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***Annex to* :**

The Communication on Thematic Strategy on Air Pollution

and

The Directive on "Ambient Air Quality and Cleaner Air for Europe"

Impact Assessment

{COM(2005)446 final}
{COM(2005)447 final}

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GLOSSARY AND ABBREVIATIONS

Acidification	Excess acidity from the deposition of ammonia, nitrogen oxides and sulphur dioxide can lead to the damage of freshwater and terrestrial ecosystems.
Aerosol	A dispersion of solid particulate matter or droplets in air.
Air quality limit value	A legally binding pollutant concentration in air which may be exceeded on a prescribed number of occasions per calendar year (c.f. *target value,* an air quality objective which is not legally binding).
Air Quality Proposal	Proposed Directive to merge the Air Quality Framework Directive, first, second and third daughter directives, and the Council Decision on the reciprocal exchange of air quality monitoring information.
Ammonia (NH_3)	A gas which is emitted mainly from animal wastes and following the application of fertilisers.
Background	Urban background represents locations in urban areas where the level of air pollutants is not mainly influenced by any single source, but rather by the integrated contribution from all sources upwind of this location. The air pollution level in these locations should typically be representative for several km^2. Rural background represents locations with lower population density, far removed from urban and industrial areas and away from local emissions. The air pollution level in these locations should typically be representative for an area of at least 1000 km^2.
CAFE	Clean Air for Europe programme
CAFE baseline (called also "Business-as-usual" or "Current Legislation")	The expected evolution in EU-25 pollutant emissions up to 2020 assuming that current legislation to reduce air pollution is implemented. The baseline is based upon forecasts of economic growth and changes in energy production, transport and other polluting activities.
CAIR	Clean Air Interstate Rule
CAP	Common Agricultural Policy
CBA	Cost-benefit analysis
CLTRAP	UN ECE Convention on Long Range Transboundary Air Pollution
Critical level	A pollutant concentration level in air below which significant adverse impacts on vegetation are not expected.
Critical load	A level of deposition below which significant adverse impacts on ecosystems are not expected
EMEP	Protocol on long-term financing of the co-operative programme for monitoring and evaluation of long-range transmission of air

	pollutants in Europe
Eutrophication	Excess nutrient nitrogen (mainly in the form of ammonia or nitrogen oxides) can lead to changes in the composition of ecosystem communities and a loss of biodiversity.
GEM-E3	General equilibrium macro-economic model – Economy, Energy & Environment
Ground-level ozone (O_3)	Ozone formed in the lowermost part of the atmosphere from the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight. Ozone is a strongly oxidising gas.
IA	Impact Assessment
IAM	Integrated Assessment Modelling
IIASA	International Institute of Applied Systems Analysis
IPPC	Integrated pollution prevention and control (Directive 96/61/EC)
LRS	Lower respiratory symptoms
MRAD	Minor restricted activity day
MTFR	Maximum Technically Feasible Reduction
National emission ceiling	The maximum amount of a substance expressed in kilotonnes that may be emitted by a Member State in a particular calendar year.
NECD	National Emissions Ceiling Directive
NewExt	New Elements for the Assessment of External Costs from Energy Technologies
Nitrogen oxides (NO_x)	The gases nitric oxide (NO) and nitrogen dioxide (NO_2). NO is predominantly formed in high temperature combustion processes and can subsequently be converted to NO_2 in the atmosphere.
PM_{10}, $PM_{2.5}$	Particulate matter in ambient air with a diameter less than 10 or 2.5 millionths of a metre respectively.
PRIMES	Energy model
RAD	Restricted activity day
RAINS	Regional Acidification Information Simulation Integrated Assessment Model
SCHER	Scientific Committee on Health and Environmental Risks
SCNR	Selective Non-Catalytic Reduction
Secondary pollutant	Secondary pollutants are not emitted directly but are formed by subsequent chemical processes in the atmosphere. Examples include ground-level ozone, and nitrate and sulphate aerosols.
Strategy	Thematic Strategy on Air Pollution
SOMO35	Sum of daily maximum ozone concentrations above a threshold of 35 ppb (70 µg/m^3)

Sulphur dioxide (SO_2)	Gas formed from the combustion of fuels which contain sulphur.
Transboundary air pollution	Pollutants emitted in one country are transported in the atmosphere and may contribute to adverse health and environmental impacts in other countries.
Volatile Organic Compounds (VOC)	VOC are volatile carbon-based chemical compounds (such as solvents or components of paints and varnishes) which are emitted to the atmosphere from natural sources or as a result of human activities.
VOLY	Value of life year
VSL	Value of statistical life
WGI	Working Group on Implementation
WG PM	Working Group on Particulate Matter
WG TSPA	CAFE Working Group on Target Setting and Policy Assessment
WHO	The World Health Organization
YOLL	Years of life lost

Summary

Part One - Impact Assessment on the Thematic Strategy on Air Pollution

The objectives

The Sixth Environment Action Programme (6th EAP) is a programme of Community action on the environment with key objectives covering a period of ten years. The priorities of the 6th EAP cover climate change, nature and biodiversity, environment, health and quality of life, and natural resources and waste. Within these key priorities, the 6th EAP calls for the development of seven thematic strategies including a coherent and integrated strategy on air pollution.

The Thematic Strategy on air pollution is to present a coherent and integrated policy on air pollution which: (1) sets out priorities for future action; (2) reviews existing ambient air quality legislation and the National Emission Ceilings Directive with a view to reaching long-term environmental objectives; and (3) develops better systems for gathering information, modelling and forecasting air pollution.

The 6th EAP establishes the objective of achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment. This includes no exceedence of critical loads and levels for natural ecosystems (a critical load being a level of exposure below which there is not expected to be any risk).

Air pollution is complex. There are local components and transboundary contributions to observed effects. Several pollutants contribute to the same or multiple effects and pollutants interact. Moreover, there are prominent synergies and tensions between air pollution and other environmental problems such as climate change. These issues must be addressed in a systematic and cross-cutting way so that benefits can be maximised. The Thematic Strategy on air pollution is built upon an integrated assessment of different environmental and health effects and aims to provide the most cost-effective solution for the chosen level of objectives.

The Strategy assesses the prospects for making further progress towards the objectives set out in the 6th EAP. It considers the economic, social and environmental dimensions in an integrated and balanced manner.

Development of the Thematic Strategy and Stakeholder Consultation

In its Communication on the *Clean Air For Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality* the Commission set out its intention to develop the Thematic Strategy based upon sound technical information. The CAFE Programme was set up to develop, collect and validate scientific information about air pollution with the aim of reviewing current policies and assessing progress towards long-term objectives. It established five working groups to provide assistance and advice (see box below).

There were over one hundred stakeholder meetings during the CAFE programme including conferences to disseminate results, to share experiences on the use of different policy instruments (including economic instruments), and to discuss issues relating to the implementation of current air quality legislation. In addition, there was a two-month "non-expert" web-based public consultation on the content and objectives of the Thematic Strategy. Of the 11,578 responses received, over 10,000 were from private individuals. Respondents indicated a clear need for better public information, a greater desire for protection from air pollution and a willingness to pay for reduced risks on a par with those for drinking water.

Working Groups under the Clean Air For Europe Programme

- The CAFE Steering Group;
- The Target Setting and Policy Assessment Working Group (TSPA);
- The Technical Advisory Group (TAG);
- The Working Group on Particulate Matter (WGPM);
- The Working Group on Implementation (WGI).

The Steering Group was and continues to be the main forum for stakeholder participation on air pollution issues. Members include representatives of the Member States, several industry sectors (energy production, petroleum, VOC industries, automotive sector and general industry), environmental NGOs, EEA countries, the European Environment Agency, the Joint Research Centre and the CLRTAP. The Steering Group met fourteen times during the four years of the CAFE programme.

The TSPA included selected experts from the Member States, industry, NGOs, the European Environment Agency and the JRC. Its role was to assist the Commission in managing the technical service contracts that were launched to provide information on the development of cost-effective control strategies and to estimate health benefits. The TSPA's main role was to provide feedback on the environmental targets to be used in developing cost-effective control strategies using the RAINS integrated assessment model. The TAG was a forum for different modelling groups to discuss and give advice on technical and scientific issues relating to the analyses undertaken.

The WGPM was convened to review the latest health evidence and scientific information regarding the effects and presence of particulate matter in ambient air and to make recommendations for modifications to existing legislation. The WGPM was led by experts from the UK and Germany. The WGI was convened by the Commission to gather and report on the implementation of existing air quality legislation and to report to the Commission on potential modifications and improvements. Its members consisted primarily of experts from the Member States.

As well as the various working groups, the Commission launched several contracts for services during the CAFE Programme. The total value of these contracts and agreements amounted to several million euros. The most important of these are listed below.

Service contracts launched under the CAFE Programme

(1) Energy Baseline Scenarios for the Clean Air For Europe Programme (CAFE) – service contract to verify consistency between air quality and climate change policies in the CAFE baseline scenarios, National Technical University of Athens, Contract N° 070501/2004/377552/MAR/C1;

(2) Baseline Scenarios for the Clean Air For Europe (CAFE) Programme. Service contract for the development of the baseline and policy scenarios and integrated assessment modelling framework for the CAFE programme, International Institute for Applied Systems Analysis, Contract N° B4-3040/2002/340248/MAR/C1;

(3) Service Contract for Carrying Out Cost-Benefit Analyses of Air Quality Related Issues, in particular in the Clean Air For Europe (CAFE) Programme; AEA Technology plc, Contract N° ENV.C.1/SER/2003/0027;

(4) Service Contract for the Review of the RAINS Integrated Assessment Model; The Swedish Environmental Research Institute & AEA Technology plc, Contract N° ENV.C1/SER/2003/0079;

(5) Peer-Review of the Methodology of the Cost-Benefit Analysis of the Clean Air For Europe Programme; Alan Krupnick (editor), Bart Ostro and Keith Bull, October 2004, (under contract N° 070501/2004/382805/MAR/C1);

(6) Systematic Review of Health Aspects of Air Pollution in Europe, European Centre for Environment & Health of the World Health Organisation (Bonn), Grant agreement 2001/321294.

(7) Assessment of the effectiveness of European Air Quality Policies and Measures; Millieu Ltd, Contract N° B4-3040/2003/365967/MAR/C1.

An overriding principle of the CAFE programme was to ensure that the analyses were conducted on the basis of the best available information. It is for this reason that the main analytical tools (the RAINS integrated assessment model and the cost-benefit methodology) were both subject to independent peer-review before being used to develop and analyse policy scenarios. In addition, the World Health Organisation was asked to provide its best information on the impacts of air pollutants on health.

The problem

The main sources of air pollution are transport, power generation, industry, agriculture, and heating. All these sectors emit a variety of air pollutants - sulphur dioxide, nitrogen oxides, ammonia, volatile organic substances, and particulate matter – many of which interact with others to form new pollutants. These are eventually deposited and have a whole range of effects on human health, biodiversity, buildings, crops and forests.

Air pollution results in several hundreds of thousands of premature deaths in Europe each year, increased hospital admissions, extra medication, and millions of lost working days. The health costs to the European Union are huge. While the environmental damage through acidification of ecosystems and damage to crops and forests is impossible to quantify, it is likely to be substantial as well. The pollutants of most concern for human health are airborne particulates and ozone – indeed no safe levels have yet been identified for either.

Particulates consist of the "primary" particles emitted directly into the atmosphere from certain processes and "secondary" particles (or "aerosol"). The latter are emissions of gaseous pollutants, such as sulphur dioxide (SO_2), nitrogen oxides (NO_X) and ammonia (NH_3), which are altered through chemical reaction in the atmosphere and add to the particulate mass. Particulates in ambient air are classified according to size, so PM_{10} and $PM_{2.5}$ refer to all particles with diameter less than 10 micrometers (the "coarse" fraction) and 2.5 micrometers (the "fine" fraction) respectively. Fine particles tend to originate more from human activities than coarse particles.

Ozone occurs naturally in the stratosphere and in the troposphere, but is formed by very different chemical processes. Ozone in the stratosphere is valuable as it protects us from harmful ultraviolet radiation, but tropospheric ozone near ground level is harmful to ecosystems and human health. Ground-level ozone is formed in the atmosphere by reaction between volatile organic compounds (VOC) and NO_X in the presence of sunlight. The VOC come from petrol stations, car exhausts, and the use of solvents and paints.

In the environment, emissions of SO_2, NO_X and NH_3 contribute to the acidification of lakes, rivers, forests and other ecosystems, although it is possible to identify a "critical load" below which the ecosystem is not expected to be at risk. But after fauna and flora are lost it may take several decades for an ecosystem to recover, even when acidifying inputs are reduced to sustainable levels. Excess nitrogen from NO_X and NH_3 can lead to eutrophication, while ground-level ozone can damage forests, crops and vegetation. Ozone damage is the most serious regional air pollution problem affecting agriculture in Europe. Air pollution also has an impact on materials, buildings and cultural heritage.

The approach

The present document explains how the Strategy was build up, the options chosen or discarded and the costs and benefits of each of them. It assesses the impact of the Strategy based on the best scientific understanding of emissions, atmospheric transport, and the human health and environmental impacts of air pollution. It concentrates on the five major impacts of the five major pollutants shown in this table.

Multi-pollutant/multi-effect approach of the Strategy

	Primary PM	SO_2	NO_x	VOC	NH_3
Health effects:					
- Particulate matter	√	√	√	√	√
- Ground-level ozone			√	√	
Vegetation effects:					
- Ground-level ozone			√	√	
- Acidification		√	√		√
- Eutrophication			√		√

The method used for the Strategy was first to establish a **baseline** showing air pollution up to 2020 if no extra measures or additional legislation are implemented. This was then set against Community **long-term objectives of** *achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment. This includes no exceedence of critical loads and levels for natural ecosystems.* Then, **various scenarios** were examined to close the "gap" between the baseline and the achievement of the long terms objectives. On the basis of cost-effectiveness and cost/benefit analysis **interim objectives** for the Strategy have been set. Peer reviews and sensitivity analyses were used to minimise uncertainties in modelling, assumptions, and assessments of alternative strategies.

The baseline

The baseline scenario takes account of the effects of emissions control legislation, against the background of future economic development. The baseline scenario is sometimes called also the "business-as-usual" or "current legislation" scenario. Existing legislation – e.g. on cars, large combustion plants, fuel quality, the VOC content of products, emission limits for major pollutants – will deliver reductions in emissions of most air pollutants (SO_2, NO_X and VOC) in the 25 Member States of the European Union, in a context of economic growth. The exception is ammonia emissions, although the recent reforms of the Common Agricultural Policy should bring considerable improvements. Emissions of all particulates should also continue to decline, but background concentrations of ozone will increase and are of concern.

The relationship between the decrease of primary pollutant emissions and the improvement of air quality is not straightforward. Air quality is affected not only by local emissions, but also by interactions between these pollutants, their long-range transport in the atmosphere, natural emissions and meteorological conditions. So the picture varies across the EU.

In the natural environment it is possible to determine "critical loads" for individual ecosystems, namely sustainable levels of deposition **above** which the ecosystem will be at risk of harmful effects. For human health, the situation is more complex as no safe levels of exposure have yet been identified for some pollutants, such as particulate matter and ground-level ozone.

The improvements in pollutant emissions, health impacts from air pollution across the EU are therefore still projected to be considerable in 2020. The effects on life expectancy of exposure to particulates (estimated at over 300 000 premature deaths equivalent a year in 2000) are expected to be much greater than those associated with ozone (some 21 000 premature deaths). Total health damage costs – including illness – associated with particulate matter and ozone are estimated to be between €189 billion and €609 billion per annum in 2020.

The options

Since by 2020 the EU will still be a long way from achieving the two objectives of the 6th EAP with current legislation, further action is required. To help decide on the costs and benefits of different levels of action, various options were considered with reference to a scenario whereby all possible emissions abatement measures are deployed irrespective of cost. This is called the "Maximum Technically Feasible

Reduction" (MTFR) scenario, but even if the EU undertook all measures available, irrespective of costs, there would still be significant negative impacts on health and the environment.

So, various options between the baseline and the MTFR scenario were assessed to establish interim environment objectives that deliver progress in a balanced and cost-effective way. At the outset, and following discussion and advice from the Working Group on Target Setting and Policy Assessment, three different levels of ambition[1] were considered in four areas, combining the health-related $PM_{2.5}$ and ozone objectives with those of environmental protection for acidification and eutrophication as shown in the table below

Scenarios considered in the Thematic Strategy

	2000	Baseline 2020	Scenario A	Scenario B	Scenario C	MTFR[2]
EU-wide cumulative years of life years lost (YOLL, million)	203	137 (0%)	110 (65%)	104 (80%)	101 (87%)	96 (100%)
Acidification (country-wise gap closure on cumulative excess deposition)[3]	120	30 (0%)	15 (55%)	11 (75%)	10 (85%)	2 (100%)
Eutrophication (country-wise gap closure on cumulative excess deposition)[4]	422	266 (0%)	173 (55%)	138 (75%)	120 (85%)	87 (100%)
Ozone (gap closure on SOMO35)[5]	4081	2435 (0%)	2111 (60%)	2003 (80%)	1949 (90%)	1895 (100%)

Impact assessment of the options

The three scenarios between the baseline and the maximum technically feasible reduction were subjected to a full cost-benefit analysis, together with analysis of impacts on competitiveness and employment. The analysis focuses on the most significant impacts and the most important distributive effects, and the depth of analysis matches the significance of the impacts.

The reduction in pollutant emissions for each ambition level is not homogeneous across pollutants and Member States. For example, it can be seen from the table below that under Scenario B, SO_2 emissions would be reduced by a further 44% from where they would be with current legislation in 2020, but NO_X emissions by only 272%.

1 The assessment focuses on the range between 50% and 100% of MTFR, as control costs started to increase significantly at about 75% between the baseline and MTFR in 2020.

2 The percentage refers to the difference between Baseline 2020 and Maximum Technically Feasible Reduction (MTFR)

3 Average accumulated excess acidification equivalents per hectare

4 Average accumulated excess eutrophication equivalents per hectare

5 SOMO35 in parts per billion days

Emission reductions for the three ambition levels in 2020 (in kilotonnes)

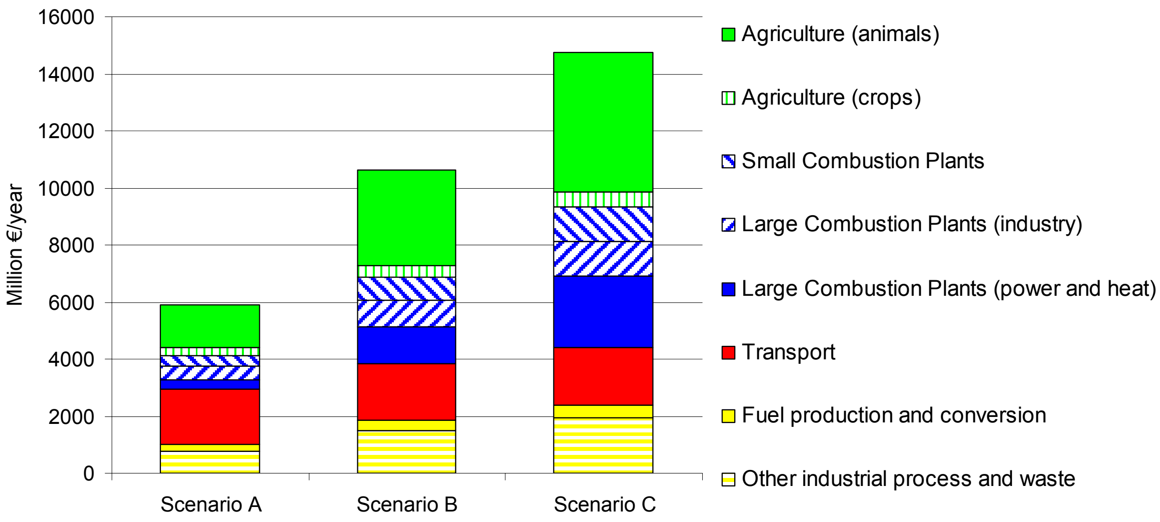
	Baseline		Ambition level in 2020		
	2000	2020	Scenario A	Scenario B	Scenario C
SO_2	8735	2805	1704	1567	1462
NOx	11581	5888	4678	4297	4107
VOC	10661	5916	5230	4937	4771
NH_3	3824	3686	2860	2598	2477
$PM_{2.5}$	1749	964	746	709	683

The direct costs of these measures have been calculated at between €5.9 billion for Scenario A and €14.9 billion for Scenario C. The tables show a preliminary estimate of costs by pollutant and by major source for 2020.

Abatement costs by pollutant in 2020 (€ million per year)

	Ambition level			
Pollutant	Scenario A	Scenario B	Scenario C	MTFR
SO_2	800	1,021	1,477	3,124
NOx	903	2,752	4,255	6,352
NH_3	1,785	3,770	5,410	13,584
Primary $PM_{2.5}$	411	695	908	12,335
VOC	157	573	935	2,457
$PM_{2.5}$ and NOx from road transport	1,868	1,868	1,868	n/a
Total	**5,923**	**10,679**	**14,852**	**over 39,720**

Abatement costs by sector in 2020 (millions of euros per year)



Health benefits of the different policy options have been assessed using the methodology outlined in Section 2.3 and given in detail in the CBA methodology reports. The major monetised benefits of policy options would come from reduced premature deaths and reduced loss of life expectancy. Also benefits from reduced morbidity contribute significantly to the overall benefits, although it must be kept in mind that the basis of evidence for quantifying the most influential morbidity health endpoints is more limited than for mortality.

A way of defining the optimal ambition level would be to compare the cost per life year saved against the marginal benefit of a life year saved. This balance should be limited to the costs for reducing $PM_{2.5}$ concentration only (therefore excluding additional costs linked with acidification, eutrophication and ground-level ozone targets), with the monetary valuation of both mortality and morbidity effects due to reduced $PM_{2.5}$ concentration. The optimum is the point where marginal costs and marginal benefits are equalized. The reason is that at this point the total benefits minus the total costs (i.e. the net benefits) are maximised. Such an analysis was carried as part of this impact assessmentThis happens (see figure) beyond Scenario B. It should be noted, though, that with different assumptions of the value of statistical life, a higher ambition level could be justified.

For environmental benefits, a comparative analysis was made of the impacts of reduced air pollution on ecosystems, using a precise ecosystem-specific deposition methodology. For acidification, although improvements are expected following the present environment policies, but major problems would remain in areas with sensitive ecosystems and high emissions. Regarding eutrophication, the scenarios would reduce the area with excess deposition of nitrogen above the critical load, but substantial and severe eutrophication problems would remain in many Member States. As there is still no sound basis at present for further quantification impacts and valuation of impacts on different types of ecosystems, omission of monetised ecosystem benefits outside of agriculture[6] may trigger a significant bias towards underestimation of total benefits and further research will be undertaken. There will also be benefits in other environmental areas. There are linkages and overlaps with climate change policy, and air pollution directly affects soil and water quality.

Economic and social impacts

The macro-economic effects of the options, as estimated using the GEM-E3 general equilibrium model,[7] do not appear to be significant: The costs of meeting Scenarios A, B and C were estimated at 0.04%, 0.08% and 0.12% of EU-25 GDP in 2020 respectively The Strategy has very little impact on overall employment. There are some sectoral shifts and some differences between Member States. However, they cancel each other out. There would be a small positive impact to exports. However, imports are estimated to grow more, mainly due to the terms of trade effect.

6 Damage to crops (mainly wheat yield loss) from ozone would be reduced by 0.3-0.5 billion euros in 2020.

7 The model was developed with the support of the 5th Research Framework Programme and is currently being used to develop the modelling capability of the Commission in the IQ-TOOLS project under the 6th Framework Programme.

Macroeconomic impacts of three scenarios compared to baseline in 2020

	Scenario A	Scenario B	Scenario C
Gross Domestic Product	-0.04%	-0.08%	-0.12%
Employment	0.00%	0.00%	0.00%
Private consumption	-0.06%	-0.13%	-0.20%
Investment	-0.01%	-0.02%	-0.03%
Final energy consumption	-0.12%	-0.24%	-0.34%
Exports to rest of the world	0.00%	0.01%	0.02%
Imports from rest of the world	0.04%	0.10%	0.15%
Real wage rate	-0.04%	-0.09%	-0.14%
Relative consumer price	0.00%	0.00%	0.00%
Real interest rate	0.01%	0.02%	0.03%
Terms of trade	0.04%	0.08%	0.12%

These calculations do not take into account efforts to improve the environment in non-EU industrialised and developing countries and the increased compliance costs and the demand for technologies to reduce air pollution. These factors would contribute to enhancing the competitiveness aspects for European industry.

Indeed, other developed countries, such as the USA[8] and Japan, have similar or more stringent air pollution policies in place. Moreover, awareness of air pollution issues is increasing in developing countries, such as China[9] and India, and measures to improve environmental performance are being implemented.

By focusing research and development on the resource-efficient and less polluting technologies that other countries will eventually need to adopt, the EU can gain advantages in terms of innovation, business opportunities and export potential. Reducing damage to human health and the environment could help improve the EU's competitiveness.

Conclusion: Proposed interim objective up to 2020

All scenarios deliver benefits far in excess of costs. However, the additional costs relative to benefits start to increase steeply at around the mid range (Scenario A/B). Furthermore, the changes in ecosystem improvements between the lower (Scenario A) and mid range scenario (Scenario B), balanced against costs, argue in favour of choosing a level between the low and mid range that delivers the lowest levels of air pollution that can be justified in terms of benefits and costs while preventing undue health risks for the population. It should also be noted that the largest improvements are estimated to materialise from moving from the baseline to Scenario A. The costs of moving from Scenario A to B are estimated almost to double and increase further

8 The recent air pollution laws, such as the "Clean Air Interstate Rule", which are comparable to the interim objectives in the Strategy, are estimated to cost for transport and power generation sectors alone in the US between $12 and $14 billion per annum.

9 For instance, practically all newly built and expanded coal-fired units must install flue gas desulphurization units to meet new Chinese emission limit values. From 2007 all new cars sold in China must meet "Euro 3" emission limit values and the feasibility of raising this requirement to "Euro 4" from 2010 is being evaluated. In sum, the Chinese policies to reduce SO2 and NOx emissions are similar to those of the EU and trailing by about 5 to 10 years.

by about €4 billion in Scenario C for relatively small additional benefits. This is why the Commission is proposing an ambitious, yet prudent, approach to setting environment and health objectives for 2020 coupled with a review in about five years from the adoption of the Strategy. The alternative environmental interim objectives up to 2020 and the proposed Strategy are given in the table below.

Alternative environmental interim objectives up to 2020

		Human health		**Natural environment**					
Ambition level	Cost of reduction (€bn)	Life Years Lost due to $PM_{2.5}$ (million)	Premature deaths due to $PM_{2.5}$ and ozone (thousands)	Range in monetised health benefits[10] (€bn)	Ecosystem area exceeded acidification (000 km^2)			Ecosystem area exceeded eutrophication (000 km^2)	Forest area exceeded ozone (000 km^2)
					Forests	Semi-natural	Fresh-water		
2000		3.62	370	-	243	24	31	733	827
Baseline 2020		2.47	293	-	119	8	22	590	764
Scenario A	5.9	1.97	237	37 – 120	67	4	19	426	699
Scenario B	10.7	1.87	225	45 – 146	59	3	18	375	671
Scenario C	14.9	1.81	219	49 – 160	55	3	17	347	652
MTFR	39.7	1.72	208	56 – 181	36	1	11	193	381
Strategy	**7.1**	**1.91**	**230**	**42 – 135**	**63**	**3**	**19**	**416**	**699**

Note: Ecosystem benefits and the damage to materials and buildings have not been monetised but still need to be considered. MTFR is the Maximum Feasible Technical Reduction and includes the application of all possible technical abatement measures irrespective of cost. Only costs and benefits of moving beyond the baseline are presented. Lower value is based on the median of the value of a life year lost (VOLY) & higher value is based on mean value of a statistical life (VSL). Costs and benefits are annual amounts. In addition to the benefits the damage to agricultural crops is around €0.3-0.5 billion lower in 2020 under scenarios A-C.

This level of ambition will entail improvements by 2020 relative to 2000 of:

– 47% in life expectancy lost from exposure to particulate matter

– 10% fewer cases of acute mortality from exposure to ozone

– 74% less forest area and 39% less freshwater area where acidification critical loads are exceeded

– 43% less area where critical loads for eutrophication are exceeded

– 15% less forest area where critical levels are exceeded due to ozone

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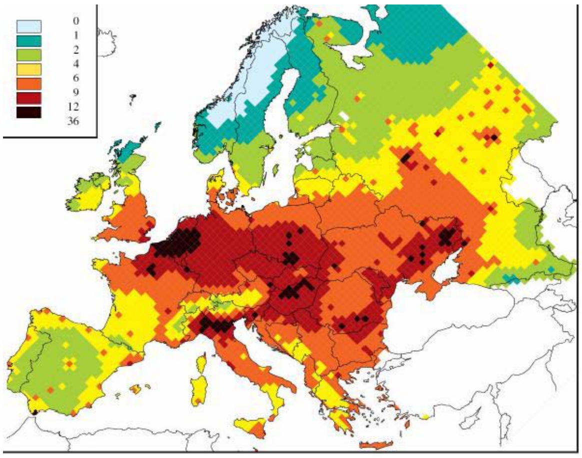
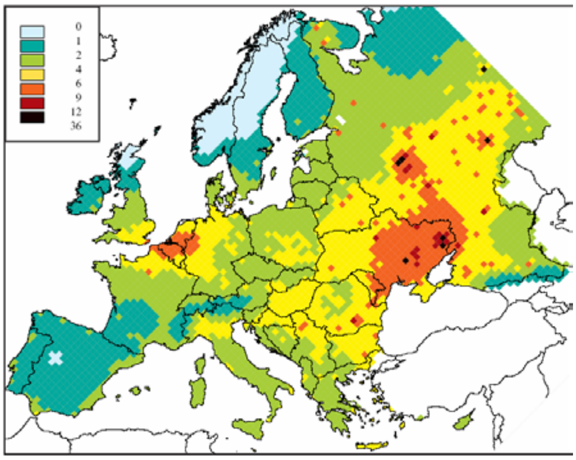
[10] Lower value is based on the median of the value of a life year lost (VOLY) and higher value is based on mean value of a statistical life (VSL).

