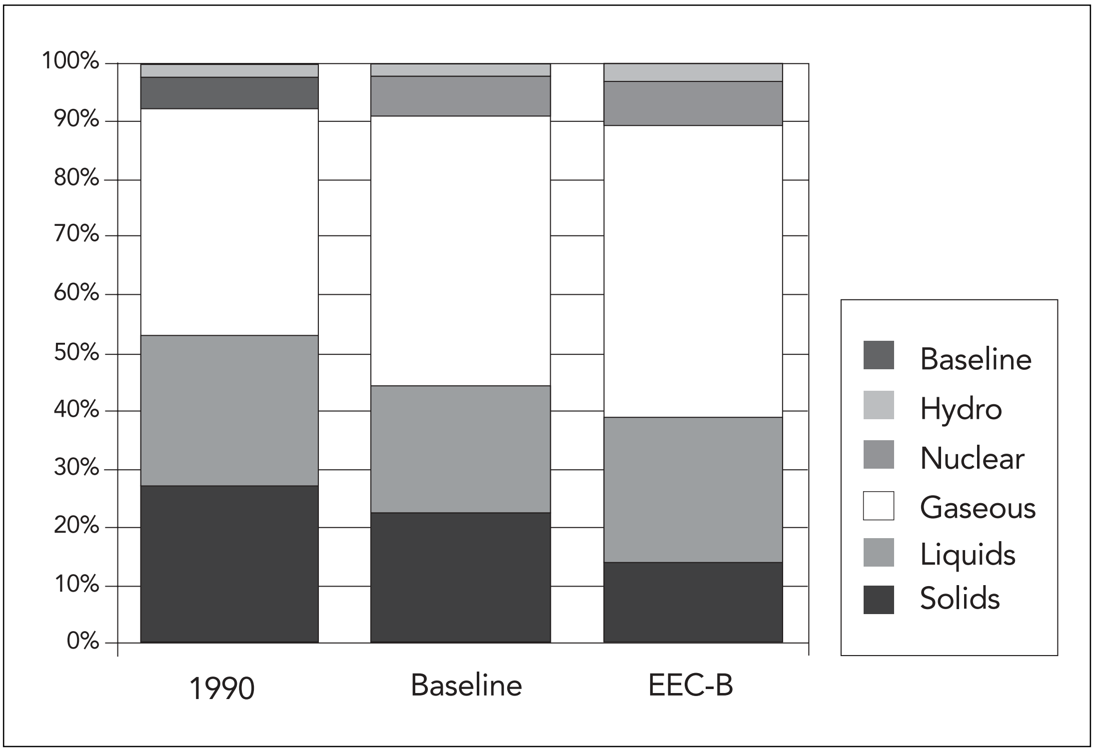
[2] According to the RAINS aggregation, the transport sector includes road transport and other mobile sources and machinery. It excludes energy consumed by air transport and international marine bunkering.

[3] Gross production of electricity and heat is presented with negative numbers.

Table 4.7 Energy consumption by fuel and by sector in the CEE countries for the Energy Efficiency Convergence (EEC-B) scenario in the year in 2010, in PJ

Fuel/Sector	Industry 1)	Domestic	Transport 2)	Power plants	Sum
Brown coal/lignite	28	96	0	1,634	1,757
Hard coal	209	427	0	1,931	2,568
Derived coal (Coke, briquettes)	286	128	0	12	426
Other solid fuels (wood, waste)	72	198	0	61	331
Heavy fuel oil	1,356	223	32	1,041	2,652
Medium distillates (gas oil)	271	484	2,083	146	2,983
Light fractions (gasoline, naphtha, LPG)	174	172	3,398	10	3,753
Natural gas and derived gases	5,620	3,746	1	9,469	18,836
Renewables	0	4	0	0	4
Hydropower	0	0	0	1,079	1,079
Nuclear	0	0	0	2,825	2,825
Electricity3)	2,393	2,285	292	-4,955	16
District heat3)	2,854	2,674	28	-5,555	0
Total	**13,263**	**10,435**	**5,834**	**7,698**	**37,230**

Figure 4.1 Structure of energy consumption of the EEC-B scenario by fuel



Energy consumption by country in the EEC-B scenario and comparison with the baseline, PJ **Table 4.8**

Country	1990	2010 Baseline	2010 EEC-B	Baseline=100
Albania	128	143	247	173%
Belarus	1,762	1,553	1,252	81%
Bosnia-H.	311	297	340	115%
Bulgaria	1,296	1,262	1,057	84%
Croatia	413	447	455	102%
Czech Republic	1,956	1,837	1,544	84%
Estonia	423	366	256	70%
Hungary	1,109	1,350	1,243	92%
Latvia	399	359	280	78%
Lithuania	677	565	439	78%
Poland	4,202	4,951	4,858	98%
FYR Macedonia	151	138	170	123%
Rep. Of Moldova	392	324	359	111%
Romania	2,425	2,525	2,437	97%
Russian Fed.	18,237	16,617	13,735	81%
Slovakia	987	982	796	81%
Slovenia	231	234	263	112%
Ukraine	9,970	8,559	6,606	77%
Yugoslavia	790	725	893	123%
CEE	45,859	43,235	37,230	86%
Accession countries	**13,705**	**14,431**	**13,174**	**91%**
EU-15	**54,357**	**64,665**	**64,665**	**100%**
Cohesion countries	5,691	7,668	7,668	100%
Total Europe	**102,931**	**110,847**	**104,843**	**95%**

Note:
Total Europe includes also energy consumption in Norway and in Switzerland.

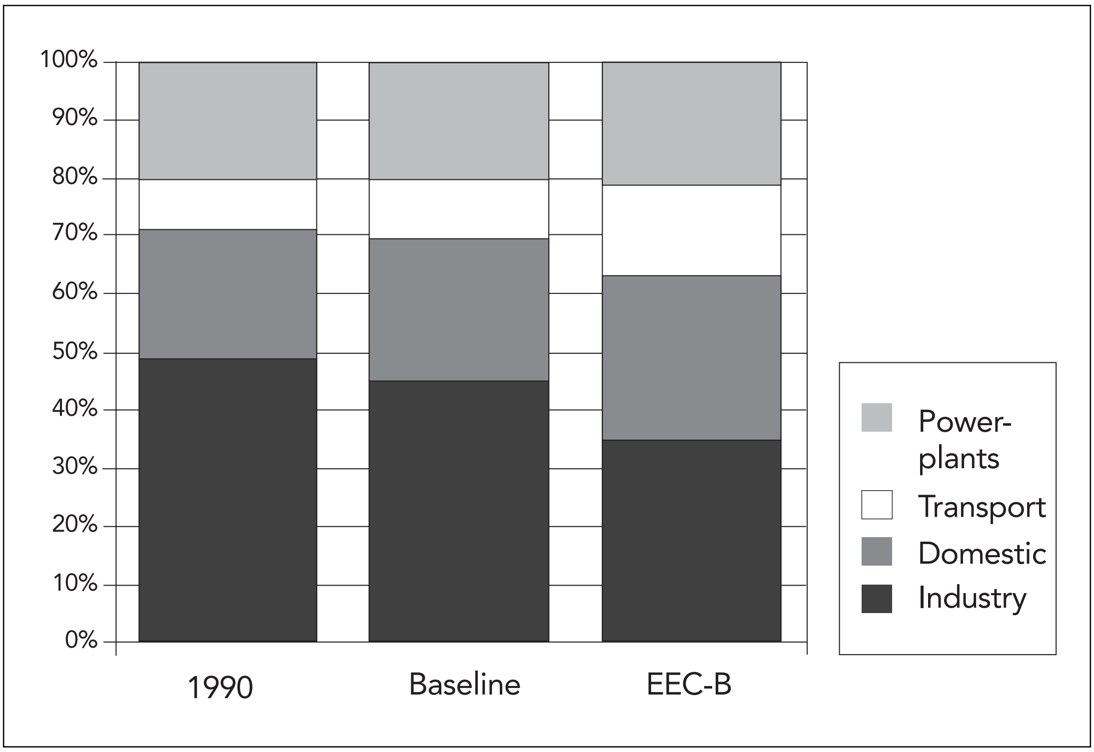
sector. Data for individual countries is presented in Table 4.8.

Using the assumptions made for the Energy Efficiency Convergence (EEC-B) scenario, the data results in an increase in energy consumption for those countries with a relatively low per capita consumption level (Albania, Moldova and countries of the former Yugoslavia), if compared with the baseline. For other countries, energy consumption decreases (Figures 4.1 and 4.2).

4.3. Modifications of the scenario assumptions

As mentioned, the scenario technique applied in this study aims at analysing the influence of important input assumptions on the level and the structure of energy consumption rather than attempting to predict the actual development in the future. Consequently, an important step of this approach is to study the response to

Figure 4.2 Structure of energy consumption of the EEC-B scenario by sector



modified assumptions, and thereby to identify important factors determining future energy development.

In this section, the report will explore variations in the resulting energy structures due to two modifications in the input assumptions:

- The energy convergence and efficiency scenario described above assumes a partial movement toward the energy intensities and levels currently observed in the EU. A sensitivity analysis will explore the (hypothetical) situation of full convergence, i.e. if the current EU values were fully achieved in all CEE countries.
- Another sensitivity analysis addresses assumptions regarding sectoral development. The baseline scenario postulates the convergence of the energy intensities of all sectors towards the EU levels, i.e. a decrease of the energy intensities in the industrial sector and an increase of specific energy use for private purposes (transportation, housing). A variant explores the situation if the energy efficiencies in the industrial sector improved towards EU standards and private consumers do not increase their energy consumption beyond the levels projected in the baseline scenario.

The first sensitivity run (exploring full convergence) is motivated by the arbitrary nature of the assumption taken in the EEC-B scenario about the pace and extent of the convergence process until the year 2010. The sensitivity run sketches the long-term potential for the transition process and enables the assessment of the sensitivity of model results against changes in the assumptions about the progress of transformation.

The second analysis addresses the assumption that, on a per capita basis, private households in EU countries consume more energy for transport and domestic

Summary of the energy scenario characteristics **Table 4.9**

Energy pathway	Description	Country group
OEP’96	Official Energy Pathway, 1996 update countries	CEE and EFTA
CW	DGXVII Conventional Wisdom	EU-15
EEC-B	Energy Efficiency and Convergence Scenario, Baseline case (Gap in sectoral energy intensities and per capita consumption between each individual CEE country and the EU-15 average are reduced by at least 50 %)	All CEE countries
EEC-BL	Energy Efficiency and Convergence Scenario, Baseline case with Limits (as in the Baseline case, but growth of fuel consumption by private cars and electricity consumption in the residential/commercial sector are limited to the values in the OEP’96)	All CEE countries
EEC-F	Energy Efficiency and Convergence Scenario, Full convergence case (energy intensities and per capita consumption in all CEE countries reach the EU-15 average)	All CEE countries
EEC-FL	Energy Efficiency and Convergence Scenario, Full convergence case with Limits (energy intensities and per capita consumption in all CEE countries reach the EU-15 average, but growth of fuel consumption by private cars and electricity consumption by the residential/commercial sector are limited to the values in the OEP’96)	All CEE countries

purposes than do those of the CEE countries. The change in lifestyles implied by the EEC-B scenario would therefore cause substantial increases in energy demand for these purposes.

Before 1990, official policies in the centrally planned economies tried to restrict the development of private transport by limiting the availability of vehicles and keeping their prices artificially high. The consumption of motor fuel was rationed either directly, e.g. through a system of fuel coupons, or indirectly through queuing at gasoline stations. The economic reform lifted these restrictions, and resulted in the rapid growth of private transport. For instance, in Poland fuel use in the transport sector increased by 50% during the period 1990–1995, despite the drop in per capita GDP. The fact that 60% of the growth in traffic predicted until the year 2010 has already materialised in the first five years of the restructuring process, illustrates that this rapid development was not anticipated in at least some of the official forecasts. It also demonstrates that the growth of the EEC-B scenario might not be entirely unrealistic.

The higher per capita consumption of electricity by the domestic sector in the EU countries is caused by more energy-intensive lifestyles and consumption patterns (including more living space in the residential sector, use of electricity for space heating[3], and better infrastructure in commerce).

Since the future evolution of energy demand by private households is somewhat uncertain, the sensitivity analysis simulates the effects of policies aimed at sustaining the less energy-intensive lifestyles in the CEE countries into the future. This might be achieved through, e.g. preferences for public transport and disincentives for private transport, such as high fuel prices, high vehicle taxes and duties, etc. In practice it is assumed that fuel consumption

[3] In the pre-reform period the use of electricity for space heating was banned in some CEE countries

Table 4.10 **Energy consumption by fuel and by sector in 2010 for the full convergence (EEC-F) energy pathway, in PJ**

Fuel/Sector	Industry [1)]	Domestic	Transport [2)]	Power plants	Sum
Brown coal/lignite	21	105	0	1,754	1,879
Hard coal	125	398	0	2,112	2,635
Derived coal (Coke, briquettes)	56	48	0	14	118
Other solid fuels (wood, waste)	39	90	0	58	188
Heavy fuel oil	993	230	31	984	2,238
Medium distillates (gas oil)	90	575	1,266	84	2,015
Light fractions (gasoline, naphtha, LPG)	140	120	5,229	17	5,506
Natural gas and derived gases	2,856	3,301	11	7,960	14,128
Renewables	0	4	0	0	4
Hard	0	0	0	1,073	1,073
Nuclear	0	0	0	2,782	2,782
Electricity[3)]	1,770	2,924	250	-5,005	-60
District heat[3)]	1,342	2,570	19	-3,932	0
Total	**7,433**	**10,365**	**6,806**	**7,901**	**32,504**

for private transport as well as electricity consumption by the domestic sector will remain at the levels of the baseline (OEP) scenario. Such variants are calculated both for the partial convergence (EEC-B) and the full convergence (EEC-F) scenarios. Table 4.9 presents a summary of the energy pathways used in the study.

Tables 4.10 to 4.12 present the energy demand by fuel and by economic sector in the year 2010 in the whole CEE region for the alternative energy pathways. Country totals are presented in Table 4.13. Compared with the baseline case (EEC-B, see Section 4.2), energy consumption in the EEC-F scenario decreases by about 13%. Gross electricity demand remains at the level of the baseline case. However, consumption of electricity by the domestic sector is 28% higher, which compensates for the lower consumption by industry. In absolute terms, motor fuels consumption for transport is 19% higher than in the baseline scenario. For the full convergence case, per capita consumption of gasoline is 54% higher, but there is less demand for diesel fuel due to a lower intensity of freight transport.

The sensitivity runs with limits on fuel consumption by private cars and on electricity use in the domestic sector (EEC-BL and EEC-FL) result in a lower demand for total primary energy (-11%), electricity (-15%), and motor fuels (-36%) than in the EEC-B scenario.

Restricting private energy consumption for the full convergence case, results in a 29% decline of overall energy use. Demand for electricity is 59% lower, and for motor fuel 24%. This means that this scenario, which adopts the most optimistic assumptions regarding the possibilities of reducing energy demand in the CEE region, reduces primary energy demand by about one third.

Table 4.11

Energy consumption by fuel and by sector in 2010 for the partial convergence/limited growth in private consumption (EEC-BL) energy pathway, in PJ

Fuel/Sector	Industry [1)]	Domestic	Transport [2)]	Power plants	Sum
Brown coal/lignite	28	96	0	1,410	1,533
Hard coal	209	427	0	1,764	2,400
Derived coal (Coke, briquettes)	286	128	0	11	425
Other solid fuels (wood, waste)	72	198	0	51	321
Heavy fuel oil	1,356	223	32	874	2,486
Medium distillates (gas oil)	271	484	1,972	120	2,846
Light fractions (gasoline, naphtha, LPG)	174	172	1,546	8	1,899
Natural gas and derived gases	5,620	3,746	1	7,964	17,332
Renewables	0	4	0	0	4
Hydro	0	0	0	1,079	1,079
Nuclear	0	0	0	2,825	2,825
Electricity[3)]	2,301	1,643	292	-4,220	16
District heat[3)]	2,854	2,674	28	-5,555	0
Total	**13,171**	**9,794**	**3,871**	**6,330**	**33,165**

Table 4.12

Energy consumption by fuel and by sector in 2010 for the full convergence/limited growth in private consumption (EEC-FL) energy pathway, in PJ

Fuel/Sector	Industry [1)]	Domestic	Transport [2)]	Power plant	Sum
Brown coal/lignite	21	105	0	1,333	1,459
Hard coal	125	398	0	1,729	2,252
Derived coal (Coke, briquettes)	56	48	0	11	115
Other solid fuels (wood, waste)	39	90	0	46	175
Heavy fuel oil	993	230	31	674	1,928
Medium distillates (gas oil)	90	575	1,115	54	1,834
Light fractions (gasoline, naphtha, LPG)	140	120	1,564	10	1,834
Natural gas and derived gases	2,856	3,301	1	5,287	11,444
Renewables	0	4	0	0	4
Hydro	0	0	0	1,073	1,073
Nuclear	0	0	0	2,782	2,782
Electricity[3)]	1,585	1,641	250	-3,536	-60
District heat[3)]	1,342	2,570	19	-3,932	0
Total	**7,247**	**9,081**	**2,980**	**5,531**	**24,839**

For explanations see Table 4.5.

Figure 4.3 **Structure of energy consumption by fuel for the alternative scenarios**

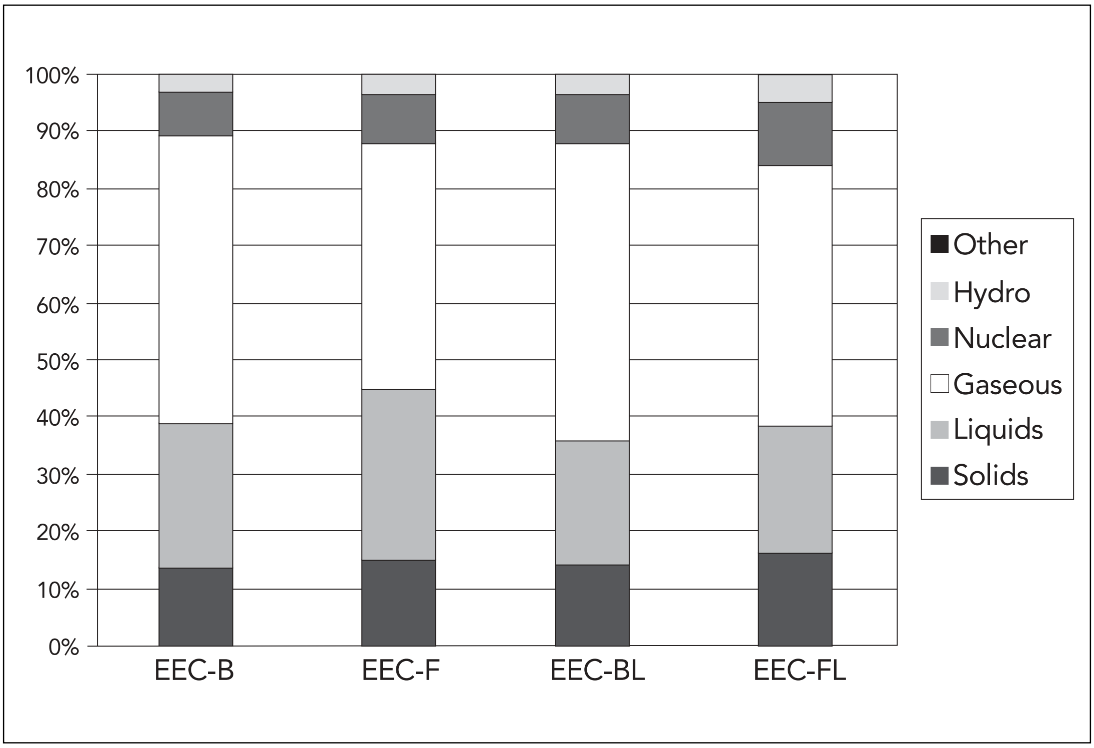
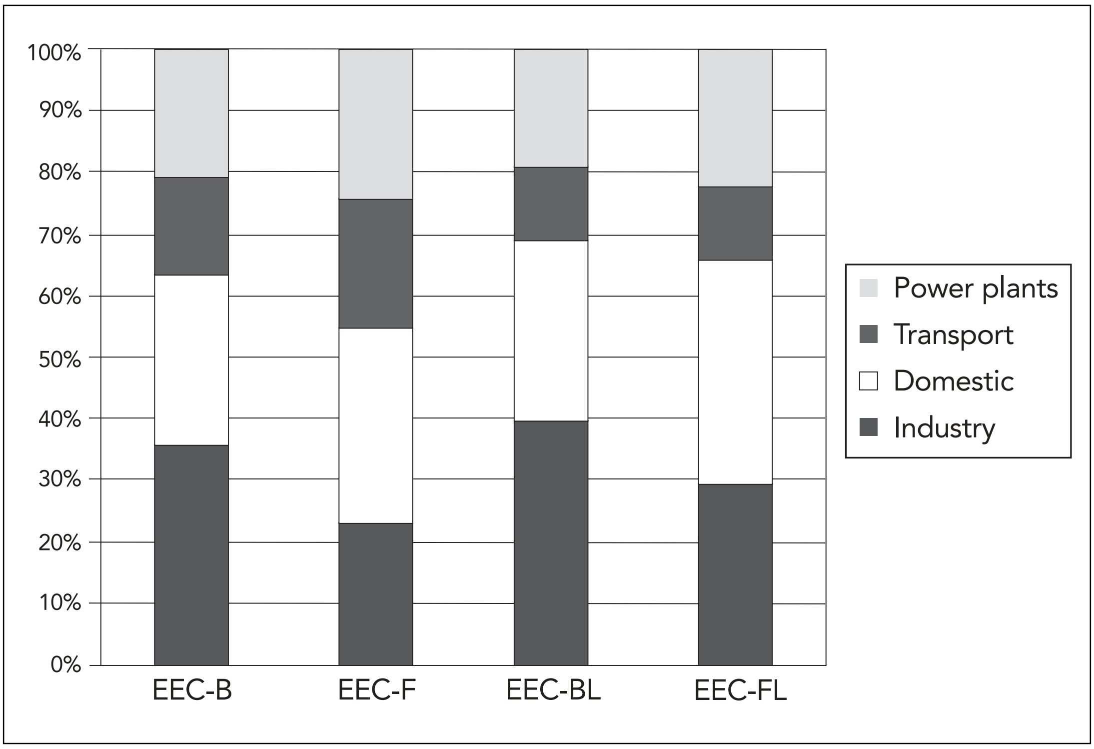


Figure 4.4 **Structure of energy consumption by sector for the alternative scenarios**



Energy consumption by country for the variants of the EEC pathway, in PJ **Table 4.13**

Country	Partial convergence EEC-B	Full convergence EEC-F	Partial convergence limited private consumption EEC-BL	Full, convergence limited private consumption EEC-FL
Albania	247	360	158	186
Belarus	1,252	1,000	1,130	764
Bosnia-H.	340	401	264	255
Bulgaria	1,057	879	987	740
Croatia	455	471	412	381
Czech Republic	1,544	1,494	1,457	1,382
Estonia	256	208	254	201
Hungary	1,243	1,181	1,199	1,099
Latvia	280	234	255	190
Lithuania	439	386	417	331
Poland	4,858	4,914	4,403	3,989
FYR Macedonia	170	206	128	129
Rep. of Moldova	359	422	274	258
Romania	2,437	2,399	1,952	1,512
Russian Fed.	13,735	10,934	12,335	8,326
Slovakia	796	676	736	562
Slovenia	263	287	246	270
Ukraine	6,606	4,976	5,852	3,544
Yugoslavia	893	1,077	706	721
CEE	37,230	32,504	33,165	24,839
Accession countries	**13,174**	**12,658**	**11,906**	**10,276**

5. Atmospheric emissions and environmental impacts

5.1. Emissions of carbon dioxide (CO_2)

Tables 5.1 and 5.2 show the effects of the scenarios on emissions of carbon dioxide (CO_2), which is a major greenhouse gas. All energy pathways analysed in the study cause a decrease in CO_2 emissions. By 2010, emissions decrease in the whole CEE region by 11% compared with 1990 for the baseline scenario (the Official Energy Pathway) and by 26% for the EEC-B scenario. This decrease is higher than 50% for the EEC-FL scenario. In addition, the emissions from the accession countries decrease, though to a lesser extent. For comparison, the energy scenario assumed for the EU-15, i.e. the 'Conventional Wisdom' scenario, shows a 9% increase in CO_2 emissions by 2010 (DG XVII, 1996).