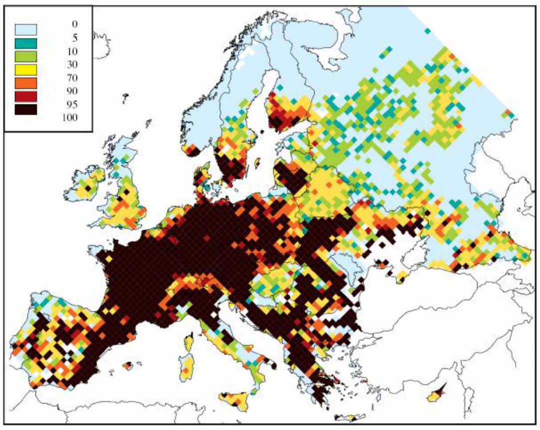
Changes in loss of life expectancy in the EU in 2000 and in the interim objective in 2020 (Strategy)

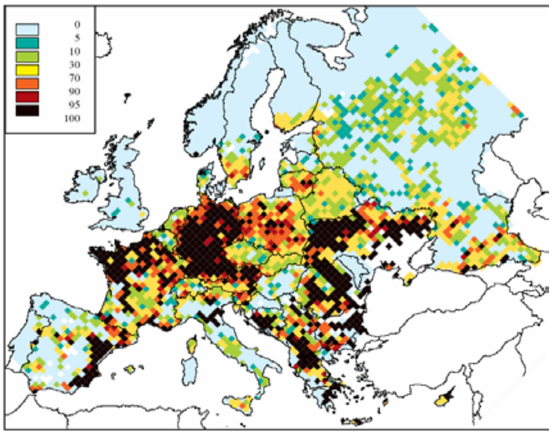




2000 **Strategy in 2020**

Percentage of total ecosystems area receiving nitrogen deposition above the critical loads in 2000 and in the proposed interim objective for eutrophication in 2020

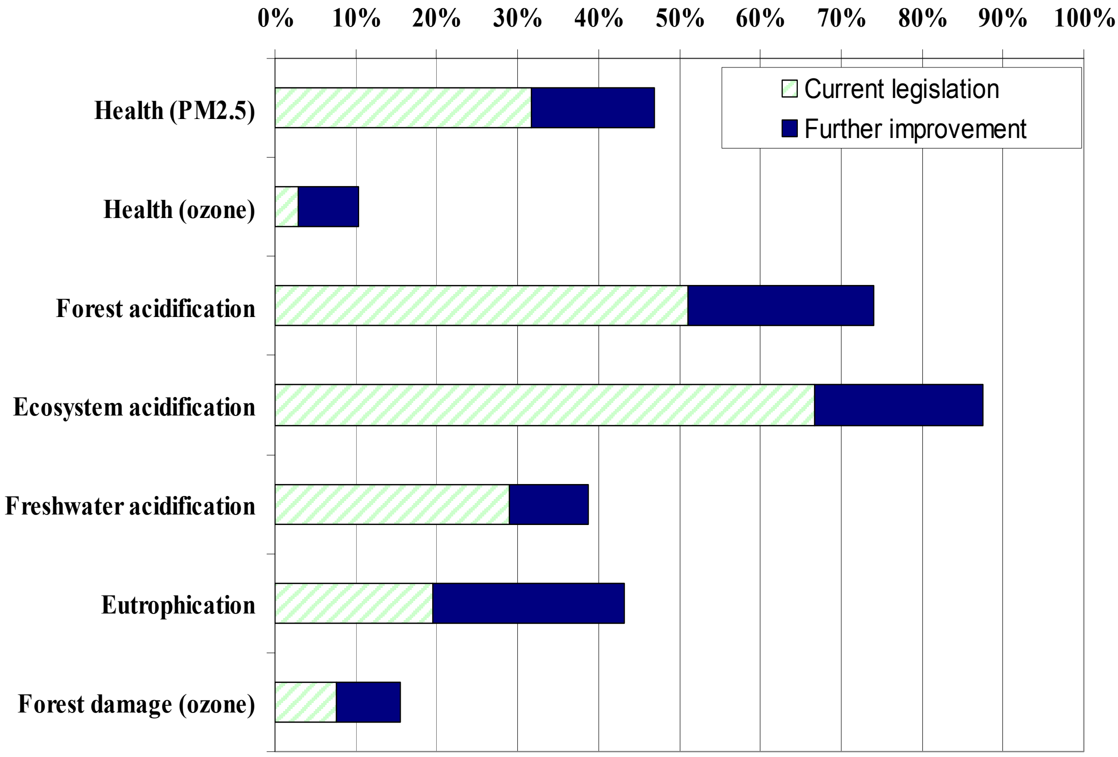




2000 **Strategy in 2020**

These improvements will require by 2020 emission reductions in the EU-25 of 82% for SO_2, 60% for NOx, 51% for VOCs, 27% for NH_3 and 59% for primary $PM_{2.5}$ relative to emissions in 2000. The following graph illustrates the reduction requirements and shows to what extent the reductions are due to current legislation being implemented up to 2020.

Improvement of health & environment indicators following the Strategy



The level of ambition chosen for this Strategy has been estimated to deliver at least €42 billion per annum of benefits in monetary terms representing between 0.35-1.0% of the EU-25 GDP in 2020. These benefits include fewer premature deaths, less sickness, fewer hospital admissions, improved labour productivity etc. Although there is no agreed way to monetize ecosystem benefits, the environmental benefits of reduced air pollution will be significant. In addition, damage to buildings and materials will also be reduced. Similarly, for agricultural crops the damage would be reduced by around €0.3 billion per annum.

Attainment of these targets is estimated to cost approximately €7.1 billion per annum representing about 0.05% of the EU-25 GDP in 2020, though no net change in employment is expected. Production lost through ill health would be reduced. Low income groups generally exposed to the highest levels of air pollution may benefit most.

The chosen level of ambition represents an optimal balance between economic and environmental goals, contributing to Lisbon and the Community's Sustainable Development Strategy objectives.

Measures and instruments

The impact assessment of the different options is based on the analysis of a set of technological measures with the RAINS model. The level of ambition of the Strategy, is based on a set of specific measures which would need to be undertaken at Community and Member State level. These possible measures – in addition to current legislation – relative to the main pollutants are outlined below:

– to reduce SO_2 emissions: the use of low–sulphur heavy fuel oils; flue gas desulphurisation; reducing the sulphur content of fuels;

– to reduce NO_x emissions: modifications to domestic and industrial combustion plant including selective catalytic reduction; bans on open burning of waste;

– to reduce $PM_{2.5}$ emissions: using cyclones and fabric filter dedusters for boilers in the commercial sector and new residential boilers;improvements to diesel vehicles;

– to reduce NH_3 emissions: reducing nitrogen content in animal feed; fertilizer substitution; low-emission housing for poultry; more use of low-ammonia application measures for pig and cattle manures;.

– to reduce VOC emissions: control of fugitive losses in the chemicals industry and in refineries; control of the use of paints and solvents.

In order to attain the strategic objectives defined above, current air quality legislation will be simplified and other legislation revised where appropriate. Further initiatives will be taken on new vehicles and, subject to careful impact assessment, new measures may be envisaged for small combustion plants, ships and aircraft emissions. Community structural funds, international cooperation and improved implementation will all form part of the suggested policy mix. Finally, it is clear that other sectors – like agriculture, energy and transport – will have to be involved with some of these measures. Recent reform of the Common Agricultural Policy should bring about a reduction in emissions from agricultural sources. In keeping with the commitments made in the White Paper on a common transport policy, the Commission will further encourage shifts towards less polluting modes of transport, alternative fuels, reduced congestion and the internalisation of externalities into transport costs.

PART TWO - IMPACT ASSESSMENT OF THE PROPOSED DIRECTIVE ON "AMBIENT AIR QUALITY AND CLEANER AIR FOR EUROPE"

In order to improve the regulatory framework on air quality in line with the Commission's Strategic Objectives 2005-2009 calling for Better Regulation, it is indispensable to modernise and simplify current air quality legislation – and to reduce its volume – in order to improve the competitiveness of the European economy.

Better regulation – cutting red tape and streamlining legislation

Therefore, the Commission proposes to combine the Framework Directive,[11] the First,[12] Second[13] and Third[14] Daughter Directives, and the Exchange of Information Decision[15] into one Directive on "Ambient Air Quality and Cleaner Air for Europe". This will cut red tape, clarify and simplify ambiguous provisions, repeal obsolete provisions, modernise and reduce reporting requirements, and introduce new provisions on fine particulates. The Fourth Daughter Directive[16] will be merged later through a simplified "codification" process. While the impacts of this modernisation and simplification exercise cannot be quantified in monetary terms, it is certain to have positive effects on competitiveness by reducing bureaucracy and increasing transparency.

Addressing specific implementation problems

It is necessary to address some implementation problems that have occurred with current air quality legislation. The Commission proposes to allow Member States to request an extension to extend the deadline for compliance in affected zones if objectively verifiable conditions are met, including information on the compliance with certain Community legislation contributing to improvement of air quality. As a quid pro quo the Member State would have to develop and implement an air pollution abatement programme to ensure that the limit values are attained upon expiry of the extension. It has not been possible to quantify the impact of this proposal, which is a "safety valve" against unduly high abatement costs in exceptional situations.

Modernising reporting requirements

It is also necessary to bring the reporting requirements for air quality into the 21st century by using the internet as the main means of delivery and making this compatible with INSPIRE.[17]

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11 Council Directive 96/62/EC OJ L 296, 21.11.1996, p. 55
12 Council Directive 1999/30/EC OJ L 163, 29.6.1999, p.41
13 Directive 200/69/EC OJ L 313, 13.12.2000, p. 12
14 Directive 2002/3/EC OJ L 67, 9.3.2002, p.14
15 Council Decision 97/101/EC O.J. L 35, 5.2.1997, p. 14
16 Directive 2004/107/EC OJ L 23, 26.1.2005, p. 3
17 Proposal for a Directive of the European Parliament and of the Council establishing an infrastructure for spatial information in the Community (INSPIRE) COM(2004) 516 final, SEC (2004) 980.

In the light of recent health evidence, the Commission is proposing the following approach.

No change in current limit values

Based on the advice received from the scientific community – WHO *'Systematic review on air pollution health aspects in Europe'* and the Commissions' Scientific Committee on Health and Environmental Risks – the Commission is not proposing to revise the current limit and target values for air pollutants set by European air quality legislation. However, the Commission proposes to repeal the indicative limit value of PM_{10} for 2010 and – on the basis of scientific advice and health evidence – to start regulating fine particulate matter below 2.5 microns (called $PM_{2.5}$) differently.

Reducing annual average urban background concentrations of $PM_{2.5}$ between 2010 and 2020

The latest scientific evidence confirms that $PM_{2.5}$ is responsible for significant negative effects on human health, and thus leads to substantial loss of life by European citizens. Further, there is no identifiable threshold below which particulate matter would not pose a risk to human health. Because of this evidence, it is vital to regulate fine particulate matter differently from some other air pollutants. The Commission considers that the proposed effective and proportional approach – namely reduction of the average annual urban background concentration of $PM_{2.5}$ – is justified

The Commission proposes a two-stage approach by first setting a concentration reduction target of 20% between 2010 and 2020 for $PM_{2.5}$. Based on actually monitoring data of 2008-2010 the Commission would secondly propose a legal requirement each Member State to reduce average annual urban background concentrations of $PM_{2.5}$ by a definited minimum percentage between 2010 and 2020 possibly calculated for each microgram per cubic metre of $PM_{2.5}$ measured in the baseline concentration. It also proposes that average annual urban background concentrations be calculated as a three-year running average – starting from the period between 2008 and 2010, thus moderating the impact of meteorological variability. The reduction would be based upon the arithmetic (or population weighted, if data allows) mean of all measurements of $PM_{2.5}$ concentrations made in urban background locations in the territory of the individual Member State. The reduction requirement is described in detail in Section 7.4 of the Impact Assessment.

Benefits and costs of regulating $PM_{2.5}$ at EU level

The benefits of the Commission's proposal to require a reduction of the average urban background concentration, between 2010 and 2020, between €37 billion and €119 billion per annum in 2020. These are between seven and 24 times higher than the estimated costs of between €5 and €8 billion per annum.

Capping unduly high risk

The Commission also proposes a "cap" of 25 micrograms per cubic metre expressed as an annual average to be attained by 2010. The level of the cap is such as to be entirely consistent with the existing limit value for PM_{10}, so Member States are not expected to incur any additional burden. The cap will apply throughout the territory of the Member States.

The main justification for proposing the “cap” is to ensure that there are no unintended consequences of reducing $PM_{2.5}$ average concentrations. No European should be exposed to unduly high levels of $PM_{2.5}$ concentrations.

Follow-up: New proposals to reduce emissions

Since a large fraction of air pollution – including the precursors to $PM_{2.5}$ concentrations – travels very long distances, the Commission intends to make legislative proposals in the near future to reduce the transboundary component of urban background concentration of $PM_{2.5}$. These measures include reviewing emissions limits for light- and heavy-duty vehicles (e.g. to go beyond current Euro standards) and revision of the National Emission Ceilings for 2015 or 2020 in order to reduce urban background concentrations of $PM_{2.5}$ consistent with the proposed new way of regulating $PM_{2.5}$.

MONITORING, EVALUATION AND CONSULTATION

The EEA and Eurostat have developed indicators to monitor the impacts of air emissions on human health and the environment, and there will be long-term monitoring under the UNECE Convention on Long-range Transboundary Air Pollution. Monitoring, modelling, assessment and mapping will follow agreed methodologies. Since Community air pollution policy is built on robust scientific and technical knowledge, continual further research will be needed to refine current and future policies and measures. Our understanding of adverse health and environmental impacts is improving all the time, so it is important to keep targets and policies under review, and to take account of changes in the costs and effectiveness of measures. The Commission plans to carry out a first review in about five years from the adoption of the Strategy.

Public consultation has shown that more than half of Europeans are worried about air pollution, particularly its impacts on the environment and health. They attach a high priority to improving air quality and call for a level of environmental ambition resembling Scenario C. The international and European levels were seen as the most appropriate for taking action. Respondents identified industrial production and traffic most often as the targets for measures. They were also prepared to take individual action themselves and to pay to improve air quality.

These results were taken into account in the Strategy, particularly when defining the environmental ambition level, when developing the health and environment objectives, and when identifying measures to simplify legislation and improve information to the public.

In addition to consultation of stakeholders and the public, internal consultation between the various Commission services has been a regular feature of the preparation of the Strategy.

1. INTRODUCTION

This Impact Assessment (IA) describes the options considered in developing the Thematic Strategy on Air Pollution ("the Strategy") and justifies the choices presented in the Strategy and in the Commission's proposal to revise the air quality framework directive,[18], the first three daughter directives[19] and the Council decision on the exchange of air quality information[20] ("the Air Quality Proposal"). The Strategy is part of the Sixth Community Environment Action Programme[21] (6th EAP), which sets objectives for action and several thematic strategies to address important aspects of the environment. The EAP lays down the objective for the Strategy as "achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment".

This assessment follows closely the Impact Assessment Guidelines of the Commission[22] and considers the economic, social and environmental dimensions in an integrated and balanced manner. The guidelines emphasise the need to concentrate on those impacts that are likely to be the most significant and/or will lead to important distributive effects. The analysis presented here is consistent with these principles and is proportionate to the nature of the proposal

The problem of air pollution and the trends in emissions and impacts foreseen up to 2020 are described in Chapter 2. Chapter 3 examines the long-term objectives defined by the 6th EAP, and Chapter 4 describes the process used for the definition of a set of policy options corresponding to interim levels of ambition for air quality by 2020. Chapter 5 provides a detailed assessment of the environmental, economic and social implications of each level of ambition. Chapter 6 describes the measures that would have to be implemented for each level of ambition. The impact assessment for the legislative proposal accompanying the Thematic Strategy (revised directives on ambient air quality) is presented in Chapter 7. Chapter 8 details the monitoring and evaluation implications of the Thematic Strategy, and Chapter 9 reports on the stakeholder and public consultation undertaken for the definition and evaluation of the Thematic Strategy.

The assessment is underpinned by a substantial body of knowledge generated by Commission service contracts, studies, health advice from the World Health Organisation (WHO), advice from Commission working groups, and by workshops and conferences under the Clean Air for Europe (CAFE) Programme. It also builds on information provided by Commission RTD projects and assessment programmes under the UN ECE Convention on Long Range Transboundary Air Pollution (CLRTAP). A comprehensive list and references to these reports and activities is given in Annex 1.

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18 Directive 96/62/EC, OJ L 296, 21.11.1996, p. 55.

19 Directive 99/30/EC, OJ L163, 29.6.1999, p. 41; Directive 2000/69/EC, OJ L 313, 13.12.2000, p. 12; Directive 2002/3/EC, OJ L 67, 9.3.2002, p. 14.

20 Decision 97/101/EC, OJ L 35, 5.2.1997, p. 14.

21 Decision 1600/2002/EC OJ L242, 10.9.2002, p 1.

22 See http://europa.eu.int/comm/secretariat_general/impact/key.htm

The methodology and the modelling framework used in the integrated assessment of options presented in the Strategy are described in Annex 2. The main elements were: (1) establishment of baseline scenario for air pollution up to 2020; (2) analysis of the "policy gap" between the baseline and Community long-term objectives; (3) assessment of policy options; and (4) definition of interim objectives for the Strategy.

The assessment uses our best scientific understanding of the emissions, atmospheric transport, and human health and environmental impacts of air pollution. Where there is sufficient consensus and robust information a quantitative assessment has been provided i.e. for human health impacts. Many health impacts have also been estimated in monetary terms, but this has not been possible for the assessment of impacts on the natural environment. Because of this, an "Extended Cost-Benefit Analysis" has been set up, in order to include effects that are not quantified or assessed in monetary terms but are likely to be important and potentially capable of changing the balance of costs and benefits.

The methodology used has also been subject to independent scientific peer reviews.[23] These reviews give details of possible uncertainties caused by model simplifications, assumptions, boundary conditions and inherent technical uncertainties. Extensive sensitivity analyses[24] have also been performed to assess uncertainties and the robustness of the model results, particularly uncertainties in energy demand and agricultural production, emissions data and emissions abatement factors, the various ambition levels, or target-setting methods. These aspects are described in Annex 2, and were thoroughly discussed with contractors and stakeholders during work on the Strategy.[25] This process will lead to improvements in the impact assessment modelling used for revision of the National Emission Ceilings Directive[26] in 2006.

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[23] See http://europa.eu.int/comm/environment/air/cafe/activities/rain_model.htm and http://europa.eu.int/comm/environment/air/cafe/activities/krupnick.pdf

[24] i.e. numerous models with different key assumptions in order to estimate to what extent optimised strategies are dependent on various input parameters

[25] In particular the Working Group of Target Setting and Policy Assessment as well as the CAFE Steering Group.

[26] Directive 2001/81/EC, OJ L 309, 27.11.2001, p. 22.

2. WHAT PROBLEM DOES THE THEMATIC STRATEGY ON AIR POLLUTION SET OUT TO TACKLE?

2.1. The problem of air pollution

Air pollution is a significant public health concern. It is responsible for a significant reduction in average life expectancy, several hundred thousand premature deaths, thousands of additional hospital admissions, increased use of medication and millions of days every year where activities are restricted. The pollutants of most concern for human health are ozone and airborne particulate matter.

There are many sources of air pollution; the main contributing sectors are transport, power generation, industry, agriculture, domestic use of products, and heating. All these sectors emit a variety of air pollutants, such as sulphur dioxide, nitrogen oxides, ammonia, volatile organic substances and particulate matter. Other important air pollutants include persistent organic pollutants, heavy metals and polyaromatic hydrocarbons. The relationship between the economic sectors, emissions, air pollution and the negative effects is schematically outlined in Figure 1. The pollutants of most concern for human health are ozone and airborne particulate matter.

Two environmental problems are worth setting out in more detail.

Particulate matter (particles in the range PM_{10} – $PM_{2.5}$) consists both of (i) "primary particles", which are emitted directly into the atmosphere from combustion processes, industrial processes and mechanical, like grinding, and (ii) emissions of gaseous pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3), which are altered through chemical reactions in the atmosphere, adding to the particulate mass, and are referred to as "secondary particles" or "secondary aerosol".[27] Varying amounts of water also contribute to the aerosol particulate mass. The total atmospheric burden of aerosol particulate matter depends on the total emissions of primary particles and the contribution of secondary particulate matter. The contribution of gaseous pollutants to the fraction of secondary inorganic aerosol particulate matter is well described and validated through comparison with monitoring data, whereas there is a lack of understanding about the formation of secondary organic aerosols particulate matter and also very limited monitoring data for model validation. At present the assessment of aerosol particulate matter with models systematically underestimates the contribution of secondary aerosols, and the total particulate matter as the contribution to secondary organic aerosol is not included. The modelled values of aerosol particulate matter are some 20 to 30 percent lower than the observed values of particulate matter. Part of the reason for the difference is that secondary organic aerosol is not accounted for in the model.

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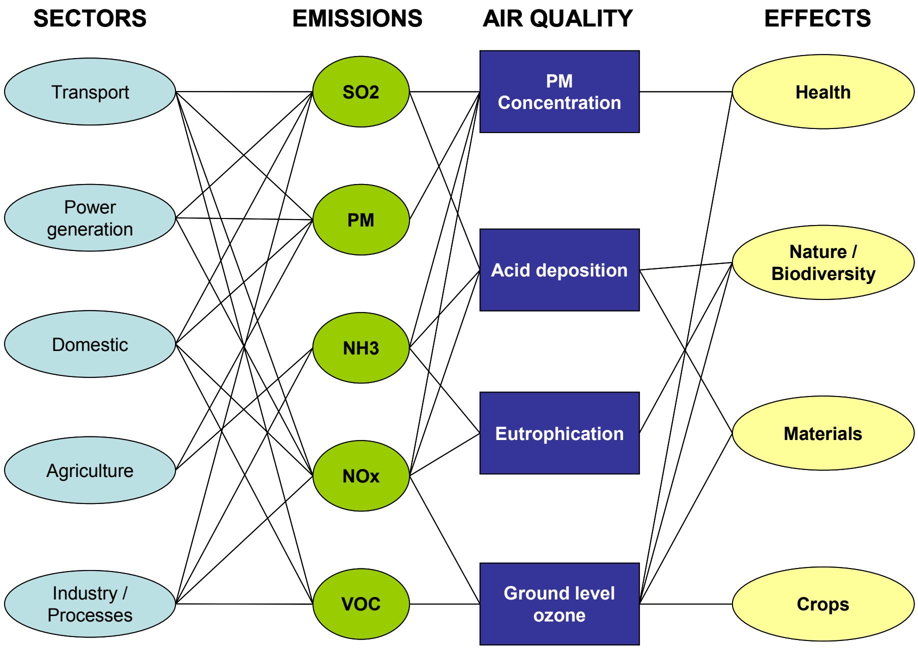
[27] Particulate matter in ambient air is classified according to its aerodynamic diameter, so PM_{10} and $PM_{2.5}$ refer to all particles with a diameter of less than 10 micrometer (µm) and 2.5 micrometer (µm) respectively. The "fine fraction" ($PM_{2.5}$) is more strongly associated with anthropogenic activities than the "coarse fraction" (particles in the range PM_{10} – $PM_{2.5}$), which may contain for example wind-blown dust and Saharan sand. Secondary aerosol falls into the fine fraction.

Ozone occurs naturally in the stratosphere and in the troposphere, but ozone concentrations close to ground-level are harmful to ecosystems and human health. Ground-level ozone is formed from the complex chemical reactions between volatile organic compounds (VOC) and NO_x in the presence of sunlight. VOC are emitted from many different sources, including petrol stations, tailpipe emissions from cars, and the use of solvents and solvent containing products such as paints and varnishes.

Figure 1: The problem of air pollution



Source : RAINS, CBA, based on EEA, Air pollution in Europe 1990-2000, Topic report 4/2003

2.1.1. Air pollution impacts

Air pollution can have a number of impacts: damage to human health, acidification, eutrophication, and damage to other ecosystems such as forests. Other impacts have been identified and assessed, such as damage to materials, buildings and cultural heritage, as well as wider economic and social effects. Chapter 5 of this report provides a more detailed review of these impacts and the methodology used for their assessment.

Ozone and airborne particulate matter can affect **human health**[28]. They are responsible for several hundred thousand premature deaths every year. They also cause thousands of additional hospital admissions and millions of days every year where individuals have to restrict their activities. These health impacts are caused by both long-term (chronic) and short-term (acute) exposure, resulting in both mortality (death) and morbidity (illness). The "Systematic Review of Health Aspects of Air

[28] Scientific evidence exists also concerning health effects caused by nitrates, sulphates and ammonia as aerosols. These effects however are significantly smaller (results of ExternE projects). In addition, for the purpose of CAFÉ, those effects are considered that are explicitly recognized by international bodies such as WHO.

Pollution in Europe" carried out by WHO[29] revealed significant impacts of exposure to particulate matter and ozone even at low concentrations. Indeed, no safe level for effects has currently been identified for either of these pollutants.[30]

Emissions of SO_2, NO_x and NH_3 contribute to the **acidification of lakes, rivers, forests and other ecosystems**, including Natura 2000 sites. [31] Acidification can result in the loss of fauna and flora, and ecosystems may take many decades to recover after acidifying inputs are reduced to sustainable levels.[32]

Eutrophication can occur when nutrient nitrogen is deposited. This can lead to changes in the composition of species in plant communities and loss of biodiversity. Emissions of NO_x and NH_3 contribute to nutrient nitrogen deposition.

Ground level ozone can also **damage forests, crops and vegetation** where a critical level of ambient concentration is exceeded.[33] Ozone damage is recognised as the most serious regional air pollution problem affecting the agricultural sector in Europe.

Air pollution also has an impact on **material and cultural heritage.** The main damage was earlier due to high levels of sulphur dioxide, but the increase in vehicle emissions created a new multi-pollutant situation. A recent EU research project MULTI-ASSESS[34] developed dose-response functions for corrosion and soiling of indicator materials for the multi-pollutant situation involving the effect of both climate and pollution. These have been used to propose new quality objectives to protect various materials, expressed as "acceptable" concentrations of air pollution. For SO_2, an "acceptable" level of 10µg/m^3 is proposed that protects 80% of European territory at present HNO_3 levels. Taking an "acceptable" soiling level and intervals between cleaning, an acceptable PM_{10} level of 15 µg/m^3 has been calculated. These objectives would be relevant in areas with cultural assets and other materials that require protection from corrosion and soiling.

The quantitative impact assessment of the Strategy concentrated on five major impacts of the five major pollutants, as illustrated in Table 1

29 http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20020530_1

30 Given that there is a finite background concentration of ozone, the analyses presented here are only based upon situations where 8-hour mean ozone concentrations exceed 35 parts per billion (ppb), which corresponds to an ozone equivalent concentration of 70 micrograms per cubic metre (µg/m^3).

31 For many of these impacts a "critical load" is defined. This represents a quantified amount of, for example, acid deposition below which the ecosystem is not expected to be at risk.

32 The compensating effects of pollutants should also be considered : in some cases, the acidification effects persist as compensating effects between PM and SOx do not take place anymore, given the reduction of PM but the still high level of SOx from Eastern Europe might balance this (results from the GARP II report - Chapter 11 "Forest and Ecosystem damage").

33 Such a critical level is expressed in terms of an accumulated concentration in hours above a threshold of 40 ppb (equivalent to 80 µg/m^3). For forest the critical level is 5,000 part per billion hours (ppb.hours).

34 http://www.corr-institute.se/MULTI-ASSESS/

Table 1: Multi-pollutant/multi-effect approach of the Strategy

	Primary PM	SO_2	NO_x	VOC	NH_3
Health effects:					
- Particulate matter	√ (22%)	√ (19%)	√ (13%)		√ (46%)
- Ground-level ozone			√	√	
Vegetation effects:					
- Ground-level ozone			√	√	
- Acidification		√ (27%)	√ (24%)		√ (49%)
- Eutrophication			√ (37%		√ (63%)

Source: RAINS. Percentages represent the relative contribution of each primary pollutant to the effect, as estimated by RAINS at EU-25 level, for a marginal change over 2020 baseline. This calculation is not available for ground-level ozone.

2.1.2. Current trends in air quality

Air pollution travels long distances and it has long been recognised as posing significant risks to human health and the environment. Therefore, air pollution has long been regulated at European level. For example, the first Community legislation to reduce air pollution from passenger cars was introduced as early as 1970,[35] followed by legislation on ambient air quality.[36] Subsequently, there have been Community measures to address emissions from large combustion plants, to prevent emissions from large industrial installations in an integrated way, to improve fuel quality, to reduce the VOC content of products, to improve the framework for the management of ambient air quality, and to set national emission limits for important atmospheric pollutants.

Reductions in air emissions should lead to better air quality. However, the relationship between primary pollutant emissions and air quality is not straightforward. Air quality is affected not only by local emissions but also by the interactions between these pollutants, their long-range transport in the atmosphere, natural emissions and meteorological conditions. There is increasing evidence that air pollution travels even longer distances than thought before. Such hemispheric transport of air pollution between the continents is a new emerging issue and will be discussed in section 8.3.

Ambient concentrations of PM_{10} before 2000 decreased due to measures tackling contributing sources such as large combustion plant and diesel vehicles. More recent measurement data over the period 1997 to 2001 show a decreasing trend in ambient PM_{10} concentrations up to 1999 and then a slight increase up to 2001. Over the entire period concentrations have been reduced by around 15-20%, though the picture varies across Europe as there is a mix of decreasing, static and increasing trends in

35 Directive 70/220/EEC, L 76, 6.4.1970, p.1.

36 Council Directive 85/203/EEC of 7 March 1985 on air quality standards for nitrogen dioxide, and Council Directive 80/779/EEC of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particulates.

concentrations. Whilst there has been some monitoring of $PM_{2.5}$ concentrations since legislative requirements were introduced in 1999, it is insufficient to determine long-term trends.

The situation for ozone pollution is partly dependent on emissions in the EU, but also on the background ozone concentrations of air coming to Europe (also known as hemispheric background). That ozone background concentration has been observed to increase in recent decades and is projected to increase further due to the increased emissions of ozone precursors over the Northern hemisphere. Hence, there are concerns that the reduction in emission of ozone precursors in Europe is being partly neutralised by the increased background ozone levels over the northern hemisphere.[37]

2.2. Trends in air pollution levels up to 2020: the CAFE Baseline

2.2.1. Trends in pollutant emissions

Community-wide and national policies have brought about and will continue to deliver substantial emissions reductions in Europe. The CAFE programme has brought together information on the likely levels of air pollution given present policies for the period 2000-2020. This CAFE baseline[38,39] (see Annex 2 for details) takes into account future economic development, as well as the effect of emissions control legislation. Some legislation has not been included because it leaves the Member States substantial discretion as to its implementation or attainment.[40]

Emissions of most air pollutants are projected to decline in the EU-25 even if economic growth takes place (Figure 2). The forecasts for emissions in the EU-25 of specific air pollutants under the baseline scenario are as follows.

– Large reductions for **sulphur dioxide (SO_2)** (68% by 2020 compared to 2000) are expected as a consequence of the decline in coal consumption and full implementation of the large combustion plant directive amongst others.

– Emissions of **nitrogen oxides (NO_x)** are projected to decrease by 49% over the period 2000-2020 because of a decline in traditional emissions (e.g. from road transport) so that in the future other sectors such as domestic heating, industrial and combustion processes, maritime shipping and non-road machinery will make more important contributions.