5.2. Scenarios for controlling SO_2 and NO_x emissions

This section assesses the potential for emission reductions offered by the economic reform process in the CEE countries and evaluates the impacts on some air pollution problems in Europe (acidification, eutrophication and ground-level ozone). Energy combustion is the major source of anthropogenic emissions of sulphur dioxide and nitrogen oxides, and changes in the energy structure, as outlined in the energy pathways developed above, could be an important instrument to control these emissions. The second method for controlling emissions is the application of emission control measures. The following sections analyse the interaction between the potential contribution of the convergence of the CEE energy systems towards the present EU standards and the harmonisation of the emission control legislation in the CEE countries with the current EU emission standards. For this purpose, ten combinations of energy scenarios and emission control legislation have been developed. Table 5.3 presents a brief picture of the scenarios.

In addition to emissions of sulphur dioxide and nitrogen oxides, emissions of ammonia also make an important contribu-

Table 5.1 **Emissions of carbon dioxide for the CEE countries, in million tons of $C0_2$**

Fuel	1990	2010				
		OEP'96	EEC_B	EEC-F	EEC-BL	EEC-FL
Coal	1,087	836	449	438	412	362
Oil	870	685	688	715	530	410
Gas	1,012	1,131	1,057	793	972	642
Total	**2,969**	**2,653**	**2,194**	**1,946**	**1,915**	**1,414**

Table 5.2 **Emissions of carbon dioxide for the accession countries, in million tons of $C0_2$**

Fuel	1990	2010				
		OEP'96	EEC_B	EEC-F	EEC-BL	EEC-FL
Coal	558	491	358	357	334	307
Oil	246	250	261	274	208	175
Gas	183	238	241	213	225	185
Total	**987**	**979**	**860**	**844**	**767**	**667**

Summary of the scenarios for SO_2 and NO_x emissions **Table 5.3**

Scenario name	Control strategy	Energy pathway	Country group
REF	Current national and international legislation (emission standards + internationally agreed emission ceilings)	OEP'96	CEE and EFTA
	EU legislation on top of national legislation	CW	EU-15
CLBA	**C**urrent national and international **L**egislation	EEC-**B**	**A**ccession countries*
CLB	**C**urrent national and international **L**egislation	EEC-**B**	All CEE countries*
ELBA	**E**U legislation on top of national **L**egislation	EEC-**B**	**A**ccession countries*
ELB	**E**U legislation on top of national **L**egislation	EEC-**B**	All CEE countries*
ELBL	**E**U legislation on top of national **L**egislation	EEC-**BL**	All CEE countries*
CLFA	**C**urrent national and international **L**egislation	EEC-**F**	**A**ccession countries*
CLF	**C**urrent national and international **L**egislation	EEC-**F**	All CEE countries*
ELFA	**E**U legislation on top of national **L**egislation	EEC-**F**	**A**ccession countries*
ELF	**E**U legislation on top of national **L**egislation	EEC-**F**	All CEE countries*
ELFL	**E**U legislation on top of national **L**egislation	EEC-**FL**	All CEE countries*

* Other countries as in the REF scenario.

tion to acidification and eutrophication. Therefore, a comprehensive analysis of these environmental problems must also include ammonia emissions, although they are caused by agricultural activities (livestock, fertiliser use) rather than energy combustion. Since control strategies and alternative emission scenarios for ammonia were not within the scope of this study, ammonia emissions were assessed only for the reference scenario, using identical assumptions as for the acidification strategy report developed for DG-XI (Amann *et al.*, 1996).

As a reference point, the study simulates the current national emission control regulations in the various countries. These simulations take into account the national legislation in force, as well as the international obligations applicable to the country, even if they are not yet turned into national law.

5.2.1. Emission control in the EU-15 countries

The analysis is based on the following: a detailed inventory of emission control regulations in the individual countries of the EU, the relevant EU Directives [in particular the 'Large Combustion Plant Directive' (OJ, 1988) and the Directive on the Sulphur Content of Gas Oil (Johnson and Corcelle, 1995)], as well as the obligatory clauses regarding emission standards from the protocols under the Convention on Long-Range Transboundary Air Pollution. For instance, the Second Sulphur Protocol (UN/ECE, 1994) obliges its signatories to meet mandatory emissions control standards according to 'Best Available Technology' (BAT) for new plants. In addition to the emission standards for new and existing sources in each country, signatories to the Second Sulphur Protocol should reduce the sulphur content in gas oil for stationary sources to 0.2% and to 0.05% if used as diesel fuel for road vehicles.

For the control of NO_x emissions from mobile sources, the scenario considers the implementation of the current EU standards for all new cars, light duty trucks and heavy duty vehicles (that is, the Directives

Table 5.4 Sulphur dioxide emission control measures in the CEE countries

Country group/country	Measures
Current Legislation	
Signatories of the 2nd Sulphur Protocol (Bulgaria, Croatia, Czech Republic, Hungary, Poland, Russian Federation, Slovak Republic, Slovenia and Ukraine)	New plant emission standards and limits on S content of gas oil. Emission ceilings as in the Protocol or UN/ECE Current Reduction Plans (CRP) ceilings, whichever is stricter
Czech Republic, Croatia, Poland, Slovak Republic, Slovenia, Romania and F. Yugoslavia	National emission standards on existing plants and new plants
Other CEE countries	No emission standards, caps on emissions according to UN/ECE CRP
European Union Legislation	
All CEE countries	Current Legislation plus standards from the Large Combustion Plant Directive (LCPD) – if stricter than national legislation. EU directives on sulphur content of liquid fuels

94/12/EC, 70/220/EEC and 88/77/EEC; see McArragher *et al.*, 1994) in the Member States of the European Union. Additionally, the scenario assumes the implementation of the measures proposed by the EU Auto/Oil Program (Touche Ross & Co., 1995, European Commission, 1996). This includes vehicle-related measures like improved catalytic converters, engine modifications and on-board diagnostic systems. Furthermore, the impacts of the proposed improved inspection and maintenance practices and the changes in fuel quality are incorporated. The pace of the implementation of the vehicle-related measures depends on the turnover of vehicle stock and has been based on modelling work performed for the Auto/Oil study.

5.2.2. Emission control in CEE countries

For the CEE countries, two emission control strategies were considered. The first scenario captures the current national and international legislation applicable to each individual country. The second case simulates, on a country-by-country basis, the harmonisation of the present regulations with EU emission standards .

The first scenario, the 'Current Legislation' control strategy, is based on information compiled by CITEPA (CITEPA, 1996), the reviews of national policies and strategies published by the UN/ECE (UN/ECE, 1995b) and the database on environmental standards available at the Environmental Standards Centre of the Central European University in Budapest (CEU, 1997). In some CEE countries (Czech Republic, Hungary, Poland, Romania, Slovak Republic, Slovenia, as well as in other countries of former Yugoslavia), regulations use the concept of emission limit values, specifying for particular source categories the maximum allowable emissions in relation to flue gas volume, for example. Other countries determine the maximum emissions on a case-by-case basis during the licensing process. Furthermore, countries that signed the Second Sulphur Protocol, will become subject to the emission limit values specified in the Protocol, and will limit the sulphur content in gas oil as required by the Protocol.

In most CEE countries, regulations on the emissions from mobile sources combine elements of the ECE and EU specifications (CITEPA, 1996). A number of countries (Czech Republic, Hungary, Poland, Slovak Republic and Slovenia) already require the use of catalytic converters for new passenger cars, and the emission standards for heavy-duty trucks are similar to the EURO-1 limits for the EU.

The second case, or the 'EU Legislation' control strategy, superimposes the relevant

Nitrogen oxides emission control measures in the CEE countries **Table 5.5**

Country group/country	Measures
Current Legislation	
Parties to the Sofia (Nitrogen) Protocol (Belarus, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Russian Federation, Slovak Republic, Slovenia and Ukraine)	Emission ceilings as in the Nitrogen Protocol (UN/ECE, 1988) or UN/ECE Current Reduction Plans (CRP) ceilings, whichever is stricter
Czech Republic, Croatia, Poland, Slovak Republic, Slovenia, Romania and F. Yugoslavia	National emission standards on stationary sources (new and existing plants)
Czech Republic, Poland, Slovak Republic and Slovenia	National mobile source standards comparable with 1992 and 1996 standards for the EU (requirement for catalytic converters for gasoline engines and combustion modifications on diesel engines)
Other CEE countries	No stationary source emission standards[5], caps on emissions according to UN/ECE CRP. Pre-1990 UN/ECE standards on mobile sources (no requirement for catalytic converters for gasoline engines and combustion modifications on diesel engines)
European Union Legislation	
All CEE countries	Current Legislation plus stationary source standards from the Large Combustion Plant Directive (LCPD) – if stricter than national legislation. Mobile source standards from Auto/Oil Programme

pieces of EU legislation on the present national legislation in each individual country. This means that new plants in the CEE countries would have to meet the requirements of the Large Combustion Plant Directive of 1988 and that countries that did not sign the Second Sulphur Protocol would enforce the Directive on the Sulphur Content of Gas Oil[4]. For mobile sources, the current EU emission standards would apply from the year 1998, and the tightened standards of the Auto/Oil programme would also affect the CEE countries from the year 2000 onwards.

Due to the two-track nature of current European emission control strategies (using emission limit values for specific source categories and imposing national caps on total emissions), both control strategies (the ‘Current Legislation’ and the ‘European Union Legislation’) simulate the effects of the two types of legislation and select the more binding results. The types of emission limit values adopted for individual countries in the CEE region are described in Tables 5.4 and 5.5. Emission ceilings for each country have been adopted according to the so-called ‘Current Reduction Plans’ published by the UN/ECE (UN/ECE, 1995b).

5.3. The reference scenario

5.3.1. Emissions and emission control costs

To provide a reference point against which the changes in emissions and impacts resulting from the economic transition process could be compared, the reference scenario simulates the situation for the year 2010 , assuming the continuation of current policies and trends. The reference scenario takes the emission level for each country resulting from the implementation of emission limit values according to the ‘Current Legislation’ and compares it with the emission ceilings from the ‘Current Reduction Plans’ (CRP). Finally, the more stringent value is used for each country.

[5] Because measures depending on implementation of primary NO_x reduction measures on new power plants are state-of-the-art technology, such controls were assumend by default in all countries.

The SO_2 emission levels expected for the year 2010 are presented in Table 5.6. Emissions of NO_x and ammonia are shown in Tables 5.7 and 5.8. For comparison, data for 1990 and 1994 are also presented. Values for 1994 were submitted by the Parties to the Convention on Long-Range Transboundary Air Pollution (EMEP, 1996). If 1994 data were lacking, 1993 data were used instead and the numbers presented in *italics*.

According to the Reference scenario, the European emissions of SO_2 are likely to be reduced by 54% compared to 1990. Reductions of NO_x and ammonia are 20% and 17% respectively. It is interesting to note that the Czech Republic, the Slovak Republic and Slovenia are expected to reduce their SO_2 emissions by more than 80%, due to (i) the strict emission limit values recently introduced and (ii) the shift from coal to less polluting fuels. In the EU-15 as a whole, SO_2 emissions will be reduced by 66% compared to 1990; NO_x will drop by 48% and ammonia by 15%.

Table 5.9 presents estimates of emission control costs for the reference scenario for the year 2010. Total European costs amount to about ECU 47 billion/year, but only 12% of these expenditures occur in the CEE region. For the EU-15 countries, more than three-quarters of the total cost of about ECU 40 billion/year are attributed to the abatement of NO_x, and one-fifth to the control of SO_2. This is in sharp contrast to the CEE countries, where 63% of the total costs are related to the control of SO_2 emissions.

5.3.2. The reference scenario: impacts on acidification and eutrophication

Critical loads are defined as the maximum level of exposure of one or several pollutants, below which no harmful effects occur to sensitive ecosystems. With the help of the RAINS model it is possible to assess, for any given pattern of sulphur and nitrogen deposition resulting from an emission control scenario, the ecosystems facing acid deposition above or below their critical loads. From this it is therefore possible to judge whether sustainable conditions can be met by a specific emission control strategy. Critical loads are established for the natural and semi-natural ecosystems in Europe (including forests, lakes, heath land, raised bogs, etc.) but are not established for agricultural areas, built-up land, and other, non-natural use of land. Figure 5.1 presents, for each grid cell, the percentage of ecosystems that in 1990 experienced acid deposition above their critical loads for acidity. Grids left empty in the map experienced full protection of their ecosystems, i.e. experienced 0% excess. The figure shows that there were strong regional differences with regards to exceeding critical loads. In most parts of Greece, southern Italy, France, Spain, Portugal, Ireland and Russia, acid deposition was below the critical loads. However, critical load thresholds were exceeded on a widespread basis in many grids in Germany, Poland and the Czech Republic. In the latter countries more than 90% of the ecosystems were unprotected. A summary of the situation is provided in Figure 5.3, giving both the shares of ecosystems in each country, as well as the absolute size of unprotected ecosystems (in hectares). In Europe, about 83 million hectares of ecosystems (i.e. 15% of the total ecosystem area) was not protected against acidification (Table 5.10). In the EU-15, 33 million hectares, an area larger than the whole of Germany, received acid deposition above critical loads. Within the EU-15, the least protection occurred in the Netherlands (89% unprotected) and Germany (81%), whereas Greek and Portuguese ecosystems enjoyed full protection. In the CEE region, the situation was the worst in the Czech Republic and Poland with 95% and 93% of the ecosystems unprotected, respectively. The average protection level for the accession countries was therefore low (39% unprotected).

SO_2 emissions in the years 1990, 1994 and for the reference scenario in the year 2010 (in kilotons)

Table 5.6

		SO_2		*Change*
Country	1990	1994	2010	*2010/1990*
Albania	120	-	54	*-55%*
Belarus	710	381	490	*-31%*
Bosnia-H	480	-	410	*-15%*
Bulgaria	2,020	1,485	835	*-59%*
Croatia	180	89	69	*-62%*
Czech R.	1,876	1,270	151	*-92%*
Estonia	275	-	172	*-37%*
Hungary	1,010	741	544	*-46%*
Latvia	115	-	105	*-9*
Lithuania	222	-	107	*-52%*
Poland	3,210	2,605	1,397	*-56%*
R. Moldova	91	-	91	*0%*
Romania	1,311	912	590	*-55%*
Russia	4,459	2,983	2,350	*-47%*
Slovakia	543	238	113	*-79%*
Slovenia	195	177	37	*-81%*
FYR Macedonia	106	-	81	*-24%*
Ukraine	2,782	1,715	1,486	*-47%*
F. Yugoslavia	581	424	262	*-55%*
CEE	20,286	-	9,344	-54%
Accession countries	**10,777**	**-**	**4,053**	***-62%***
Austria	90	74	57	*-37%*
Belgium	317	253	215	*-32%*
Denmark	180	156	71	*-61%*
Finland	260	117	116	*-55%*
France	1,298	*1,121*	691	*-47%*
Germany	5,331	2,997	740	*-86%*
Greece	510	-	361	*-29%*
Ireland	178	*157*	155	*-13%*
Italy	1,678	*1,490*	847	*-50%*
Luxembourg	14	12	4	*-71%*
Netherlands	205	154	56	*-73%*
Portugal	283	272	194	*-31%*
Spain	2,266	*2,071*	1,035	*-54%*
Sweden	136	97	97	*-29%*
UK	3752	2,709	980	*-74%*
EU-15	**16,497**	**-**	**5,619**	***-66%***
Norway	54	35	33	*-39%*
Switzerland	43	31	30	*-30%*
Atlantic Ocean	891	-	891	*0%*
Baltic	72	-	72	*0%*
North Sea	475	-	475	*0%*
SEA	**1,438**	**-**	**1,438**	***0%***
TOTAL	**38,318**	**-**	**16,464**	***-57%***

Table 5.7 **NO_x emissions for 1990, 1994 and the reference scenario in the year 2010 (in kilotons)**

Country	1990	NO_x 1994	2010	*Change 1990/2010*
Albania	30	-	30	*0%*
Belarus	285	203	184	*-35%*
Bosnia-H	80	-	48	*-40%*
Bulgaria	376	327	290	*-23%*
Croatia	83	59	64	*-23%*
Czech R.	742	369	226	*-70%*
Estonia	72	0	72	*0%*
Hungary	238	183	196	*-18%*
Latvia	93	0	93	*0%*
Lithuania	158	-	137	*-13%*
Poland	1,279	1,105	821	*-36%*
R. Moldova	35	-	66	*89%*
Romania	546	319	453	*-17%*
Russia	2675	1,995	2,658	*-1%*
Slovakia	227	173	110	*-52%*
Slovenia	57	66	31	*-46%*
FYR Macedonia	39	-	22	*-43%*
Ukraine	1,097	568	1,094	*0%*
F. Yugoslavia	211	52	118	*-44%*
CEE	8,322	-	6,713	-19%
Accession countries	**3,788**	**-**	**2,429**	***-36%***
Austria	222	177	116	*-48%*
Belgium	352	345	196	*-44%*
Denmark	269	272	119	*-56%*
Finland	300	283	163	*-46%*
France	1,585	*1,544*	895	*-44%*
Germany	3,071	2,872	1,279	*-58%*
Greece	306	-	282	*-8%*
Ireland	115	*122*	73	*-37%*
Italy	2,047	*1,997*	1,160	*-43%*
Luxembourg	23	21	10	*-57%*
Netherlands	575	542	140	*-76%*
Portugal	215	253	206	*-4%*
Spain	1,178	*1,227*	851	*-28%*
Sweden	411	392	207	*-50%*
UK	2,702	2,219	1,224	*-55%*
EU-15	**13,370**	**-**	**6,921**	***-48%***
Norway	230	225	161	*-30%*
Switzerland	165	139	78	*-53%*
Atlantic Ocean	1,275	-	1,275	*0%*
Baltic	80	-	80	*0%*
North Sea	710	-	710	*0%*
SEA	**2,065**	**-**	**2,065**	***0%***
TOTAL	**24,152**	**-**	**15,938**	***-34%***

Ammonia emissions for 1990, 1994 and the reference scenario in the year 2010 (in kilotons) **Table 5.8**

		NH_3		*Change*
Country	1990	1994	2010	*1990/2010*
Albania	30	-	34	*13%*
Belarus	257	4	163	*-37%*
Bosnia-H	36	-	23	*-36%*
Bulgaria	141	146	126	*-10%*
Croatia	37	24	38	*3%*
Czech R.	105	92	124	*18%*
Estonia	29	-	28	*-3%*
Hungary	176	*140*	136	*-23%*
Latvia	38	-	28	*-26%*
Lithuania	84	-	80	*-5%*
Poland	508	384	545	*7%*
R. Moldova	50	-	48	*-4%*
Romania	300	221	300	*0%*
Russia	1,191	772	894	*-25%*
Slovakia	62	47	53	*-15%*
Slovenia	27	-	20	*-26%*
FYR Macedonia	17	-	16	*-5%*
Ukraine	926	-	648	*-30%*
F. Yugoslavia	99	-	83	*-16%*
CEE	4,112	-	3,387	*-18%*
Accession countries	**1,470**	**-**	**1,440**	***-2%***
Austria	91	93	93	*2%*
Belgium	95	96	106	*12%*
Denmark	140	126	103	*-26%*
Finland	41	41	30	*-27%*
France	700	666	669	*-4%*
Germany	759	622	539	*-29%*
Greece	78	-	76	*-3%*
Ireland	126	126	126	*0%*
Italy	416	394	391	*-6%*
Luxembourg	7	8	6	*-14%*
Netherlands	236	171	81	*-66%*
Portugal	93	92	84	*-10%*
Spain	353	345	373	*6%*
Sweden	61	58	53	*-13%*
UK	320	320	270	*-16%*
EU-15	**3,516**	**3,158**	**3,000**	***-15%***
Norway	39	41	39	*0%*
Switzerland	62	60	58	*-6%*
Atlantic Ocean	0	-	0	*0%*
Baltic	0	-	0	*0%*
North Sea	0	-	0	*0%*
SEA	**0**	**-**	**0**	***0%***
TOTAL	**7,729**	**-**	**6,484**	***-16%***

Table 5.9 **Emission control costs for the reference scenario in the year 2010 (in million ECU/year)**

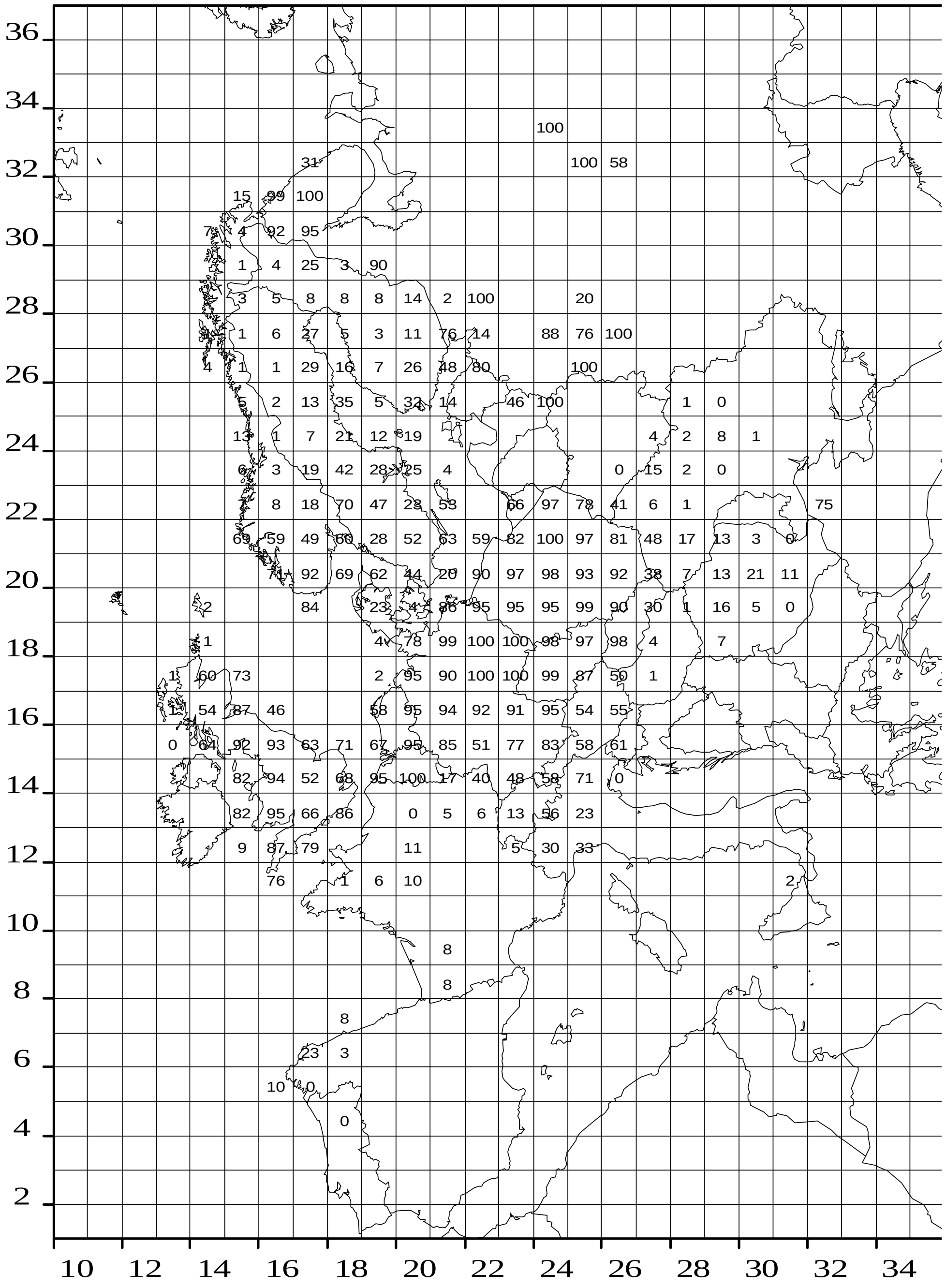
	SO_2	NO_x	NH_3	TOTAL
Albania	0	7	0	7
Belarus	0	160	0	160
Bosnia-H	0	1	0	1
Bulgaria	155	4	0	159
Croatia	62	1	0	63
Czech R.	423	319	0	741
Estonia	0	0	0	0
Hungary	187	269	0	456
Latvia	0	19	0	19
Lithuania	0	0	0	0
Poland	875	682	0	1,557
R. of Moldova	8	0	0	8
Romania	198	0	0	198
Russia	987	19	0	1,006
Slovakia	120	185	0	304
Slovenia	57	69	0	126
FYR Macedonia	0	1	0	1
Ukraine	463	128	0	591
F. Yugoslavia	88	3	0	91
CEE	3,623	1,867	0	5,490
Accession countries	**2,015**	**1,547**	**0**	**3,562**
Austria	259	625	0	884
Belgium	234	770	0	1,004
Denmark	102	306	41	449
Finland	159	449	0	608
France	1,344	4,797	0	6,141
Germany	2,610	7,355	0	9,965
Greece	220	382	0	602
Ireland	80	176	194	450
Italy	1,625	5,223	0	6,848
Luxembourg	10	49	7	66
Netherlands	244	1,488	772	2,504
Portugal	165	790	0	955
Spain	226	3,337	0	3,563
Sweden	291	699	16	1,006
UK	844	4,333	0	5,177
EU-15	**8,413**	**30,779**	**1,030**	**40,222**
Norway	50	411	0	461
Switzerland	64	504	0	568
TOTAL	**12,150**	**33,241**	**1,030**	**46,741**

Ecosystems with acid deposition above their critical loads for acidification in the year 1990 and in the reference (REF) scenario in the year 2010

Table 5.10

Country	1990	REF		
	1000 ha	%	1000 ha	%
Albania	0	0.0	0	0.0
Belarus	365	19.2	53	2.8
Bosnia-H	0	0.0	0	0.0
Bulgaria	0	0.0	0	0.0
Croatia	13	0.8	1	0.1
Czech R.	2,534	95.4	656	24.7
Estonia	391	20.7	10	0.6
Hungary	142	8.8	44	2.7
Latvia	374	13.8	0	0.0
Lithuania	82	4.3	12	0.7
Poland	5,921	92.9	1,968	30.9
R. of Moldova	0	3.3	0	1.2
Romania	578	9.3	66	1.1
Russia	27,485	8.0	4,369	1.3
Slovakia	1,345	67.5	83	4.2
Slovenia	431	47.6	49	5.4
FYR Macedonia	0	0.0	0	0.0
Ukraine	1,085	13.2	107	1.3
F. Yugoslavia	0	0.0	0	0.0
CEE	40,745	10.3	7,419	1.9
Accession countries	**11,798**	**39.2**	**2,889**	**9.6**
Austria	2,909	59.7	961	19.7
Belgium	478	77.1	126	20.3
Denmark	193	19.8	43	4.4
Finland	5,089	15.8	1,220	3.8
France	687	4.7	86	0.6
Germany	7,053	81.1	2,750	31.6
Greece	0	0.0	0	0.0
Ireland	25	5.0	6	1.2
Italy	1,161	17.5	288	4.3
Luxembourg	15	17.2	7	7.9
Netherlands	284	88.9	139	43.5
Portugal	1	0.0	0	0.0
Spain	80	0.9	25	0.3
Sweden	10,557	24.2	1,370	3.1
United Kingdom	4,918	62.3	2,407	30.5
EU-15	**33,452**	**24.8**	**9,428**	**7.0**
Norway	8,373	26.1	4,037	12.6
Switzerland	358	30.1	108	9.1
Total Europe	**82,928**	**14.8**	**20,992**	**3.7**

Figure 5.1 Ecosystems with acid deposition above their critical loads for acidification (ecosystems not protected from acidification) in the year 1990 (in % of the area of the ecosystems)



Ecosystems with nitrogen deposition above their critical loads for eutrophication (ecosystems not protected against eutrophication) in the year 1990 (in % of the area of the ecosystem)

Figure 5.2

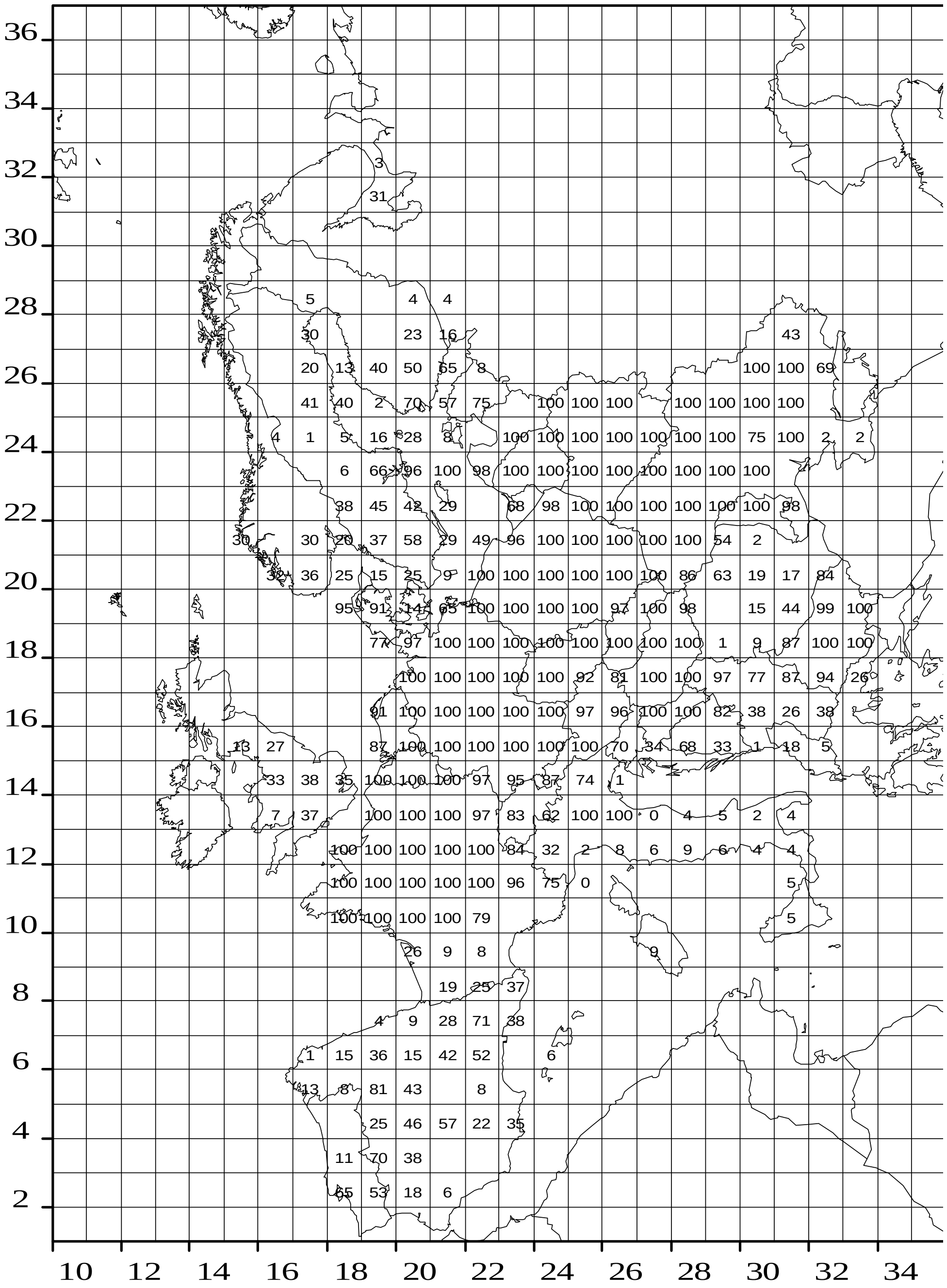
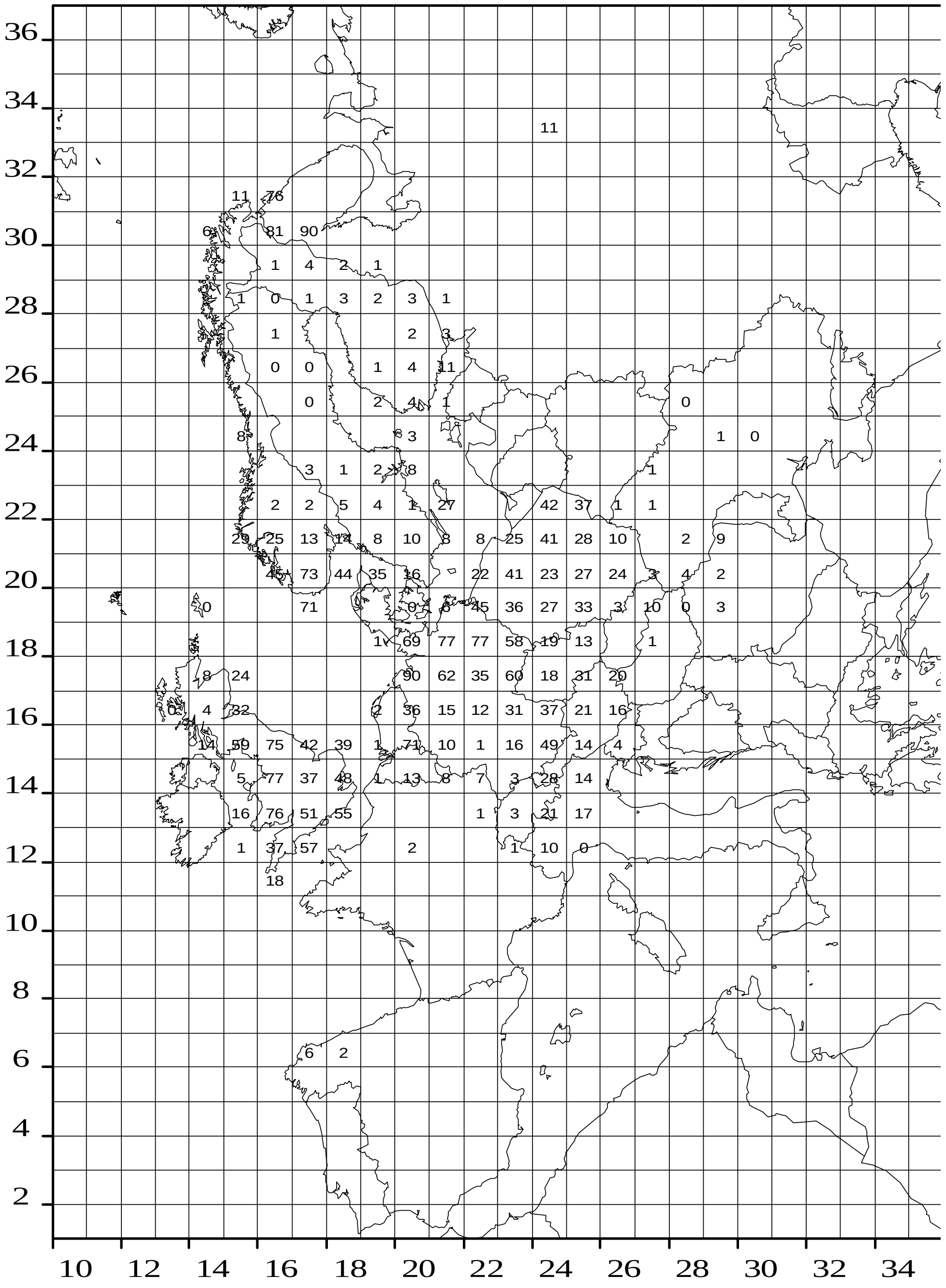
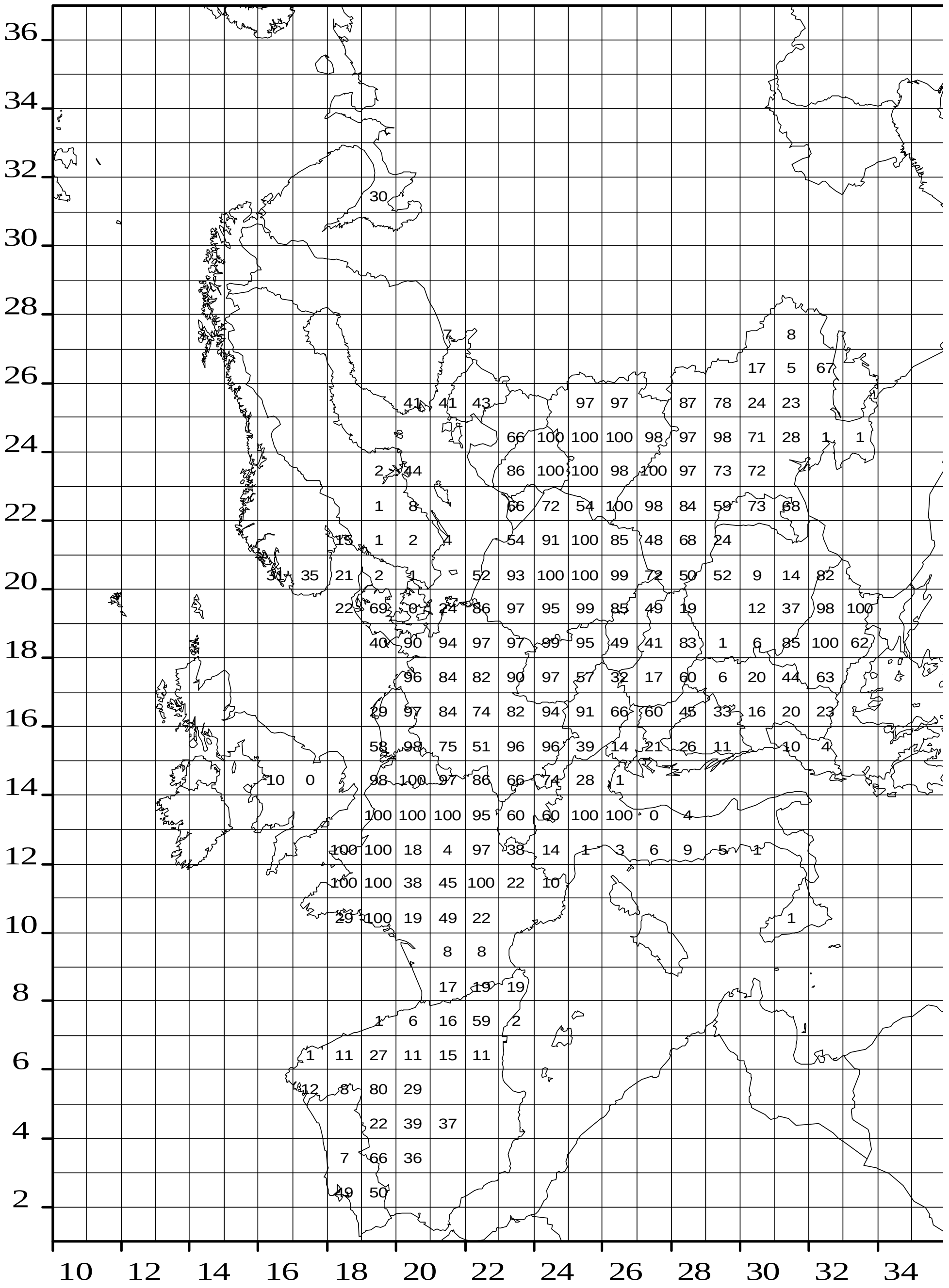


Figure 5.3 **Percentage of ecosystems with sulphur and nitrogen deposition above their critical loads for acidification for the reference scenario in the year 2010**



Emissions of nitrogen oxides and ammonia contribute also to the eutrophication of terrestrial ecosystems. In a way similar to acidity, critical loads for eutrophication have been developed for the European ecosystems (Hettelingh *et al.*, 1995). Figure 5.2 displays the percentage of ecosystems with total nitrogen deposition above the critical loads for eutrophication. Table 5.11 provides the protection levels for individual countries, as well as for country groups. For Europe as a whole, protection was even lower than for acidification, with virtually all ecosystems in northern France, Germany, Poland, the Czech Republic and Belarus facing excess nitrogen deposition. In the EU-15 more than 36% of the ecosystems (40 million hectares) were unprotect-

Percentage of ecosystems with nitrogen deposition above critical loads for eutrophication for the reference scenario in the year 2010 **Figure 5.4**



ed in 1990. In the whole CEE region about 9% of ecosystems were unprotected. For the accession countries the protection level was very low (75% of ecosystems unprotected).

As can be derived from Figure 5.3, efforts to reduce emissions, that have already been agreed, will achieve significant improvements in ecosystems' protection compared to the year 1990. Looking at acidification, by the year 2010, unprotected ecosystems in Europe will shrink from 83 million hectares to 21 million hectares; in other words, to 4%. In Central and Eastern Europe, only 2% of ecosystems remain unprotected. In the Czech Republic and in Poland, protection against acidification

Table 5.11 Ecosystems with nitrogen deposition above critical loads for eutrophication for the reference scenario in the year 2010

	1990		REF	
Country	**1000 ha**	**%**	**1000 ha**	**%**
Albania	113	10.7	69	6.5
Belarus	1,757	92.4	1,682	88.5
Bosnia-H	970	67.0	386	26.7
Bulgaria	3,394	89.7	2,696	71.3
Croatia	977	59.6	518	31.6
Czech R.	2,628	98.9	2,338	88.0
Estonia	903	47.8	510	27.0
Hungary	1,601	98.8	655	40.4
Latvia	1,541	56.8	709	26.1
Lithuania	1,863	98.3	1,706	90.0
Poland	6,349	99.2	5,712	89.2
R. of Moldova	3	36.2	2	20.0
Romania	1,669	26.8	1,112	17.8
Russia	1,171	0.3	889	0.3
Slovakia	1,959	98.3	1,154	58.0
Slovenia	626	69.1	228	25.2
FYR Macedonia	376	35.2	246	23.1
Ukraine	6,969	84.4	5,498	66.6
F. Yugoslavia	1,774	52.0	729	21.4
CEE	36,644	9.3	26,839	6.8
Accession countries	**22,532**	**74.9**	**16,820**	**55.9**
Austria	4,535	93.1	3,055	62.7
Belgium	621	100.0	603	97.1
Denmark	608	62.4	385	39.5
Finland	4,806	14.9	830	2.6
France	10,355	71.5	6,191	42.8
Germany	8,602	99.0	7,216	83.0
Greece	204	8.3	92	3.7
Ireland	0	0.0	0	0.0
Italy	1,994	30.1	1,209	18.2
Luxembourg	88	100.0	85	97.0
Netherlands	313	97.9	278	86.9
Portugal	767	27.1	588	20.8
Spain	2,246	26.4	1,370	16.1
Sweden	4,565	22.2	216	1.1
United Kingdom	590	7.4	43	0.5
EU-15	**40,291**	**36.0**	**22,160**	**19.8**
Norway	686	12.5	321	5.8
Switzerland	1,715	80.9	1,262	59.5
Total Europe	**79,223**	**15.4**	**50,512**	**9.8**

SO_2 emissions for the scenarios based on EEC-B energy pathway in the year 2010 (in kilotons)

Table 5.12

Emission standards		Current legislation		EU emission standards	
Energy pathway Countries	REF	EEC-B accession countries (CLB-A)	EEC-B for all CEE countries (CLB)	EEC-B accesion countries (ELB-A)	EEC-B for all CEE countries (ELB)
Albania	54	54	50	54	20
Belarus	490	490	272	490	211
Bosnia-H	410	410	291	410	208
Bulgaria	835	773	773	773	773
Croatia	69	69	65	69	65
Czech R.	152	78	78	78	78
Estonia	172	107	107	94	94
Hungary	545	397	397	397	397
Latvia	105	50	50	38	38
Lithuania	107	54	54	37	37
Poland	1,397	1,382	1,382	1,369	1,369
R. Moldova	91	91	80	91	66
Romania	590	561	561	561	561
Russia	2,350	2,350	1,209	2,350	1,207
Slovakia	113	44	44	44	44
Slovenia	37	37	37	37	37
FYR Macedonia	81	81	80	81	41
Ukraine	1,486	1,486	609	1,486	609
F. Yugoslavia	262	262	268	262	268
CEE	9,347	8,778	6,408	8,721	6,122
Accession countries	**4,053**	**3,484**	**3,484**	**3,427**	**3,427**
Other CEE	5,294	5,294	2,924	5,294	2,695

increases from below 10% to more than 70%. The average protection level in the accession countries increases from 60% to 90%. Also in the EU-15 countries, the fraction of unprotected ecosystems declines from 25% to 7%, though almost nine million hectares will still be left with sulphur and nitrogen deposition above their critical loads.