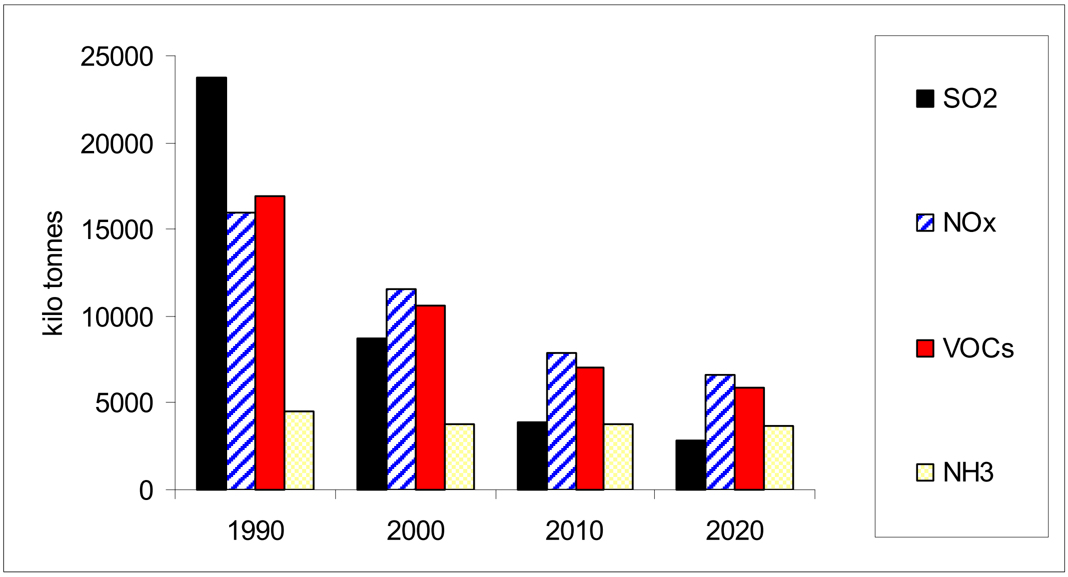
– The emissions of **volatile organic compounds (VOC)** are projected to decline by 45% over the period 2000-2020. The largest reduction should come from mobile sources and the use of solvents and paints.

37 See EMEP/CCC Report 1/2005, http://www.nilu.no/projects/ccc/reports/cccr1-2005.pdf
38 http://www.europa.eu.int/comm/environment/air/cafe/general/pdf/cafe_lot1.pdf
39 http://europa.eu.int/comm/environment/air/cafe/general/pdf/scenarios_cafe.pdf
40 For example, the current ambient air quality legislation has not been included directly in the baseline because it sets environmental quality standards but does not propose the measures that the Member States must take to meet those standards. A second example is attainment of the ceilings in the National Emissions Ceiling Directive, as this Directive does not prescribe the measures to be implemented but only imposes an obligation for the ceilings to be attained. However, in both cases where the national source-based measures are known (Community-wide or national) these have been included in the baseline.

– **Ammonia (NH_3)** emissions are not likely to change. As the vast majority of ammonia emissions come from agriculture it would have been important to include the impact of the recent Common Agriculture Policy (CAP) reform on ammonia emissions. However, as it was not yet known, at the moment of the assessment, how Member States will exactly implement the CAP reform, it has not been possible to revise the baseline emissions. The impact of CAP reform on ammonia emissions has to be carefully estimated, and this will be done in the context of the review of the NECD.

– Emissions of primary **particulate matter in the PM_{10} size fraction** are projected to decrease by 39% for the EU-25 over the period 2000-2020.[41] Reductions in the power generation and transport sectors are primarily responsible for these improvements. The fine fraction (i.e. **$PM_{2.5}$**) is predicted to decline by around 45%. This is partly due to the implementation of more stringent emission standards for road vehicles such as the Euro 5 emission limits for heavy duty engines.

Figure 2: EU-25 land-based emissions of pollutants from 1990 to 2020



Source: CAFE Baseline final report. Land-based emissions of pollutants covered by the NECD

With the effect of all these policy changes, the relative importance of different land based sources is also forecast to change. (Table 2) In contrast to the expected reductions in emissions from land-based sources, the **maritime sector** is becoming an even larger source of air pollution. It is projected that emissions of SO_2 from the maritime sector will increase by around 45% while emissions of NO_x will increase by approximately 67%. With these growth rates, emissions of SO_2 and NO_x from the maritime sector should surpass total emissions from land-based sources by 2020.

41 So far 14 out of 25 Member States have reported PM emission inventories, thus limiting the validation of the quality of the RAINS calculations.

Table 2: Emissions by sector for EU-25 (% total)

	% land based sources									
	SO_2		***NO_X***		***VOC***		***NH_3***		***$PM_{2.5}$***	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Power generation	57.4	21.6	17.8	13.6	0.9	1.3	0.4	0.6	8.5	5.7
Industry	18.7	29.8	9.6	14.5	0.5	0.7	0.1	0.1	1.9	1.9
Households	7.6	7.2	5.5	10.1	7.2	9.0	0.7	0.6	38.7	39.3
Transport	4.6	7.7	61.3	51.2	38.9	17.5	2.0	0.6	28.9	20.3
Agriculture	0.0	0.0	0.0	0.0	0.5	1.0	91.1	92.7	3.9	7.1
Processes	11.7	33.7	5.8	10.6	51.9	70.5	5.8	5.4	18.2	25.8
Total land (kt)	**8,735**	**2,805**	**11,581**	**5,888**	**10,661**	**5,916**	**3,824**	**3,686**	**1,749**	**964**
International sea transport (kt)	2,430	3,526	3,557	5,951	n/a	n/a	n/a	n/a	n/a	n/a
Share of land based sources %	*27.8*	*125.7*	*30.7*	*101.1*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*

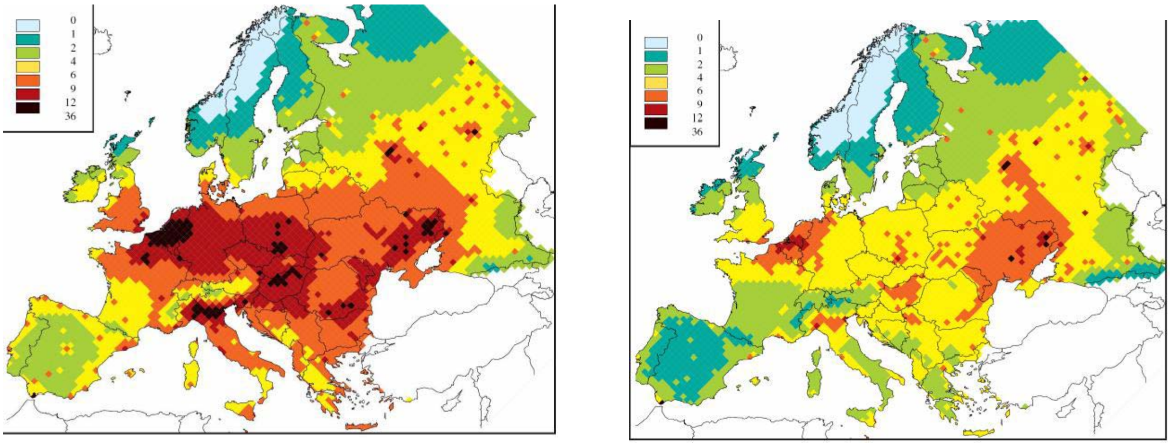
Source: RAINS

Most of the significant emission reduction was achieved for emitting sectors regulated at European level. In that sense European legislation has been successful and ensured a real decoupling between emissions of pollutants and economic growth. The important future emitting sectors are not regulated at European level and often consist of a large number of smaller emitters which are more complicated to regulate and control.

2.2.2. *Trends in particulate matter concentrations*

Ambient concentrations of $PM_{2.5}$ are projected to decrease from 2000 to 2020 (Figure 3) as a result of changes in primary emissions and also in the precursor emissions of secondary aerosol (SO_2, NO_x, and NH_3). As explained above (Section 2.1)) the secondary aerosol contribution is systematically underestimated in models. The changes in $PM_{2.5}$ levels over time shown in Figure 3 give an estimate of reductions in $PM_{2.5}$ levels than can be expected from the reductions in emissions in 2000 and 2020. It should also be kept in mind, however, that these changes may be masked year to year by changes in meteorological conditions.

Figure 3: Loss in life expectancy attributable to anthropogenic $PM_{2.5}$ in 2000 and 2020



2000 **Baseline 2020**

Source: RAINS. Note: Calculation based on meteorological conditions of 1997.

Rationale for using 1997 meteorological conditions in this Impact Assessment

Impacts of air pollution depend not only on the emissions but also on meteorology. For instance, in 2003 the concentrations of ozone and particulate matter were high in many EU Member States which experienced an exceptionally hot and sunny summer. In the CAFE baseline report an average meteorology was calculated for 1997, 1999, 2000 and 2003 and these results were used for the CAFE Baseline report.

However, the impact assessment was calculated using 1997 meteorology because it was not possible to calculate all combinations of meteorological conditions in time for this impact assessment[42]. Year 1997 was chosen as it was considered the most representative of all four available years. In order to compare *like-with-like* the environmental and health effects of different scenarios baseline calculations up to 2020 were calculated by using 1997 meteorological conditions and these were compared with the situation in 2000 using also the meteorological conditions of 1997[43]. Thus, unless otherwise stated, **all environmental and health effects of different scenarios in this Impact Assessment use the same meteorological conditions of 1997.**

2.2.3. Trends in ground-level ozone concentration

Following the WHO advice that "*the largest burden on public health may be expected from the many days with mildly elevated concentrations, and not with the few days with very high concentrations*",[44] control strategies now address general

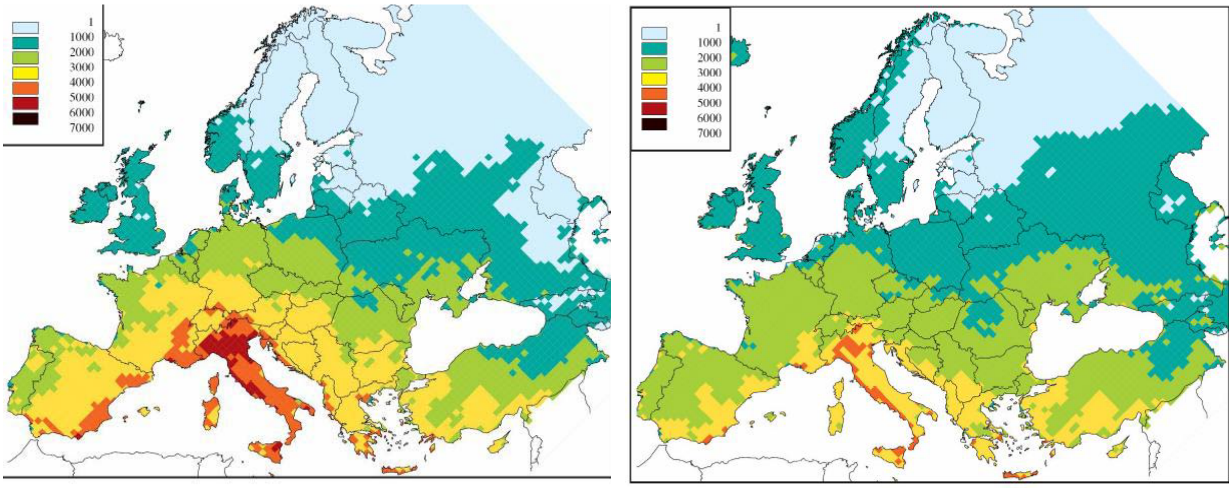
42 It takes about 3 months for a supercomputer to run all scenarios for one meteorological year. Thus, only one year could be counted for this impact assessment and 1997 was chosen as the most representative year. For the calculations of the revision emissions ceilings directive, five meteorological years will be calculated.

43 Had a different meteorogical conditions been selected, the results in the Impact Assessment would have been biased and reflected rather the impact of meteorology rather than the change of anthropogenic emissions of air pollution.

44 Modelling and assessment of the health impact of particulate matter and ozone*:* Summary report prepared by the joint Task Force on the Health Aspects of Air Pollution of the World Health Organization/European Centre for Environment and Health and the Executive Body http://www.unece.org/env/documents/2004/eb/wg1/eb.air.wg1.2004.11.e.pdf

background concentrations[45] and not just very high but short-term concentrations, because of the observed health effects of high ozone levels from relatively low atmospheric concentration. While the health problems related to $PM_{2.5}$ are most severe in North-West Europe, the issue of ozone is particularly important in the Mediterranean Member States. Despite appreciable improvements, many of the densely populated areas in the south could still be at risk by 2020 (Figure 4).

Figure 4: Health effects attributable to exposure ground-level ozone (ppb.days) in 2000 and 2020



2000 **Baseline 2020**

Source: RAINS. Note: Calculation based on meteorological conditions of 1997.

The ozone critical level[46] for forests was frequently passed in 2000 in large parts of the European Union. Baseline emission reductions will improve the situation, but will not be sufficient to eliminate the risk even by 2020 (Figure 5)).

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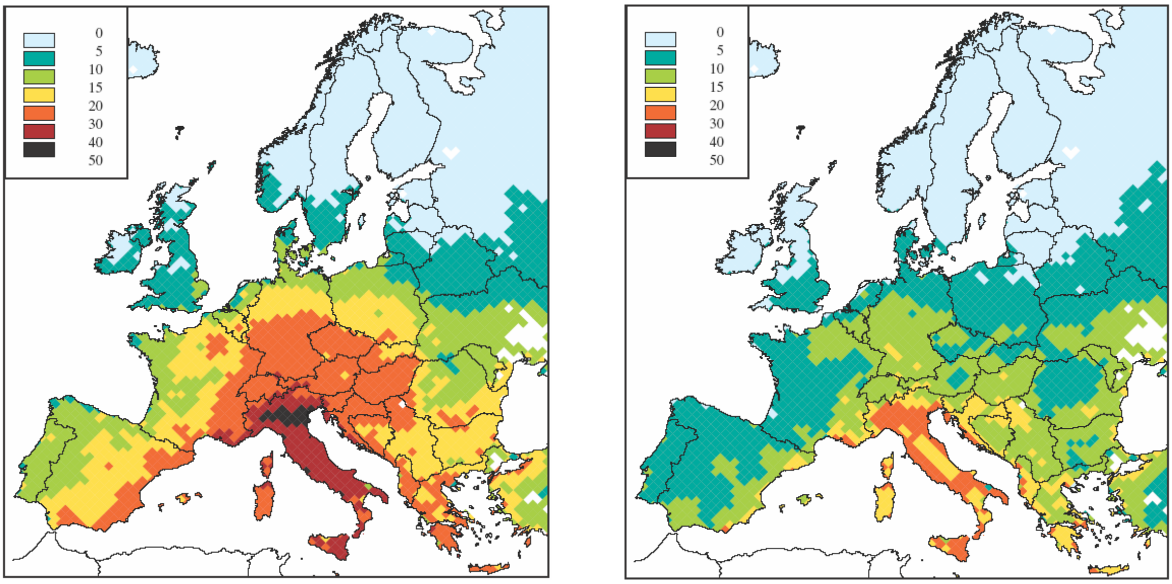
45 The indicator used for assessing ozone health impacts is called SOMO35, and corresponds to the sum of excess of daily maximum 8-h means over the cut-off of 35 ppb (which is equivalent to 70 µg/m3) calculated for all days in a year. Previous Community objectives for ozone focused on reducing human exposure to concentrations above a threshold of 60 parts per billion (120 µg/m3).

46 The Working Group on Effects of the LRTAP Convention recommended that the metric "accumulated ozone over a threshold of 40 ppb" (AOT40) be used as the indicator for ozone damage to vegetation. The revised ozone critical level for forests is 5,000 parts per billion hours (ppb.hours).

Figure 5: Evolution of ozone exposure for forests in 2000 and 2020



2000 **Baseline 2020**

Source: RAINS. Note: Calculation are based on the meteorological conditions of 1997, 1999, 2000 and 2003, using ecosystem-specific deposition to forest. The maps were not available for 1997 meterological data alone. However, the difference would be small. The critical level for forest trees is set at 5 ppm.hours.

2.2.4. Trends in acidification and eutrophication

Sulphur deposition has fallen significantly over the past 20 years and large areas are now expected to be protected from further acidification. In 2000, acidifying deposition was still above critical loads[47] in parts of central and north-west Europe. The percentage of EU-25 **forest** areas receiving acid deposition above their critical load is projected to decrease from 23% in 2000 to 13% in 2020 (Figure 6). For those areas still at risk, ammonia is projected to be the dominant source of acidification in the future.[48] The projected trend for so-called **"semi-natural" ecosystems**[49] is similar (decrease from 23% to 9%) (Figure 7).

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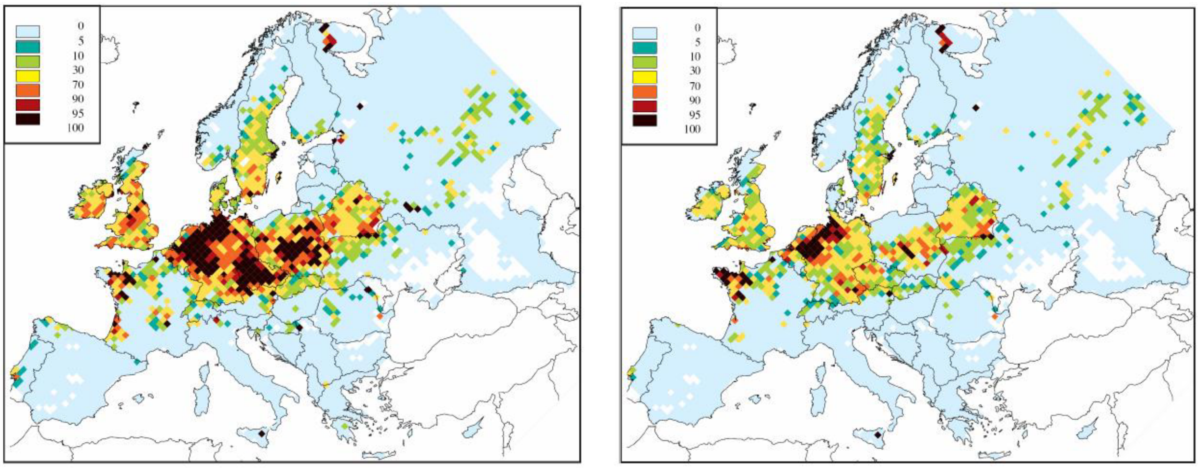
47 The concept of critical loads is used as the quantitative indicator for sustainable levels of sulphur and nitrogen deposition. Critical loads databases are compiled by the Coordination Centre for Effects (CCE) of the CLRTAP, which combines quality-controlled critical load estimates submitted by each of the national focal centres designated by each party to the CLRTAP. Currently more than 1.6 million monitoring sites are included in the database

48 The compensating effects of pollutants should also be considered. In some cases acidification effects persist because compensating effects between PM and SO_X do not take place anymore, given the reduction of PM but the still high level of SO_X from Eastern Europe (results from the GARP II report - Chapter 11 "Forest and Ecosystem damages").

49 Only six Member States have provided estimates of critical loads for "semi-natural" ecosystems, which are nature and landscape protection areas, many of them designated as "Natura 2000" areas under the EU Habitat directive : France, Germany, Ireland, Italy, the Netherlands and the UK

Figure 6: Evolution in forest area with acid deposition above critical loads in 2000 and 2020

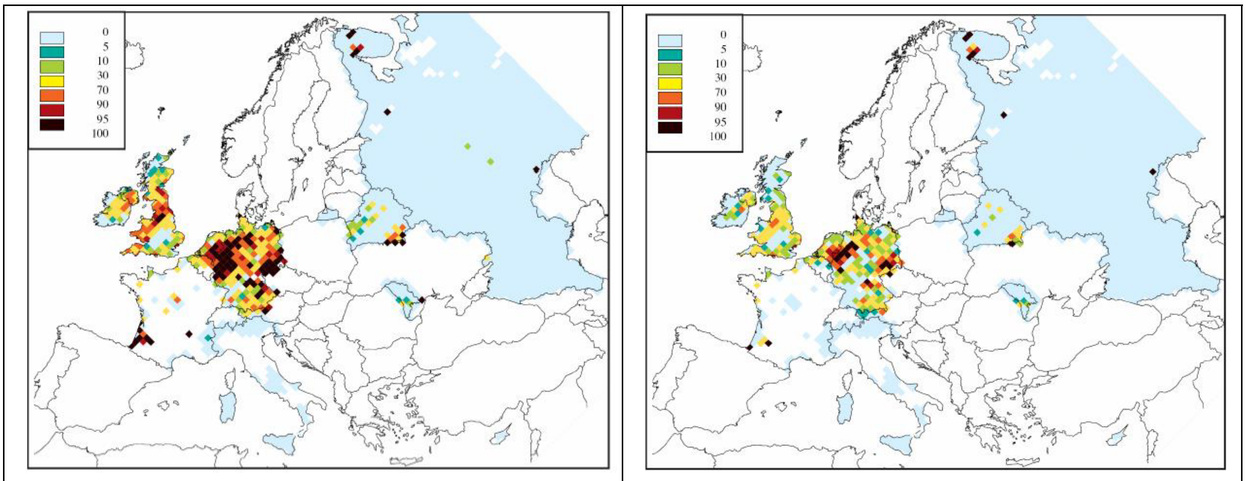


2000	Baseline 2020

Source: RAINS. Note: Calculation results are based on the meteorological conditions of 1997, using ecosystem-specific deposition to forests.

Critical loads for freshwater bodies (**lakes and streams**) have been estimated only for three EU Member States and Norway.[50] Figure 8 shows a significant decline in acid deposition between 2000 and 2020, but this may not allow recovery from acidification as deposition may remain above the critical loads. Even when acidic deposition can be reduced to levels below the critical load, there may be a time-lag of several decades before chemical and biological recovery

Figure 7: Percentage of the area of semi-natural ecosystems receiving acid deposition above the critical loads in 2020 and 2020

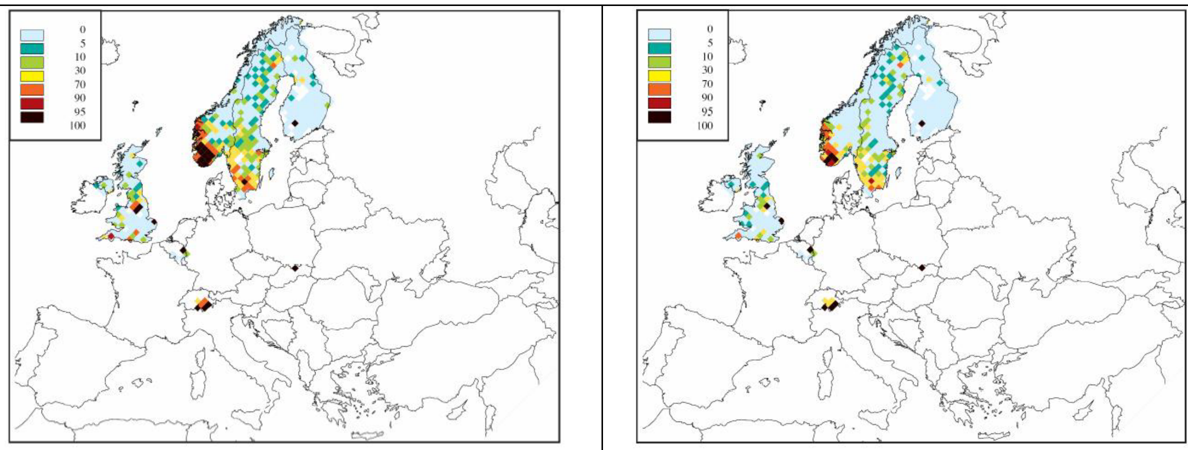


2000	Baseline 2020

Source: RAINS. Note: Calculation results are based on the meteorological conditions of 1997, using ecosystem-specific deposition.

[50] Finland, Sweden and the UK.

Figure 8: Percentage of freshwater ecosystems area receiving acid deposition above the critical loads in 2020 and 2020

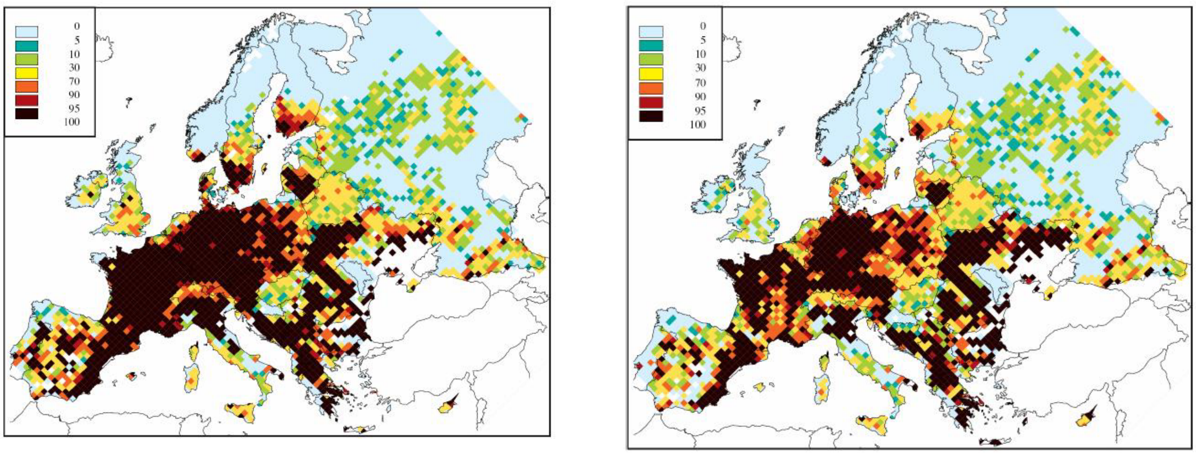


2000	Baseline 2020

Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997, using ecosystem-specific deposition.

Excess nitrogen deposition poses a threat to a wide range of ecosystems endangering bio-diversity through changes in plant communities. Excess nitrogen deposition above critical loads is currently widespread, due to the limited reductions in nitrogen deposition over the past 10 years. For the period 2000-2020, the protection of ecosystems from eutrophication is expected to improve only slightly (Figure 9) mainly because of the relatively small decline in ammonia emissions.

Figure 9: Evolution of the percentage of the total ecosystem area receiving nitrogen deposition above the critical loads for nutrient nitrogen in 2000 and 2020



2000 **Baseline 2020**

Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997, using grid-average deposition. Critical loads data base of 2003.

2.3. Quantification and valuation of health impacts of air pollution

As explained above, in principle the impacts of air pollution fall into two categories, those on health and those on the environment. Health impacts can be quantified and monetised, while for environmental impacts this is only possible for the impacts of ozone on crop yield and of acidic deposition on buildings.

2.3.1. Quantification of health impacts

The methodology followed by the impact assessment (See Annex 2) aimed to neither systematically over-estimate nor under-estimate the health effects. The impact assessment is consistent with the WHO's *"Systematic Review of Health Aspects of Air Quality in Europe"* [51] and the advice of UNECE WHO Joint Task Force on Health. Health impacts have been estimated for both particulate matter and ozone for short-term (acute) and long-term (chronic) exposure.

Despite the improvement in pollutant emissions, health impacts from air pollution across the EU are still projected to be very large in 2020. Mortality and morbidity effects from exposure to particulate matter are expected to be significantly larger than those associated with ozone.

For particulate matter, the average loss in statistical life expectancy should decrease from around 8.1 months in 2000 to 5.5 months in 2020 (Figure 3). Correspondingly, in 2020 it is estimated that some 2.5 million life years will be lost in the EU-25. This is equivalent to about 271,000 premature deaths. The morbidity effects associated with particulate matter include around 66,000 serious/cardiac hospital admissions in 2020 and larger numbers of less serious effects such as 23 million respiratory medication-use days and two hundred million restricted activity days.

For ozone, the annual impacts are projected to include some 20,000 acute mortalities (cases of deaths brought forward) in 2020 without any notable decrease from the situation in 2000.[52] Ozone exposure is also projected to lead to less serious health impacts, including more than 20 million respiratory medication-use days.

Table 3 summarises the total annual health impacts across the EU-25 for the baseline situation from 2000 to 2020. The impacts are split into acute and chronic mortality (i.e. premature deaths) and morbidity (i.e. illness) for particulate matter and ozone. Note two alternative metrics are used for the presentation of chronic mortality for particulate matter. The first is in terms of years of life lost and the second in terms of numbers of deaths.

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51 See http://www.euro.who.int/document/e79097.pdf and answers to follow-up questions http://www.euro.who.int/document/e82790.pdf

52 The relative stability in health impacts from ozone is due to the nature of ozone concentrations changes, but also the population at risk (i.e. the aging population in Europe) which increases.

Table 3: Estimated health effects of air pollution in from 2000 to 2020

Effect	Unit	2000	Baseline 2020
Chronic and acute mortality			
PM Chronic mortality*)	Thousands life years lost	3,619	2,467
*PM Chronic mortality**)	*Premature deaths*	*347,900*	*271,600*
PM Infant mortality	Premature deaths	680	350
Ozone acute mortality	Premature deaths	21400	20800
PM morbidity effects			
Chronic bronchitis	Cases	163,800	128,100
Respiratory hospital admissions	Cases	62,000	42,300
Cardiac hospital admissions	Cases	38,300	26,100
Restricted activity days (RADs)	Million days	347.7	222.0
Respiratory medication Use (children)	Million days	4.2	2.0
Respiratory medication Use (adults)	Million days	27.7	20.9
LRS (including cough) among children	Million days	192.8	88.9
LRS among adults with chronic symptoms	Million days	285.3	207.6
Ozone morbidity effects			
Respiratory hospital admissions	Cases	14000	20100
Respiratory medication Use (Children)	Million days	21.4	12.9
Respiratory medication Use (Adults)	Million days	8.8	8.2
Minor Restricted Activity Days (MRADs)	Million days	53.9	42.4
Cough and lower respiratory symptoms (LRS) (children)	Million days	108.1	65.3

***) Chronic mortality due to PM has been calculated in two alternative ways.**
Note: Assuming 1997 meteorological year. Source: CBA CAFE Baseline (2005)

The methodology used has been developed following extensive stakeholder dialogue and has been peer-reviewed by leading experts in the field. The values used for expressing health impacts in monetary terms are the most up-to-date available. The values are presented as an annual impact in euros for the EU-25.

Methodologically, there is still debate as to how mortality should be valued. Two methods can be used. The first is the "value of statistical life" (***VSL***) approach where a pre-determined monetary VSL is multiplied by the change in the number of deaths to arrive at a monetary valuation. The second is the "value of life year" (***VOLY***) approach, which applies a value to changes in life expectancy to arrive at a monetary valuation. The two methods have contrasting strengths and weaknesses. Following the independent external peer review of the CAFE Cost-Benefit Analysis methodology, this impact assessment presents results for both the VSL and the VOLY approaches to show in a transparent manner the inherent uncertainty of both approaches.