The situation also improves for eutrophication. Unprotected ecosystems shrink from 15% to 10%. Within the EU-15, the area under the threat declines from 36% to about 20% (Table 5.11). However, as displayed in Table 5.11, eutrophication remains a widespread problem with dramatically low protection levels in many Central European countries. In the accession countries, 56% of ecosystems remains unprotected, mainly due to a relatively low reduction of emissions of nitrogen oxides in the region and the high sensitivities of ecosystems in Central Europe.

Table 5.13 **NO_x emissions for the scenarios based on EEC-B energy pathway in the year 2010 (in kilotons)**

Emission standards		Current legislation		EU emission standards	
Energy pathway	REF	EEC-B accession countries (CLB-A)	EEC-B for all CEE countries (CLB)	EEC-B accesion countries (ELB-A)	EEC-B for all CEE countries (ELB)
Countries					
Albania	30	30	58	30	26
Belarus	184	184	299	184	185
Bosnia-H	60	60	78	60	47
Bulgaria	290	265	265	172	172
Croatia	91	91	102	91	54
Czech R.	226	188	188	165	165
Estonia	72	58	58	36	36
Hungary	196	188	188	147	147
Latvia	93	85	85	52	52
Lithuania	137	111	111	66	66
Poland	821	829	829	658	658
R. Moldova	66	66	84	66	50
Romania	453	524	524	329	329
Russia	2,658	2,658	2,791	2,658	1,689
Slovakia	110	86	86	74	74
Slovenia	31	40	40	30	30
FYR Macedonia	29	29	41	29	23
Ukraine	1,094	1,094	1,264	1,094	760
F. Yugoslavia	152	152	210	152	109
CEE	6,792	6,738	7,301	6,091	4,671
Accession countries	**2,429**	**2,375**	**2,375**	**1,728**	**1,728**
Other CEE	43,63	4,363	4,926	4,363	2,943

5.4. The EEC scenario

5.4.1. Emissions and emission control costs

This section discusses the emissions and emission control costs for the scenarios based on the EEC-B energy pathway. Since the energy pathway was only constructed for CEE countries, the results presented are also restricted to these countries.

Tables 5.12 and 5.13 present emissions for the four different scenarios outlined in Table 5.3. Looking at SO_2 emissions, the 'halfway convergence' scenario EEC-B, if assumed for all CEE countries, would cause a 30% SO_2 decline (CLB case) in the region, even without further measures to control emissions beyond the 'current legislation'. Restricting the convergence scenario to the accession countries (CLB-A) would yield only a 6% cut, underlining the fact that the non-accession countries have not yet signed the Second Sulphur Protocol and they are therefore not bound to the strict emission control measures for new plants. It is interesting to note, that

SO_2 emission control costs for the scenarios based on the EEC-B energy pathway in the year 2010 (in million ECU/year) **Table 5.14**

Emission standards		Current legislation		EU emission standards	
Energy pathway Countries	REF	EEC-B accession countries (CLB-A)	EEC-B for all CEE countries (CLB)	EEC-B accesion countries (ELB-A)	EEC-B for all CEE countries (ELB)
Albania	0	0	0	0	43
Belarus	0	0	0	0	86
Bosnia-H	0	0	0	0	43
Bulgaria	155	120	120	121	121
Croatia	62	62	63	62	63
Czech R.	423	340	340	340	340
Estonia	0	0	0	19	19
Hungary	187	177	177	177	177
Latvia	0	0	0	30	30
Lithuania	0	0	0	34	34
Poland	875	736	736	743	743
R. Moldova	8	8	0	8	17
Romania	198	184	184	184	184
Russia	987	987	756	987	757
Slovakia	120	79	79	79	79
Slovenia	57	58	58	58	58
FYR Macedonia	0	0	0	0	28
Ukraine	463	463	308	463	308
F. Yugoslavia	88	88	79	88	79
CEE	3,623	3,302	2,900	3,393	3,208
Accession countries	**2,015**	**1,694**	**1,694**	**1,785**	**1,785**
Other CEE	1,608	1,608	1,206	1,608	1,423

the application of the current EU emission standards to the accession countries will not influence SO_2 emissions dramatically (a further 2% decline, ELB-A case), but would have significant effects for the other CEE countries (-45%, ELB case).

The situation is different for NO_x. The adoption of the EEC-B energy pathway, without changes in environmental standards (scenario CLB), causes an 8% increase in emissions compared to the REF case. In such a situation, harmonisation with the EU emission standards would have distinct effects and reduce NO_x by more than 30%. Most of this improvement emerges in the transport sector.

There are differences, however, between the accession countries and the other CEE countries. Since some accession countries have already adopted stricter emission standards for mobile sources, the EEC-B energy scenario with the higher energy intensities in private transport would not increase total NO_x emissions in these coun-

Table 5.15 **NO_x emission control costs for the scenarios based on the Energy Efficiency Convergence (EEC-B) pathway in the year 2010 (in million ECU/year)**

Emission standards		Current legislation		EU emission standards	
Energy pathway Countries	REF	EEC-B accession countries (CLB-A)	EEC-B for all CEE countries (CLB)	EEC-B accesion countries (ELB-A)	EEC-B for all CEE countries (ELB)
Albania	7	7	0	7	153
Belarus	160	160	0	160	480
Bosnia-H	1	1	1	1	167
Bulgaria	4	3	3	428	428
Croatia	1	1	1	1	224
Czech R.	319	507	507	724	724
Estonia	0	0	0	91	91
Hungary	269	344	344	598	598
Latvia	19	0	0	132	132
Lithuania	0	0	0	188	188
Poland	682	1,144	1,144	2,130	2,130
R. Moldova	0	0	0	0	156
Romania	0	0	0	889	889
Russia	19	19	0	19	4,486
Slovakia	185	245	245	351	351
Slovenia	69	81	81	143	143
FYR Macedonia	1	1	1	1	95
Ukraine	128	128	0	128	2,126
F. Yugoslavia	3	3	3	3	471
CEE	1,867	2,644	2,330	5,994	14,030
Accession countries	**1,547**	**2,324**	**2,324**	**5,674**	**5,674**
Other CEE	320	320	6	320	8,357

tries. In addition, the increase of emissions from private transport is partly compensated for by lower emissions from industry and freight transport because of lower energy intensities in these two sectors.

Emission control costs for the scenarios are shown in Tables 5.14 and 5.15. Changing the energy pathway from the baseline (OEP) case to the EEC-B scenario and maintaining the ‘current legislation’ on the emission side would decrease costs for SO_2 measures, but increase NO_x control costs. For the accession countries the net effect would be an increase in control costs by about 13%, whereas for other CEE countries costs would decrease by 37%. This opposite trend is caused by the decrease in emission control costs for SO_2 (due to lower coal consumption), and the rise in NO_x control costs, mainly for the transport sector.

This general trend also holds if the national emission regulations are harmonised with current EU standards. Despite stricter

SO_2 emissions for the alternative scenarios in the year 2010 (in kilotons) **Table 5.16**

Scenario	**ELB-L**	**CLF-A**	**CLF**	**ELF-A**	**ELF**	**ELF-L**
For accession countries:	EU standards, EEC-BL	Current legislation, EEC-F	Current legislation, EEC-F	EU standards, EEC-F	EU standards, EEC-F	EU standards, EEC-FL
For other CEE countries:	EU standards, EEC-BL	Current legislation, OEP	Current legislation, EEC-F	Current legislation, OEP	EU standards, EEC-F	EU standards, EEC-FL
Albania	12	54	125	54	26	21
Belarus	198	490	149	490	126	107
Bosnia-H	196	410	375	410	231	193
Bulgaria	766	711	711	711	711	633
Croatia	62	69	69	69	69	66
Czech R.	78	76	76	76	76	75
Estonia	94	82	82	77	77	77
Hungary	397	323	323	323	323	322
Latvia	35	29	29	24	24	20
Lithuania	37	29	29	22	22	21
Poland	1,357	1,390	1,390	1,376	1,376	1,350
R. Moldova	59	91	97	91	69	61
Romania	520	553	553	552	552	483
Russia	1,137	2,350	1,100	2,350	1,100	967
Slovakia	43	39	39	39	39	38
Slovenia	37	37	37	37	37	37
FYR Macedonia	39	81	98	81	45	41
Ukraine	566	1,486	535	1,486	535	441
F. Yugoslavia	258	262	283	262	283	268
CEE	5,891	8,561	6,100	8,530	5,719	5,221
Accession countries	**3,364**	**3,267**	**3,267**	**3,236**	**3,236**	**3,056**
Other CEE	2,527	5,294	2,833	5,294	2,483	2,165

controls, in both groups of countries SO_2 costs would be lower than in the REF case due to lower coal consumption. Costs for NO_x measures, however, would increase dramatically so that total emission control costs for the accession countries would be twice as high as in the REF case, and five times higher in the other CEE countries, reaching about 1% of the GDP.

5.4.2. Sensitivities towards changes in input assumptions

Seven additional emission scenarios have been developed to check the sensitivity of emission levels and control costs with the assumptions about energy pathways and control strategies in individual countries. The scenarios analyse the impacts of the EEC-F energy pathway (full convergence with consumption patterns and energy intensities to the EU-15 average), as well as the effects of putting limits (L) on use of motor fuels by private transport and on electricity use in the residential/commercial sector (pathways EEC-BL and EEC-FL). Again, both the F energy pathway and

Table 5.17 NO$_x$ emissions for alternative scenarios in the year 2010 (in kilotons)

Scenario	**ELB-L**	**CLF-A**	**CLF**	**ELF-A**	**ELF**	**ELF-L**
For accession countries:	EU standards, EEC-BL	Current legislation, EEC-F	Current legislation, EEC-F	EU standards, EEC-F	EU standards, EEC-F	EU standards, EEC-FL
For other CEE countries:	EU standards, EEC-BL	Current legislation, OEP	Current legislation, EEC-F	Current legislation, OEP	EU standards, EEC-F	EU standards, EEC-FL
Albania	17	30	83	30	32	15
Belarus	171	184	272	184	143	116
Bosnia-H	38	60	101	60	51	33
Bulgaria	164	234	234	134	134	116
Croatia	49	91	115	91	54	44
Czech R.	158	178	178	155	155	146
Estonia	36	50	50	30	30	29
Hungary	142	172	172	130	130	121
Latvia	50	59	59	31	31	26
Lithuania	62	93	93	46	46	37
Poland	609	878	878	669	669	567
R. Moldova	40	66	105	66	54	35
Romania	279	594	594	310	310	217
Russia	1,540	2,658	2,629	2,658	1,335	1,041
Slovakia	70	69	69	59	59	50
Slovenia	28	44	44	32	32	31
FYR Macedonia	18	29	50	29	25	16
Ukraine	680	1,094	1,228	1,094	596	435
F. Yugoslavia	91	152	269	152	120	85
CEE	4,239	6,734	7,221	5,959	4,006	3,159
Accession countries	**1,597**	**2,371**	**2,371**	**1,595**	**1,595**	**1,341**
Other CEE	2,643	4,363	4,850	4,363	2,411	1,818

the limits are assumed to be implemented either in the whole CEE region or only in the accession countries. For instance, scenario ELB-L assumes the implementation of the EEC-BL energy pathway (pathway with limits on use of motor fuels and electricity) and the EU legislation applied in the whole CEE region. Scenario ELF-A simulates the effects of the EU legislation for the EEC-F energy pathway in the accession countries.

Tables 5.16 and 5.17 summarise the emissions levels for the respective scenarios. The EEC-F pathway (, full convergence of the energy systems) would result in 3% to 5% lower SO$_2$ emissions compared to the EEC-B pathway. For obvious reasons, emissions are also lower for scenarios with limitations on fuel and electricity use. The lowest emissions are for the ELF-L scenario (EU legislation, full convergence, limits on fuel and electricity use). In this case, the

SO_2 emission control costs for the scenarios based on EEC-B energy pathway in the year 2010 (in million ECU/year)

Table 5.18

Scenario	**ELB-L**	**CLF-A**	**CLF**	**ELF-A**	**ELF**	**ELF-L**
For accession countries:	EU standards, EEC-BL	Current legislation, EEC-F	Current legislation, EEC-F	EU standards, EEC-F	EU standards, EEC-F	EU standards, EEC-FL
For other CEE countries:	EU standards, EEC-BL	Current legislation, OEP	Current legislation, EEC-F	Current legislation, OEP	EU standards, EEC-F	EU standards, EEC-FL
Albania	27	0	0	0	57	23
Belarus	81	0	0	0	44	37
Bosnia-H	27	0	0	0	50	21
Bulgaria	109	44	44	44	44	34
Croatia	58	62	64	62	64	54
Czech R.	324	318	318	318	318	303
Estonia	19	11	0	11	11	10
Hungary	174	153	153	153	153	150
Latvia	29	10	0	10	10	10
Lithuania	33	11	0	11	11	10
Poland	656	833	826	833	833	649
R. Moldova	15	8	0	8	16	10
Romania	130	171	171	171	171	81
Russia	741	987	413	987	413	393
Slovakia	72	63	63	63	63	47
Slovenia	53	60	60	60	60	55
FYR Macedonia	17	0	0	0	31	13
Ukraine	296	463	134	463	134	127
F. Yugoslavia	39	88	78	88	79	14
CEE	2,902	3,281	2,322	3,281	2,560	2,041
Accession countries	**1,600**	**1,673**	**1,633**	**1,673**	**1,673**	**1,350**
Other CEE	1,302	1,608	689	1,608	887	691

emissions are 44% lower than in the REF scenario and 74% lower than in 1990.

Total CEE emissions of NO_x are lower for the group of scenarios analysed. However, in the CLF scenario (current legislation in all countries, full convergence, no limits) countries with low per capita GDP and low car ownership in the baseline increase their emissions above the level of the REF scenario. This is due to the assumption made for the full convergence scenario, namely that all countries achieve the average EU-15 per capita consumption of motor fuels. In the (ELF-L) scenario, emissions decrease to 34% of the REF level.

The necessity of controlling emissions from a larger number of private vehicles in the scenario ELF causes a dramatic increase of NO_x control costs. Compared with the scenario ELB, these costs increase

Table 5.19 **NO$_x$ emission control costs for the scenarios based on EEC-B energy pathway in the year 2010 (in million ECU/year)**

Scenario	**ELB-L**	**CLF-A**	**CLF**	**ELF-A**	**ELF**	**ELF-L**
For accession countries:	EU standards, EEC-BL	Current legislation, EEC-F	Current legislation, EEC-F	EU standards, EEC-F	EU standards, EEC-F	EU standards, EEC-FL
For other CEE countries:	EU standards, EEC-BL	Current legislation, OEP	Current legislation, EEC-F	Current legislation, OEP	EU standards, EEC-F	EU standards, EEC-FL
Albania	45	7	0	7	256	37
Belarus	287	160	0	160	607	251
Bosnia-H	56	1	1	1	270	48
Bulgaria	269	527	2	527	527	218
Croatia	147	1	1	1	295	139
Czech R.	416	806	563	806	806	403
Estonia	79	91	0	91	91	73
Hungary	437	696	406	696	696	407
Latvia	96	133	0	133	133	75
Lithuania	120	226	0	226	226	95
Poland	1,247	2,936	1,590	2,936	2,936	1,168
R. Moldova	41	0	0	0	247	35
Romania	320	1,414	0	1,414	1,414	277
Russia	2,384	19	0	19	5,961	1,995
Slovakia	232	412	285	412	412	204
Slovenia	123	146	82	146	146	127
FYR Macedonia	32	1	1	1	132	29
Ukraine	997	128	0	128	3,009	808
F. Yugoslavia	197	3	3	3	725	185
CEE	7,524	7,708	2,934	7,708	18,888	6,574
Accession countries	**3,339**	**7,388**	**2,929**	**7,388**	**7,388**	**3,047**
Other CEE	4,185	320	6	320	11,501	3,527

by ECU 5 billion/year. In turn, in the ELF-L scenario, the NO$_x$ control costs decrease to ECU 6.6 billion/year. For the latter scenario the total control costs of acidifying pollutants are only ECU 8.6 billion / year or 0.5% of the regional GDP (compare Tables 5.18 and 5.19), which is only about half of the costs of the ELB scenario. For accession countries the costs differential between these two scenarios is more than 40%.

The analysis demonstrates that the improvement of energy efficiency in the CEE region could substantially decrease emission levels and emission control costs. Equally important are promoting continued, less energy-intensive lifestyles and consumption patterns, including less private transport and less energy intensive infrastructure in the residential/commercial sector.

5.4.3. Impacts on acidification and eutrophication

Since the emission levels for the scenarios developed within the study do not differ dramatically, only three scenarios have been selected for the analysis of environmental impacts. The scenarios selected are:

- EU legislation and EEC-B energy pathway in accession countries only (ELBA);
- as above, but for the whole CEE region (ELB);
- EU legislation, full convergence in energy intensities and limits on motor fuel and electricity use (ELFL).

For each scenario the percentage of ecosystems not protected against acidification and eutrophication has been calculated and compared with the REF case. The results are presented in Tables 5.20 and 5.21. The spatial distribution of the protection levels is presented in a series of maps (Figures 5.5 to 5.9).

The maps clearly demonstrate that already the emission control measures assumed for the REF scenario would significantly improve the situation concerning acidification. The share of unprotected ecosystems - ecosystems that receive acid deposition above their critical loads - decrease in the CEE region from 10% in 1990 to less than 2%. This improvement is even greater in accession countries, which reduce their unprotected ecosystems from a 40% share down to less than 10%. The scenarios analysed in this study trigger further improvement. In the Czech Republic, the ELBA scenario (EU legislation and B energy pathway in accession countries) increases the protection level from 75% to 82% of ecosystems. In the ELFL scenario, the share of unprotected ecosystems in the whole CEE region decreases from 1.9% to about 0.9%.

Even larger improvements in the protection levels occur if eutrophication is considered. Again, the most drastic change occurs with the REF scenario. For the whole CEE region, the percentage of unprotected ecosystems decreases from 74% in 1990 to 56% in 2010. The ELBA scenario brings protection for an additional 5% of ecosystems in the accession countries. Assuming the ELFL case, unprotected ecosystems in these countries decrease to 47%.

While the data currently available on critical loads in Russian ecosystems suggest only a rather low sensitivity towards eutrophication, it should be mentioned that the sheer amount of ecosystems in Russia masks the overall improvements achieved in the CEE region. Despite representing only a small share in total CEE ecosystems (1.2%), the protection in Belarus and Ukraine remains low, with more than 80% of the ecosystems in Belarus and more than 60% in the Ukraine not protected. Furthermore, in some accession countries (Czech Republic and Poland), even in the ELFL scenario more than 85% of ecosystems remain unprotected. Further measures, inter alia, the reduction of emissions of ammonia, will therefore be necessary for the situation to be further improved.

The stricter control of emissions in the CEE also brings benefits for the neighbouring EU countries. For instance, the measures assumed in the ELFL scenario would reduce acid deposition by an additional 1.6% in Austrian and 2% in German ecosystems, bringing them beneath critical loads. There are also marginal improvements for eutrophication (an additional 1%–2% of ecosystems protected in Austria, Finland, Germany and Sweden).

It is not feasible to achieve the same protection levels for all grids in EU countries as brought about by the ELFL scenario, exclusively with measures within the European Union. In turn, if CEE countries keep their emissions at a level of the ELFL scenario, achieving the 50% gap closure target set in the EU Acidification Strategy (COM (97) 88, 1987) would be ECU1.3 billion/year (nearly 20%) cheaper. These examples clearly indicate the importance of emission control policies in the CEE region for achieving environmental goals in the EU.

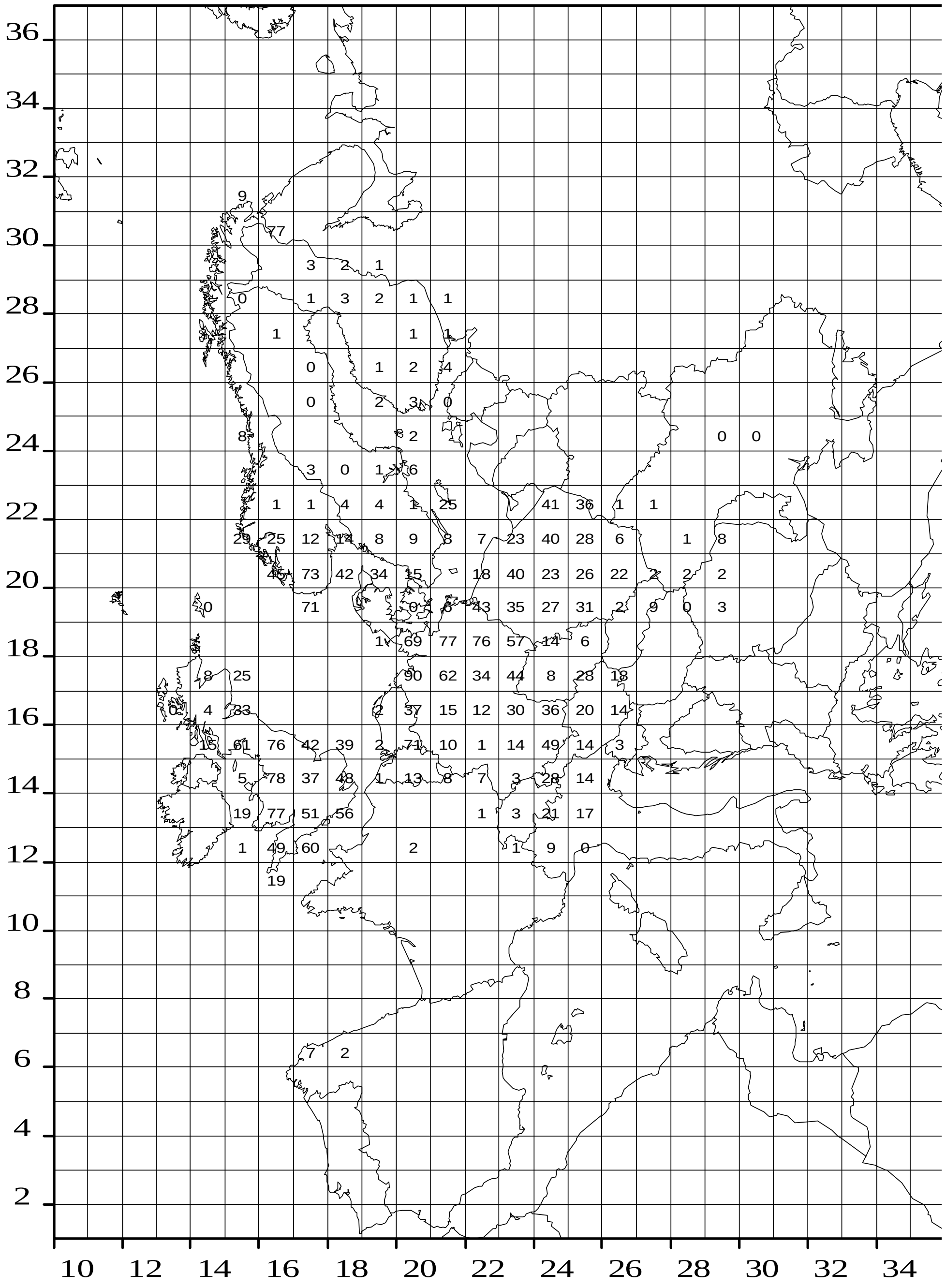
Table 5.20 **Ecosystems with acid deposition above their critical loads**

Scenario	**REF**		**ELBA**		**ELB**		**ELFL**	
For accession countries:	Current legislation, OEP		EU standards, EEC-B		EU standards, EEC-B		EU standards, EEC-FL	
For other CEE countries:	Current legislation, OEP		Current legislation, OEP		EU EEC-B		EU EEC-FL	
Country	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%
Albania	0	0.0	0	0.0	0	0.0	0	0.0
Belarus	53	2.8	53	2.8	50	2.6	49	2.6
Bosnia-H	0	0.0	0	0.0	0	0.0	0	0.0
Bulgaria	0	0.0	0	0.0	0	0.0	0	0.0
Croatia	1	0.1	1	0.1	1	0.0	1	0.0
Czech R.	656	24.7	475	17.9	468	17.6	448	16.9
Estonia	10	0.6	6	0.3	5	0.2	3	0.2
Hungary	44	2.7	39	2.4	39	2.4	30	1.9
Latvia	0	0.0	0	0.0	0	0.0	0	0.0
Lithuania	12	0.7	12	0.6	12	0.6	12	0.6
Poland	1,968	30.9	1,895	29.7	1,880	29.5	1,851	29.1
R. Moldova	0	1.2	0	1.2	0	1.2	0	1.1
Romania	66	1.1	63	1.0	61	1.0	58	0.9
Russia	4,369	1.3	4,065	1.2	1,123	0.3	1,095	0.3
Slovakia	83	4.2	75	3.8	73	3.7	47	2.4
Slovenia	49	5.4	42	4.7	40	4.5	38	4.2
FYR Macedonia	0	0.0	0	0.0	0	0.0	0	0.0
Ukraine	107	1.3	95	1.2	74	0.9	59	0.7
F. Yugoslavia	0	0.0	0	0.0	0	0.0	0	0.0
CEE	7,419	1.9	6,822	1.7	3,825	1.0	3,691	0.9
Accession Countries	**2,889**	**9.6**	**2,609**	**8.7**	**2,577**	**8.6**	**2,488**	**8.3**
Austria	961	19.7	912	18.7	900	18.5	881	18.1
Belgium	126	20.3	125	20.2	125	20.2	125	20.1
Denmark	43	4.4	42	4.3	42	4.3	41	4.2
Finland	1,220	3.8	1,125	3.5	837	2.6	775	2.4
France	86	0.6	86	0.6	86	0.6	86	0.6
Germany	2,750	31.6	2,624	30.2	2,611	30.0	2,584	29.7
Greece	0	0.0	0	0.0	0	0.0	0	0.0
Ireland	6	1.2	6	1.1	6	1.1	6	1.1
Italy	288	4.3	284	4.3	282	4.3	280	4.2
Luxembourg	7	7.9	7	7.9	7	7.9	7	7.9
Netherlands	139	43.5	138	43.2	138	43.2	138	43.1
Portugal	0	0.0	0	0.0	0	0.0	0	0.0
Spain	25	0.3	25	0.3	25	0.3	25	0.3
Sweden	1,370	3.1	1,290	3.0	1,228	2.8	1,175	2.7
UK	2,407	30.5	2,402	30.5	2,401	30.4	2,399	30.4
EU-15	**9,428**	**7.0**	**9,068**	**6.7**	**8,688**	**6.4**	**8,521**	**6.3**
Norway	4,037	12.6	3,971	12.4	3,892	12.1	3,840	12.0
Switzerland	108	9.1	107	9.0	107	9.0	107	9.0
Total Europe	**20,992**	**3.7**	**19,968**	**3.6**	**16,512**	**2.9**	**16,159**	**2.9**

Ecosystems with nitrogen deposition above their critical loads for eutrophication **Table 5.21**

Scenario	**REF**		**ELBA**		**ELB**		**ELFL**	
For accession countries:	Current legislation, OEP		EU standards, EEC-B		EU standards, EEC-B		EU standards, EEC-FL	
For other CEE countries:	Current legislation, OEP		Current legislation, OEP		EU EEC-B		EU EEC-FL	
Country	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%
Albania	69	6.5	68	6.4	67	6.3	64	6.1
Belarus	1,682	88.5	1,564	82.3	1,560	82.1	1509	79.4
Bosnia-H	386	26.7	319	22.0	271	18.7	232	16.0
Bulgaria	2,696	71.3	2,097	55.4	2,028	53.6	1714	45.3
Croatia	518	31.6	430	26.2	310	18.9	205	12.5
Czech R.	2,338	88.0	2,295	86.4	2,292	86.3	2268	85.4
Estonia	510	27.0	505	26.7	503	26.6	498	26.4
Hungary	655	40.4	548	33.8	519	32.0	429	26.5
Latvia	709	26.1	405	14.9	250	9.2	133	4.9
Lithuania	1,706	90.0	1,587	83.7	1,550	81.8	1505	79.4
Poland	5,712	89.2	5,579	87.1	5,562	86.9	5465	85.4
R. Moldova	2	20.0	2	19.8	2	19.5	2	19.2
Romania	1,112	17.8	991	15.9	972	15.6	910	14.6
Russia	889	0.3	144	0.0	106	0.0	106	0.0
Slovakia	1,154	58.0	1,050	52.7	1,034	51.9	967	48.6
Slovenia	228	25.2	217	23.9	195	21.6	183	20.2
FYR Macedonia	246	23.1	221	20.8	212	19.9	178	16.8
Ukraine	5,498	66.6	5,292	64.1	5,251	63.6	5,102	61.8
F. Yugoslavia	729	21.4	696	20.4	648	19.0	601	17.6
CEE	26,839	6.8	24,009	6.1	23,333	5.9	22,072	5.6
Accession Countries	**16,820**	**55.9**	**15,273**	**50.7**	**14,905**	**49.5**	**14,072**	**46.8**
Austria	3,055	62.7	2,994	61.5	2,979	61.1	2,936	60.3
Belgium	603	97.1	602	97.0	602	97.0	602	97.0
Denmark	385	39.5	383	39.4	383	39.3	382	39.2
Finland	830	2.6	644	2.0	477	1.5	253	0.8
France	6,191	42.8	6,189	42.7	6,189	42.7	6,188	42.7
Germany	7,216	83.0	7,184	82.6	7,182	82.6	7,165	82.4
Greece	92	3.7	63	2.6	58	2.4	48	2.0
Ireland	0	0.0	0	0.0	0	0.0	0	0.0
Italy	1,209	18.2	1,189	17.9	1,183	17.9	1,140	17.2
Luxembourg	85	97.0	85	97.0	85	97.0	85	97.0
Netherlands	278	86.9	278	86.8	278	86.8	277	86.8
Portugal	588	20.8	588	20.8	588	20.8	588	20.8
Spain	1,370	16.1	1,368	16.1	1,368	16.1	1,367	16.0
Sweden	216	1.1	160	0.8	146	0.7	127	0.6
UK	43	0.5	43	0.5	43	0.5	43	0.5
EU-15	**22,160**	**19.8**	**21,771**	**19.5**	**21,560**	**19.3**	**21,203**	**19.0**
Norway	321	5.8	320	5.8	320	5.8	320	5.8
Switzerland	1262	59.5	1260	59.4	1,260	59.4	1,259	59.4
Total Europe	**50512**	**9.8**	**47292**	**9.2**	**46,406**	**9.0**	**44,789**	**8.7**

Figure 5.5 **Ecosystems with acid deposition above their critical loads for acidification (ecosystems not protected from acidification) in the scenario ELB (in % of the area of the ecosystems)**



Ecosystems with acid deposition above their critical loads for eutrophication (ecosystems not protected from eutrophication) in the scenario ELB (in % of the area of the ecosystems)

Figure 5.6

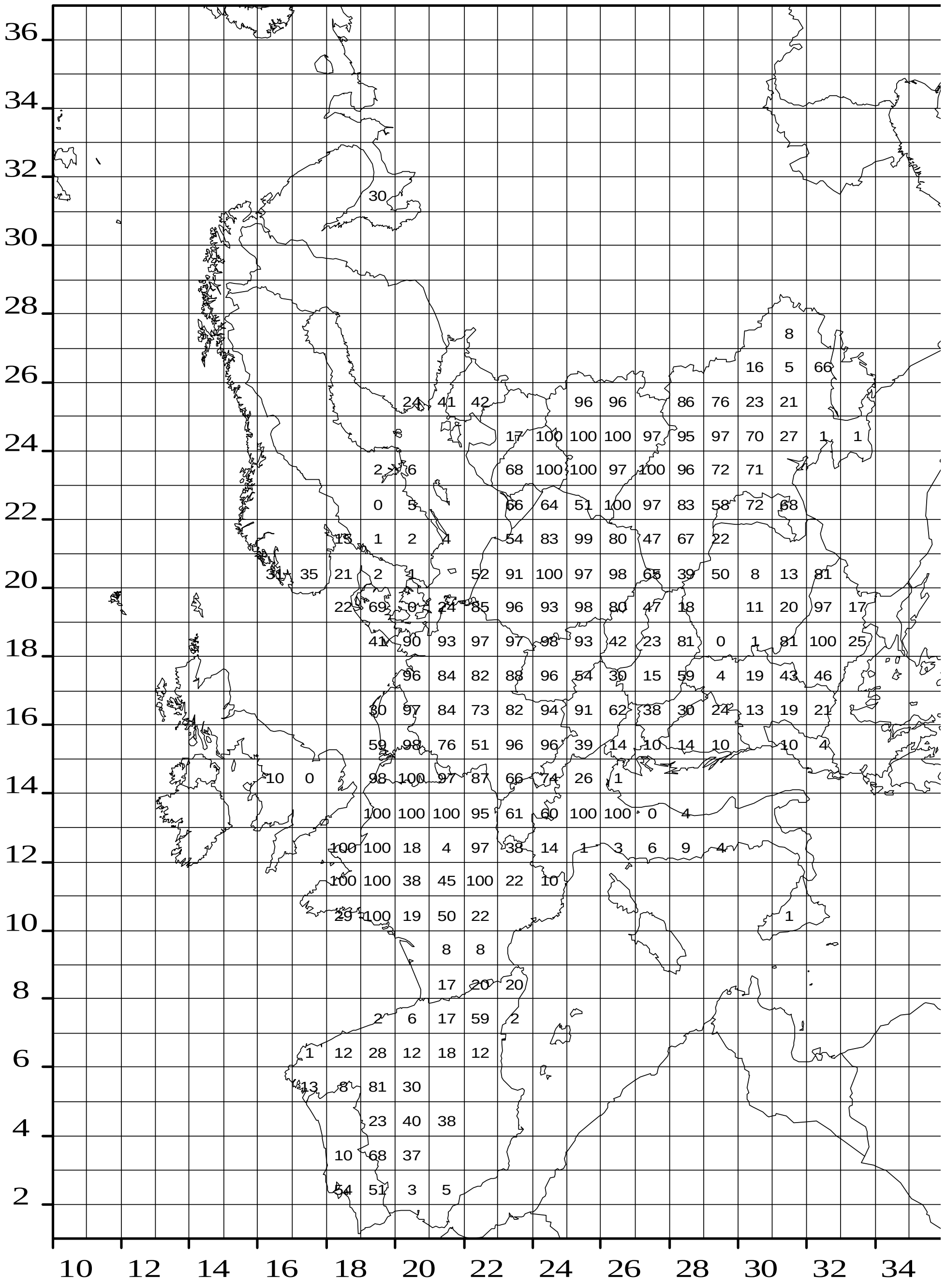
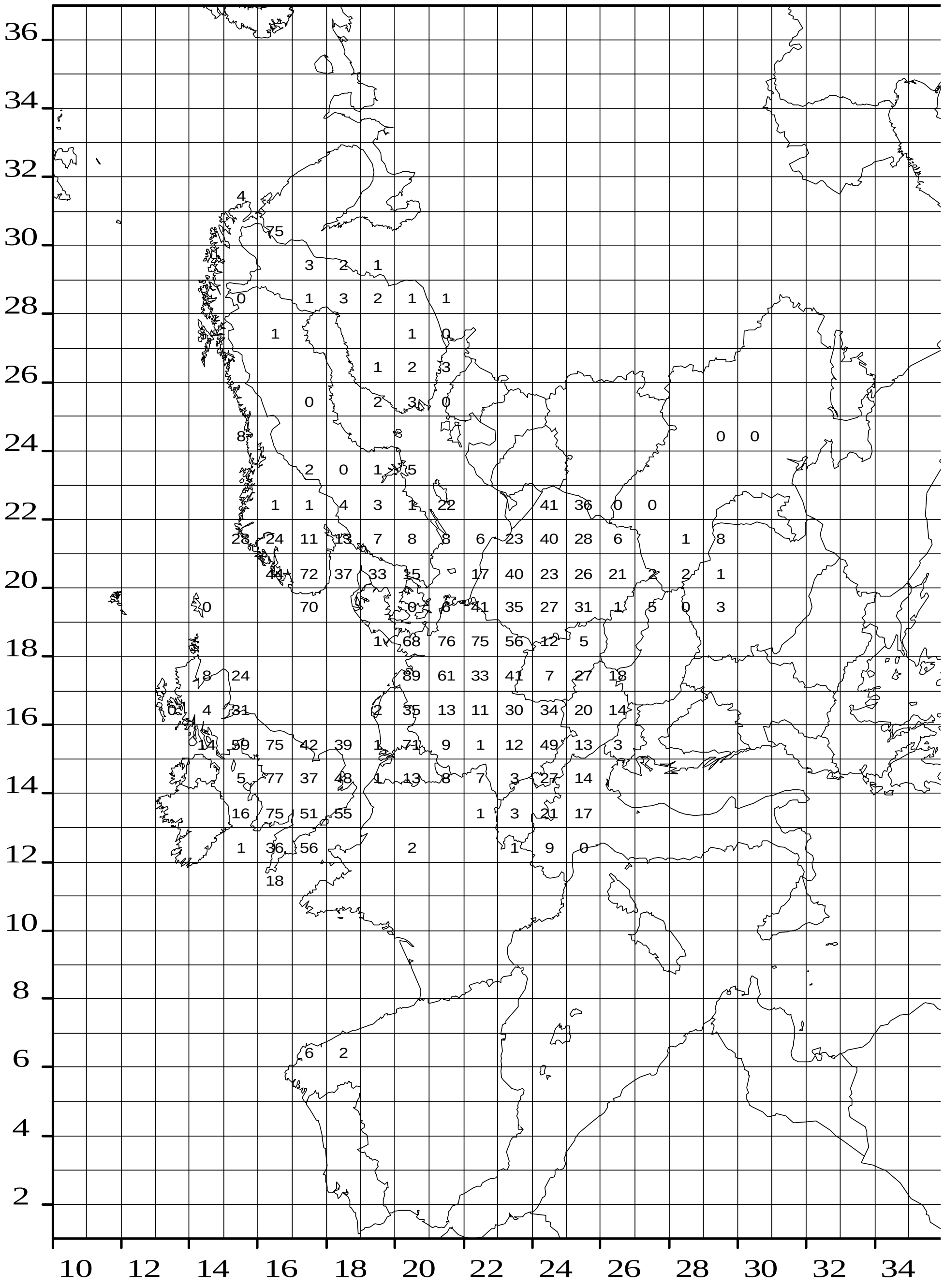


Figure 5.7 Ecosystems with acid deposition above their critical loads for acidification (ecosystems not protected from acidification) in the scenario ELFL (in % of the area of the ecosystems)



Ecosystems with acid deposition above their critical loads for eutrophication (ecosystems not protected from eutrophication) in the scenario ELFL (in % of the area of the ecosystems) **Figure 5.8**

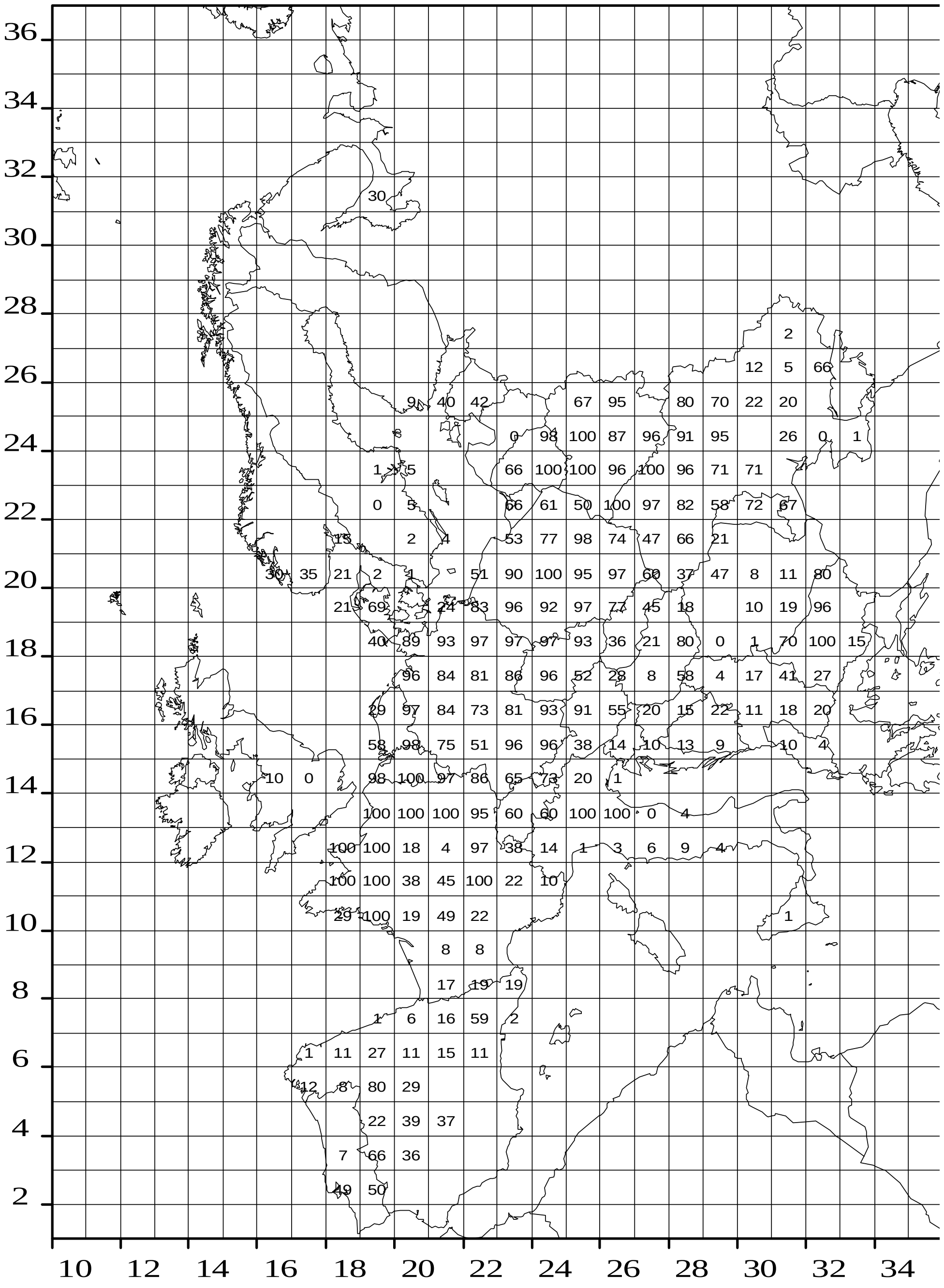
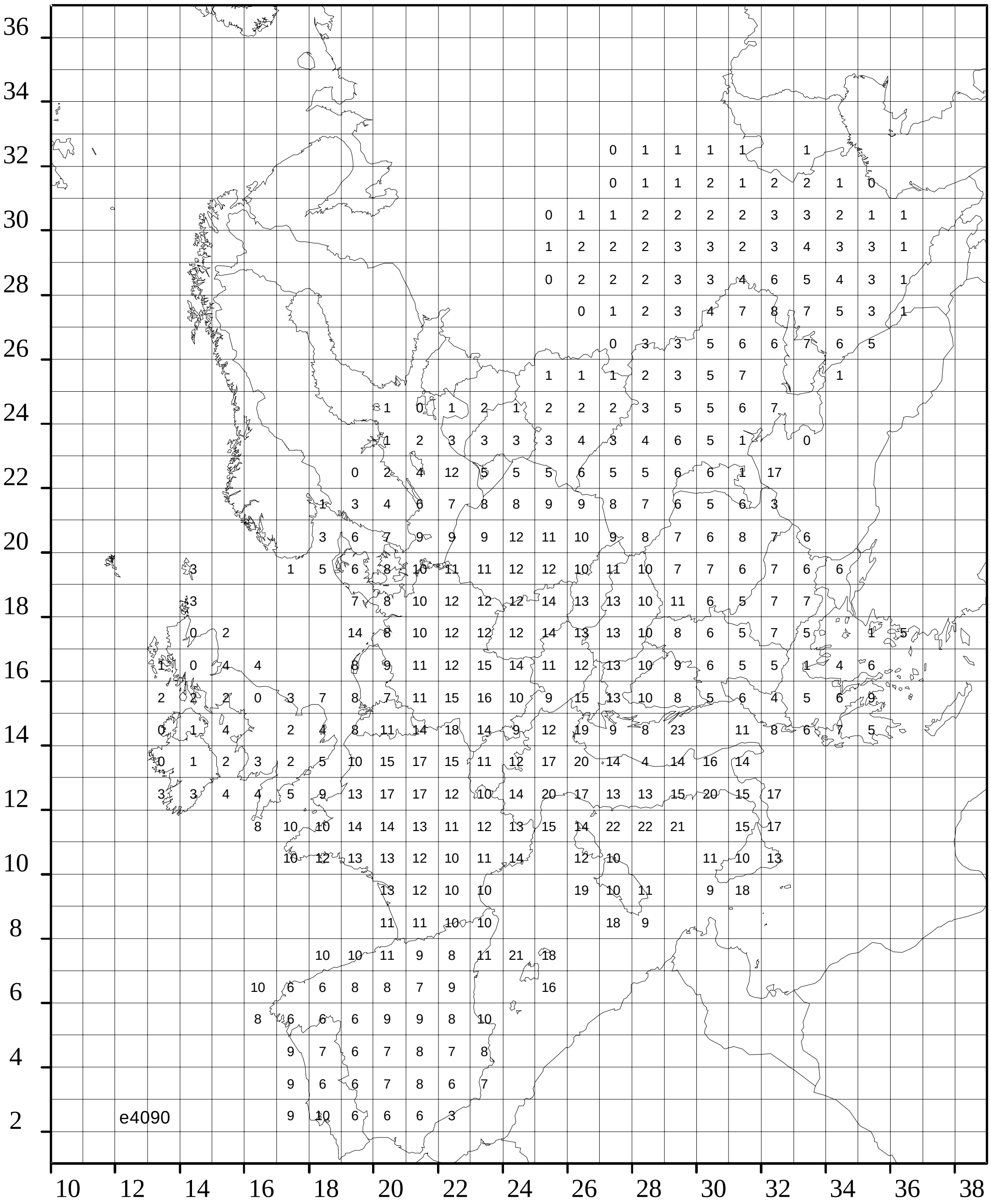


Figure 5.9 Indicates where the AOT40 for natural vegetation is exceeded over the critical level of 3 ppm hours in 1990. Grids with exposure below the critical level of 3 ppm hours are left blank.