Thus, for chronic mortality due to particulate matter, alternative values have been used (Table 4). The first two values are based on the VSL approach. The first uses the median of values of VSL, i.e. the value for which half of the values are greater and half of the values are smaller. The second uses the arithmetic mean (i.e. non-weighted average) of the responses. The third and fourth values use the VOLY approach based upon the median and mean values of life years lost.

The health damage costs are dominated by particulate matter, with premature mortality being most important. Morbidity is also significant however. The most important categories for particulate matter related morbidity arise from restricted activity days (***RADs***), minor restricted activity days (***MRADs***), cases of chronic bronchitis, and to a lesser extent additional days with lower respiratory symptoms (***LRS***). These morbidity effects contribute significantly to the total damage costs of PM. However, it should be kept in mind that the basis of evidence for quantifying them is more limited than for mortality, and it has been evaluated much less intensively by the air pollution research community.[53]

Table 4: Values of health effects of air pollution

	Value of statistical life (VSL) (€)	Value of life years (VOLY) (€)
Median	980,000	52,000
Mean	2,000,000	120,000

Source: NewExt[54] (2004) and CAFE Cost-Benefit Analysis methodology (2005)

2.3.2. Health damage of air pollution up to 2020

The total annual damage costs associated with particulate matter and ozone in 2020 are estimated at between €189 billion and €609 billion, depending on the mortality valuation method used. (Table 5). These costs are dominated by particulate matter, with mortality being more important than morbidity. Table 6 breaks down the figures for the different Member States, where the costs reflect their specific situation.

It could be important to include the effects of chronic exposure to ozone on health, and the social implications of air pollution health impacts, but there is inadequate evidence available to make a firm conclusion at this point in time.

53 For example, the exposure-response functions for the most influential endpoints are based on a few studies, mostly in the USA. They build on structured interviews about occurrence of symptoms and days when activity is restricted by health, whereas mortality is a definite end-point; and there are limited data on background rates in Europe. On the other hand, these are endpoints which are expected to be affected by PM. They have been included in many other major cost-benefit analysis of air pollution, including by the US EPA. The WHO-UNECE Task Force on Health considers that the morbidity evaluations for CAFE CBA are a significant step forward and should be included, with due regard to the uncertainties. The methodology for the morbidity effects is described in more detail in Volume 2 of the Methodology for the Cost-Benefit Analysis of the CAFE Programme (AEAT, March 2005)

54 « New Elements for the Assessment of External Costs from Energy Technologies », project financed by DG Research, Technological Development and Demonstration (RTD). EU 5th FP, duration 2001-2003. Project co-ordinator : Institute of Energy Economics and the Rational Use of Energy (IER), University of Stuttgart (http://www.ier.uni-stuttgart.de)

Table 5: Values of health damage due to air pollution in EU-25 in 2020 (millions of euros)

	Median values based on		Mean values based on	
	Value of Life Years	Value of Statistical Life*)	Value of Life Years	Value of Statistical Life*)
Mortality from particulate matter*)				
Chronic mortality from particulate matter	129,000	289,556	265,965	547,200
Infant (0-1yr) mortality	495	990	495	990
Sub-total	**129,495**	**290,546**	**266,460**	**548,190**
Morbidity from particulate matter				
Chronic bronchitis	24,011	24,011	24,011	24,011
Restricted activity days (RADs)	18,515	18,515	18,515	18,515
Lower respiratory symptoms among children	3,413	3,413	3,413	3,413
Lower respiratory symptoms in adults with chronic symptoms	7,974	7,974	7,974	7,974
Other morbidity effects	159	159	159	159
Sub-total	**54,072**	**54,072**	**54,072**	**54,072**
Total particulate matter	**183,567**	**344,618**	**320,532**	**602,262**
Mortality from ozone				
Acute mortality from ozone	**1,085**	**2,435**	**1,085**	**2,435**
Morbidity from ozone				
Lower respiratory symptoms among children	2,508	2,508	2,508	2,508
Minor Restricted Activity Days	1,629	1,629	1,629	1,629
Other morbidity effects	60	60	60	60
Sub-total ozone morbidity	**4,197**	**4,197**	**4,197**	**4,197**
Total ozone	**5,282**	**6,6334**	**5,282**	**6,633**
TOTAL PM AND OZONE	**188,848**	**351,250**	**325,813**	**608,893**

*) Distinction is made only in the case of chronic mortality due to particulate matter

Source: CBA CAFE Baseline (2005)

Table 6: Values of health damage due to air pollution in Member States in 2020 (billions of euros)

	Median values based on		Mean values based on	
	Value of Life Years	Value of Statistical Life*)	Value of Life Years	Value of Statistical Life*)
Austria	3.3	6.2	5.6	10.3
Belgium	7.1	13.3	12.0	22.4
Cyprus	0.3	0.5	0.4	0.6
Czech Republic	4.4	8.1	7.7	14.4
Denmark	1.8	3.4	3.2	6.1
Estonia	0.2	0.5	0.5	0.9
Finland	0.9	1.6	1.5	2.8
France	26.9	50.1	42.4	78.7
Germany	40.6	75.8	73.8	139.0
Greece	4.2	7.9	8.2	15.4
Hungary	5.0	9.4	9.9	18.6
Ireland	0.9	1.6	1.2	2.2
Italy	23.0	42.6	44.6	84.2
Latvia	0.8	1.5	1.2	2.1
Lithuania	0.8	1.4	1.9	3.6
Luxembourg	0.3	0.5	0.4	0.7
Malta	0.2	0.3	0.3	0.5
Netherlands	10.4	19.5	16.8	31.3
Poland	18.0	33.3	30.2	56.1
Portugal	2.4	4.4	4.3	8.0
Slovakia	2.5	4.7	4.1	7.7
Slovenia	0.9	1.6	1.5	2.9
Spain	10.0	18.3	17.3	32.2
Sweden	1.9	3.6	3.2	6.0
United Kingdom	22.1	41.2	33.7	62.2
Total	188.8	351.2	325.8	608.9

Source: CBA CAFE Baseline (2005)

2.4. Environmental and non-health impacts

Non-health impacts have been estimated across EU-25 for the baseline from 2000 to 2020. Some of these impacts have been valued in monetary terms. For these, the main effects are damage to crops (i.e. reduced crop yield) and damage to materials (excluding historic buildings and cultural heritage). The two main pollutants of concern are ozone (for crops) and SO_2 (for materials).

The impacts and benefits of reduced crop damage due to ozone and reduced material damage due to reduced SO_2 emissions have been expressed in monetary terms, using the approach outlined in the CAFE CBA methodology (Table 7). These impacts are small in relation to health damage overall. However, effects from ozone on crops are similar in magnitude to ozone-related health impacts.

Table 7: Ozone and SO_2 damage to crops and materials in 2000 and 2020 (billion of euros)

	2000	Baseline 2020	Difference
Crop damage due to ozone	2.8	1.5	1.3
Materials damage due to SO2 and ozone	1.1	0.7	0.4
Total	**3.9**	**2.2**	**1.7**

Source: CAFE CBA.

As there is a lack of objective valuation methodology at EU Level, other effects have not been quantified in monetary terms. However, the Thematic Strategy still tries to provide information to prompt stakeholders to consider whether the impacts that have not been quantified are likely to be important enough to change the balance of costs and benefits. As explained in the CAFE CBA methodology[55]:

- inclusion of impacts on forests, freshwaters and other ecosystems could add significantly to the benefits quantified for emission reductions.
- inclusion of the damage to cultural assets and some impacts on crops from interactions with pests and pathogens may be important. However, there is inadequate evidence available to make a firm conclusion at this point in time.

55 Methodology for the Cost-Benefit Analysis of the CAFE Programme (AEAT, March 2005)

3. THE LONG-TERM OBJECTIVES

The 6th EAP gives a clear obligation to develop a thematic strategy that will achieve "**levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment**". The 6th EAP also reiterates the long-term objective contained in the National Emissions Ceilings Directive of **no exceedence of critical loads and levels for acidification, eutrophication and ground-level ozone.**[56]

3.1. Current policies will not bring about the long term objective

The discussion in Section 2 sets out the expected levels of air quality and the degree of protection for natural ecosystems in 2020 that will be provided by effective implementation of current policies. Clearly, the long-term objective will not be met under current policies:

– $PM_{2.5}$ would still reduce average statistical life expectancy by 5.0 months and cause some 272,000 premature deaths;

– 46% of ecosystem areas would still be subject to unsustainable deposition levels of nutrient nitrogen;

– Critical loads for acidification would be exceeded in about 10% of the area of European forests;

– About 55% of forest areas would still be exposed to ozone above the critical level.

In 2020, therefore, the EU would still be a long way from the long-term objectives laid down in the 6th EAP and so further action is required.

3.2. A point of reference – The maximum technically feasibly reduction

In order to assess the potential for further action to meet the long term objective, a scenario has been analysed in which all possible technical emissions abatement are deployed irrespective of cost. This is the "Maximum Technically Feasible Reduction" scenario (MTFR). This scenario is made up of cost-effective sets of measures which go beyond current legislation and which deliver environmental improvements in a cost-optimal manner.[57]

The MTFR scenario was used to find out how far it is possible to reduce environmental and health damage due to air pollution irrespective of cost. The human health and environmental improvements associated with the MTFR scenario were projected in the same manner as for the baseline situation.

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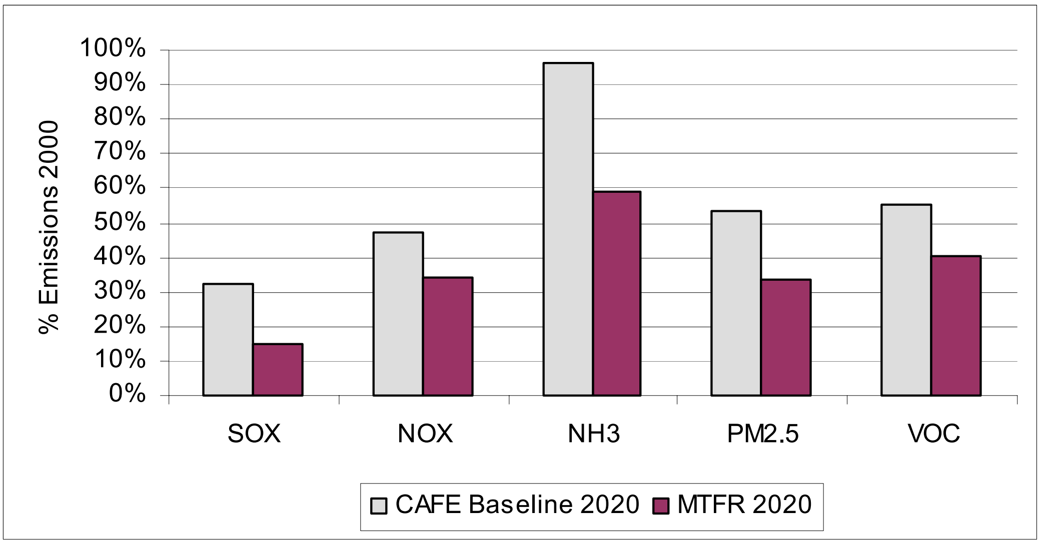
56 Article 1, Directive 2001/81/EC, L 309, 27.11.2001, p. 22.

57 See a description of the measures included in MTFR in CAFE Report #2: The "Current Legislation" and the "Maximum Technically Feasible Reduction" cases for the CAFE baseline emission projections. (http://www.iiasa.ac.at/rains/CAFE_files/baseline3v2.pdf)..

The implementation of the MTFR scenario would bring about a considerable additional decrease of all pollutants compared with the baseline, but would not eliminate them altogether. This improvement is particularly important in the case of ammonia (additional 37%) while for VOC the improvement is limited to 15%. (Figure 10)

Figure 10: Levels of pollutant emissions in the CAFE Baseline and in Maximum Technologically Feasible Reduction in 2020 (2000 emissions = 100%)



Source: RAINS

The impact on health from particulate matter and ground-level ozone would decrease by 30% and 15% respectively. This means that, even with the MTFR scenario, 190.000 people would be estimated to die prematurely every year, and average European average life expectancy would still have to be reduced by 3.8 months from exposure to air pollution. Also other significant health impacts related to morbidity would remain of concern.

Environmental impacts would also still occur. Even after application of technical measures in the MTFR scenario, 28% of forest would still be exposed to ozone above the critical level, 15% of ecosystems would be at risk from excessive nutrient nitrogen, while 3 % of European forests and 5% of lakes would still be at risk from acidification.

In addition to the MTFR option above, other non-technical measures are also possible, e.g. changing demand in the different sectors. An “illustrative” scenario for such a structural shift was examined using the PRIMES energy model, assuming a carbon constrained economy that would lead to a carbon price of €90/tonne CO_2 in 2020 (see Annex 2). This scenario gives a reduction in EU-25 CO_2 emissions of about 20% compared with 1990. However, effects on air pollution were not negligible under this scenario but represent only an additional decrease in emissions of around 2% in the case of NO_x, and 0.2% for VOC. In addition, such a scenario would also necessitate policy measures to shift demand (i.e. a tax on carbon or CO_2), with the consequent costs. These were not examined further. This was partly due to the fact that such a scenario was extremely likely to be less cost-effective in terms of air pollution reduction than the options considered further below.

Against a backdrop of the energy consumption and economic activity described in the baseline, it is apparent that the long-term objective cannot be met. Even if the EU undertook the most expensive and currently available emission control measures there would still be significant negative impacts on health and the environment.

More needs to be done to attain Community long-term objectives for air pollution. However, the application of all technical measures irrespective of cost will still not deliver those objectives – and may be excessively costly.

This Thematic Strategy is ambitious, but at the same time strikes a fair balance between economic and environmental dimensions. It recognises and is consistent with the Lisbon Strategy objectives and the Community's Sustainable Development Strategy.

Reflecting this, the policy options dealt with in the following chapter reflect the need to find a balance between the costs and benefits of action and determine how far to go in closing the gap between the current environmental problems and the long-term objective.

4. THE MAIN POLICY OPTIONS CONSIDERED FOR THE STRATEGY

4.1. The broad approach for setting the interim objectives

The approach taken in the Strategy to set interim objectives was similar in many respects to that followed earlier when developing the National Emissions Ceilings Directive. The scenarios were explored, using the RAINS model in an iterative way, and the cost and benefits of closing the gap in environmental impact between the baseline emissions in 2020 and the MTFR scenario. However, there were differences, too. During the development of the NEC Directive, the target setting was based mainly on closing the gap between the base year (which was then 1990) and the "no effect" level (in 2010). As an interim objective "50% gap closure" between the initial situation and "no effect" was agreed. During the development of the Thematic Strategy it was realised that the approach used in NEC Directive could not be repeated mainly because in the enlarged EU, Member States were in different initial positions. Thus, new approaches were called for setting targets (see Box).

Approaches to target setting

One traditional approach (applied, e.g., in the air quality directives) focuses on environmental improvements at the most polluted sites by imposing absolute limits (or caps) on air quality (or effect indicators) that need to be achieved throughout the entire territory of the EU. Applied to the air quality management problems at hand, it turned out that substantial spatial variations in the environmental indicators exist over Europe, even if the values of these indicators for individual grid cells are aggregated to the Member States level. The adoption of an absolute target, while it would force maximum measures in some Member States, would not require any improvements for other Member States, because they would achieve this level already in the baseline (current legislation case) without any additional measures. Thus, such uniform targets expressed in absolute terms of air quality or environmental impact indicators would result in uneven distributions of environmental improvements and abatement burdens. In addition, economic analysis has shown that, especially for pollution problems where no clear 'no effect' threshold could be identified, larger benefits could be accrued from wide-spread improvements at moderately polluted places compared to approaches that focus solely on a few hot spots, and thus benefit only a limited number of people or ecosystems.

As an alternative, earlier analyses for the national emission ceilings directive and for the CLRTAP Gothenburg Protocol applied the "gap closure" concept, which calls for uniform relative improvements of the environmental indicators as an interim target. For NEC Directive, the "gap closure" concept specified environmental targets in relation to the gap between the present environmental situation (at that time the status of 1990) and the ultimate environmental policy target of achieving no-effects levels (quantified through critical loads or at that time AOT40/60 for ozone). With this approach, more even or "equitable" distributions of economic burdens and environmental benefits could be achieved, which made these accords politically acceptable. However, if, in order to establish a notion of "equity" in terms of environmental improvements, a uniform gap closure percentage target were used for all Member States, this target would be constrained by the Member State with the lowest feasibility, and would in the end make only a minor contribution to ambient levels of pollution.

This process was undertaken within the CAFE Working Group on Target Setting and Policy Assessment (WG TSPA). The objective was to find a balance between cost-effective measures that would give optimum environmental and health benefits for Member States and the EU as a whole, and accounting for aspects of equity so that no population group or Member State would experience disproportionately high risks or costs. The process is described below.

4.1.1. First set of policy options

Three scenarios have been explored in depth to assess the cost and benefits of closing the gap between the environmental situation calculated in the baseline scenario in 2020 and the MTFR scenario for 2020. These scenarios represent differing levels of ambition based on the gap closure concept, i.e. the percentage of the gap to be closed between the 2020 baseline and the MTFR (excluding transport sector), for losses in life expectancy from exposure to particulate matter, for the cases of premature deaths attributable to ozone, for accumulated excess deposition over the critical loads for acidification, and for accumulated excess deposition for eutrophication.[58]

As mentioned in Section 4.1 the definition of a "gap" was different in the development of the Strategy compared with the development of the National Emissions Ceilings Directive. Now the "gap" was defined as the difference between the MTFR and the baseline in 2020. In the NEC Directive the "gap" was the difference between "no effect" level and the starting point. In other words, the "gap" in the Strategy is in between the "gap" as this was defined in the NEC Directive.

The following four metrics are used as impact indicators, for which the gap closure is applied[59]: expectancy from exposure to particulate matter; cases of premature deaths attributable to ozone; accumulated excess deposition over the critical loads for acidification; accumulated excess deposition for eutrophication.

– For **health impacts attributable to $PM_{2.5}$**, RAINS used the loss in statistical life expectancy as calculated by RAINS for each grid cell as the impact indicator for which the environmental gap closure target is specified. Formally, this is equivalent to a gap closure calculated for the annual mean concentrations of $PM_{2.5}$, for each grid cell of 50 km x 50 km.[60] Grid average values have been used for this exploratory series of calculations, but inclusion of City-Delta results in subsequent runs allowed a better representation of human exposures in urban areas. (see Annex 2)

– For **health impacts attributable to ozone**, RAINS calculated the number of premature deaths attributable to ozone (SOMO35) on a grid basis and summed them for each Member State. The gap closure was then applied to the country-balance only, i.e. it is not requested for each individual grid cell as long as the overall improvement within a given country is achieved. Formally, this is

58 The detail of these initial scenarios is described in: IIASA Report A - Results from the RAINS Multi-Pollutant/Multi-Effect Optimization including Fine Particulate Matter; Background paper for the meeting of the CAFE Working Group on Target Setting and Policy Advice, January 14, 2005

59 In the RAINS optimization, emission reductions are driven by the environmental targets specified for the various environmental endpoints. Thus, the choice of the environmental endpoint and of the absolute and relative improvements imposed on the selected criteria has critical influence not only on the absolute levels of resulting emission reductions, but also on the distribution of abatement burdens across countries and sectors.

60 See Annex 2

equivalent to a gap closure calculated on the basis of population-weighted SOMO35 grid data.

– For **acidification**, RAINS applied the gap closure concept to the total deposition of acidifying compounds in excess of the critical loads for acidification, accumulated over all ecosystem types (forests, semi-natural, water) and ecosystem areas in a country. While this accumulated excess deposition cannot be interpreted to be proportional to ecological damage in a strict sense, it provides a continuous scale for quantifying excess deposition. For this exploratory set of computations, RAINS uses a linear representation of the accumulated excess deposition function. The implications of an optimized emission reduction scenario can then be displayed for each grid cell in terms of ecosystems area with acid deposition above/below critical loads.

– For **eutrophication**, RAINS applied the same "accumulated excess deposition" concept as for acidification. The gap closure is requested on a country basis, i.e. there is flexibility to compensate improvements at "hard to attain" targets at individual receptor sites by additional gains in other areas within the same country.

After analysing these three ambition levels two issues became apparent. Firstly, reduction of concentrations of particulate matter in air was closely correlated to reduction not only of primary particulate matter emissions but also of NO_x, SO_2 and NH_3, as the latter are also precursors to secondary $PM_{2.5}$ concentrations. Only VOC emissions were not correlated with $PM_{2.5}$ concentrations. Secondly, it was evident that control costs started to increase significantly at about 75% between the baseline and MTFR in 2020. Thus, it was concluded that the following model rounds would concentrate on $PM_{2.5}$ exposure **and focus on the range between 50% and 100% of MTFR**.[61] Thirdly, it became evident that difficulties may arise when imposing improvements where air pollution impacts are relatively small ("cleaning already clean air") or in peripheral regions.

4.1.2. Focusing on particulate matter

It became clear during the first set of policy options that the reduction of NO_x, SO_2, ammonia and $PM_{2.5}$ are collinear. In other words, reducing $PM_{2.5}$ concentrations also reduces emissions of NO_x, SO_2, ammonia and $PM_{2.5}$, albeit not in equal proportions. Thus, during subsequent model runs, several particulate matter emission reduction options were investigated. Three target setting principles for particulate matter were explored[62]:

- **A "capping value" concept**. This requires $PM_{2.5}$ concentrations in urban background air sheds everywhere in the EU-25 to be below a certain upper level. The RAINS model, with the City-Delta corrected urban concentrations of

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61 Given that it was also known that it was possible to incorporate road transport and international maritime emissions reduction into the MTFR, subsequent model rounds in the Impact Assessment include these sources.

62 The results of these scenario runs are described in IIASA Report B - Target Setting Approaches for Cost-effective Reductions of Population Exposure to Fine Particulate Matter in Europe (IIASA, February 2005)

particulate matter, is capable of reproducing concentrations of $PM_{2.5}$ at urban background locations, although the model cannot reproduce "hot spots" in street canyons nor can it account for components derived from organic aerosol. A separate study has been done by the EEA[63] on the increment in narrow street canyons. The study shows that in such street canyons with heavy traffic the PM2.5 levels could be up to 10 ug/m3 higher than the urban background with the present vehicle fleet and about 5 ug/m3 higher than the urban background with the vehicle fleet of the 2020 CAFE baseline. Hence, an adjustment[64]of up to 5 $\mu g/m^3$ would need to be added to computed values by the City-Delta methodology to obtain concentrations at street canyons. To be feasible, a generally applicable "cap" must be achievable everywhere. In some cities (excluding the port cities) in the model calculations is was not possible to reduce urban background_$PM_{2.5}$ in 2020 much below modelled concentrations of 15 $\mu g/m^3$, even with full application of all available control measures at the European scale. On the other hand, there are very few places where a modelled level of 20 $\mu g/m^3$ would remain exceeded. Thus, a sequence of scenarios has been calculated to bring modelled $PM_{2.5}$ concentrations in urban background air below uniform target levels of 15, 15.5, 16, 16.5, 17 and 19 $\mu g/m^3$.

– **A "gap closure" approach**. The gap closure is a fixed percentage of improvement in $PM_{2.5}$ exposure for each grid, between the baseline scenario and the MTFR. As vehicle emission standards need to be introduced as a Community-wide measure, and not for individual Member States, the RAINS optimization exploring the scope for additional measures on stationary sources was carried out twice for given environmental targets, with and without further road measures introduced in all Member States. With equal environmental objectives, a comparison of the emission control costs between these two cases allowed conclusions to be drawn about the cost-effectiveness of further road measures.

– **A "Europe-wide" target**. This would explore the cost-effectiveness of measures to achieve health improvements irrespective of the location of the improvement. The optimization identified those measures in the EU-25 that would achieve a given improvement of years of life lost (**YOLL**) at least cost. The location where the health benefit occurs was thus not taken into account, and the optimization allocated measures to those regions where benefits are largest across the EU. The benefit of a unit of reduced $PM_{2.5}$ concentration, however depends on the population density in the affected area. The more people living in an area, the more effective will be a reduction of PM concentration in that area. While this approach optimizes the use of resources, it might compromise on (perceived) equity aspects, because not all Member States may receive equitable environmental improvements.

[63] Air pollution levels at hotspot areas of selected cities, EEA ETC/ACC Final report June 2005 draft

[64] As the EMEP model, on which the RAINS model rests its calculations of PM dispersion, does not quantify contributions from natural sources, i.e., mineral dust, sea salt and biogenic material and of secondary organic aerosols, an assumption has been made that the mineral contribution amounts in Mediterranean countries at 3 µg/m3, in Scandinavia at 1 µg/m3, and all other countries at 2 µg/m3.

In addition two other proposals were made on setting targets. These will be explored in detail during the impact assessment of the National Emissions Ceilings Directive.

It was decided to refine further the three target setting approaches ("capping", "country specific gap closure" and "EU-wide target setting") with three ambition levels for PM and the carrying out of sensitivity analysis and robustness tests.[65]

– The "capping" approach showed difficulties bringing annual mean $PM_{2.5}$ concentrations below 17 µg/m^3 in urban areas with high local emission densities (*inter alia*, due to PM emissions from ships in harbours) and the low wind speeds given in the available data set. If two of the binding cities were excluded[66] from the optimization process the cost-effectiveness of this approach improved. However, this approach still remained less cost-effective and triggered an uneven distribution of costs and benefits across Member States.

– Uniform "gap closure" in terms of health-relevant $PM_{2.5}$ exposure was performed including a sensitivity case with a cut-off threshold of the concentration-response function at 7µg/m^3 for less polluted sites.[67] This approach increased equity and efficiency, reducing annual costs for a given scenario by €800 million for e.g. 80% of the MTFR at EU level, with visible effects for those Member States where the lack of cut-off entailed high abatement costs with only marginal benefits.

– Finally, the Europe-wide approach of improvement of $PM_{2.5}$ health impacts irrespective of their locations, remained most cost-effective, but also superior to the other approaches for many equity criteria. However, the difference between alternative approaches were narrow, due to the adjustments made in the target setting (exclusion of some of the "driving grids or cities" and cut-off for $PM_{2.5}$ exposure) (Figure 11).

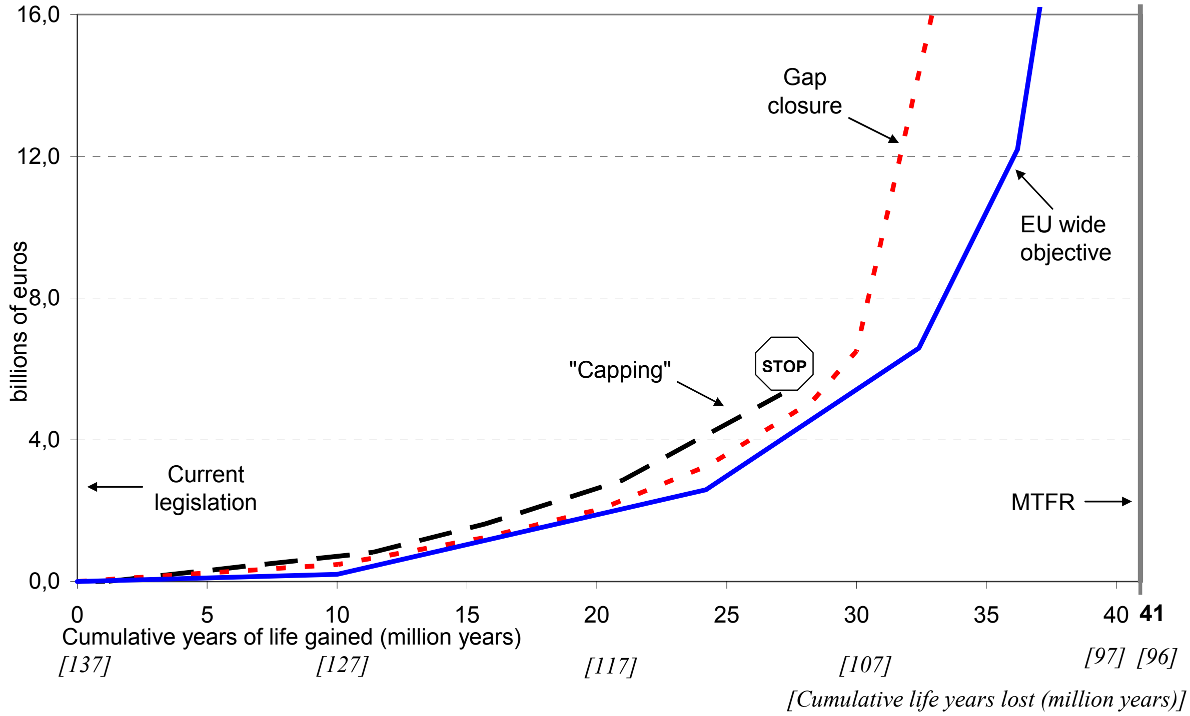
A preliminary cost-benefits analysis (where benefits are calculated only from reduced exposure to particulate matter) of these scenarios showed that benefits are higher than costs, even with low estimates of benefits. The gap closure approach was proven to be more cost-effective and have higher benefit/cost ratio than the limit value approach at comparable ambition levels. This empirical result was an expected outcome as the gap-closure approach is theoretically more efficient than the limit value approach.

65 The results of these scenarios are described in IIASA Report C - Exploratory CAFE scenarios for further improvements of European air quality (IIASA, March 2005)

66 These cities were Genoa and Thessaloniki. While there are obvious uncertainties in the present modelling approach that call for caution in calculating results for individual cities, the general features of such a limit value approach and of potential exceptions will hold also for practical implementation in the real world.

67 There is some logic for the use of this somewhat arbitrary cut-off of 7µgm^{-3} as this lies at the lower end of the range of concentrations used to derive the dose response function from epidemiological studies.

Figure 11: Cost-effectiveness of the target setting approaches: Emission control costs (billions of euros per year) vs. Years of life gained (million years)



Source: IIASA Note: The line for the "capping" approach does not continue to the MTFR, where the concentration limit approach becomes infeasible, because the limit value will be exceeded in some area, even if all countries are at MTFR emissions.

4.2. Final set of policy options

The different environmental and health targets on PM, acidification, eutrophication and ozone were combined in a joint optimization. Such an approach builds on important economic synergies between control measures for different air quality problems. PM and ozone are complementary targets, and appropriate combination of ambition levels for different end points needed further exploration. For that purpose, a screening of ambition levels for the individual optimization runs was performed, calculating 24 sets of different ambition levels of joint optimization scenarios. This resulted in 360 model runs.[68] The proposed ambition levels combine the health-related $PM_{2.5}$ and ozone objectives with those of environmental protection for acidification, eutrophication and ozone damage to vegetation (Table 8).