5.4.4. Impacts on ground-level ozone

This section explores the impacts on ground-level ozone in Europe of the changes in emission levels implied by the previously explored scenarios. The calculations have been carried out by IIASA with the 'reduced-form' model of ozone formation that describes the ozone formation depending on emission fields in Europe (Heyes *et al.,* 1996). The IIASA model is based on the results of the EMEP ozone model (Simpson, 1996) developed by the Norwegian Meteorological Institute. The calculations used the meteorological conditions of the year 1990.

Currently, only preliminary estimates of the likely emissions reductions of VOC are available. These estimates were used for the calculation of ozone patterns for the REF scenario. As far as possible, data for 1990 was derived from the EMEP database. Projections for the year 2010 were derived assuming either the UN-ECE current reduction plans (CRP) values, or the implementation of the VOC Protocol and of the final package of the Auto/Oil legislation, whichever gives the lowest VOC emission estimate. A summary of the VOC estimates is presented in Table 5.22. According to these estimates, emissions in the EU-15 are likely to be reduced by 40%, whereas emissions in the CEE region in the REF case decline by only 3%.

The study also explores the effects of some other emission scenarios. At the moment there are no detailed plans available for reducing VOC emissions in the CEE region. Therefore it has been assumed that implementation of EU legislation for the CEE countries will yield the same relative (40%) reduction of emissions beyond the REF scenario, as was achieved in the EU-15 compared to the year 1990. On this basis, two emission scenarios have been developed. The first assumes that the legislation is implemented only in the accession countries (an equivalent to ELBA). The second scenario assumes the reductions in all CEE countries (an equivalent to the ELB scenario).

Two indicators are used to compare the impacts of the different scenarios on ground-level ozone:

- The first indicator refers to the protection of natural vegetation and crops and thus displays the AOT40, i.e., the accumulated ozone over a threshold of 40 ppb. This measure is the integral of hourly ozone levels exceeding the 40 ppb level, accumulated over a period of three months (May to July). The critical level to protect natural vegetation and crops is currently set at 3000 ppb hours of the AOT40.

- The second indicator resembles a health-related ozone criterion. The recently revised World Health Organisation (WHO) air quality guideline value for ozone is set at 60 ppb (moving eight-hour average). Although an immediate translation of the excess dose into actual health-effects is currently not considered possible, the UN/ECE - WHO Workshop on Health Effects of Ozone and Nitrogen Oxides held in June 1996 in Eastbourne, UK, concluded that the accumulated exposure over the 60 ppb threshold (AOT60) could be considered a preliminary indicator for health impacts. Any excess of the 60 ppb level (i.e., any AOT60 larger than zero) indicates, therefore, an excess of the WHO air quality guideline.

Changes in the values of the above ozone exposure indices by country are presented in Table 5.2.3. The table compares the average exposure values of AOT40 and AOT60 in each country for 1990 with the exposures for 2010 in the REF and the ELB scenarios. The table shows that, as a result of current legislation (the REF case), ozone levels are expected to significantly change in Europe in the future. On average, the envisaged emission reductions will lead to a decline of the AOT60 for the whole of Europe by 50 percent (from 2.0 to 1.0 ppm hours). For the EU this indicator decreases by 60 percent, whereas for the CEE countries, the improvement is 43 percent (35 percent for the accession countries). However, according to the model estimates, current measures will not be sufficient to eliminate everything in excess of the WHO guideline value. Emission reductions as in the ELB scenario cause a 35 percent decrease of the AOT60 for the whole CEE region and a 10 percent reduction for the group of accession countries.

In addition, the vegetation-related indicator (the AOT40) declines sharply for most regions in Europe for the REF case. The average exposure in Europe decreases from 7.5 to 5.5 excess ppm hours. The ELB scenario brings further improvements – the indicator for the CEE region decreases by 28 percent compared with REF. The increase of the AOT40 for the UK in the REF case compared with 1990 can be explained by the non-linear response of ozone formation towards changes in NO_x emissions without adequate reductions in VOC emissions. Such ozone chemistry is observed in the Northwest of Europe. It should be stressed that that modest increase of the AOT40 in the UK does not happen in the grids, which currently experience the highest AOT40.

Spatial distribution of changes in ozone indicators is illustrated by a series of graphs. Figure 5.9 and Figure 5.10 show the AOT40 values in EMEP grids for 1990 and 2010 for the REF scenario. Figure 5.11 shows the relative improvement brought about by the ELB scenario. For instance, for a grid 26/18 the excess AOT40 decreases from 11 ppm hours in 1990 (Figure 5.10) to 8 ppm hours in 2010 for the REF scenario (Figure 5.10). Emission levels from the ELB scenario decrease this exposure by 31 percent compared with REF (Figure 5.11). Similar information for AOT60 is presented in Figure 5.12 to Figure 5.14.

As with acidification and eutrophication, the highest benefits in terms of reducing excess ozone are obtained already by the REF scenario. In Central Europe (Germany, Poland and Czech Republic) the AOT40 indicator decreases by about 40 percent. The health-related excess criterion is reduced by up to 80 percent. In Eastern Europe the improvement is much lower, though starting already from a lower level. Implementation of measures that go beyond the REF scenario further reduces the excess exposure, first of all those for natural vegetation. In the ELB scenario, where measures are applied to all CEE countries, the protection in Ukraine and in the southern part of Russia also improves.

Simulations demonstrate that the implementation of measures that reduce the emission of ozone precursors in Central and Eastern Europe also decrease ozone levels in the EU countries. For the ELB scenario this improvement is 6 percent for AOT60 and 4 percent for AOT40 (compare Table 5.23).

It should be mentioned that the model calculations presented in this section refer to rural ozone levels with a 150 x 150-km spatial resolution. Further work will be necessary to derive urban ozone concentrations.

VOC emissions assumed for the ozone calculations (in kilotons VOC) **Table 5.22**

Country	1990	2010 REF	ELBA	ELB
Albania	32	30	30	18
Belarus	533	323	323	197
Bosnia-H	101	101	101	62
Bulgaria	217	265	162	162
Croatia	105	105	105	64
Czech R.	534	534	326	326
Estonia	50	50	31	31
Hungary	205	145	88	88
Latvia	49	49	30	30
Lithuania	112	112	68	68
Poland	831	831	507	507
R. Moldova	116	116	116	71
Romania	619	619	378	378
Russia	3,566	3,566	3,566	2,175
Slovakia	149	149	91	91
Slovenia	35	25	15	15
FYR Macedonia	7	7	7	4
Ukraine	1,369	1,369	1,369	835
F. Yugoslavia	112	112	112	68
CEE	8,742	8,508	7,424	5,190
Accession Countries	**2,801**	**2,779**	**1,695**	**1,695**
Austria	430	305	305	305
Belgium	362	209	209	209
Denmark	169	95	95	95
Finland	209	109	109	109
France	2,404	1,453	1,453	1,453
Germany	2,985	1,750	1,750	1,750
Greece	325	266	266	266
Ireland	180	121	121	121
Italy	2,498	1749	1,749	1749
Luxembourg	19	10	10	10
Netherlands	444	120	120	120
Portugal	206	167	167	167
Spain	1,134	669	669	669
Sweden	528	287	287	287
UK	2,287	1,276	1,276	1,276
EU-15	**14,180**	**8,586**	**8,586**	**8,586**
Norway	266	182	182	182
Switzerland	292	173	173	173
TOTAL	**23,480**	**17,449**	**16,365**	**14,131**

Figure 5.10 Indicates where the AOT40 for natural vegetation is exceeded over the critical level of 3 ppm hours for the reference scenario in 2010. Grids with exposure in 1990 below the critical level of 3 ppm hours are left blank.

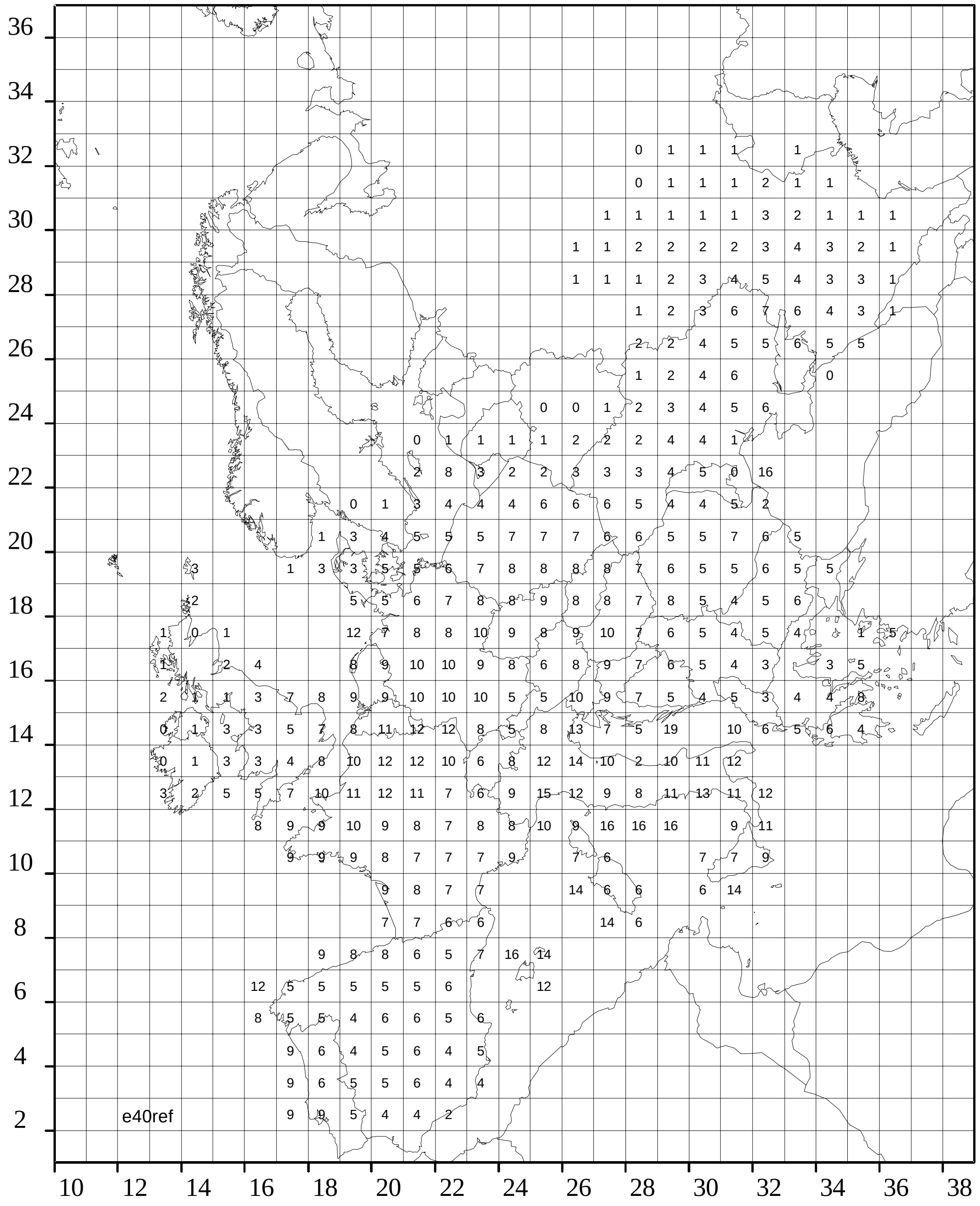


Figure 5.11

Percentage reduction of the excess-AOT40 achieved by the ELB scenario in comparison to the reference scenario. Only grids with excess of more than 0.8 ppm hours in the reference scenario are displayed.

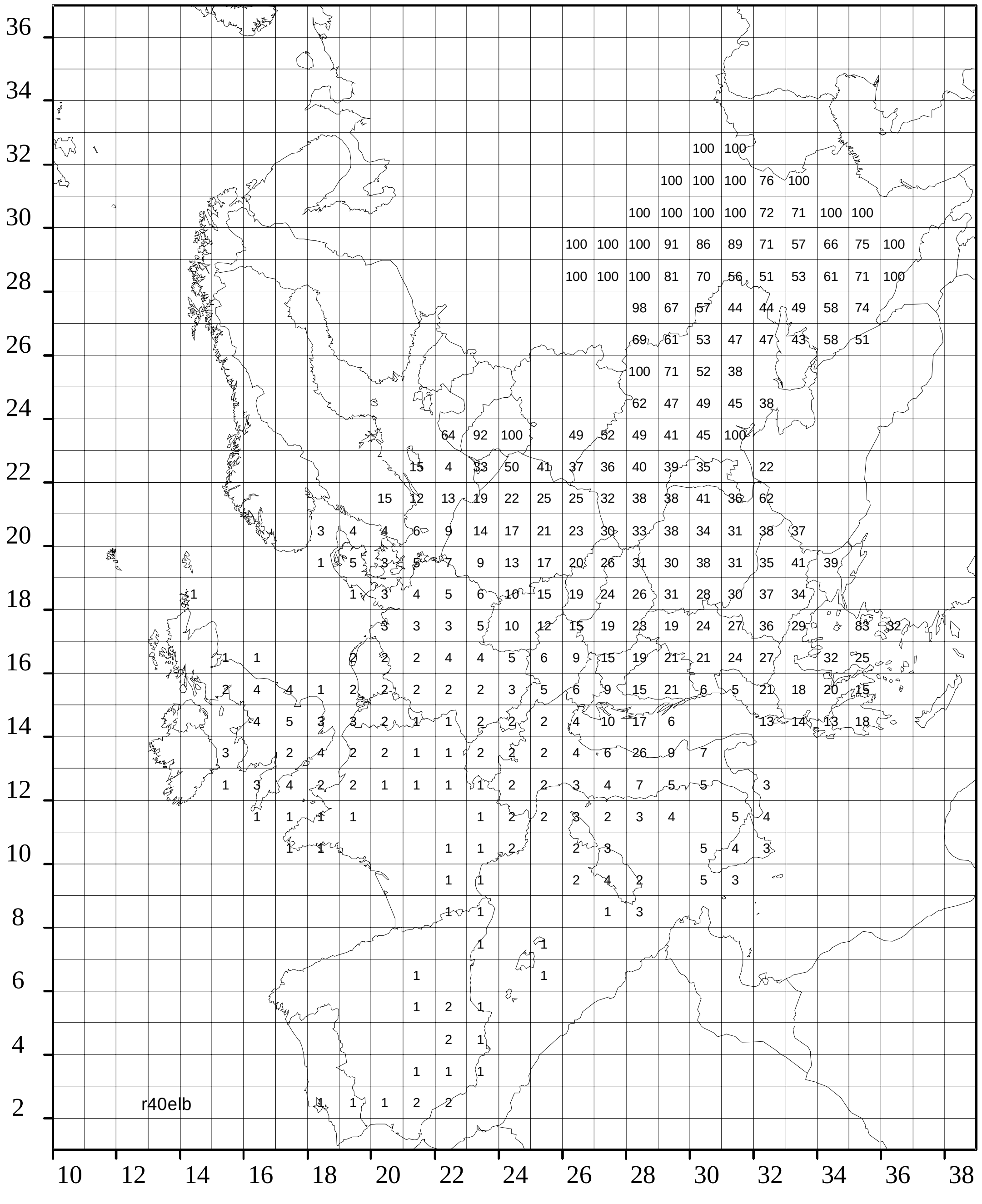
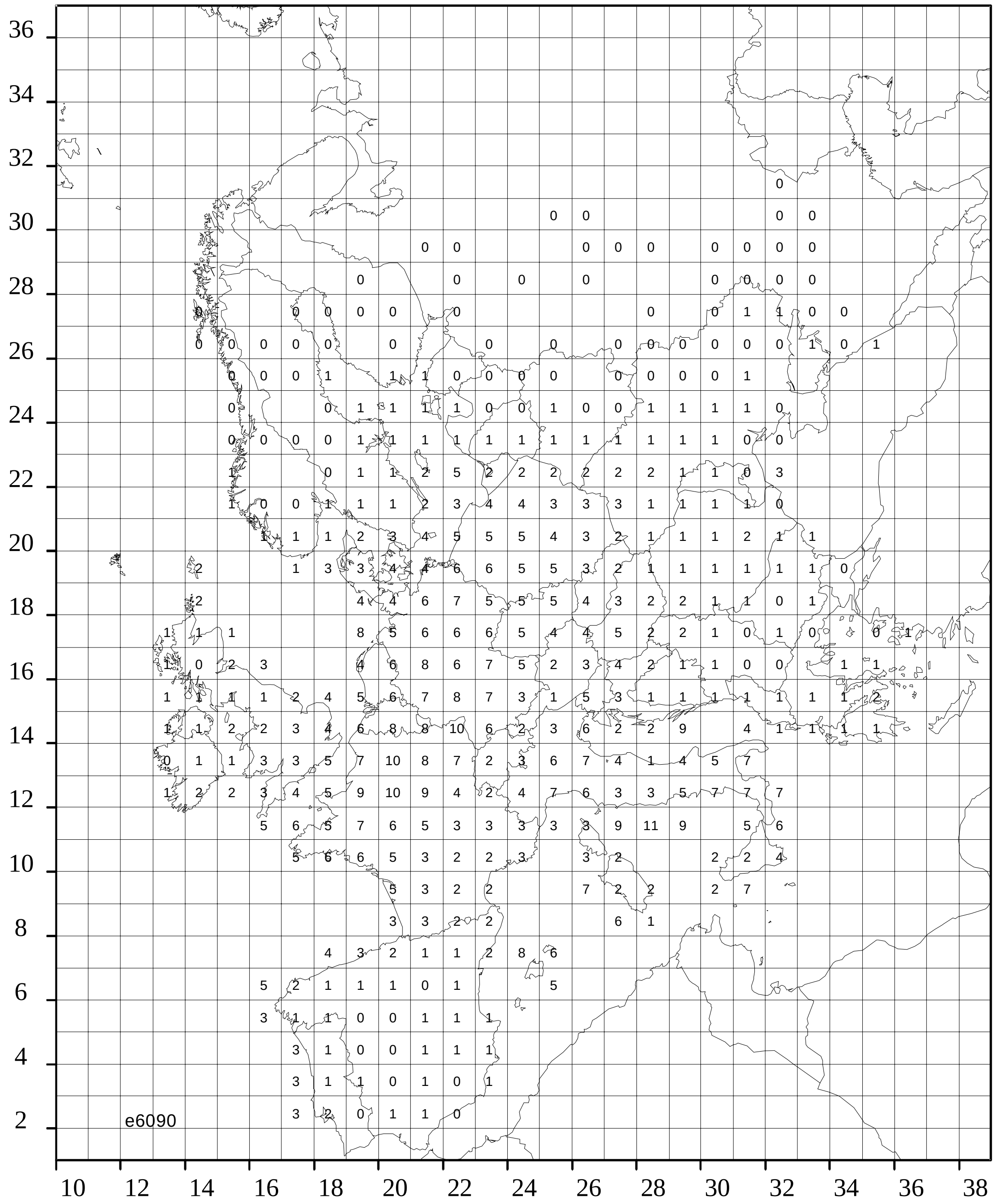


Figure 5.12 Model estimates for the AOT60 for 1990 (in ppm hours, grids with less than 0.1 ppm hours are left blank).



AOT60 for the reference scenario in 2010 (in ppm hours, grids with less than 0.1 ppm hours are left blank).