Table 8: Definition of three ambition levels for interim targets for air pollution up to 2020

	2000	Baseline 2020	Ambition level Scenario A	 Scenario B	 Scenario C	MTFR[69]
EU-wide cumulative years of life years lost (YOLL, million)	203	137 (0%)	110 (65%)	104 (80%)	101 (87%)	96 (100%)
Acidification (country-wise gap closure on cumulative excess deposition)[70]	120	30 (0%)	15 (55%)	11 (75%)	10 (85%)	2 (100%)
Eutrophication (country-wise gap closure on cumulative excess deposition)[71]	422	266 (0%)	173 (55%)	138 (75%)	120 (85%)	87 (100%)
Ozone (gap closure on SOMO35)[72]	4081	2435 (0%)	2111 (60%)	2003 (80%)	1949 (90%)	1895 (100%)

68 These model runs are reported in IIASA, A final set of scenarios for the Clean Air for Europe (CAFE) programme, CAFE Scenario Analysis Report #6, April 2005

69 The percentage refers to the difference between Baseline 2020 and Maximum Technically Feasible Reduction (MTFR)

70 Average accumulated excess acidification equivalents per hectare

71 Average accumulated excess eutrophication equivalents per hectare

72 SOMO35 in parts per billion days

5. IMPACT ASSESSMENT OF THE OPTIONS

Throughout this section the three ambition levels for interim objectives till 2020, labelled Scenarios A, B and C will be assessed. The overall purpose is to have enough information to decide which of the Scenarios would for the basis for the interim objective.

The three levels of ambition between the baseline and the maximum technically feasible reduction were subjected to a full cost-benefit analysis. This was complemented by analysis with the GEM-E3 general equilibrium model to see the impact on competitiveness, employment and other general equilibrium effects. This impact assessment does not include the detailed assessment of individual measures[73] of each interim objective, as this will be performed in due time together with each legislative proposal.

The impact assessment of the range of policy options responds to the objectives of the Lisbon and Sustainable Development strategies. On the one hand it aims at defining the most effective and efficient regulation as part of the efforts of the European Institutions and Member States to fulfil the Lisbon objectives in 2010; on the other hand it ensures policy coherence between the economic, environmental and social dimensions. Following the principle of proportionality, the analysis focuses on the most significant impacts and the most important distributive effects, and the depth of analysis matches the significance of the impacts.[74]

5.1. Impact on pollutant emissions

The reduction in pollutant emissions corresponding to the different ambition levels is not homogeneous across pollutants and Member States. The dispersion is more evident in the case of SO_2 and PM, for which the levels of ambition are the greatest, together with NH_3. Tables 9 and 10 indicate that the reduction effort for different pollutants varies. For instance, under Scenario B, SO_2 emissions would be reduced by a further 44% but VOC emissions by only 17% from where they would be with current legislation in 2020. Furthermore, the reduction efforts in different Member States vary depending on the pollutant and the abatement options. (See Figure 12 for details.)

Table 9: Emission reductions for the three ambition levels in 2020, in kilotonnes

	Emissions in 2000	Baseline emissions in 2020	Ambition level in 2020		
			Scenario A	Scenario B	Scenario C
SO_2	8735	2805	1704	1567	1462
NOx	11581	5888	4678	4297	4107
VOC	10661	5916	5230	4937	4771
NH_3	3824	3686	2860	2598	2477
$PM_{2.5}$	1749	964	746	709	683

Source: RAINS

73 Except for the impact of proposed limit values for $PM_{2.5}$ which is described in Chapter 7.

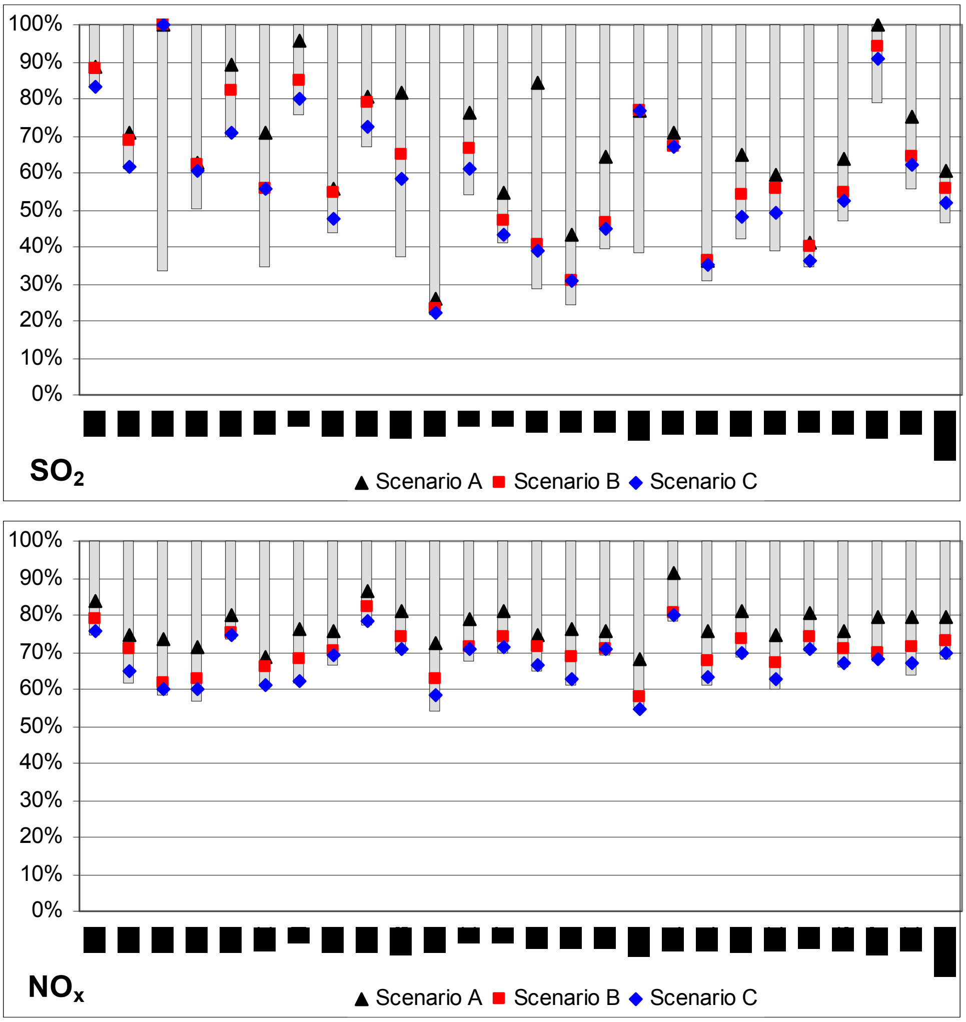
74 "Impact Assessment: Next Steps - In support of competitiveness and sustainable development", SEC(2004)1377

Table 10: Emission reductions for the three ambition levels in relation to baseline emissions in the EU in 2020, in percentage

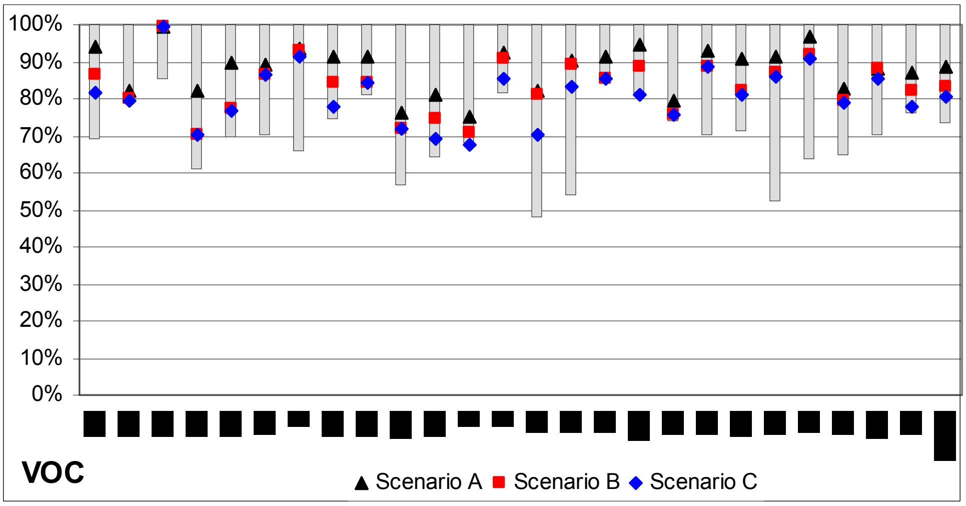
	Baseline emissions in 2020	Ambition level in 2020		
		Scenario A	Scenario B	Scenario C
SO_2	100%	-39%	-44%	-48%
NOx	100%	-21%	-27%	-30%
VOC	100%	-10%	-17%	-19%
NH_3	100%	-22%	-30%	-33%
$PM_{2,5}$	100%	-23%	-26%	-29%

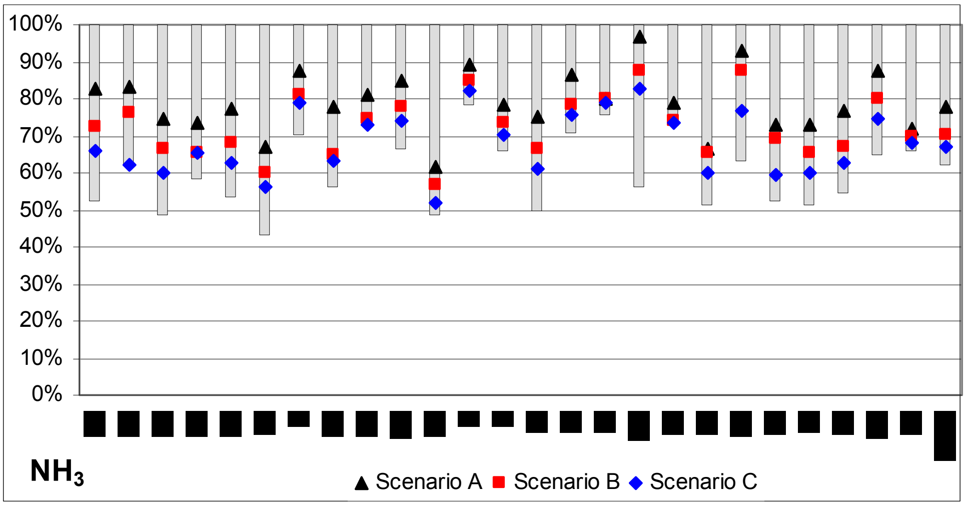
Source: RAINS

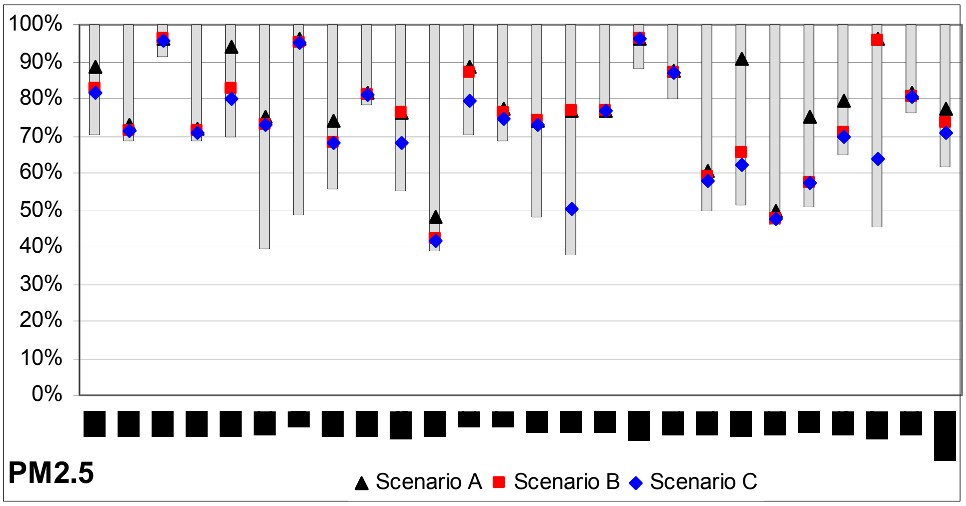
Figure 12: Emission reductions for the three ambition levels and the MTFR in relation to baseline emissions in Member States in 2020 [Baseline emissions in 2020 = 100%]



Source: RAINS. Note: The grey area represents the scope for emission reduction in the MTFR in relation to baseline emissions in 2020







Source: RAINS. Note: The grey area represents the scope for emission reduction in the MTFR in relation to baseline emissions in 2020

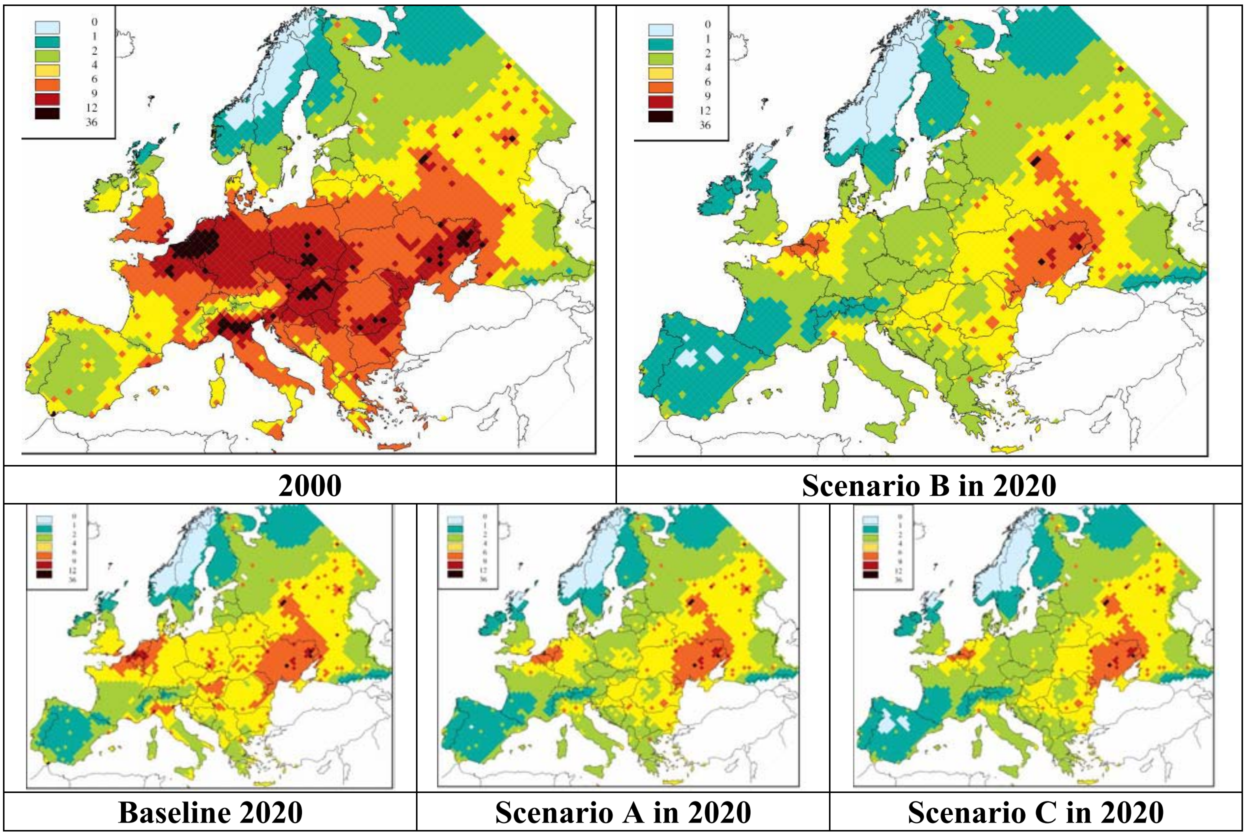
5.2. Impact on air quality and human health

5.2.1. Loss in life expectancy attributable to exposure to fine particulate matter

Exposure to fine particulate matter has several severe effects on human health and is clearly linked to increased mortality and morbidity. The mortality effect may be expressed as changes in life expectancy or as numbers of premature deaths. Scenario B would, on average, reduce loss of life expectancy due to exposure to $PM_{2.5}$ to 4.1 months instead of 5.5 months in the baseline for 2020. Changes in life expectancy could also be expressed as changes in the cumulative number of life years lost in the EU: the RAINS model estimates that in 2020 the cumulative number of years of life lost (EU-wide YOLL) is about 137 million, and Scenario B would reduce number of life years lost to about 104 million.

Based on the calculations from RAINS further analysis within the CBA framework allowed an assessment of the number of people dying prematurely every year. Scenario B would correspond to a reduction of premature deaths by about 66,000 people per year compared with the baseline for 2020. Regional differences in the EU are projected to prevail (Figure 13) and some regions in North-West EU would still have loss of average life expectancy in the range of 9 to 12 months in 2020. However, all regions in the EU would see a major improvement over and above the baseline in 2020 with Scenario B.

Figure 13: Loss in life expectancy attributable to anthropogenic $PM_{2.5}$ (months) for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020



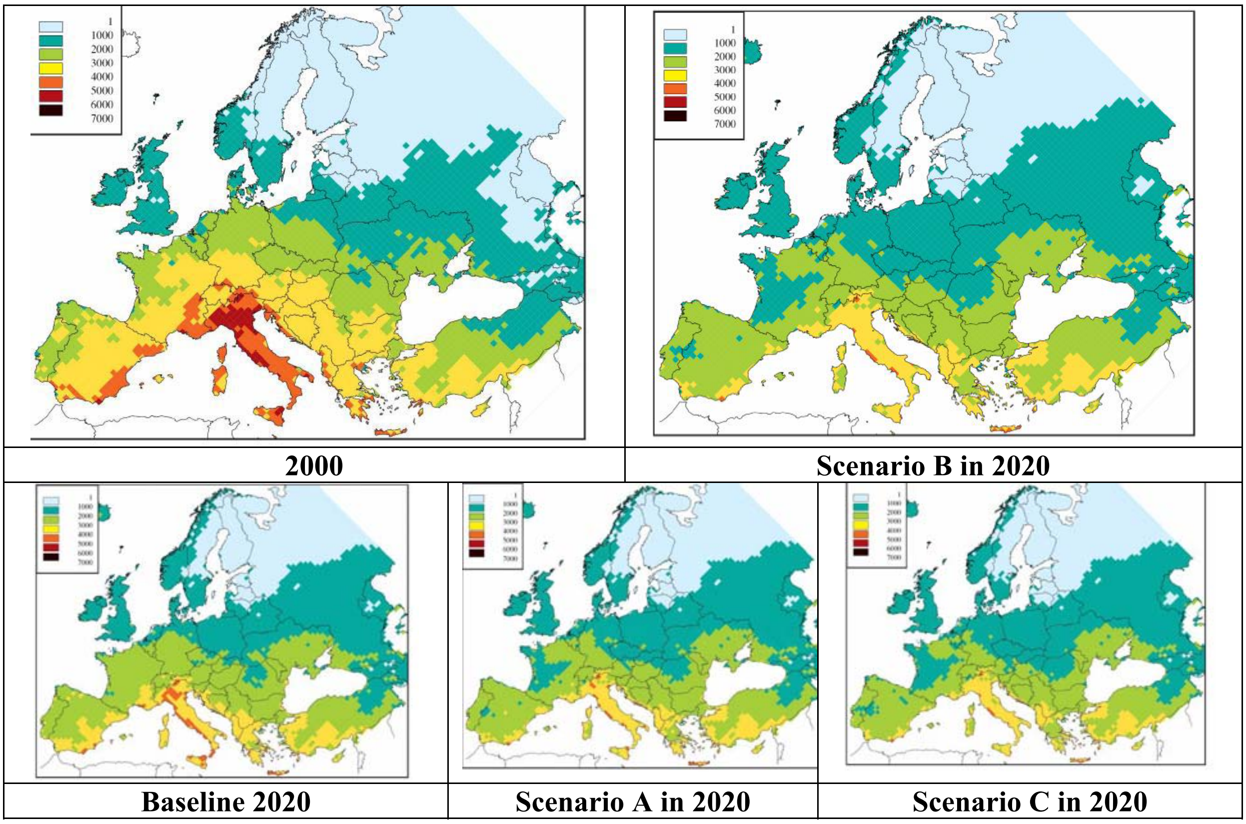
Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997.

5.2.2. *Health effects attributable to exposure to ground-level ozone*

Scenario B would considerably reduce the number of deaths brought forward due to ozone exposure[75] all over the EU (Figure 14). At the same time, other health-related impacts due to ozone would also be reduced. It is estimated that almost 5000 people less would die prematurely due to ozone exposure in Scenario B, bringing the number down to 17,000 by 2020. In Scenario A, the reduction would be about 1000 people less. However, in Scenario C the situation is no longer projected to improve.

Reaching the interim objective would bring about considerable improvement but some regions would still have elevated levels of ozone in 2020.

Figure 14: Health effects attributable to exposure ground-level ozone (ppb.days) for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020



Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997.

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75 above a cut-off of 35 ppb

5.3. Direct costs of measures

Annual abatement costs of the measures included in the three ambition levels are estimated to vary from €5.9 billion in Scenario A to €14.9 billion in Scenario C. Table 11 disaggregates the costs by pollutant and major source. It should be noted that the impact in terms of health and environment is not the same between different scenarios. For instance, the difference between Scenarios A and B is not the same as the difference between B and C.

Table 11: Annual abatement cost per pollutant for each ambition level in 2020 (millions of euros)

Ambition level	Scenario A	Scenario B	Scenario C	MTFR
SO_2	800	1,021	1,477	3,124
NOx	903	2,752	4,255	6,352
NH_3	1,785	3,770	5,410	13,584
Primary $PM_{2.5}$	411	695	908	12,335
VOC	157	573	935	2,457
Road transport (both $PM_{2.5}$ and NOx)	1,868	1,868	1,868	n/a
Total	**5,923**	**10,679**	**14,852**	**over 39,720**

Source: RAINS.

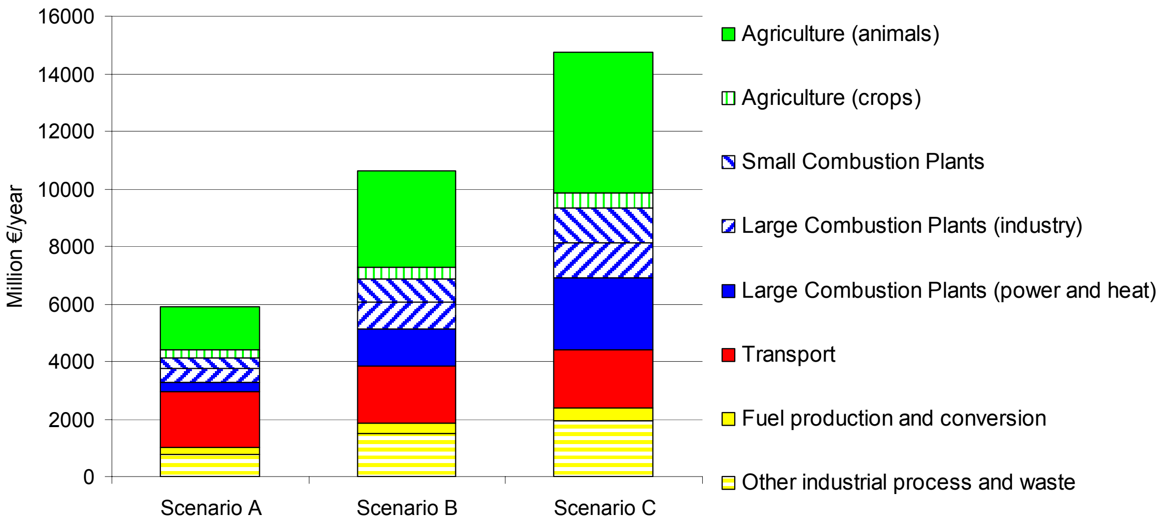
Figure 15 gives a sectoral breakdown of the costs of the measures. As further explained in Chapter 6, this is a preliminary estimate that does not take into account substantial issues:

– For transport, the costs forecast relate to one emission reduction scenario based on a single source of data. Future emissions standards will be defined on the basis of a more detailed impact assessment (See Section 5.5.2.). Accompanying and non-technological measures may also influence in a positive way the cost-effectiveness of these standards.

– For energy, additional measures of energy efficiency could trigger additional emissions reduction.

– For agriculture, estimates do not take into account the impact of the Common Agricultural Policy reform or the implementation of the nitrate and IPPC directives (see section 5.5.1). All these elements will be analysed in depth during the review of the national emission ceilings. The objective will be to promote measures which are synergetic for the various environmental media and at the same time to help achieve various environmental objectives with cost effective measures. Moreover, the decrease in ozone damage to crops has to be taken into account (see section 5.7.5.). For Scenario B, it would amount to 415 million euros in 2020, corresponding to more than 10% of the direct cost of the measures for Agriculture.

Figure 15: Sectoral distribution of the cost of the measures associated with each ambition level in 2020 (millions of euros)



Source: RAINS.

5.4. Uncertainties

If the costs and benefits of air pollution control were known with absolute confidence there would be no problem in comparing the two. However, costs and benefits are subject to uncertainties, some of which (on both sides of the cost-benefit equation) are significant. This section provides an analysis of the major sources of uncertainty[76], as well as an indication of the direction and potential importance of the biases. In the following section, a sensitivity analysis is provided on the most relevant uncertainties.

5.4.1. Modelling framework

The peer-review of the RAINS integrated assessment model (which underpins the development of the strategy) has highlighted uncertainties due to (1) biases in the model; (2) a lack of scientific understanding; and (3) and an inability to predict future behaviour. The model has been constructed by the International Institute for Applied Systems Analysis (IIASA) so as to be conservative in its performance and assumptions. Such systematic biases therefore tend toward overestimates of parameters like costs and favour a strategy of lower ambition.

The biggest gap in the scientific understanding for this Thematic Strategy relates to the attribution of effects to individual species of particle or other pollutants: The discussion of the potential effects of different toxicities for the components of the

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[76] An extended description of the uncertainties in the quantification of benefits with both RAINS and CBA, but also in the dispersion modelling work carried out using the EMEP model and the costs analysis carried out using the RAINS model is provided in Volume 3: Uncertainty of the Methodology for the Cost-Benefit Analysis for the CAFE Programme (AEAT, March 2005), as well as in the Review of the RAINS Integrated Assessment Model (See Annex 1)

PM mixture, i.e. primary $PM_{2.5}$, sulphates and nitrates has do be done in a qualitative way, as attempts to quantify long term health impacts of individual components have not a sufficient scientific underpinning at the moment. The Systematic Review of Health Aspects of Air Pollution in Europe (WHO, June 2004) considered this issue and noted that toxicological studies have highlighted that primary, combustion-derived particles have a high toxic potency; and that several other components of the PM mix – including sulphates and nitrates – are lower in toxic potency. Unfortunately there is a lack of any established risk estimates for the different components. It is therefore currently not possible to precisely quantify the contributions from different sources and different PM components to health effects. However, we believe there is value in exploring this as a sensitivity analysis, for example to differentiate between policies that reduce primary rather than secondary particles from combustion. (See section 5.5.5. for a sensitivity analysis. As this strategy is an integrated strategy which addresses the natural environment as well as health, the results of the analysis (emissions reductions, costs) do not change significantly from the proposed scenarios).

The choice of meteorological year is important for modelling pollutant dispersion and chemistry. The economic analysis has been conducted on the basis of a single meteorological year (1997) due to resource and timing constraints. It is true that air quality can vary significantly between years, but 1997 was chosen as it represents an average year. However, more detailed baseline estimations of effects have also been undertaken which use four different and contrasting meteorological years (1997, 1999, 2000 and 2003).

There may be biases (with no indication of the direction) due to the quality of emission inventories, which will vary between pollutants (SO2 emissions, for example, are known with a far better level of confidence than PM emissions). Negative bias may also arise because of the potential for switching to cleaner fuels or production systems by the baseline year for reasons unrelated to air quality regulation. Positive bias may arise through possible legislative change in other areas that could cause emissions to increase.

Omission of some existing and future abatement measures from the RAINS model could lead to an overestimation of costs and underestimation of the maximum feasible reduction. (See below sensitivity analysis on Agriculture and Transport). Moreover, *ex-ante* cost estimates are often considerably higher than the real costs of measures as evaluated ex-post. The study performed by AEA Technology for the UK DEFRA in December 2004, clearly stated that the *ex-ante* costs of the UK National Air Quality Strategy were overestimated by up to a factor of 5 (c.a. ex-ante estimate of £16-23 billion for the period 1990 to 2001 compared to the *ex-post* cost estimate of the order of €3 billion for the same period).

5.4.2. *Health Impacts of air pollution*

For the quantification of the mortality impact of exposure to fine particles, the central estimate of the dose-response function for particulate matter, adopted by WHO Task force on health for IAM, has been chosen. This may mean that we seriously underestimate the health impacts as well as overestimate them: The results given here can be used with results from the analysis of scenarios to define probability distributions – simply divide values by a factor 2.5 to obtain the lower end of the 95% confidence interval and multiply by 1.7 to obtain the upper end.

The CAFE-CBA Methodology has identified a number of health impacts which was not felt appropriate to include in the core analysis. Sensitivity analysis has been undertaken on these effects to assess their importance. In terms of the number of additional health impacts for $PM_{2.5}$, the sensitivity analysis shows these additional impacts (Restricted Activity Days and additional cases of Chronic Bronchitis) are important, with hundreds of millions of additional potential cases or days of illness. They represent additional benefit in monetary terms between 13% and 43%, depending on the valuation method for the core mortality benefits. In terms of the number of additional health impacts for ozone (mainly Allergic rhinitis consultations), the sensitivity analysis shows these additional impacts are important in monetary terms, between 63% and 93% additional benefits, although they are not relevant compared with $PM_{2.5}$ impacts.

5.4.3. Non-health and ecosystem impacts

The integrated assessment modelling underestimates ecosystem sensitivity by ignoring the 5% most sensitive ecosystems in each grid cell of the European modelling domain. Moreover, the coarse scale atmospheric dispersion modelling (50 km resolution) can significantly underestimate actual deposition to sensitive ecosystems. There is a tendency for sensitive ecosystems to be situated in elevated regions which receive greater rainfall and orographically enhanced deposition.

In theory, it would be possible to go straight from critical loads or critical levels exceedance to valuation of benefits for ecosystems, were suitable data available from willingness to pay studies. Although the literature in this area is growing, it is not currently adequate for a Europe-wide appraisal such as this. Earlier studies tended to take a very simplistic perspective of impacts on ecosystems rendering them unsuitable for use in a policy context.

One area where there is potential for short term success in quantification of the monetary value of pollution damage relates to ozone effects on forests, as it has been done for Sweden. However, an in-depth analysis using the same methodology across Europe, capable of providing input to the core quantification, was not undertaken in the context of this Thematic Strategy, given the complexities of modelling forest growth over decades and of forecasting trends in forest management practices in response to changing supply of timber and demand.

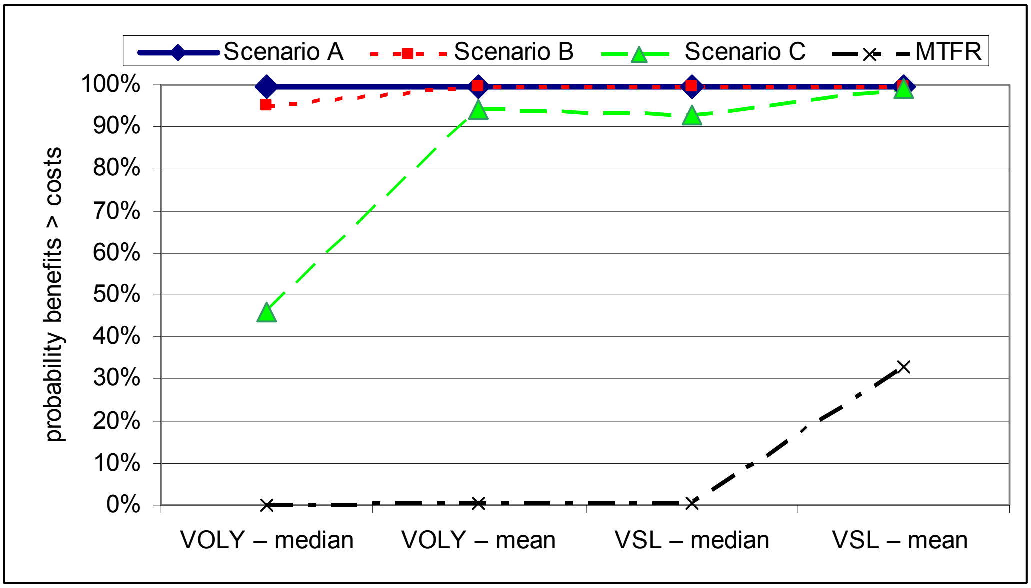
It was not possible to quantify the damage to cultural heritage in the same way as for materials in utilitarian applications because of a lack of data on stock at risk and restoration and other costs.

5.4.4. Conclusions

The costs and benefits of different Scenarios have been calculated by using the meteorological year of 1997. While 1997 is on the average a rather typical meteorological year, some uncertainties are inherent in the analysis. On the other hand, as the costs and benefits relate changes between the baseline in 2020 and different scenarios in 2020, the uncertainty of the difference is considered relatively small.

The probability that the total benefit for each scenario according to core estimates would exceed the total cost is given by Figure 16. For Scenario A and Scenario B there is a high probability that incremental benefit will exceed incremental cost, irrespective of the approach taken to mortality valuation. For Scenario C there is again a high probability of excess benefit in all cases except where mortality is valued using the median VOLY, in which case the probability falls to a little under 50%. For the MTFR scenario (Maximum Technically Feasible Reduction according to the assumptions and measures included in the RAINS model) there is little probability of incremental benefit exceeding cost, irrespective of the approach taken for mortality valuation.

Figure 16: Comparison of the probability of benefit exceeding cost



Note: This does not include consideration of sensitivity to cost uncertainty or unquantified benefits. Source: CAFE CBA.

Based on the significant body of evidence (see AEA Technology, 2005) that forecasted costs of pollution control are generally overestimated, the results summarised above were combined with sensitivity analysis on estimated costs for each scenario and on the magnitude of non quantified benefits. Variation in costs had little effect on scenarios A or B. The magnitude of unquantified benefits only became significant in one case, for Scenario B, where cost was assumed to be underestimated by the RAINS model by 20%. These are considered to be unlikely.

Based on the uncertainty analysis the following conclusions are drawn::

- Scenario A: The conclusion that benefit would exceed cost across the EU25 for Scenario A is robust according to the uncertainty assessment performed, with a probability in excess of 95% of gaining a net benefit.

- Scenario B: Again, the analysis suggests that the conclusion that benefit would exceed cost across the EU25 is robust according to the uncertainty assessment performed, though with a slightly reduced probability compared to Scenario A.

- Scenario C: There is certainly a case made for moving to Scenario C, though for stakeholders who prefer to use the median VOLY for mortality valuation it is clearly less robust than the case for moving to Scenario B.

5.5. Sensitivity analysis

Sensitivity runs were carried out by IIASA with the RAINS model.[77] The impact of variations in the baseline scenario (e.g. using national projections) were carried out for those Member States that had provided their national emission projections up to 2020. A total of 10 Member States had provided a scenario.[78] In some cases there was a discrepancy between the Member States projection and the CAFE baseline. However, in most cases the Member States projection did not include climate change measures (to be compatible with the Kyoto Protocol). Further, the emission projections were not meeting the obligations of the National Emissions Ceiling Directive. Finally, at EU level the discrepancies were still rather small given the fact that there are overall uncertainties in making projections up to 2020. Therefore, the uncertainties relating to the differences between Member States projections and the CAFE baseline were considered relatively small and not of concern for setting the interim objectives. It was noted, however, that during 2005 the Member States and the Commission need update the emission projections up to 2015 and 2020. This work underpins the urgency of the analysis to set up the National Emission Ceilings.

5.5.1. Influence of the chosen environmental endpoints

The CAFE scenarios identify sets of emission control measures that simultaneously achieve the environmental targets for the four endpoints of concern (human health effects from PM, acidification, eutrophication and ground-level ozone). Thereby, in a cost-optimized solution each measure is justified by concrete environmental achievements for at least one of these endpoints.

There is no objective procedure for allocating weights to the different environmental endpoints on a purely scientific basis. In order to provide objective elements for the judgment from decision maker, a further sensitivity analysis has been carried out targeting on health impacts attributable to $PM_{2.5}$ only.

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77 The results are be reported in IIASA, A final set of scenarios for the Clean Air for Europe (CAFE) programme, CAFE Scenario Analysis Report #6, April 2005

78 For details, see Sensitivity analysis with national energy and agricultural projections in IIASA: "Exploratory CAFE scenarios for further improvements of European air quality". Background paper for the meeting of the CAFE Working Group on Target Setting and Policy Advice, March 17, 2005

Table 12: Emission control costs for the single-effect and multi-effect optimization cases (million €/yr)

Costs	Scenario A		Scenario B		Scenario C		MTFR
	PM optimized	Joint optimization	PM optimized	Joint optimization	PM optimized	Joint optimization	
Road	1 868	1 868	1 868	1 868	1 868	1 868	1 868
SO_2	885	800	1 265	1 021	1 911	1 477	3 124
NO_X	168	903	511	2 752	1 597	4 255	6 352
NH_3	1 489	1 785	3 598	3 770	5 005	5 410	13 584
$PM_{2.5}$	565	411	837	695	1 045	908	12 335
VOC	0	157	0	573	0	935	2 457
Total	**4 974**	**5 923**	**8 080**	**10 679**	**11 426**	**14 852**	**39 720**

Source: RAINS

Difference emerge not only in overall emission reduction costs, but also in terms of reduction requirements for individual pollutants. As shown in Table 12, with the chosen target levels a purely health- and PM-driven optimization suggests more emphasis on the reduction of SO2 emissions - and obviously on PM2.5 emissions - than a case including ecosystem impacts. In contrast, a strategy including ecosystem targets (including ground-level ozone) asks for larger NOx and VOC reductions. The pressure on NH3 emissions is similar in both cases.[79] In summary, it can be stated that in the central Thematic Strategy ambition levels the stringency of SO2 and PM2.5 reductions are determined at the margin by the selected health objectives, while ecosystems-related targets (including ozone) control the resulting NOx and VOC reductions. The required levels of cuts in ammonia emissions are determined by both health and ecosystems targets.

Finally, a strategy targeting at PM Health impact only would already deliver ancillary benefits for ozone, eutrophication and acidification. Reaching the level of ambition of Scenario B for $PM_{2.5}$ health objective only would deliver a greater improvement in eutrophication and acidification than additional targets corresponding to the Scenario A of ambition. This is due to the abatement in primary pollutant that contribute not only to $PM_{2.5}$, but also to those environmental objectives (namely SO_2 and NH_3). This is not the case for ozone where additional effort would be required from the ancillary benefits of the level of ambition of Scenario A for $PM_{2.5}$ only to the achievement of the level of ambition A for ozone.

79 The joint optimization asks for some more ammonia reductions in the EU-25 as a whole than PM optimization. This is caused by the spatial differences of health and ecosystems impacts. Cost-effective achievement of the health targets require more ammonia reductions in central Europe (Germany, Czech Republic, Poland), the UK and in Italy, while the ecosystems targets imply more stringent ammonia measures in Austria, Denmark, France, Ireland, Spain, Greece, Sweden, Finland. To meet the combined targets in each country requires therefore a wider Europe-wide spread of ammonia reductions than any optimization for a single effect alone.

Table 13: Ozone and environmental ancillary benefits

		Scenario(see Table 8)		
	Optimization based on:	A	B	C
Eutrophication (country-wise gap closure on cumulative excess deposition, % MTFR)	All targets	60%	79%	89%
	PM only	47%	65%	79%
Acidification (country-wise gap closure on cumulative excess deposition, % MTFR)	All targets	78%	90%	95%
	PM only	77%	89%	94%
Ozone (gap closure on SOMO35, % MTFR)	All targets	53%	77%	88%
	PM only	16%	24%	42%

Source: RAINS

5.5.2. Agriculture

Given that this Strategy has highlighted the importance of ammonia reduction, a specific uncertainty analysis was carried out on this. The first analysis was to check whether there were differences between the RAINS cost and activity data and those supplied by Member States. For this analysis a revised set of RAINS cost curves was prepared that was first used for the scenarios incorporating the national activity projections (nine Member States had provided these). The verified cost curves include improved assumptions on incorporation of solid pig and cattle manures and result in lower costs of these options than originally estimated in the RAINS model. According to the preliminary analysis of IIASA, the annual cost of Scenario B is expected to be about €0.6 billion lower. Thus, the annual abatement costs that were estimated at €3.8 billion per annum are more likely to be €3.2 billion in 2020.

All the estimates in this impact assessment have not taken into account three developments which influence ammonia emissions. These are the reform of the Common Agricultural Policy (CAP), the implications of the implementation of the Nitrates Directive, and the impacts of reducing ammonia emission through the IPPC Directive. The main reason for not estimating these effects is the fact that it is not known in enough detail how Member States will apply CAP and what the impacts of the two directives are on emissions of ammonia at national and EU level.

IIASA recently implemented a CAP reform agricultural scenario developed with the CAPRI model by the University of Bonn. It performed an initial analysis of its impact on ammonia emissions and the costs of achieving Scenario B when a CAP scenario set of cost curves and emissions is used. In this initial analysis, ammonia emission would decrease in 18 Member States and increase in 7 up to 2020. The overall effect of the CAP reform – according to these preliminary estimates – would be a reduction of ammonia emissions by 210 kilotonnes. This change is not insignificant as it would be about 10% of the estimated need for a reduction of ammonia emissions between the baseline in 2020 and Scenario B in 2020.[80] These impacts are also likely to be important at Member State level. Thus, they need to be carefully reviewed with the Member States during revision of the NEC Directive. Preliminary analysis indicates that the CAP reform could reduce the projected annual compliance cost of reaching Scenario B level of ammonia reduction by some €0.5 billion in 2020[81].

Due to lack of data, it has not been possible at this stage to conduct a quantitative analysis on the possible impact of implementation of the Nitrates Directive. This analysis will be done during revision of the NEC Directive.

A preliminary analysis was carried out on how much the compliance costs would be reduced to meet Scenario B by 2020, if Member States applied the IPPC Directive for ammonia emissions in the agricultural sector. Full application of the IPPC Directive would reduce annual costs by about €0.9 billion per annum. Optimistically full implementation of IPPC could remove an additional 150 to 230 kilotonnes of ammonia by 2020. If it can be assumed that the IPPC Directive is fully applied, the annual compliance costs of Scenario B would be reduced by €0.6-€0.9 billion (see Table 14 for a summary of the uncertainty analysis).

In sum, when analysing the impact of four different sources of uncertainties in the emission reduction of ammonia – abatement cost data and the impact of CAP reform, Nitrates Directive and IPPC Directive – it is possible that on the one hand the cost estimates in ammonia emissions are overestimated in this Strategy, and on the other hand the baseline for NH3 is likely to underestimate the actual reduction up to 2020 by 360-450 kt. All together, the compliance costs of Scenario B could be between 40% and 50% lower than estimated. This issue will be analysed carefully during revision of the NEC Directive.

80 The difference is about 3% of the baseline emissions of ammonia in 2020.

81 The CAP reform will also have an impact on the use of fertilisers. The European Fertilizer Manufacturers Association expects a 5.1% decrease of nitrogen mineral fertilizer use in the EU15 in the period 2003 to 2013, essentially due to the recent CAP reform.

Table 14: Change in compliance costs of ammonia of Scenario B with updated cost data, the implications of the CAP reform and assuming vigorous implementation of the IPPC directive.

	Annual cost in 2020			
	Lower estimate		Higher estimate	
	€bn	%	€bn	%
Original estimate of the compliance costs to reach Scenario B	3.77		3.77	
Source of uncertainty:				
• Updated cost estimate taking into account reduced costs of manure management	-0.60	-16%	-0.60	-16%
• Possible impact of CAP reform (reduction emissions in the baseline by 210 kt)	-0.46	-12%	-0.46	-12%
• Impact of compliance costs due to vigorous implementation of the IPPC directive (reduction emissions in the baseline by 150-230 kt)	-0.60	-16%	-0.85	-23%
Sub-total cost reduction	-1.66	-44%	-1.91	-51%
Compliance cost for Scenario B taking into account all uncertainties	**2.11**		**1.86**	

Source: RAINS

5.5.3. Road Transport

In all three Scenarios A, B and C it had been assumed that emissions from road transport sector could be reduced by lowering emission limit values under current legislation. The current standards for new passenger cars and light commercial vehicles (Euro 4) have been in force since the beginning of 2005. For heavy duty vehicles, Euro 4 emission limit values are entering into force in October 2005 and Euro 5 in October 2008. Due to the internal market rules of the EU it is not possible to have different vehicle emission limits across the Member States. Thus under Scenarios A, B and C it was assumed that all Member States apply tighter emission limits.

The RAINS model had included such further emission reductions for passenger cars and light duty vehicles assuming that they would be mandatory from 2010 onwards and would reduce both particulate matter and NO_X emissions[82]. The main source for the light duty vehicle emissions reductions was RICARDO (2003)[83].For new heavy duty vehicles, the assumption was that tightened emission limit values would take effect from 2013 in all Member States. The cost data for the emission reductions were introduced to the RAINS database in the same manner as for emission reductions from all other sectors.

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82 See Section 2.1 of CAFE Report #4: (http://www.iiasa.ac.at/rains/CAFE_files/CAFE-B-full-feb3.pdf).

83 RICARDO, Support for updating the RAINS model concerning road transport – final report, November 2003, available at http://www.citepa.org/forums/egtei/RD03_162101_5.zip

It was important to see whether the assumed emission reductions in the road transport sector were cost-effective in relation to the possibilities of reducing NO_X and PM emissions from other sectors. For this purpose, three scenarios were run with the RAINS model. The environmental and health objectives of Scenarios A, B and C were maintained up to 2020. However, under these new scenarios it was assumed that the road transport sector would not be able to reduce NO_X and PM emissions beyond current legislation. This would imply that the estimated annual compliance costs of the road transport sector of €1.9 billion would be saved in 2020. To maintain the achievement of the health and environmental objectives, other sectors would need to compensate for the shortfall and take additional measures. Of specific interest was whether the costs of Scenarios A, B and C without road emission reduction measures would be higher or lower than Scenarios A, B and C with road measures. From these alternative model runs (Table 15) it became evident that if the environmental ambition level of Scenario A were maintained, other sectors would need to reduce emissions so that their annual compliance costs would increase by €2.1 billion in 2020. This compares with the savings of €1.9 billion in 2020 if road emission measures are not undertaken. Thus, under Scenario A the EU as a whole would have additional compliance costs of €200 million if road emission measures were not taken. In other words, the modelling suggests that including road sector measures to Scenario A was cost-effective compared with other sectors.

Table 15: Impact of excluding additional road emission reduction measures on annual compliance costs in 2020, billions of euros

	Scenario A	Scenario B	Scenario C	MTFR
Core scenarios				
Measures reducing emissions from all stationary sources	4.1	8.8	13.0	37.9
Measures reducing emissions from transport sector	1.9	1.9	1.9	n/a
Total core scenario	5.9	10.7	14.9	> 39.7
Alternative scenarios				
Measures reducing emissions from all stationary sources	6.1	>37.9	>37.9	>37.9
Measures reducing emissions from transport sector	0	0	0	n/a
Total core scenario	6.1	>37.9	>37.9	> 39.7
Difference	**0.2**	**>27.2**	**>27.2**	**n/a**

Source: RAINS. Note: Sums do not add up due to rounding errors

When the same analysis was repeated for Scenarios B and C it emerged that without road emission reduction measures it was not possible to reach the interim environmental and health objectives by 2020. In other words, even if all measures in the Maximum Technical Feasible Reduction Scenario were undertaken – costing each year about €40 billion per year – the interim objectives would still not be achieved. In sum, road emission reduction measures are indispensable to reach the interim objectives of Scenarios B and C cost-effectively.

Apart from the work by RICARDO (2003), the Commission had independently started preparations for new emission standards for light-duty vehicles and heavy-duty vehicles by sending out questionnaires to the stakeholders. A questionnaire on light-duty vehicles was sent in February 2004 and another one on heavy-duty vehicles in May 2004. These questionnaires requested cost and technology data on a number of emission reduction scenarios for light and heavy duty vehicles. All responses were received by the beginning of June 2004 for light-duty vehicles and somewhat later for heavy-duty vehicles. The light duty vehicle emission and cost data has been validated by a panel of independent experts and will be used in the impact assessment of the new Euro 5 standard for light duty vehicles. That work took more time than expected because of the need to interpret the rather diverse responses received, to fill data gaps and to further consult with the stakeholders. The final element of industry input was only received in February 2005. Because of the work on light-duty vehicle data, the validation of heavy duty vehicle emission reduction and cost data could not yet be started and will be undertaken later in 2005.

Based on the review of the light duty vehicle emission data, it appears that the reduction potential for NO_X is overestimated in the RICARDO (2003) data given the incremental cost. Thus, the cost estimates used in this impact assessment for light duty vehicles are likely to be underestimated for light duty vehicles.

On the other hand, , it seems that RICARDO (2003) may have underestimated the potential for NO_X reduction from heavy duty vehicles. Overall, the reduction potential for NO_X from transport measures has thus uncertainties and the same is the case for the estimated costs, which need to be considered approximative at this stage. The impact assessment of further road measures will use the updated emission reduction and cost data and will thus give a more accurate picture of the reduction potential from light and heavy duty vehicles.

5.5.4. Maritime Transport

The baseline assumes implementation of the currently decided control measures to reduce emissions from seagoing ships. These include for SO_2 the EU sulphur proposal as per Common Position, i.e., 1.5% sulphur marine fuel oil for all ships in the North Sea and the Baltic Sea; 1.5% sulphur fuel for all passenger ships in the other EU seas; low sulphur marine gas oil; and 0.1% sulphur fuel at berth in ports. For NO_X, implementation of the MARPOL NO_X standards for all ships built since 2000 have been assumed.

A sensitivity case has been analysed to explore the cost-effectiveness of further emission reduction measures for sea-going ships in the context of tightened ambition levels for land based sources. Optimizations for the Scenarios A, B and C have been repeated with the additional assumption that ships would reduce their NO_X emissions further through slide valve retrofits for slow speed engines. For 2020, costs of this measures are estimated at €28 million peryear.

The analysis reveals this option as highly cost-effective for all the three analysed cases. Maintaining the environmental interim targets of Scenarios A, B and C, respectively, implementation of this NO_X control measure would relax costly emission control measures at land-based sources and thereby lead to substantial cost savings (Table 16).

Table 16: Costs for the sensitivity case with further measures for ships compared to the central scenarios (€ million per year)

	CAFE scenario without ship measures : Costs for land based sources	Sensitivity case with measures for ships			
		Costs for land-based sources	Costs for ships	Total costs	Cost difference to the central CAFE cases
Scenario A	5923	5783	28	5811	-112
Scenario B	10679	10492	28	10520	-159
Scenario C	14852	14499	28	14527	-325

Source: RAINS

5.5.5. *Robustness of results on particulate matter*

A sensitivity case has been constructed which takes Scenario B as the starting point but ignores any reduction target for years of life lost from exposure to $PM_{2.5}$. However, the environmental interim objectives of Scenario B for ecosystems and ozone would be kept. The aim of the scenario is to understand how robust Scenario B would be if assumptions about the human health benefits derived from reduced exposure to particulate matter were altered fundamentally. The extreme case is to assume that there would be no human health benefits from reducing the concentration of particulate matter. If this were the case, the interim objectives for environmental issues would be maintained, while there would be no interim objective for particulate matter. The summary results are presented in Table 17.

Table 17: Robustness of the Strategy: Consequences if morbidity and mortality due to particulate matter exposure were excluded as an interim objective

	Unit	Scenario B	Scenario B without target for reducing life years lost ($PM_{2.5}$)	Difference %
Life years lost (cumulative)	millions	104	114	9.6%
Emissions in 2020				
SO_2	kilotonnes	1567	2034	29.8%
NOx	kilotonnes	4678	4301	-8.1%
VOC	kilotonnes	4937	4917	-0.4%
NH_3	kilotonnes	2598	2661	2.4%
$PM_{2.5}$	kilotonnes	709	938	32.3%
Annual abatement cost	**€ billion**	**10.7**	**9.0**	**-15.9%**

Source: RAINS

This sensitivity case shows that even if targets for human health were not considered at all, the chosen environmental interim objectives would still signify very similar emission reductions in the EU. While without targets on human health the EU would need to reduce its SO_2 emissions by about a third less and primary $PM_{2.5}$ emissions not at all, emission reductions of NOx would actually need to be almost 10% higher than otherwise. Compliance costs for the environmental targets alone would be 15% lower than for the scenario that addresses health targets, too.

It is possible to interpret this result differently. Assuming that reaching the ecosystem interim objectives would cost €9 billion per annum in 2020, the additional annual cost of reaching the interim objective of human health in terms of PM would cost only €1.7 billion extra. This interpretation needs to be kept in mind in the impact assessment of the reduction of the average annual urban background concentration in the EU between 2010 and 2020.

In sum, if the interim objective for human health due to particulate matter were not considered, the attainment of the interim objectives for environmental reasons would entail a very similar air pollution abatement strategy in the EU. Even the costs would be only 15% lower if the mortality and morbidity aspects of particulate matter exposure were not considered at all. The multi-pollutant/multi-effect approach with simultaneous objectives on health and environment is an important means for safeguarding robustness and thus lends support for the strategic choice made by the Commission for the Strategy, namely in favour of Scenario B.

5.6. Comparing costs and health impacts

5.6.1. Health impact

Changes in health damage of the different policy options are assessed using the methodology outlined in Section 2.3 and given in detail in the CBA methodology reports. The major monetised benefits of policy options would come from reduced premature deaths and reduced loss of life expectancy. Also benefits from reduced morbidity contribute significantly to the overall benefits. Again, it must be kept in mind that the basis of evidence for quantifying the most influential morbidity health endpoints is more limited than for mortality (see Section 2.3).

Table 18: Change in annual health impacts over baseline in 2020

End point	Pollut-ant	Unit	Scenario A	Scenario B	Scenario C	MTFR
Chronic mortality (years)	PM	thousand	492.5	600.8	654.6	744.6
Chronic mortality (premature deaths)	*PM*	*thousand*	*53.8*	*65.7*	*71.6*	*81.4*
Infant mortality (0-1 years) (premature deaths)	PM		70	80	90	100
Chronic bronchitis (over 27 years)	PM	thousand	25.5	31.1	33.9	38.5
Respiratory hospital admissions (all ages)	PM	thousand	8.5	10.3	11.2	12.8
Cardiac hospital admissions (all ages)	PM	thousand	5.2	6.4	6.9	7.9
Restricted activity days (15-64 years)	PM	million	44.4	54.1	58.9	67.0
Respiratory medication use (children 5-14 years)	PM	million	0.4	0.5	0.5	0.6
Respiratory medication use (adults over 20 years)	PM	million	4.2	5.1	5.5	6.3
Lower respiratory symptom (LRS 5-14 years)	PM	million	17.7	21.7	23.6	27.0
LRS among adults (over 15years) with chronic symptoms	PM	million	41.4	50.5	55.0	62.6
Acute mortality (premature deaths)	O_3	thousand	1.6	2.2	2.5	3.0
Respiratory hospital admissions (over 65years)	O_3	thousand	1.6	2.1	2.5	2.9
Minor restricted activity days (MRADs 15-64 years)	O_3	million	3.2	4.3	4.9	5.9
Respiratory medication use (5-14 years)	O_3	million	1.0	1.3	1.5	1.8
Respiratory medication use (over 20 years)	O_3	million	0.6	0.8	1.0	1.1
Cough and lower respiratory symptom (LRS 0-14 years)	O_3	million	4.9	6.6	7.5	9.1

Source: CAFE Cost-Benefit Analysis

Table 19: Change in annual health impacts over baseline in 2020 (millions of euros)

Endpoint	Pollut-ant	Scenario A	Scenario B	Scenario C	MTFR
Chronic mortality – VOLY – (median value)	PM	25,750	31,412	34,225	38,927
Chronic mortality – VSL – (median value)	*PM*	*52,726*	*64,313*	*70,122*	*79,680*
Chronic mortality – VOLY – high (mean value)	PM	57,798	70,508	76,822	87,377
Chronic mortality – VSL – high (mean value)	*PM*	*108,479*	*132,319*	*144,271*	*163,935*
Infant mortality (0-1 years) – (median value)	PM	100	121	132	150
Infant mortality (0-1 years) – (mean value)	*PM*	*199*	*242*	*264*	*300*
Chronic bronchitis (over 27 years)	PM	4,786	5,827	6,348	7,219
Respiratory and cardiac hospital admissions	PM	27	34	37	42
Restricted activity days (RADs 15-64 years)	PM	3,703	4,512	4,915	5,589
Respiratory medication use	PM	4	5	6	7
Lower respiratory symptoms	PM	2,272	2,774	3,022	3,440
Acute mortality (VOLY median)	O_3	83	110	127	152
Acute mortality (VOLY mean)	*O_3*	*186*	*248*	*285*	*342*
Respiratory hospital admissions and medication use	O_3	5	6	7	9
Minor restricted activity days (MRADs 15-64 years)	O_3	124	165	190	228
Cough and lower respiratory symptoms (0-14 years)	O_3	189	252	290	349
Total with mortality – VOLY – (median value)		37,043	45,218	49,299	56,112
Total with mortality – VSL – (median value)		64,019	78,119	85,196	96,865
Total with mortality – VOLY –(mean value)		*69,293*	*84,573*	*92,186*	*104,902*
Total with mortality – VSL – (mean value)		*119,974*	*146,384*	*159,635*	*181,460*

Source: CAFE Cost-Benefit Analysis

The costs and health benefits can be compared in different way based on the information in Tables 18 and 19. The cost per life year saved is estimated to increase from about €12,000 under Scenario A to over €53,000 under MTFR. The NewExt (Table 3) estimated that the value of each life year lost would be either €52,000 or €120,000 depending on whether the median or mean value is used. The cost per life saved is also estimated to increase from about €110,000 per life saved (i.e. premature fatality avoided) to about €490,000. The value of statistical life was estimated in NewExt to be between €1 and €2 million depending on whether the median or mean value is used. Thus, the cost-effectiveness of the MTFR based on human health seems justifiable, but barely so.

5.6.2. *Marginal analysis: Optimal ambition level for $PM_{2.5}$ health*

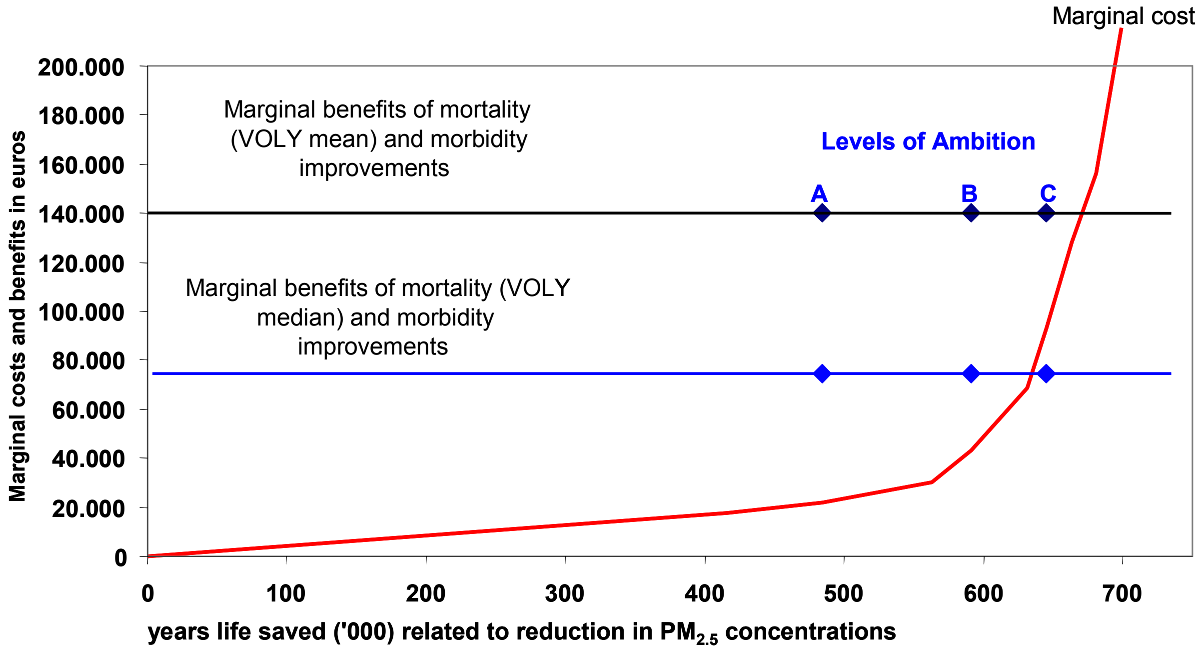
A way of defining the optimal ambition level would be to compare the cost per life year saved against the marginal benefit of a life year saved. This balance should be limited to the costs for reducing $PM_{2.5}$ concentration only (therefore excluding additional costs linked with acidification, eutrophication and ground-level ozone targets), with the monetary valuation of both mortality and morbidity effects due to reduced $PM_{2.5}$ concentration. The optimum is the point where marginal costs and marginal benefits are equalized. The reason is that at this point the total benefits minus the total costs (i.e. the net benefits) are maximised.

Converting this theoretical construct to marginal cost and marginal benefit curves is somewhat problematic in the case of costs, as a precise estimation of the marginal costs is made difficult by the small number of points available for defining the total cost curve (as marginal cost are available in RAINS at pollutant level). Marginal costs have therefore been estimated around scenarios A, B and C as well as some additional points. Marginal benefits in terms of reduced mortality and morbidity due to particulate matter have also been calculated using the lower and upper bound in the valuation range for the life of year lost as provided by the Cost Benefit Analysis. As can be seen in Figure 17, the point where marginal costs and benefits (lower bound) are equalized is between scenarios B and C.