Figure 5.13

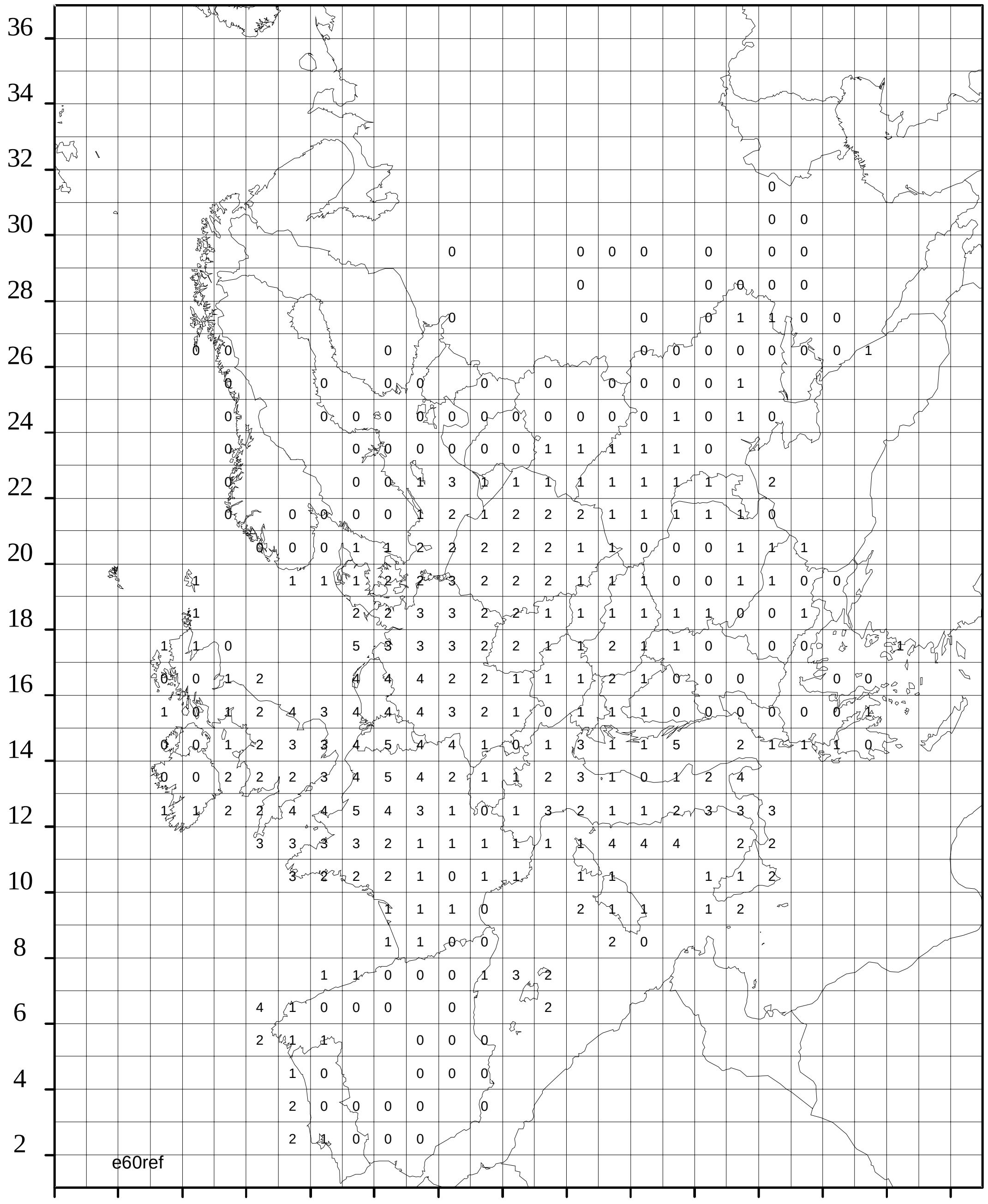
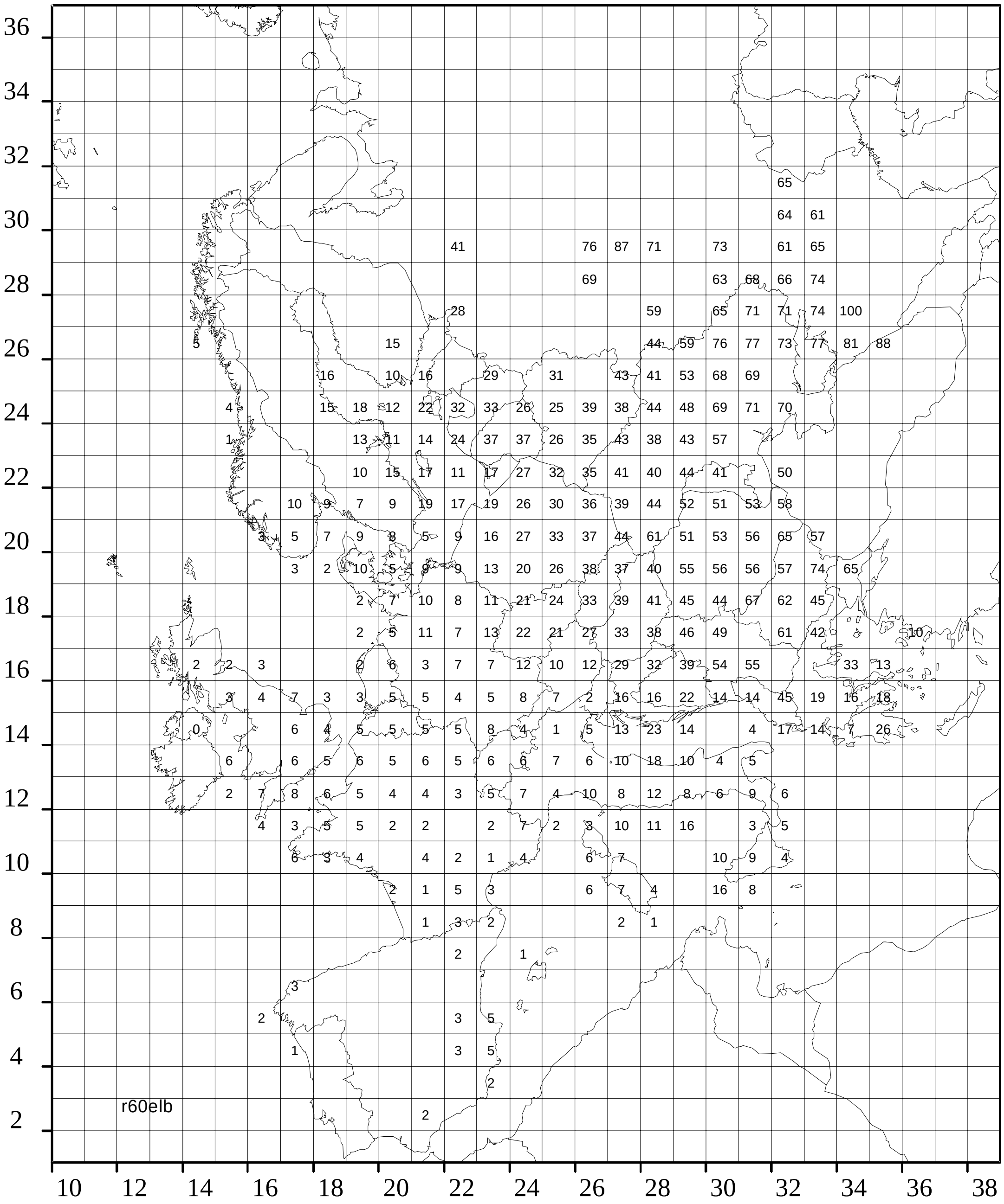


Figure 5.14 **Percentage reduction of the AOT60 achieved by the ELB scenario in comparison to the reference scenario. Only grids with excess of more than 0.1 ppm hours in the reference scenario are displayed.**



Country averages of ozone exposures indeces **Table 5.23**

	AOT40 excess over the critical level of 3 ppm.hours				AOT60 ppphours			
Country	1990	2010 REF	2010 ELB	Change ELB/REF	1990	2010 REF	2010 ELB	Change ELB/REF
Albania	5.7	4.6	4.1	*-10%*	0.9	0.4	0.3	*-20%*
Belarus	2.1	0.7	0.3	*-59%*	0.6	0.3	0.2	*-34%*
Bosnia-H.	9.3	6.4	5.3	*-18%*	1.2	0.5	0.4	*-25%*
Bulgaria	6.5	5.2	3.4	*-35%*	0.7	0.4	0.1	*-65%*
Croatia	11.7	8.3	7.2	*-13%*	2.7	1.2	1.0	*-21%*
Czech Republic	13.0	8.5	7.6	*-11%*	4.8	1.6	1.3	*-20%*
Estonia	0.0	0.0	0.0	-	0.3	0.1	0.1	*-20%*
Hungary	11.7	8.1	6.3	*-22%*	3.0	1.4	0.9	*-35%*
Latvia	1.2	0.2	0.1	*-67%*	0.6	0.2	0.2	*-28%*
Lithuania	2.8	0.8	0.2	*-79%*	0.8	0.4	0.3	*-32%*
Poland	8.2	8.7	8.5	*-2%*	5.4	4.2	4.0	*-4%*
Moldova	9.7	6.1	5.0	*-18%*	4.1	1.8	1.3	*-24%*
Romania	6.5	5.6	5.6	*0%*	0.9	0.5	0.5	*0%*
Russia	6.9	5.3	3.5	*-34%*	1.1	0.6	0.3	*-52%*
Slovakia	0.7	0.5	0.1	*-73%*	0.0	0.0	0.0	*-92%*
Slovenia	11.8	8.1	6.4	*-21%*	3.1	1.3	0.8	*-35%*
FYR Macedonia	11.0	6.4	6.3	*-2%*	2.8	0.6	0.6	*-6%*
Ukraine	4.9	3.6	2.0	*-44%*	0.9	0.6	0.3	*-53%*
F Yugoslavia	6.6	5.2	4.1	*-21%*	1.2	0.5	0.3	*-46%*
CEE Total	**6.6**	**5.1**	**3.6**	**-28%**	**1.4**	**0.8**	**0.5**	**-35%**
Accession Countries	**6.9**	**5.8**	**5.3**	***-10%***	**2.6**	**1.7**	**1.5**	***-10%***
Austria	11.5	6.8	6.3	*-8%*	2.8	0.8	0.7	*-14%*
Belgium	9.9	9.9	9.7	*-2%*	7.3	4.5	4.3	*-5%*
Denmark	6.3	3.8	3.7	*-3%*	3.0	1.3	1.2	*-6%*
Finland	0.0	0.0	0.0	-	0.1	0.0	0.0	*-12%*
France	12.6	8.8	8.7	*-1%*	5.2	2.0	1.9	*-4%*
Germany	11.9	8.3	8.0	*-3%*	6.0	2.6	2.4	*-7%*
Greece	4.7	3.6	2.9	*-20%*	0.6	0.4	0.3	*-20%*
Ireland	1.4	1.2	1.2	*0%*	0.9	0.7	0.7	*0%*
Italy	14.1	9.6	9.3	*-4%*	4.3	1.6	1.5	*-7%*
Luxembourg	14.1	11.6	11.4	*-1%*	8.4	4.2	4.0	*-5%*
Netherlands	4.9	3.8	2.8	*-25%*	0.4	0.1	0.0	*-64%*
Portugal	0.1	0.0	0.0	*-3%*	0.2	0.1	0.1	*-4%*
Spain	14.2	9.4	8.7	*-7%*	4.2	1.4	1.3	*-7%*
Sweden	7.4	5.1	5.0	*0%*	0.8	0.2	0.2	*-1%*
UK	1.8	3.2	3.1	*-3%*	2.0	1.7	1.6	*-4%*
EU-15	**9.0**	**6.3**	**6.0**	***-4%***	**3.1**	**1.3**	**1.2**	***-6%***
Total Europe	**7.4**	**5.5**	**4.4**	***-19%***	**2.0**	**1.0**	**0.7**	***-22%***

6. Interpretation of the scenario results

It was mentioned in the introductory section that the study uses the 'what if …' scenario approach to identify the potential for future emissions growth in the CEE region. This means that different scenarios have been constructed to single out the range of possibilities and to explore general trends. However, not one of the scenarios presented above claims to predict actual development, rather they aim to contribute to the overall analysis.

A comparison of energy intensities reveals that CEE countries have significantly higher energy intensities than EU Member States. This is partly caused by specific structures of CEE economies that rely heavily on intensive industry with a low value added per unit of energy used, and partly on less efficient technologies prevalent in many CEE countries. An economic reform process addressing these two aspects could achieve substantial improvements. With the GDP growth projected for the year 2010, energy consumption by industry could decrease by up to 66% compared to 1990 in the case of full convergence.

The analysis also identifies some factors that could counteract the huge efficiency improvement potential in the industrial sector.

Private energy demand in CEE countries, e.g. for transportation purposes, is on a per capita basis currently 71% below the average level in EU countries. If the economic reform in the CEE countries were accompanied by a comparable improvement of the economic wealth of households, it would not be unreasonable to assume that transport demand would also rise considerably. Starting from this low level, an enormous potential for increased car traffic in the CEE countries can be constructed from this observation. In theory, a full convergence would boost gasoline use by more than a factor of three, and an even more realistic development would outline an increase by a factor of two for the year 2010. Private households can expect similar trends for electricity consumption, which are currently per capitaabout 45% below the EU level when, measured on a per capita basis. Full convergence would imply an increase in electricity demand from private households by about 120%.

The impact on the overall energy consumption in the CEE region depends crucially on a number of assumptions about the development potentials of the industrial and private sectors. Despite the increasing level of energy consumption in the private sector, it is likely that total primary energy consumption in the CEE countries will decline in the future – in the hypothetical case of full convergence by up to 30% (Table 6.1). This means that the potential increase in energy use for transport might not be sufficient to completely offset the improvements in the industrial sector. In practice, however, it will be of utmost importance to monitor and – if necessary – to influence the development on the sectoral level.
The differences in the sectoral development of energy demand are strongly mir-

Table 6.1 **Comparison of energy consumption (in PJ) in the CEE countries**

	1990	Partial convergence (EEC-B)	Full convergence (EEC-F)
Industry	22,227	13,263 (-40%)	7,433 (-66%)
Transport (gasoline)	1,636	3,398 (+108 %)	5,229 (+220 %)
Transport (total)	4,214	5,834 (+38%)	6,806 (+62 %)
Total	45,858	37,230 (-19%)	32,504 (-29 %)

Emissions of SO_2 and NO_x for the different energy scenarios for the year 2010, assuming the current legislation on emission control (in kt)

Table 6.2

		1990	REF CLE	EEC-B CLE	EEC-F CLE
SO_2					
	Accession	10,777	4,053 (-62%)	3,484 (-68%)	3,267 (-70%)
	Other CEE	9,509	5,291 (-44%)	2,924 (-69%)	2,833 (-70%)
	Total CEE	20,286	9,344 (-54%)	6,408 (-68%)	6,100 (-70%)
NO_x					
	Accession	3,788	2,429 (-36%)	2,375 (-27%)	2,371 (-27%)
	Other CEE	4,536	4,284 (-6%)	4,926 (+9%)	4,850 (+7 %)
	Total CEE	8,322	6,713 (-19%)	7,301 (-12%)	7,221 (-13%)

rored by the growth of emissions. There is a clear tendency toward a significant decline of SO_2 emissions, caused by lower coal demand from stationary sources in the industry and the electricity sector. On the other hand, the potential for a rapid growth in the transport sector indicates the possibility for an immense increase in NO_x emissions from this sector.

When considering future emission levels, it is equally important to take account of the technical possibilities for emission reductions. The study clearly indicates that in many CEE countries new regulations for emission controls – although often not as strict as the EU regulatory framework – will have profound impacts on emissions. As shown in Table 6.2, a significant decline in emissions (-54% for SO_2 and -9% for NO_x) is expected for the Reference scenario, partly due to the structural changes implied by the energy scenario, and partly due to the application of current regulations on emission control. Keeping these regulations fixed, the convergence of the energy structure towards EU standards could yield an additional 30% cut in SO_2 emissions (13% in the accession countries and 60% in the other CEE countries). For NO_x, however, the increase in per capita energy demand in the private sector implied in the convergence process would counteract some of the improvements. In countries without strict regulations on traffic emissions, the demand could even lead to an increase in NO_x emissions compared to the year 1990.

Obviously, control measures can greatly influence emission levels. The question remains, therefore: to what extent could harmonisation of current regulations on emission control in the CEE countries with those of the European Union improve the situation?
Table 6.3 demonstrates that harmonisation of emission control legislation of the CEE countries with that of the EU will in all cases lead to lower emissions, although to a different degree for the individual pollutants. Since many of the CEE countries have signed the Second Sulphur Protocol and thereby accepted obligations to implement national emission ceilings and to apply strict emission controls on new stationary sources, a further decline of SO_2 emissions triggered by the current EU regulations is limited to a few percent. The situation is significantly different for NO_x. Compared to current legislation, an application of EU standards would cut emissions between 25% and 50%, and could avoid a possible increase in emissions relative to 1990 that would result from a growth in traffic.

Summarising the above features, the largest uncertainties about the future levels of emissions in the CEE countries obviously concern the development of car traffic and the emission regulations applicable to vehicles, though, given recent developments in the CEE region, a strong increase in traffic volumes does not appear entirely unrealistic. Therefore, the question remains: to what extent will a potential re-

Table 6.3 **Impacts of the emission control legislation on the levels of SO_2 and NO_x emissions in the year 2010 (in kilotons)**

Energy pathway		Partial convergence (EEC-B)		Full convergence (EEC-F)	
Emission legislation	1990	Current (CLE)	EU	Current (CLE)	EU
SO_2					
Accession countries	10,777	3,484 (-68%)	3,427 (-68%)	3,267 (-70%)	3,236 (-70%)
Other CEE	9,509	2,924 (-69%)	2,695 (-72%)	2,833 (-70%)	2,483 (-74%)
CEE total	20,286	6,408 (-68%)	6,122 (-70%)	6,100 (-70%)	5,719 (-72%)
NO_x					
Accession countries	3,788	2,375 (-27%)	1,748 (-54%)	2,371 (-27%)	1,595 (-58%)
Other CEE	4,536	4,926 (+9%)	2,943 (-35%)	4,850 (+7%)	2,411 (-47%)
CEE total	8,322	7,301 (-12%)	4,671 (-44%)	7,221 (-13%)	4,006 (-52%)

Table 6.4 **Comparison of NO_x emissions (in kilotons) of the CEE countries for limited and unlimited growth of private energy demand for transport and electricity**

	Current legislation	EU legislation
1990	8322	-
Reference case, 2010	6,792 (-18%)	-
Partial convergence: limited growth	5,813 (-30%)	4,239 (-49%)
unlimited growth	7,301 (-12%)	4,671 (-44%)
Full convergence: limited growth	4,334 (-48%)	3,159 (-62%)
unlimited growth	7,221 (-13%)	4,006 (-48%)

straint of growth in private car traffic – achieved by whatever measures – result in improved environmental conditions? Under the assumption that, compared to 1990, per capita energy consumption for private transport would only increase by 50% (see the Reference scenario), instead of 220% in the partial convergence (EEC-B) scenario, NO_x emissions in the CEE region would indeed be significantly lower.

The most important effect of a limited growth in the energy demand for private transport and electricity concerns NO_x emissions. Assuming a continuation of the current regulations on emission control in the CEE countries, the energy convergence process with unlimited growth in the private sector would lead to a decline in NO_x emissions by about 12% in relation to 1990 (compare, for example, the 68% cut for SO_2). Limiting private energy demand to the levels of the REF scenario, however, would increase the potential for a reduction to 30%–48%, depending on the convergence process in the other sectors. On top of this, harmonisation of NO_x-related environmental legislation in the CEE countries with present EU standards could bring total NO_x emissions in the region down to a level of about 50% compared to 1990 (Table 6.4).

7. Conclusions

The report explores the potential for environmental improvements offered by the reform process in the CEE countries.

At the beginning of the reform process, between 1990 and 1994, energy consumption in the CEE region decreased by more than one-third, accompanied by a 30% decrease in the consumption of electricity. This drop was mainly caused by the economic crisis experienced in the region; on their own, the energy efficiency measures introduced in various sectors during this period could not have effected this change.. Since regional GDP declined at a slightly higher rate than total energy consumption, energy and electricity intensities increased slightly. The latest available statistics suggest, however, that for those countries with progressive economic reforms, the reverse of this trend is likely.

Since the future fate and pace of the reform process is uncertain, the analysis focuses on the theoretical potential for environmental improvements rather than on accurate predictions of future development. The quantities of air emissions are determined by two main factors: the structures of the national economies and energy systems, and the regulations to control emissions. The economic reform process is expected to significantly influence both of these factors.

The study constructs a range of scenarios on the evolution of the energy systems in the CEE countries, based on a range of assumptions about the pace of the convergence towards the structures characteristic for EU countries . All the scenarios suggest a declining energy demand in the CEE region in the future, ranging from -6% for the projections supplied by the individual countries to -30% for the case of full convergence of energy intensities in the CEE countries with those of the EU. It is important to understand, however, that the potential development in the various sectors is fundamentally different. The convergence process would reduce the energy intensities of industries in CEE countries (with a theoretical potential of a 66% cut in energy demand compared to 1990). However, the increased wealth of private consumers associated with economic development will most likely also raise the demand from private households for transportation and for electricity closer to the levels currently observed in EU countries. This could result, for example, in an increase of, gasoline consumption by as much as 220% for the entire CEE region.

These opposing trends in energy demand also cause differentiated impacts on emissions of the various air pollutants. Depending on the extent of the convergence process, emissions of CO_2 could decline by a third compared to 1990. The type of control measures applied heavily influences emission levels for both SO_2 and NO_x. Maintaining the present emission-related legislation in the CEE countries would, in combination with the restructuring of the energy system implied with the convergence process, decrease SO_2 emissions by about 70%. The increasing private energy demand, however, would mainly affect NO_x emissions and limit the total potential for NO_x reduction to about 10% to 15%. Harmonising emission legislation with EU standards would mostly influence NO_x emissions. Stricter SO_2 standards would yield only an additional 2% reduction (on top of the 70% achieved by the energy restructuring process); for NO_x, the EU standards could cut emissions by an additional 30% to 40%.

The study clearly indicates that a future shift in the pollution problems in the CEE countries from $SO_2$to NO_x is to be expected. Several factors will lead almost inevitably to a strong decline in SO_2 emissions, yet some important conditions will hold back an equivalent reduction in NO_x emissions. Most prominently, the increase of private energy consumption towards the levels currently experienced in the EU would make a strong reduction in NO_x emissions nearly impossible. Technical measures, including the application of EU emission standards for cars, could make a considerable contribution to overcoming this problem. Of similar importance, however, are other, non-technical, measures aimed at a limited growth in private energy demand. If applied together, the NO_x emissions of the CEE countries could be reduced by up to 50%.

Stricter controls of emissions in the CEE region could also bring benefits for neighbouring EU countries. This scenario demonstrated that with the highest cut in emissions, almost 2% more ecosystems are protected in Austria, Germany, Finland and Sweden. Furthermore, the achievement of the EU Acidification Strategy targets is nearly 20% cheaper than for the reference case, in which countries of Central and Eastern Europe reduce their emissions according to current legislation. These examples clearly indicate the importance of emission control policies in the CEE region for achieving environmental goals in the EU.