It should also be noted that the largest improvements are estimated to materialise from moving from the baseline to Scenario A. The marginal costs of moving from Scenario A to B and further to C are estimated to increase rather sharply while marginal benefits remain flat.

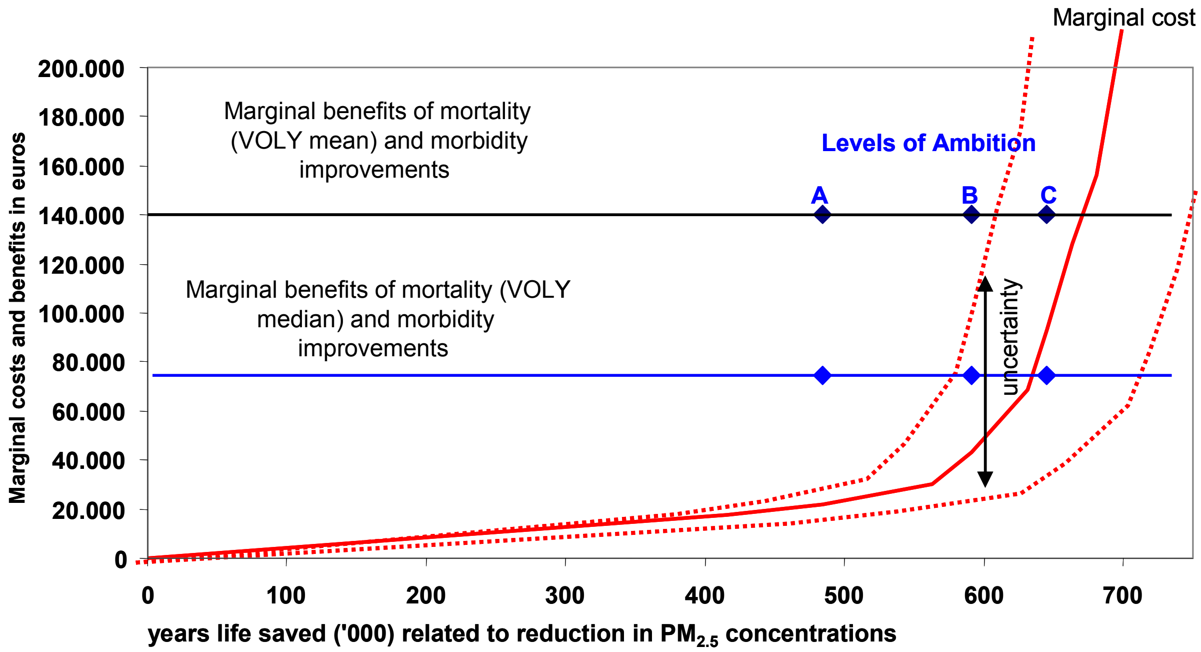
Further, it needs to be emphasized, that in the analysis thus far, the environmental benefits of reduced air pollution have not been included. A proper analysis of the environmental impacts needs therefore to be undertaken for defining the proper level of ambition for all the targets.

Figure 17: Marginal Cost and Benefits – $PM_{2.5}$ Health ambition level



In order to see how uncertainty in the effects would affect the analysis, Figure 18 illustrates the impact of a 10% increase or decrease of the effect of PM2.5 on life years. While in Figure 17 the optimal point of marginal benefits and costs -- when the median a value of life year lost is used -- would be between points B and C, it would be between A and B if the effect were lower than the central estimates of RAINS.

Figure 18: Effect of uncertainty on the ambition level related to health effects of $PM_{2.5}$



5.7. Impact on ecosystems

This section gives the impacts of reduced air pollution on ecosystems. In order to compare the situation in 2000 accurately with the projected ambition levels, it was necessary to re-run the EMEP model with exactly the same meteorological year as in the optimisation, i.e. 1997. Thus the differences presented in the three ambition levels and the base year are comparable. There were three kinds of impacts on ecosystems reported: impacts on Acid deposition to semi-natural ecosystems and freshwater bodies, and excess nitrogen deposition.

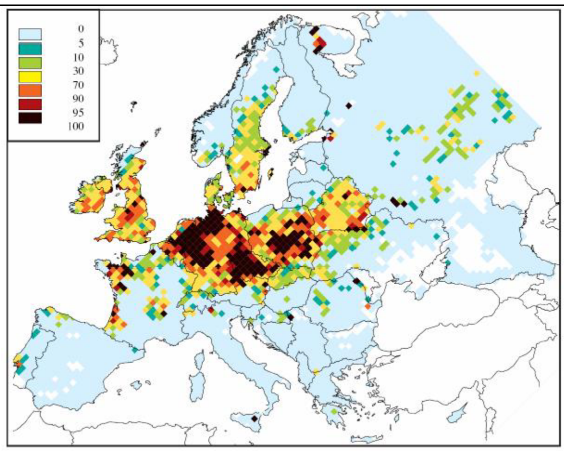
5.7.1. Acid deposition to forest ecosystems

Acidification of forest ecosystems has been reassessed using a more precise ecosystem-specific deposition to forests and nine times higher resolution in the grids[84] as compared with the previous assessment made for the development of the NEC Directive. This improved scientific knowledge and model precision has increased our understanding of the impacts of acidification on forests. Most importantly the ecosystem deposition accounted for in the new methodology has increased the estimated deposition to forests, since "dry deposition" is substantially higher to forests than to grass land or the average deposition in a 50 km x 50 km grid of the EMEP model.

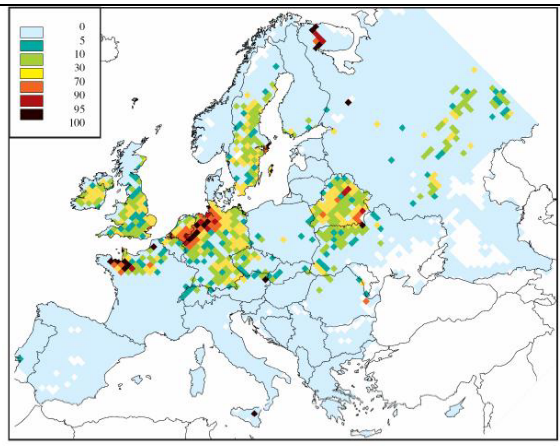
Improvements are expected following the present environment policies, but major acidification problems would remain in areas with sensitive ecosystems and high emissions (Figure 19). It is estimated that the percentage of the area of forest eco-systems receiving acid deposition above the critical loads would be reduced by over 50% i.e. by 124,000 km^2 by 2020 to 119,000 km^2. Scenario B would reduce the area receiving acid deposition above the critical load further by about 60,000 km^2. In Scenario A the reduction would be 8,000 km^2 less than in Scenario B, and in Scenario C the reduction would be 4,000 km^2 more.

84 The earlier maps were based on 150 km x 150 km grid squares while the maps in the present assessment are based on a 50x50 km resolution. You can fit nine 50x50 km grids into one 150x150 km grid.

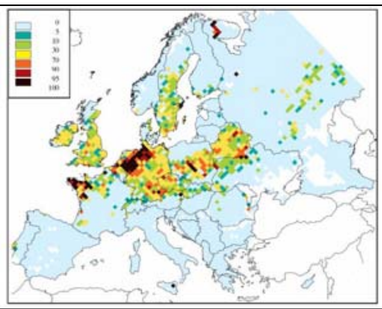
Figure 19: Percentage of forest area receiving acid deposition above the critical loads for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020



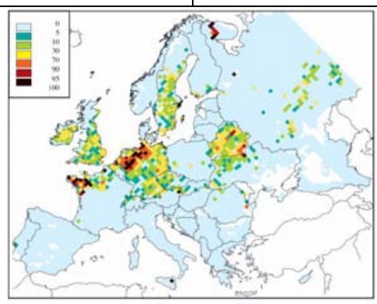
2000



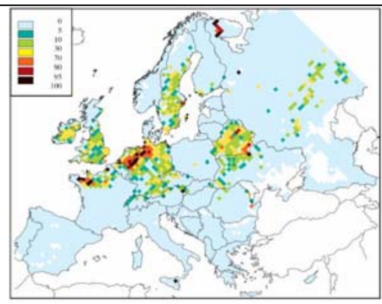
Scenario B in 2020



Baseline 2020



Scenario A in 2020



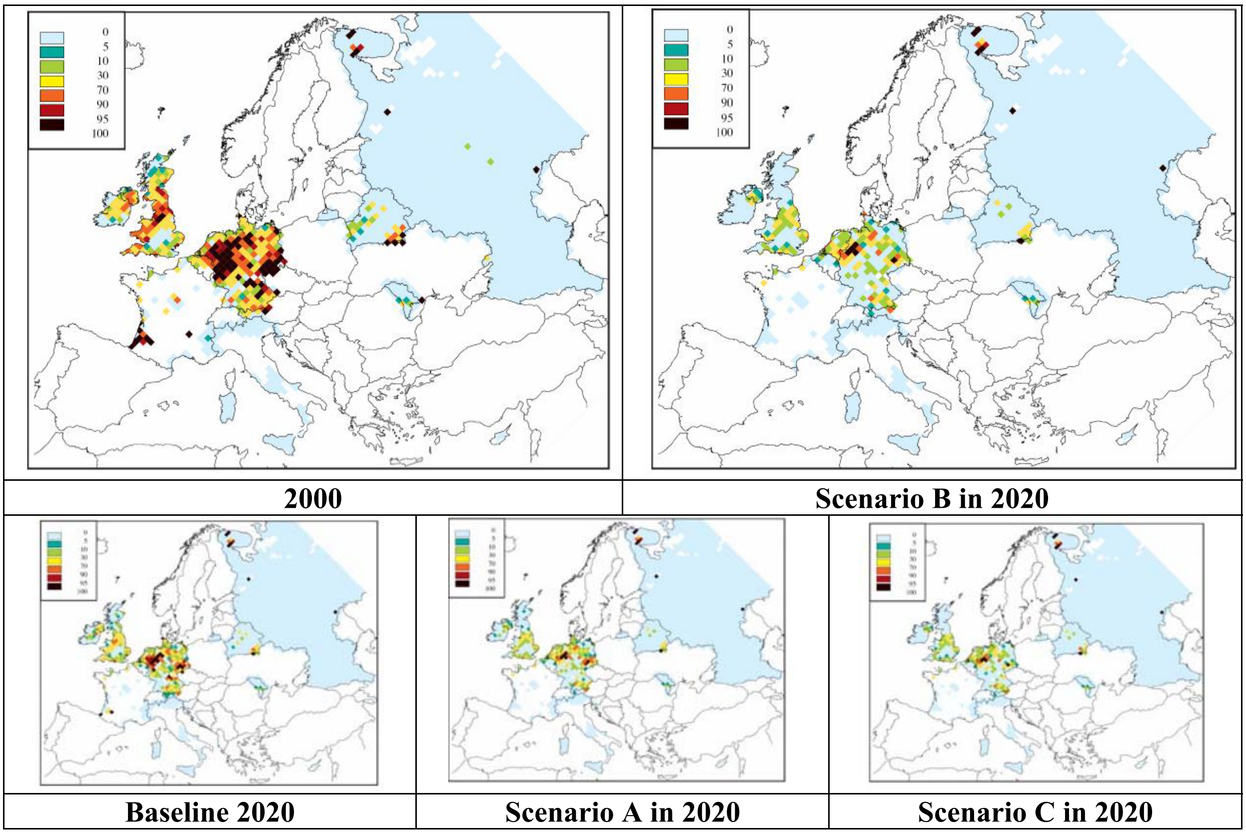
Scenario C in 2020

Note: Calculation results are based on the meteorological conditions of 1997, using ecosystem-specific deposition to forests.

5.7.2. *Acid deposition to semi-natural ecosystems*

The area of semi-natural ecosystems receiving acid deposition above the critical load is estimated only some Member States (Figure 20) due to a lack of information on critical loads for many countries. In the Member States where information is available the area of semi-natural ecosystems receiving acid deposition above the critical load is estimated to decrease by 80% in 2020 under the present policies. Under Scenario B the area would be further reduced by about 3,000 km^2 in these Member States. In Scenario A, the semi-natural ecosystems receiving deposition above critical load is estimated to be about 1,000 km^2 higher.

Figure 20: Percentage of the area of semi-natural ecosystems receiving acid deposition above the critical loads for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020

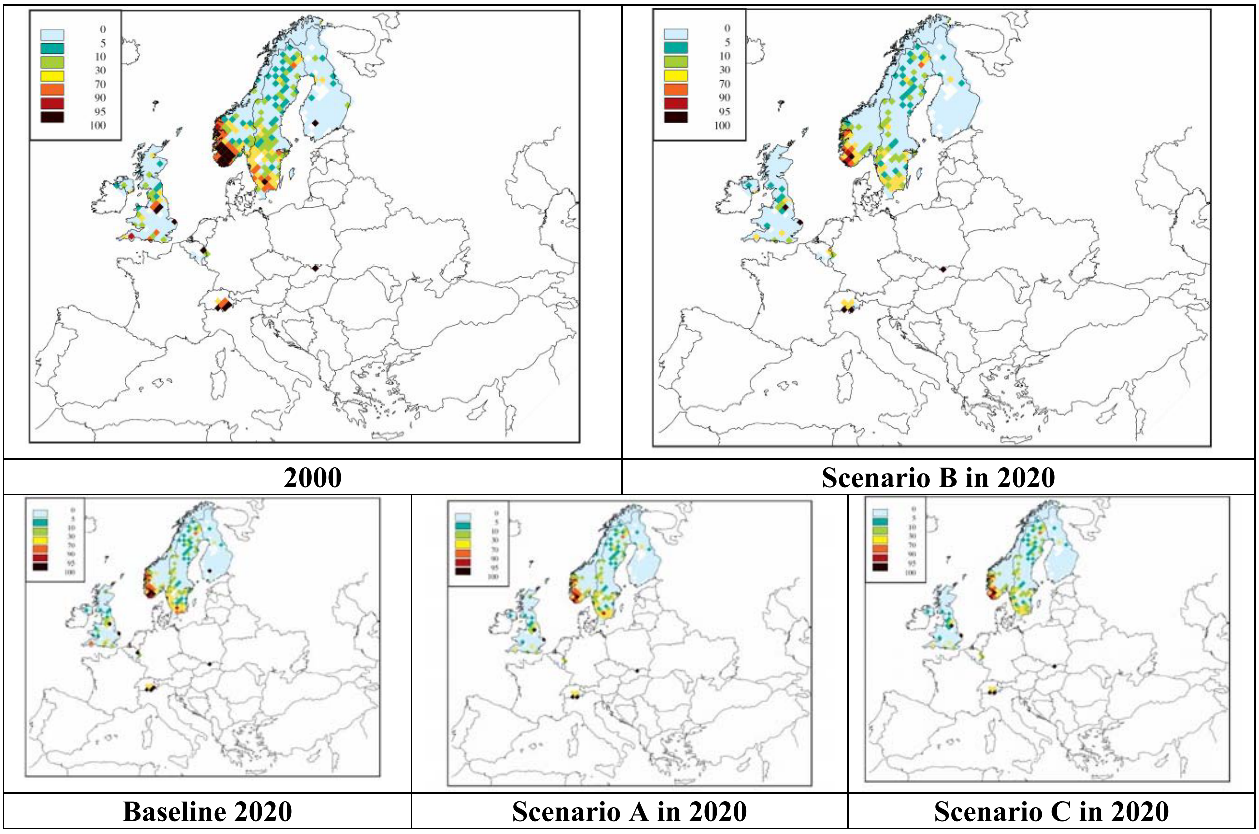


Source: RAINS. Note: Calculation results are based on the meteorological conditions of 1997, using ecosystem-specific deposition.

5.7.3. *Acid deposition to freshwater bodies*

The area of freshwater ecosystems in these EU Member States receiving a deposition of acid above the critical load is estimated to decrease by about 40% or 13,000 km^2 to about 19,000 km^2 under Scenario B between the years 2000 and 2020 (Figure 21). Under Scenario A the reduction would be about 1,000 km^2 less and under Scenario C about 1,000 km^2 more.

Figure 21: Percentage of freshwater ecosystems area receiving acid deposition above the critical loads for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020



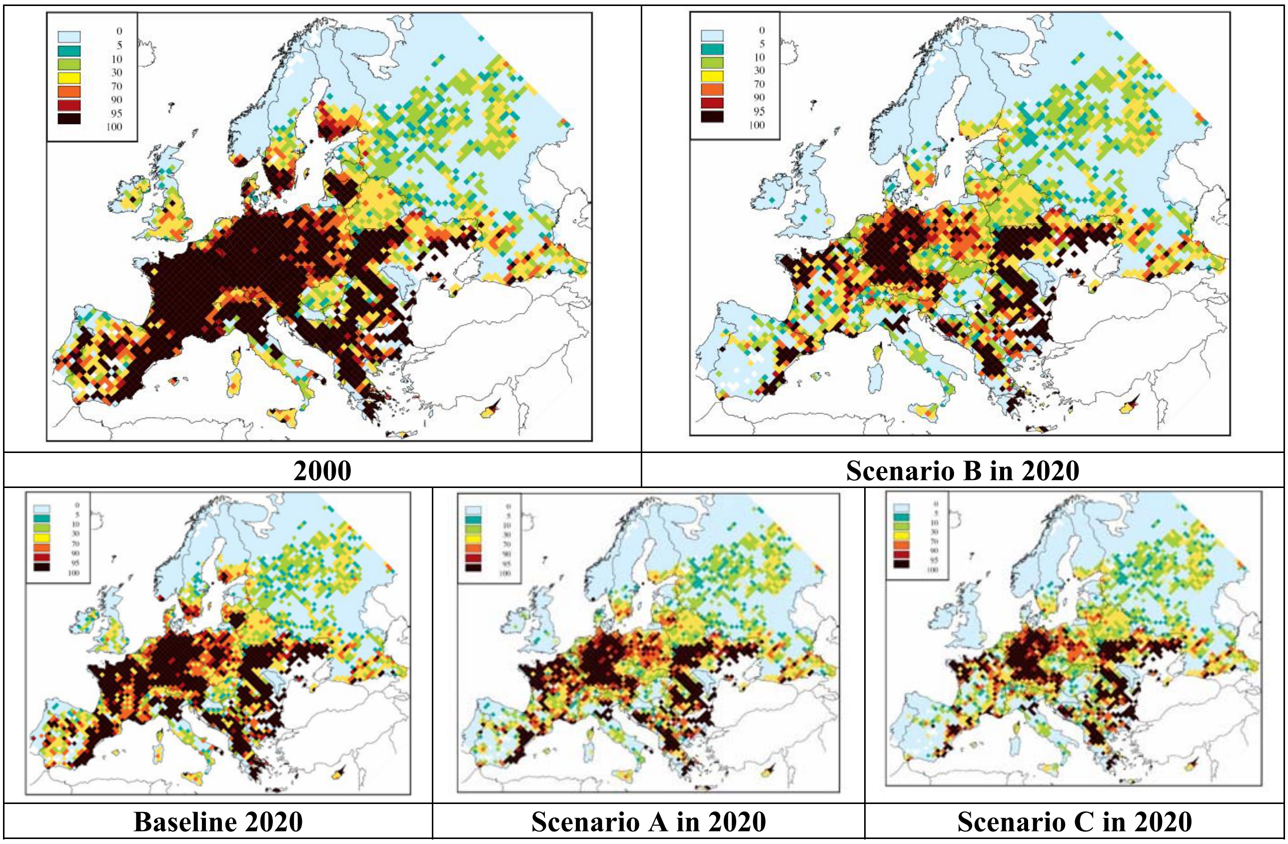
Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997, using ecosystem-specific deposition.

5.7.4. *Excess nitrogen deposition*

Emissions of nitrogen-containing pollutants, such as ammonia and nitrogen oxides, are eventually deposited on the ground in various forms of nutrient nitrogen and hence contribute to eutrophication of ecosystems, such as forests and fresh waters. In the present assessment deposition of nutrient nitrogen to the sea has not been assessed.

The present nitrogen deposition widely exceed the critical loads over large areas of the EU corresponding to about 733,000 km^2 in 2000 and down to about 590,000 in 2020 under present policies. Scenario B would reduce the area with excess deposition of nitrogen above the critical load by a further 215,000 km^2, but substantial and severe eutrophication problems would remain in many Member States (22). Under the low ambition scenario, an area about 50,000 km^2 less would be protected and under Scenario C an additional area about 28,000 km^2 would be protected as compared to Scenario B.

Figure 22: Percentage of total ecosystems area receiving nitrogen deposition above the critical loads for eutrophication for the emissions for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020



Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997, using grid-average deposition.

Information from the literature provides insight into the types of effect that could occur, but there is still no sound basis at present for further quantification impacts and valuation of impacts on different types of ecosystems. Therefore this Impact Assessment does not go further in quantifying ecological impacts outside of agriculture, other than simply using the results from RAINS in terms of critical load. However, as the omission of monetised ecosystem benefits may trigger a significant bias towards underestimation of total benefits, further research will be undertaken.

5.7.5. Other non-health effects

Ozone is recognised as the most serious regional air pollutant problem for the agricultural sector in Europe at the present time. Ozone affects vegetation by impeding growth, and hence reducing crop yield. Dose response functions are available for only a few crops and species of natural vegetation, since only a few have been studied.[85] The impact of ozone is concentrated in the growing season, mainly May to August.

There are large differences in damage to crops throughout the EU, depending on agricultural activity, soil moisture and ozone concentration (Figure 23). The loss of wheat yield in the EU due to ozone is estimated at 8028 kilotonnes in 2000. Scenario B would reduce that ozone damage to about 2960 kilotonnes in 2020. The monetary valuation (Table 20) indicates that the overall damage to crops (mainly wheat yield loss) corresponds to some 2800 million euros in 2000 and about 1500 million euros in 2020 under present policies. Scenario B would reduce the damage to crops by a further 415 million euros in 2020.

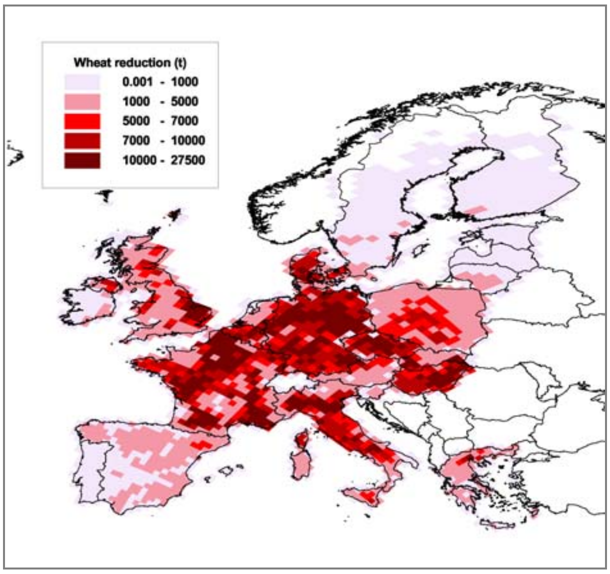
Table 20: Annual crop damage in EU-25 per in 2020 (millions of euros)

2000	Baseline 2020	Scenario A	Scenario B	Scenario C	MTFR
2799	1511	1179	1096	1052	621

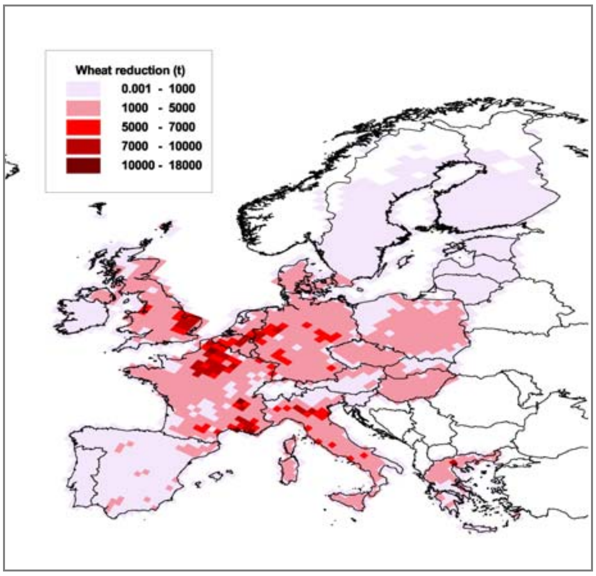
Source: CAFE Cost-Benefit Analysis

85 Impact on vegetation is closely related to the availability of soil water since the stomata, the small orifices on the leaves through which plants take up atmospheric gases like carbon dioxide and other gases, close in dry conditions.

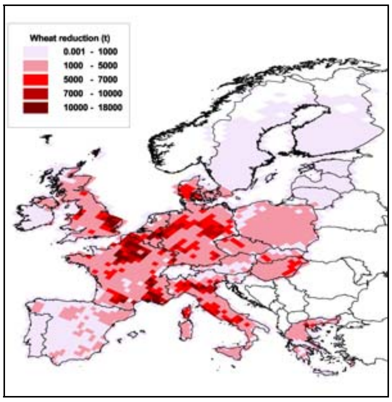
Figure 23: Reduction of impacts of ozone on wheat yields in EU-25 for emissions for the three ambition levels in 2020 – compared with 2000 and the baseline in 2020 (tonnes)



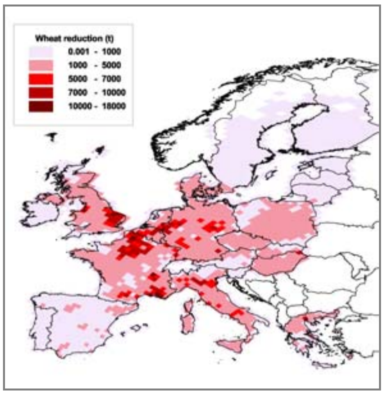
2000



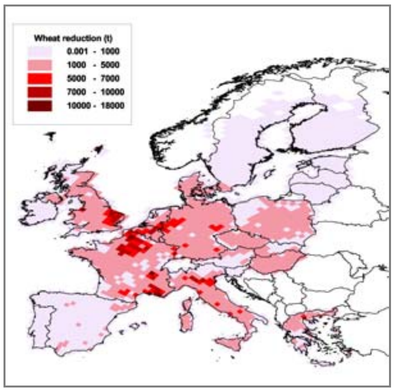
Scenario B in 2020



Baseline 2020



Scenario A in 2020



Scenario C in 2020

Source: CAFE Cost-Benefit Analysis. Note: Calculation results are based on the meteorological conditions of 1997.

5.8. Summary of costs and benefits

Table 21 summarises the results of the three ambition levels. The largest improvements are estimated to materialise from moving from the baseline to Scenario A. It seems evident that going beyond Scenario C is difficult to justify even if the overall health and environmental benefits are likely to be higher than the corresponding costs. The reason is that regarding the health impact from $PM_{2.5}$, the marginal benefits beyond Scenario C become lower than the marginal costs, and Scenario C already provides a substantial level of improvement for natural environment compared to the baseline by 2020..

Table 21: Alternative environmental ambition levels up to 2020

		Human health		Natural environment					
Ambition level	Cost of reduction (€bn)	Life Years Lost (million) due to $PM_{2.5}$	Premature deaths (thousands) due to $PM_{2.5}$ and ozone	Range in monetised health benefits[86] (€bn)	Ecosystem area exceeded acidification (000 km^2) Forests	Semi-natural	Fresh-water	Ecosystem area exceeded eutrophicat-ion (000 km^2)	Forest area exceeded ozone (000 km^2)
2000		3.62	370	-	243	24	31	733	827
Baseline 2020		2.47	293	-	119	8	22	590	764
Scenario A	5.9	1.97	237	37 – 120	67	4	19	426	699
Scenario B	10.7	1.87	225	45 – 146	59	3	18	375	671
Scenario C	14.9	1.81	219	49 – 160	55	3	17	347	652
MTFR	39.7	1.72	208	56 – 181	36	1	11	193	381

Note: In addition, the range of benefits for reduced damage to agricultural crops is between €0.3 and €0.5 billions for scenarios A, B and C. In addition, the damage to materials and buildings will be smaller. Ecosystem benefits have not been monetised but still need to be considered.

Moreover, before selecting which of the scenarios would be the most appropriate one for an interim objective, the assessment of wider economic and social impacts is required.

86 Lower value is based on the median of the value of a life year lost (VOLY) and higher value is based on mean value of a statistical life (VSL).

5.9. Wider economic and social impacts

5.9.1. Competitiveness

The Commission estimated the impacts of the interim objectives on competitiveness, using the GEM-E3 general equilibrium model,[87] described in more detail in Annex 2.

The model has already been used on a number of occasions for European policy support,[88] and allows analysis of impact on GDP, domestic production, employment and prices in Member States, and impact at sectoral level. It is not intended to convert results on either into a metric that could be combined directly with quantified impacts on health, agriculture, etc, to give a total benefit for comparison with the RAINS-generated cost information. Instead, the GEM-E3 provides an indication of the likely direction and magnitude of effects of air quality improvement policies in these areas (e.g. "Are these policies likely to have a significant effect on employment across Europe or in specific sectors or country?"). If macro-economic effects appear to be significant, it could be appropriate to adjust policies or to investigate further before finalising recommendations.

The costs of meeting Scenarios A, B and C were estimated at 0.04%, 0.08% and 0.12% of EU-25 GDP in 2020 respectively (See Table 22). Perhaps surprisingly, the Strategy has very little impact on overall employment. There are some sectoral shifts and some differences between Member States. However, they cancel each other out. There would be a small positive impact to exports. However, imports are estimated to grow more, mainly due to the terms of trade effect.

The general equilibrium analysis takes into account the possible economic effects of industrial relocation from the EU to other countries, be they industrial (e.g. the US and Japan) or developing (e.g. China and India), assuming that they do not introduce additional protection for the environment or human health from air pollution. In other words, the reductions in GDP and employment in the EU are partly driven by the assumption that environmental standards in non-EU countries are lower.

Another important caveat is that the measures from RAINS optimizations are implemented into GEM-E3 as end-of-pipe measures, without any kind of market-based instruments. This may lead to a considerable over-estimation of the impact. An alternative scenario including flexible mechanisms would be helpful, but it was not technically possible to run this scenario for this impact assessment.

Due to lack of detailed data, the modelling runs of GEM-E3 do not take into account efforts to improve the environment in non-EU industrialised and developing countries and the increased compliance costs and the demand for technologies to reduce air pollution. If developments in other countries could be modelled, the

[87] The model was developed with the support of the 5th Research Framework Programme and is currently being used to develop the modelling capability of the Commission in the IQ-TOOLS project under the 6th Framework Programme. The model and its database were updated in 2004 and extended to 8 New Member States (Hungary, Poland, Slovenia, Estonia, Latvia, Lithuania, Czech Republic and Slovakia).

[88] See Kouvaritakis, Paroussos, Van Regemorter: The macroeconomic evaluation of energy tax policies within the EU, with the GEM-E3-Europe model – Study for the European Commission DG TAXUD; http://europa.eu.int/comm/taxation_customs/resources/documents/economictaxation_final_report.pdf

impact of the Strategy on competitiveness in the EU would be mitigated, even reversed.