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Annex 1: The regional air pollution information and simulation (RAINS) model

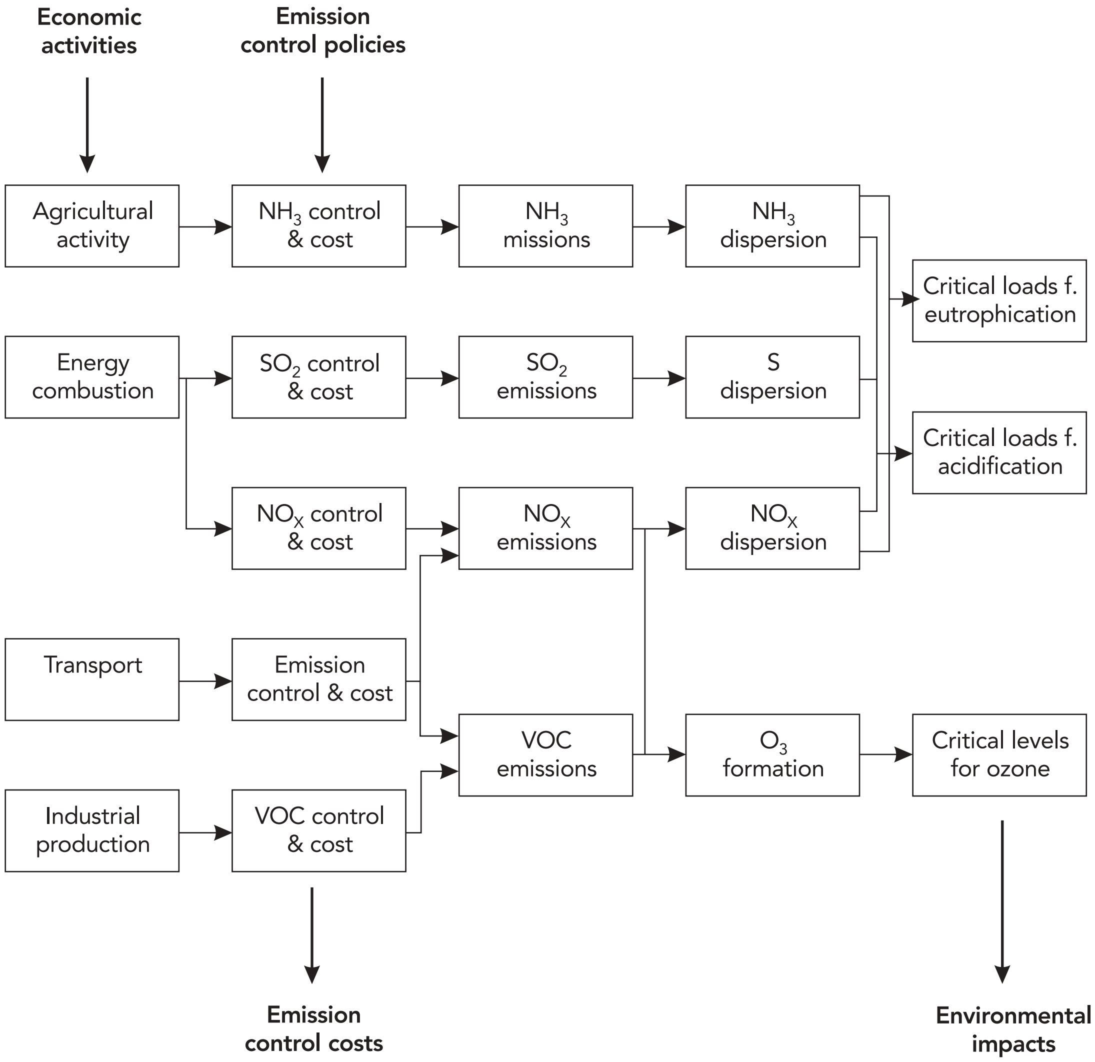
This study uses the Regional Air Pollution INformation and Simulation (RAINS) model developed at the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria). RAINS is an integrated assessment model that includes the recent databases on European energy use, emissions, emission control options and their costs, the atmospheric dispersion of pollutants, as well as critical pollution loads and levels. The model is therefore capable of fully analysing air pollution problems in the European context.
The RAINS-model provides a consistent framework for the analysis of emission reduction strategies, focusing on acidification, eutrophication and tropospheric ozone. RAINS comprises modules for emission generation (with databases on current and future economic activities, energy consumption levels, fuel characteristics, etc.), for emission control options and costs, for atmospheric dispersion of pollutants and for environmental sensitivities (databases on critical loads). To create a consistent and comprehensive picture of the options for simultaneously addressing the three environmental problems (acidification, eutrophication and tropospheric ozone), the model considers emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3) and volatile organic compounds (VOC). A detailed description of the RAINS model can be found in Alcamo *et al.*, 1990. A schematic diagram of the RAINS model is displayed in Figure 1.

For use in Europe, the RAINS model incorporates databases on energy consumption for 38 regions in Europe, distinguishing 22 categories of fuel use in six economic sectors. The time horizon extends from the year 1990 up to the year 2010 (Bertok *et al.*, 1993). Estimated emissions of SO_2, NO_x, NH_3 and VOC for 1990 are based on information collected by the CORINAIR inventory of the European Environmental Agency (EEA, 1996) and on national information. Options and costs for controlling emissions of the various substances are represented in the model by considering the technical and economic features of the most important emission reduction options and technologies. Atmospheric dispersion processes over Europe for sulphur and nitrogen compounds are modelled on the results of the European EMEP model developed at the Norwegian Meteorological Institute (Barret and Sandnes, 1996). For tropospheric ozone, source-receptor relationships between the precursor emissions and the regional ozone concentrations are derived from the EMEP photo-oxidants model (Simpson, 1992, 1993). The RAINS model incorporates databases on critical loads and critical levels compiled at the Co-ordination Centre for Effects (CCE) at the National Institute for Public Health and Environmental Protection (RIVM) in the Netherlands (Posch *et al.*, 1995).

The RAINS model can be operated in the ‘scenario analysis’ mode; that is, following the pathways of the emissions from their sources to their environmental impacts. In this case, the model provides estimates of regional costs and environmental benefits of alternative emission control strategies. Alternatively, a (linear programming) ‘optimisation mode’ is available for the acidification part to identify cost-optimal allocations of emission reductions in order to achieve specified targets. This feature of the RAINS model was used extensively during the negotiation process of the Second Sulphur Protocol under the Convention on Long-Range Transboundary Air Pollution for elaborating effect-based emission control strategies. A first version of a non-linear optimisation module for tropospheric ozone has also been completed recently.

The RAINS model estimates the emissions of sulphur and nitrogen compounds in each country, and then totals the amounts from each country with a background contribution to compute total deposition

Schematic flowchart of the RAINS model framework **Figure 1**



at any grid location. These calculations are based on source-receptor matrices derived from a Lagrangian model of long-range transport of air pollutants in Europe, developed by EMEP.

The EMEP model is a receptor-oriented single-layer air parcel trajectory model, in which air parcels follow two-dimensional trajectories calculated from the wind field at an altitude that represents transport within the atmospheric boundary layer. Chemical transformations of the relevant substances within the air parcels are described by ordinary first-order differential equations integrated in time along the trajectories as they follow atmospheric motion. During transport, the equations take into account emissions from the underlying grid of a 150-km resolution, chemical processes in the air, and wet and dry deposition on the ground. Model calculations are based on six-hourly input data of the actual meteorological conditions for specific years.

In order to capture the inter-annual meteorological variability, model runs have been performed for 11 years (1985-1995, Barret and Sandnes, 1996). For each of these years, balances of sources (aggregated to entire countries) and sinks of pollutants (in a regular grid mesh with a size of 150 x 150 km) have been calculated. These annual source-receptor relationships have been averaged over 11 years and re-scaled to provide the spatial distribution of one unit of emissions. The resulting atmospheric transfer matrices are then used as input in the RAINS model.

The use of such ‘country-to-grid’ transfer matrices implicitly assumes that the relative spatial distribution of emissions within a country will not dramatically change in the future. It has been shown that the error introduced by this simplification is within the range of other model uncertainties, when considering the long-range transport of pollutants (Alcamo, 1987).

As mentioned above, the assessment of environmental impacts in RAINS is based on the concept of critical loads. A critical load for an ecosystem is defined as the deposition ‘below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge’. Over the past years, methodologies for computing critical loads have been elaborated for acidification and eutrophication and compiled by the Mapping Program under the Working Group on Effects, which operates under the UN/ECE Convention of Long-Range Transboundary Air Pollution (LRTAP) (UBA, 1996). On a national level, critical loads data is compiled and submitted to the Co-ordination Centre for Effects (CCE), located at the Dutch National Institute for Public Health and the Environment (RIVM). This Institute collates and merges national data into European maps and databases, which are then approved by the Mapping Program and the Working Group on Effects before being used in emission reduction negotiations under the LRTAP Convention.

Information on the critical loads of sulphur has been used in the negotiations of the 1994 Second Sulphur Protocol, the first international agreement on emission reductions explicitly taking into account environmental vulnerability, in addition to technological and economic considerations (UN/ECE 1994). However, acidification is caused by the deposition of both sulphur and nitrogen, and both compounds ‘compete’ for the counteracting (neutralising) base actions, which are mostly provided by deposition and weathering. And, in contrast to sulphur, there are additional natural (sources and) sinks for nitrogen such as uptake by vegetation, immobilisation and denitrification. Consequently, it is not possible to define a single critical load for acidity, as was the case when looking at sulphur alone. It is possible, however, for acidity to define a (simple) function, called the critical load function. This function defines pairs of sulphur and nitrogen deposition, for which there is no risk of damage to the ecosystem under consideration, thus replacing the single critical load value used earlier. The critical load function for each ecosystem has a trapezoidal shape and is defined by three quantities: $CL_{max}(S)$, $CL_{min}(N)$ and $CL_{max}(N)$. $CL_{max}(S)$ is essentially the critical load of acidity (as defined earlier), $CL_{min}(N)$ summarises the net nitrogen sinks, and $CL_{max}(N)$ is the maximum deposition of nitrogen (in the case of zero sulphur deposition) taking into account $CL_{max}(S)$ and deposition-dependent nitrogen processes ($CL_{max}(N)>=CL_{min}(N)+CL_{max}(S)$).

In addition to acidification, nitrogen deposition also acts as a nutrient for ecosystems. Consequently, in order to avoid eutrophication, critical loads for nutrient nitrogen, $CL_{nut}(N)$, have been defined and calculated for various ecosystems. If the multi-effect aspects of nitrogen deposition are considered, the critical loads of nutrient nitrogen have to be introduced as additional aspects (and eventually as constraints) in the integrated assessment of reductions of NO_x and NH_3 emissions.

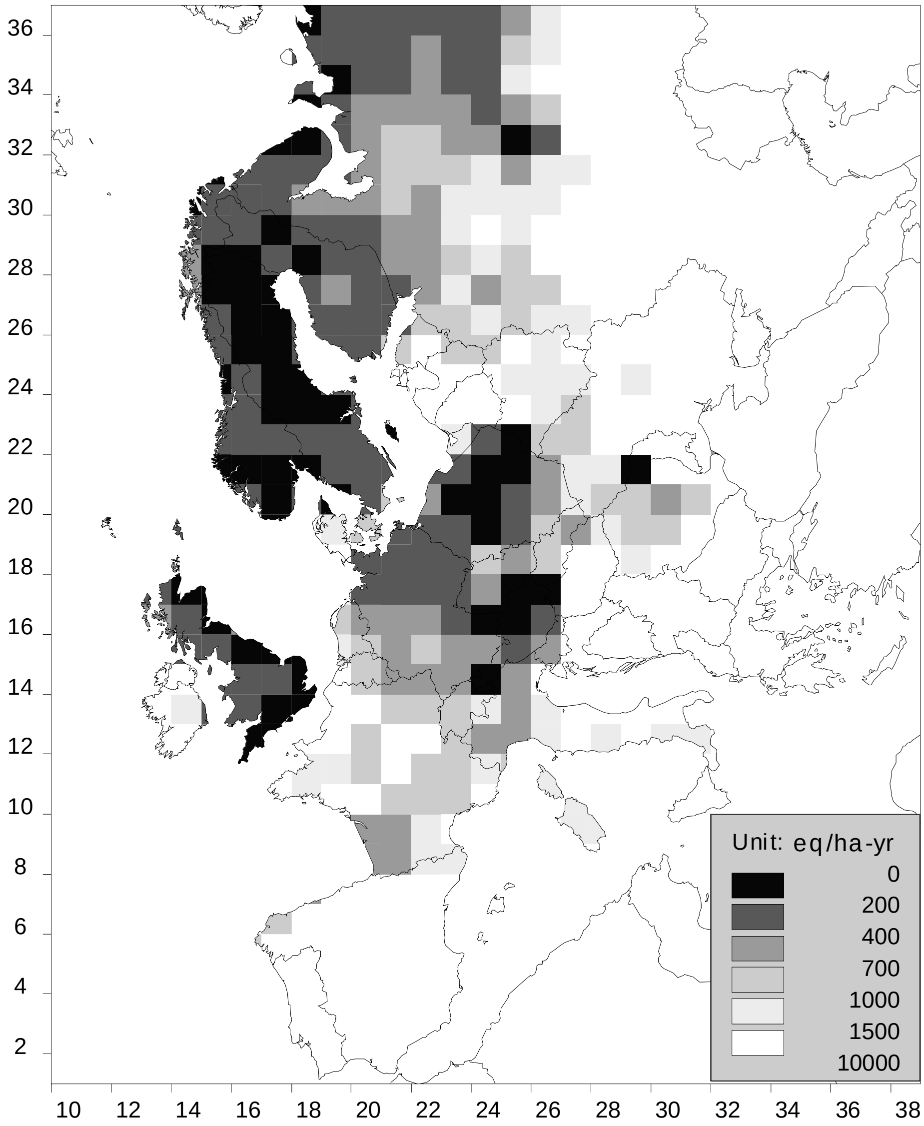
To compare critical loads with European deposition fields, the numerous critical load values and functions (currently more than half-a-million; mostly for forest soils, but also lakes and semi-natural vegetation) have to be aggregated in the 150km x 150km EMEP-grid. For single values, this is done by computing a percentile of the cumulative distribution function for all critical load values within an EMEP-grid cell. As an example, Figure 2 shows the fifth percentile of $CL_{max}(S)$ for the EMEP modelling domain.

To consider both sulphur and nitrogen deposition simultaneously, a surrogate for the multitude of critical load functions within an EMEP-grid cell has been defined: the so-called ecosystem protection isoline (for details see Posch *et al,* 1995).

These isolines are a generalisation of the percentile concept in the case of single critical load values. While more difficult to present in a map format, these isolines – and simplifications thereof – can be used in integrated assessment models, such as RAINS, to evaluate emission reduction strategies for both sulphur and nitrogen. Due to the different behaviour of sulphur and nitrogen in the environment, it is not possible to compute a unique exceedance of a critical load. However, the protection isolines derived from the critical load functions allow the computation of the percent of ecosystems protected in each grid cell, and therefore the evaluation of the effectiveness of any given emission scenario.

Finally, it should be mentioned that the critical load database is regularly updated to take into account the latest data and findings of the ongoing negotiations on emission reductions in Europe.

The fifth percentile of the critical loads for acidity ($CL_{max}(S)$) **Figure 2**



Annex 2: The energy efficiency convergence (EEC) scenario – Methodology

The starting point of the analysis for each country is energy consumption in 2010 in the baseline scenario (the Official Energy Pathway, UN/ECE, 1996). The analysis has been performed for three major economic sectors: manufacturing industry, domestic (residential and commercial), and transport; private passenger (car) transport has been treated separately. Energy consumption in the domestic and private transport sectors has been related to population. Energy used in other sectors has been related to GDP.

Currently large differences exist in energy intensities and consumption patterns between the CEE and the EU. It would not be realistic to assume that the energy intensities and consumption structures in all CEE countries will reach the EU average within the next 10-15 years. Substantial differences also exist among EU countries. Thus, in the EEC scenario, it has been assumed that the degree of similarity in energy consumption in each country depends on the distance of per capita GDP of a given country away from the EU-15 average. For the purpose of the analysis, the GDP is expressed in PPP terms. In other words, it is assumed that the gap between energy consumption patterns and intensities in the CEE, and the average EU-15 level, will diminish proportionally to the relative difference in per capita GDP.

The formulas used in calculating sectoral energy consumption in the EEC case are:

$$R_{iEEC} = R_i + (1-R_i) * G_i \qquad (1)$$

Where:

R_i .. ratio of specific energy consumption in 2010 in country i to average specific energy consumption in EU-15 in the baseline,
R_i^{EEC}.. ratio as above in the EEC scenario,
G_i .. ratio of per capita GDP in 2010 in country i to average per capita GDP in EU-15.

For countries with a per capita GDP in 2010 lower than 50% of the EU average, it has been assumed that the relative difference in energy intensities (in per unit of GDP or in per capita terms) will diminish by 50%. Such an assumption has been adopted because for countries with low GDP level the formula (1) does not result in meaningful improvement of energy intensities. The 50% improvement has been chosen arbitrarily. However, such an assumption has a reasonable justification. The average lifetime of capital stock in industry is about 30 years which implies the scrapping rate of more than 3% per year. Thus if the EU energy efficiency standards are introduced now on new investments in the CEE region, their share in 2010 will be about 50%.

If any of the CEE countries achieves a per capita GDP higher than EU-15 average, it has been assumed that energy intensity for such a country (in per capita or in per unit of GDP terms) would reach the average EU-15 level. Formulas used for these two specific cases are:

if $G_i < 0.5$:

$$R_i^{EEC} = R_i + (1-R_i) * 0.5 \qquad (2)$$

if $G_i > 1$:

$$R_i^{EEC} = 1 \qquad (3)$$

The calculations have been performed separately for each sector for total final energy and for electricity.

Calculated intensities were used next to estimate final energy demand in each sector. Then, fuel used for electricity generation and energy demand in the conversion sector other than power plants was calculated. Calculations have been made with a simple energy model. Again, the starting point was the baseline scenario for each individual country. In the case of lower demand for fuels in a given sector, it has been assumed that fuels with high emission factors (coal, heavy fuel oil) are eliminated first. Energy scenarios were created without analysing the possible developments in turnover of capital stock in individual economic sectors, nor making assumptions about evolution of energy prices in the CEE region. Such factors were taken into account in a study by Bollen *et al*, 1996. Because of high uncertainties involved in the assessment of the effects of economic restructuring in Central and Eastern Europe, a simplified approach was adopted with explicit assumptions regarding changes in energy intensities .

List of abbreviations

(a) General abbreviations

AOT40	Accumulated excess ozone concentration over the 40 ppb threshold
AOT60	Accumulated excess ozone concentration over the 60 ppb threshold
CEE	Central and Eastern Europe
CITEPA	Centre Interprofessionnel Technique d'Estudes de la Pollution Atmospheric
CMEA	Council of Mutual Economic Assistance
CO_2	carbon dioxide
CRP	Current Reduction Plans
DGVII	Directorate General VII
DG XI	Directorate General XI
EBRD	European Bank for Reconstruction and Development
EC	European Commission (European Union)
ECU	European Currency Unit
EEA	European Environmental Agency
EEC	European Commission for Europe (United Nations)
EJ	Exa joule
EMEP	European Monitoring and Evaluation Programme
EU	European Union
EU-15	European Union (15 Member States)
FYR Macedonia	Former Yugoslavic Republic of Macedonia
GDP	Gross Domestic Product
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
kWh	kilowatt hour
LPG	liquefied petroleum gas
LCPD	Long-Range Combustion Plant Directive
MEXR	market exchange rate
MJ	mega joule
NH_3	ammonia
NO_x	nitrogen oxides
PJ	peta joule
ppb	parts per billion
PPP	Purchasing Power Parity
RAINS	Regional Air Pollution Information and Simulation Model
SO_2	sulphur dioxide
TWh	Terawatt hour
UN/ECE	United Nations Economic Commission for Europe
USSR	Countries belonging to the former USSR
WHO	World Health Organisation
WIIW	The Vienna Institute for Comparative Economic Studies

(b) Abbreviations of the names of energy scenarios

Energy pathway	Description	Country group
OEP'96	Official Energy Pathway, 1996 update	CEE and EFTA countries
CW	DGXVII Conventional Wisdom EU-15	
EEC-B	Energy Efficiency and Convergence Scenario, Base case (Gap in sectoral energy intensities and per capita consumption between each individual CEE country and the EU-15 average reduced by at least 50 %)	All CEE countries
EEC-BL	Energy Efficiency and Convergence Scenario, Base case with Limits (as in the Base case but growth of fuel consumption by private cars and electricity consumption in the residential/commercial sector limited to the values in the OEP'96)	All CEE countries
EEC-F	Energy Efficiency and Convergence Scenario, Full convergence case (energy intensities and per capita consumption in all CEE countries reach the EU-15 average)	All CEE countries
EEC-FL	Energy Efficiency and Convergence Scenario, Full convergence case with Limits (energy intensities and per capita consumption in all CEE countries reach the EU-15 average but growth of fuel consumption by private cars and electricity consumption in the residential/commercial sector limited to the values in the OEP'96)	All CEE countries

(c) Summary of the scenarios for SO_2 and NO_x emissions

Scenario name	Control strategy	Energy pathway	Country group
REF	Current national and international legislation (emission standards + internationally agreed emission ceilings) EU legislation on top of national legislation	OEP'96 CW	CEE and EFTA EU-15
CLBA	**C**urrent national and international **L**egislation	EEC-**B**	**A**ccession countries*)
CLB	**C**urrent national and international **L**egislation	EEC-**B**	All CEE countries*)
ELBA	**E**U legislation on top of national **L**egislation	EEC-**B**	**A**ccession countries*)
ELB	**E**U legislation on top of national **L**egislation	EEC-**B**	All CEE countries*)
ELBL	**E**U legislation on top of national **L**egislation	EEC-**BL**	All CEE countries*)
CLFA	**C**urrent national and international **L**egislation	EEC-**F**	**A**ccession countries*)
CLF	**C**urrent national and international **L**egislation	EEC-**F**	All CEE countries*)
ELFA	**E**U legislation on top of national **L**egislation	EEC-**F**	**A**ccession countries*)
ELF	**E**U legislation on top of national **L**egislation	EEC-**F**	All CEE countries*)
ELFL	**E**U legislation on top of national **L**egislation	EEC-**FL**	All CEE countries*)

*) Other countries as in the REF scenario.

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