Table 22: Macroeconomic impacts of three scenarios compared to baseline in 2020

	Scenario A	Scenario B	Scenario C
Gross Domestic Product	-0.04%	-0.08%	-0.12%
(€ Billion)	*-5.616,5*	*-11.565,7*	*-17.115,8*
Private consumption	-0.06%	-0.13%	-0.20%
(€ Billion)	*-4.668,7*	*-9.679,9*	*-14.387,4*
Investment	-0.01%	-0.02%	-0.03%
(€ Billion)	*-292,2*	*-607,3*	*-881,7*
Final energy consumption	-0.12%	-0.24%	-0.34%
Exports to rest of the world	0.00%	0.01%	0.02%
Imports from rest of the world	0.04%	0.10%	0.15%
Employment	0.00%	0.00%	0.00%
(thousand jobs)	*-6.5*	*4.0*	*10.4*
Real wage rate	-0.04%	-0.09%	-0.14%
Relative consumer price	0.00%	0.00%	0.00%
Real interest rate	0.01%	0.02%	0.03%
Terms of trade	0.04%	0.08%	0.12%

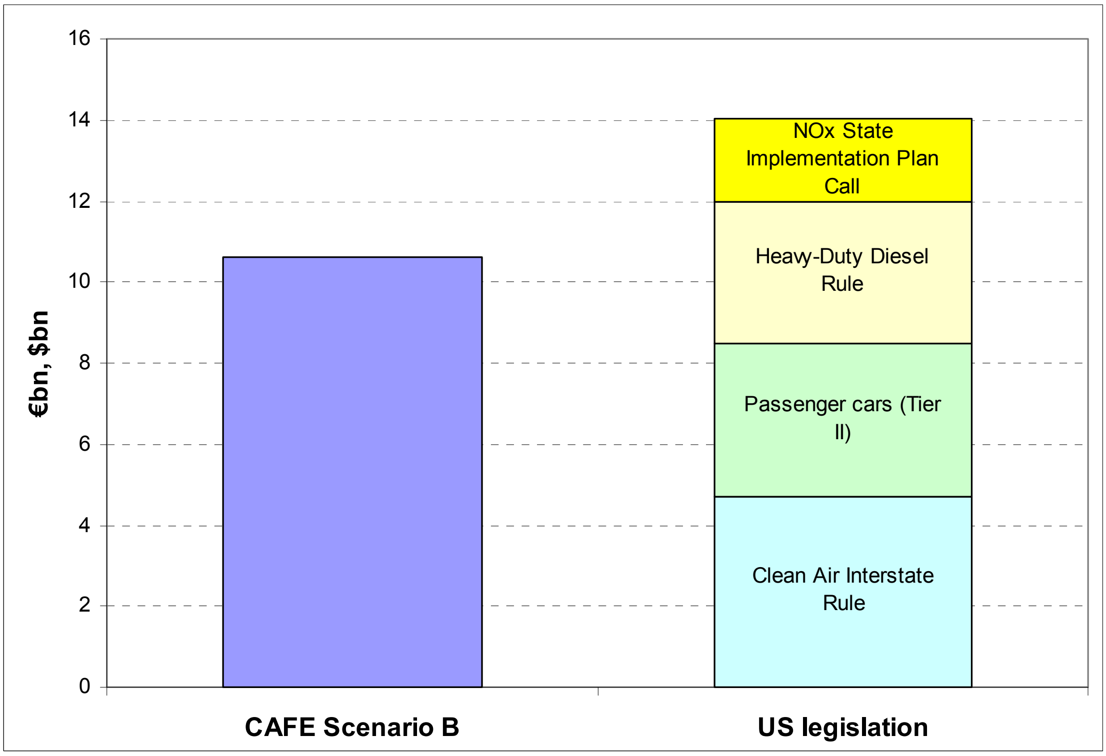
Source: GEM-E3

The analysis should be completed taking into consideration the fact that other countries are also taking important steps to reduce their air pollution, for instance on March 10, 2005, the US EPA issued the Clean Air Interstate Rule (***CAIR***) in 28 Eastern States covering a population of over 200 million. With an estimated annual compliance cost of $4.6 billion in the power plant sector, CAIR will reduce SO_2 emissions in all States by over 70% and NO_x emissions in the 28 Eastern States by over 60% from 2003 levels to 2020. In addition, the US has emission limit values for passenger cars that are much more stringent that current Euro 4 standards in the EU and the situation is the same for heavy duty vehicles.[89] These recent air pollution laws in the US cost policies cost about $12 billion per annum in 2020.

In addition, the NOx State Implementation Plan ***(SIP)*** addressed reduces significantly ozone non-attainment problems in North-Eastern US costing about $2 billion. However, some of these costs have been subsumed by CAIR and are thus not completely additional to the other policies. In sum, the recent air pollution laws -- which are comparable to the interim objectives in the Strategy -- are estimated to cost for transport and power generation sectors alone in the US between $12 and $14 billion per annum (Figure 24).

89 The recent vehicle emission standards are "Tier II Vehicle (Final Rule 12/1999)" and "Heavy-Duty Diesel Rule (Final Rule 12/2000)". Source: www.epa.gov

Figure 24: Annual cost of transport and other past rules that US EPA has promulgated – comparison with Scenario B



Source: US EPA and this impact assessment

Many developing countries are taking action against air pollution. For instance, China has started to take serious action against air pollution by requiring coal- fired power plants to reduce SO_2 and NO_x emissions and has adopted "Euro 3" emission limit values for light vehicles from 2007 onwards (see Box).

The positive impacts of reduced mortality and increased health status were not estimated in GEM-E3. For instance, improved air quality reduces the number of illnesses and thus not only increases the quality of life but also increases productivity. Reduction in sick days will directly contribute by increasing GDP. However, due to modelling uncertainties this feedback to the economy was not modelled, and thus the general equilibrium results overestimate the compliance costs in this respect.

Overall, the attainment of the interim objectives in the Strategy is not expected to impact European competitiveness relative to other developed countries such as the USA and Japan. This is because these countries have similar or more stringent air pollution policies in place. For instance, current vehicle emission standards in the USA and Japan are more stringent and their air quality limit values are similar.

Improving competitiveness and mitigating damage to human health and the environment can be complementary. The EU can gain advantages and create opportunities by focusing research and development on resource-efficient and less polluting technologies that other countries will eventually need to adopt. For instance, as some Member States in the 1980s introduced new technologies to reduce

NO_X and SO_2 emissions, they are now selling this technology to other parts of the world, including developing countries

Reducing SO_2 and NO_X emissions in China

In China, coal-fired power plants are subject to several regulations. China has had demanding air pollution emission standards since 2003. Almost all newly built and expanded coal-fired units must install flue gas desulphurization (FGD) units to meet these new standards. For old coal fired power plants, sulphur content of coal needs to be below 0.5% to meet the emission standard by 2010. China has also set a levy on SO_2 emissions which is currently 630 RMB (i.e. about €60) per tonne of SO_2, roughly equivalent to annualized cost of FGD installation in China[90]. China intends to set a similar levy also on NO_X emissions. Furthermore, all pure condensing type generators below 50 MW are phased out due to legislation.

Chinese government offers an incentive to electricity producers to install FGDs. The incentive varies regionally but the intent is to cover the operation costs of FGD. Chinese government is also monitoring the emissions through continuous emission monitoring systems to ensure full compliance to the emissions standards. Finally, China is looking carefully at the feasibility of starting a cap and trade programme to reduce air pollution.

Concerning mobile sources, new emission standards for heavy duty trucks entered into force in China from 1 July 2005. For light duty vehicles, the current emission limits in China are Euro 2, and all new light duty vehicles to need to meet Euro 3 standards from on 1 July 2005 in Beijing, and from 1 January 2007 in other parts of China. The feasibility of setting Euro 4 standards (which entered into force in the EU in 2005) for 2010 are currently being assessed.

In sum, the Chinese policies to reduce SO_2 and NO_x emissions are similar to those of the EU and trailing by about 5 to 10 years.

Source: Air Pollution Control Division, State Environmental Protection Administration of China.
For details, see: http://www.zhb.gov.cn/english/

The sectoral impacts are rather small (Table 23). The price increase remains small, which can be partly explained by the cost effectiveness of the measures. The equipment goods sectors benefit from increased demand for abatement equipment, while the consumer goods industry is projected to suffer from the decrease in consumption.

The reduction of SO2 and NO_X emissions from power generation sector will increase the power generation costs by (about 2) billion euros per annum in 2020. As production costs of power generation will be increased these costs will eventually be reflected in the wholesale price of power. In 2020, the predicted electricity consumption in the CAFE baseline was 3856 TWh. Thus, the estimated increase in electricity price is about 0.05 eurocents per kWh being about 1 % of the wholesale price of electricity. The exact increase will depend on the fuel mix in each Member State.

90 For comparison, in Galicia (Spain), there is a levy of up to €42 per tonne of SO_2 while in Denmark the levy for power plants is €2670 per tonne of SO_2. In the US the price of SO_2 in their emission trading market has been between €50 and €200 per tonne of SO_2.

The thematic strategy will also benefit the agricultural sector. This is because the reduced ozone concentrations will increase agricultural productivity. It has been estimated that the monetary value alone of increase crop (wheat) production due to lower ozone concentrations will be about 0.5 billion euros (check) per annum.

Table 23: Sectoral impact on production at air pollution scenarios (% difference compared to the baseline in 2020)

	Scenario A	Scenario B	Scenario C
Agriculture	-0.19%	-0.46%	-0.72%
Energy production	-0.09%	-0.16%	-0.23%
Ferrous and non-ferrous metals	-0.01%	0.03%	0.07%
Chemical products	-0.01%	-0.01%	0.01%
Other energy-intensive sectors	-0.05%	-0.03%	-0.01%
Electrical goods	0.12%	0.26%	0.40%
Transport equipment	-0.01%	-0.02%	-0.04%
Other equipment goods	0.24%	0.53%	0.81%
Consumer goods industries	-0.05%	-0.13%	-0.21%
Construction	-0.01%	-0.02%	-0.03%
Telecommunication services	0.02%	0.05%	0.08%
Transport	0.00%	0.02%	0.05%
Services of credit and insurances	0.01%	0.03%	0.04%
Other market services	-0.01%	-0.02%	-0.04%
Non market services	-0.01%	-0.02%	-0.03%

Source: GEM-E3

5.9.2. Social Impacts

The net effect on employment at EU-25 level was estimated to be neither positive nor negative. This is because of the fact that sectoral variations cancel each other out (Table 24). The demand decrease (except for the sectors delivering abatement equipment) has a negative effect on employment, but on the other hand the real wage decrease (to get an equilibrium on the labour market) and the energy price increase favour the demand for labour. These effects balance each other out.

GEM-E3 model projects that there would be no impact on households through variations in consumer prices (Table 22).

Regarding impact on social inclusion, CAFE cost-benefit analysis has been reviewing evidence on the following issues: (a) variation of exposure to air pollution amongst communities who rate poorly on social deprivation indices; (b) variation in susceptibility of different groups to health impacts (e.g. due to poorer nutrition or less access to health care). Quantitative assessment of links between air pollution impacts and social deprivation is not possible at this stage because of a lack of data, although there is evidence that air quality tends to be worse in poorer communities. Therefore the benefits of reduced air pollution are likely to favour proportionally more lower income groups and thus have a positive impact on social inclusion.

Table 24: Sectoral impact on employment at EU level in 2020

Variation vs. Baseline 2020	Scenario A		Scenario B		Scenario C	
EU-25	thousand	%	thousand	%	thousand	%
Agriculture	-25.1	-0.17%	-45.8	-0.31%	-73.8	-0.50%
Coal	-3.6	-1.51%	-4.8	-2.01%	-6.3	-2.64%
Oil	-0.4	-0.11%	-0.8	-0.23%	-0.9	-0.26%
Gas	-0.4	-0.12%	-1.1	-0.34%	-1.6	-0.49%
Electricity	4.2	0.22%	5.8	0.30%	9.2	0.48%
Ferrous and non-ferrous metals	0.4	0.01%	2.1	0.05%	4.7	0.11%
Chemical products	0.7	0.02%	1.1	0.03%	2.1	0.06%
Other energy intensive	-1.6	-0.02%	1.6	0.02%	4.7	0.06%
Electric goods	6.6	0.15%	12.7	0.29%	19.7	0.45%
Transport equipment	0.0	0.00%	0.0	0.00%	-0.5	-0.01%
Other equipment goods	30.6	0.35%	56.9	0.65%	86.6	0.99%
Consumer goods industries	-4.2	-0.03%	-8.4	-0.06%	-12.6	-0.09%
Construction	0.0	0.00%	0.0	0.00%	0.0	0.00%
Telecommunication services	0.7	0.02%	1.6	0.05%	2.6	0.08%
Transport	2.1	0.02%	5.2	0.05%	8.3	0.08%
Services of credit and insurances	2.6	0.04%	4.6	0.07%	6.6	0.10%
Other market services	-14.9	-0.02%	-22.4	-0.03%	-29.8	-0.04%
Non market services	-4.3	-0.01%	-4.3	-0.01%	-8.5	-0.02%
Total	**-6.5**	**0.00%**	4.0	**0.00%**	10.4	**0.00%**

Source: GEM-E3

Finally, job quality would improve together with needs for retraining in firms. For example, better technology is required to achieve reductions in vehicle or plant emissions and so this could correlate with a shift towards relatively hi-tech production.

5.9.3. *Impact on innovation and research*

Recent evidence indicates that in general high environmental standards coupled with a transparent and non-discriminatory regulatory framework constitute an engine for business opportunities and innovation.[91] Implementation of the Strategy is expected to lead to increased use of pollution control technologies to reduce air pollution. Historical evidence indicates that as a result of this capacity expansion, learning-by-doing will be enhanced.[92] Consequently, the costs of air pollution control technologies may be reduced by around 10 % every time capacity doubles. Global expansion of capacity in flue gas desulphurization and de-NO_x installations in the past entailed a reduction in investment costs by around 40% over the last 20 years.[93] The number of patents in response to air quality legislation increased in Germany, Japan and the US.

91 See SEC (2005) Main report: overall summary. Impact assessment and ex-ante evaluation for the proposal for the Council and European Parliament decisions on the 7th Framework Programme (EC and Euratom), Draft Commission Staff Working Paper, page 7.

92 No assumption on this basis is already included in the cost estimates.

93 See Rubin, E. (2004) Clean coal: oxymoron or bridge to a sustainable (low carbon) future? Paper presented at the workshop on Technology Policy for Climate Change Mitigation, 16 December Paris. Carnegie Mellon University, Pittsburgh, Pennsylvania.

The European Council of March 2003[94] reiterated the important contribution of environment policy to growth and employment, and also to the quality of life, in particular through the development of eco-innovation and eco-technology as well as the sustainable management of natural resources, which lead to the creation of new outlets and new jobs. In addition to its growth in the internal market, this sector has considerable export potential.

5.10. Other environmental impacts

Measures to further improve air quality will also help to achieve environmental improvements in other policy areas.

5.10.1. Climate

The CAFE programme has shown that there are additional benefits to be obtained by ensuring coherence between climate change and air pollution policies, particularly in respect of simultaneously reducing climate and air emissions in the most cost-effective way[95]. There are other specific linkages and overlaps.

– Tropospheric ozone is a regional and hemispheric air pollutant but also a direct greenhouse gas. It has increased in concentration to the point where ozone is now estimated to have provided the third largest increase in direct radiative forcing since the pre-industrial era.

– Control of methane and NO_x emissions on a hemispheric scale would reduce the formation of ozone considerably.

– Primary particulate matter in the form of "black/elementary carbon" has a deleterious effect on human health and contributes to atmospheric warming.

Thus reduced ozone concentrations and reduced emissions of particulate matter from road vehicles are 'no regrets' policies from the perspective of both climate change and air pollution policy.

There may, however, be instances where policies will conflict. For example, secondary aerosols formed in the atmosphere from emissions of sulphur dioxide and nitrogen oxides have a negative impact on human health, but significantly cool the atmosphere.

5.10.2. Links to soil and water quality

Atmospheric deposition of acidifying substances and nitrogen compounds contribute directly to potential critical load exceedences for terrestrial ecosystems and freshwater ecosystems. Soil processes and chemistry dictate the quantity and rate at which chemical substances leach from soil into groundwater and freshwater ecosystems. The critical load formulations for terrestrial and freshwater ecosystems are based upon soil properties and chemistry, and so there is a direct link between

94 Paragraph 19 of Presidency Conclusions – Brussels, 22 and 23 March 2005

95 GEM-E3 scenarios show that CO2 emissions in the EU-25 will be smaller in scenarios B and C than in the baseline.

atmospheric deposition, critical loads, soil quality and water quality. Ultimately, detailed soil and water quality monitoring can assist in assessing the effectiveness of air pollution policies.

Contributions to marine pollution come from direct anthropogenic riverine inputs but also from atmospheric deposition. It is possible to quantify the atmospheric inputs of pollutants such as nitrogen into European seas using the atmospheric modelling and integrated assessment modelling tools, which are used routinely in developing the thematic strategy on air pollution.

5.10.3. Sustainable use of resources and waste recycling

The measures undertaken in the framework of the Strategy will contribute to a reduced requirement to utilise natural resources (e.g. fossil fuels).

Increase recycling (thereby reducing other processes such as incineration) can reduce combustion-related air emissions.

5.10.4. Other

The recently adopted fourth daughter directive on ambient air quality addresses the atmospheric deposition of mercury. The directive will introduce methods to monitor such deposition as a means to understand better the behaviour of mercury in the environment. No amendments are proposed to this legislation. The proposed reductions in combustion-related emissions from fossil fuel burning will lead indirectly to lower emissions of mercury into the atmosphere.

These interim objectives will be used as the basis for the revision of the NEC Directive in 2006 as well as other legislation covering air pollution. To the extent sources not covered by the NEC directive are included, the percentages would be adjusted as appropriate.

6. MEASURES AND INSTRUMENTS

In order to meet the interim objectives of the Strategy, specific measures will need to be undertaken at Community and Member State level. The RAINS model is capable of providing a broad indication of the sectors and types of measures that could be addressed to attain particular emissions reductions for individual pollutants. These are discussed below, along with the measures that the Commission is currently considering proposing. It should be noted that the abatement measures included in the databases of the RAINS model are constantly updated with latest information. Thus, the measures below provide a snapshot of those measures that were particluarly cost-effective in the estimations made for the Thematic Strategy on Air Pollution.

6.1. Emission reduction measures for meeting the ambition level of the Strategy – indicative outcome of RAINS optimisation process

Tables 25a to 25e below show which sectors require additional measures (beyond those in the "current legislation" baseline) in order to achieve the cost-optimal emissions reductions associated with Scenario B. Broad categories of measures in individual sectors are also indicated, along with their contribution to the level of emissions reduction associated with each of the three scenarios.

6.1.1. SO_2 emissions

For emissions of SO_2, the use of low-sulphur heavy fuel oil (below 1%) is selected for most Member States, even for the lowest ambition level, while the use of flue gas desulphurisation depends more on country-specific conditions and the ambition level.

Table 25a: RAINS - sectoral contribution and measures to reduce SO_2 emissions

		Scenario A		Scenario B		Scenario C	
	Baseline emissions in 2020 (kt)	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25
Conversion	645	325	*30%*	356	*29%*	364	*27%*
Process	693	261	*24%*	294	*24%*	304	*23%*
Industry	435	191	*17%*	221	*18%*	229	*17%*
Power plants	606	199	*18%*	208	*17%*	240	*18%*
Transport	217	98	*9%*	130	*11%*	138	*10%*
Domestic	202	23	*2%*	24	*2%*	63	*5%*
Waste	7	4	*0%*	5	*0%*	5	*0%*
Total	**2805**	**1101**	**100%**	**1238**	**100%**	**1343**	**100%**

Measures identified by the RAINS model to bring about these emissions reductions are as follows:

- *Low-sulphur heavy fuel oil with sulphur content of less than 1% and gas oil with less than 0.1% for use for residential and commercial boilers*
- *Low-sulphur coal and fuel oil in industrial combustion, in-furnace sulphur control measures and flue gas desulphurisation in the higher ambition case*
- *Retrofitting flue gas desulphurisation for existing power generation plants and use of high-efficiency FGD in new plants*
- *In the fuel production sector, use of low-sulphur fuel oil, controls on refinery processes and flue gas desulphurisation for the higher ambition case*
- *Restrictions on open burning of agricultural and municipal wastes and better waste management*
- *Further reductions in the sulphur content of fuels used in national shipping/fishing*

6.1.2. NO_x emissions

Table 25b: RAINS - sectoral contribution and measures to reduce NO_x emissions

		Scenario A		Scenario A (without further road transport measures)		Scenario B		Scenario C	
	Baseline emissions in 2020 (kt)	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25
Transport	3013	388	32%	0	*0%*	388	24%	388	22%
Industry	660	284	23%	364	*32%*	375	24%	404	23%
Process	538	286	24%	314	*28%*	322	20%	327	18%
Power plants	801	112	9%	225	*20%*	271	17%	403	23%
Conversion	264	118	10%	154	*14%*	160	10%	174	10%
Domestic	596	10	1%	56	*5%*	63	4%	71	4%
Waste	15	12	1%	13	*1%*	13	1%	13	1%
Total	**5888**	**1210**	**100%**	**1125**	**100%**	**1592**	**100%**	**1780**	**100%**

Measures identified by the RAINS model to bring about these emissions reductions are as follows:

- *Primary combustion measures for oil-fired and gas-fired boilers in the residential and commercial sectors and also light fuel-fired boilers in the higher ambition case*
- *Primary combustion measures and selective non-catalytic reduction (SNCR) for industrial combustion for lower ambition levels, and selective catalytic reduction (SCR) in the higher ambition case*
- *For power plants, changes in primary combustion for all plants not required to fit SCR and fitting of SCR for all new coal- and oil-fired power plants*
- *In the fuel production sector, use of SNCR for all countries and all levels of ambition and SCR for the higher case in countries where NO_x reductions are required*
- *Restrictions on open burning of agricultural and municipal wastes and better waste management*
- *Further measures on light-duty and heavy-duty diesel vehicles*

Primary measures to reduce NO_x emissions from small combustion sources have been clearly identified as a cost-effective option by the RAINS model. For large combustion sources, Selective Non-Catalytic Reduction (SCNR) and Selective Catalytic Reduction have been identified as cost-effective depending on the level of environmental ambition chosen. Measures on all types of diesel vehicles have also been identified as cost-effective by the RAINS modelling, though will be subject to more detailed review in the impact assessment for future emission standards.

6.1.3. $PM_{2.5}$ emissions

For reducing emissions of particulate matter, particle filters of various types (electrostatic precipitators, cyclones or fabric filters) are clearly identified as being cost-effective in nearly all sectors. Particle filters for diesel road vehicles have also been identified as cost-effective measures, though will be subject to more detailed review in the impact assessment for future emission standards.

Table 25c: RAINS - sectoral contribution and measures to reduce $PM_{2.5}$ emissions

		Scenario A		Scenario A (without further road transport measures)		Scenario B		Scenario C	
	Baseline emissions in 2020 (kt)	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25
Domestic	319	70	*32%*	77	*39%*	104	*41%*	127	*45%*
Process	213	49	*22%*	49	*25%*	51	*20%*	52	*18%*
Waste	46	42	*19%*	42	*21%*	42	*16%*	42	*15%*
Power plants	55	22	*10%*	22	*11%*	22	*9%*	22	*8%*
Industry	12	4	*2%*	4	*2%*	4	*2%*	5	*2%*
Other	112	3	*2%*	3	*2%*	3	*1%*	3	*1%*
Conversion	15	3	*1%*	3	*1%*	3	*1%*	4	*1%*
Transport	194	26	*12%*	0	*0%*	26	*10%*	26	*9%*
Total	**964**	**218**	**100%**	**200**	**100%**	**255**	**100%**	**282**	**100%**

Measures identified by the RAINS model to bring about these emissions reductions are as follows:

- *Use of cyclones and fabric filter dedusters for boilers in the commercial sector and new residential boilers (mainly biomass-fired)*
- *Use of high-efficiency dedusters for all countries and all ambition levels and maintenance measures*
- *For power plants, use of high-efficiency dedusters for all existing and new boilers using solid fuels and good-housekeeping measures on oil-fired boilers (for all countries and all ambition levels). Likewise for the fuel production sector and coking plants*
- *Restrictions on open burning of agricultural and municipal wastes and better waste management*
- *Further measures on light-duty and heavy-duty diesel vehicles and low-sulphur fuels for national shipping and fishing vessels*

6.1.4. Ammonia emissions

With respect to reducing ammonia emissions under Scenario A, it is estimated that about 65% of the reduction comes from livestock activities, and the remaining 35% from reduced use of mineral fertiliser where urea is used more effectively and partly replaced by ammonium nitrate. This is the case for all ambition levels. The reduction from livestock is achieved primarily through greater use of low-ammonia manure-spreading methods, which produces 80 to 90% of the required reduction in this sector. The rest is achieved through the introduction of low-emission housing with integrated closed storage for poultry. Measures on poultry and fertiliser use appear cost-effective for all scenarios and for all countries. Use of low-ammonia manure-spreading methods is suggested by the model for dairy cows and pigs and to a lesser extent for other cattle and is required in about half of the EU Member States.

Under Scenario B about half of the required reduction is achieved from poultry and fertiliser use as described above. The additional reductions over Scenario A are achieved primarily through more extensive application of pig and cattle manures with low-ammonia spreading methods in most Member States. In addition, better storage of manure from pigs and cattle is suggested for some countries. Small reductions are also made through efficient application of sheep manure and better control of end-of-pipe emissions from the nitrogenous fertiliser industry. The latter measures feature for nearly half of the EU Member States.

Table 25d: RAINS - sectoral contribution and measures to reduce NH_3 emissions

		Scenario A		Scenario B		Scenario C	
	Baseline emissions in 2020 (kt)	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25
Poultry	470	267	*32%*	272	*25%*	274	*23%*
Fertiliser use	660	275	*33%*	275	*25%*	275	*23%*
Pigs	800	110	*13%*	183	*17%*	250	*21%*
Dairy cows	644	122	*15%*	174	*16%*	199	*16%*
Other cattle	676	44	*5%*	150	*14%*	161	*13%*
Processes	54	5	*1%*	26	*2%*	38	*3%*
Other animals	166	2	*0%*	7	*1%*	12	*1%*
Other	215	0	*0%*	0	*0%*	0	*0%*
Total	**3686**	**826**	**100%**	**1088**	**100%**	**1209**	**100%**

Measures identified by the RAINS model to bring about these emissions reductions are as follows:

- *Use of low-ammonia manure-spreading methods*
- *Better use of fertiliser and reduced emissions from fertiliser manufacture*
- *Better storage of animal wastes from the pig and cattle sectors*
- *Low-emission housing for the intensive poultry sector*
- *Low-nitrogen feedstuffs*

Scenario C requires an additional reduction of 120 kilotonnes of ammonia beyond Scenario B. The model indicates that this can be achieved through reduced nitrogen feeding strategies for pigs in about half of the Member States and greater use of low-ammonia manure-spreading methods for pigs and cattle (for nearly all Member States). Further small reductions are estimated for dairy cows using low-emission housing, low-ammonia application of sheep manures in most Member States, and further reductions in emissions from the fertiliser industry, although the latter do not amount to a major proportion of the overall emissions reductions required.

6.1.5. VOC emissions

The VOC emissions reduction requirements of the three scenarios vary between 700 and 1150 kilotonnes in 2020. Some 20 to 30% of that reduction is to come from process emissions (e.g. control of fugitive losses from the organic chemical industry) and a change in road asphalting methods (a move away from cutback to emulsion bitumen).

The other reductions can be achieved in paint application (coatings), solvent use and liquid fuel production. A Europe-wide ban on open burning of agricultural residues and more efficient combustion of biomass in the residential sector (see also the section on particulate matter) are also seen as cost-effective measures under Scenario B.

Between 10 and 15% of the reduction (for A and C respectively) is achieved from liquid fuel production, while under Scenarios A and B improved flaring and reduction of fugitive losses in refineries (process and storage) play a prominent role in most countries. Under Scenario B and especially Scenario C, reduction of emissions from oil and gas platforms in the UK makes a significant contribution (nearly half of the reduction achieved in the 'Conversion' sector under Scenario C). In addition, measures for gasoline distribution appear in countries that have not yet introduced such legislation (Stage II).

Table 25e: RAINS - sectoral contribution and measures to reduce VOC emissions

		Scenario A		Scenario B		Scenario C	
	Baseline emissions in 2020 (kt)	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25	Reduction from baseline (kt)	Share of total reduction in EU-25
Coatings	1008	183	27%	300	31%	335	29%
Solvents	1402	156	23%	246	25%	269	24%
Processes	880	219	32%	239	24%	244	21%
Conversion	763	80	12%	125	13%	167	15%
Waste	182	42	6%	51	5%	55	5%
Domestic	531	5	1%	16	2%	73	6%
Transport	1036	0	0%	0	0%	0	0%
Other	114	0	0%	0	0%	0	0%
Total	**5916**	**685**	**100%**	**977**	**100%**	**1143**	**100%**

Measures identified by the RAINS model to bring about these emissions reductions are as follows:

- *Control of fugitive emissions from the chemical industry*
- *Use of emulsified bitumen for road surfacing*
- *Decreased flaring and lower fugitive losses in fuel production processes*
- *Reduced solvent use in the coatings industry and decorative paints*
- *Restrictions on burning of agricultural residues and improved residential biomass burning*
- *Reduced solvent use and solvent content of products such as printing inks and adhesives*
- *End-of-pipe controls on solvent emissions from installations*

Further reduction of the solvent content of coatings used in industrial applications and for decorative purposes (or more widespread use of low-solvent or solvent-free coatings) still appears to be an attractive option in all scenarios. Under Scenario A about 25% of the total reduction is expected to come from the 'Coatings' sector with more than 70% achieved in industrial applications. However, these reductions appear in only a few countries. Under Scenario B more than half of the countries implement measures in this sector, achieving 30% of the total reduction required, again mostly from industrial application of paints, especially wood coatings. Under Scenario C a slightly larger reduction is expected, mostly from decorative paint applications (both professional and do-it-yourself) requiring more stringent control than under the 'Products Directive' – the so-called 'DECO Paint Directive'. This measure is one of the solutions for virtually all Member States.

The remaining 20% of the reduction required under all scenarios is in the 'solvent use' sector. This encompasses a large number of activities with installations of varying sizes. Therefore a mixture of alternative end-of-pipe measures (carbon adsorption and thermal incineration) is required to attain the estimated reductions. Especially under Scenario A a variety of sectors each contribute small amounts to the total reduction, while under Scenarios B and C further reductions in the printing sector, especially packaging, through substitution of adhesives and inks for low-solvent or solvent-free inputs, reduction in the solvent content of cleaning and dampening agents, and wider use of carbon adsorption play a significant role (up to 70% of reductions). Further reductions are expected in metal degreasing, industrial adhesive application and a number of smaller sectors.

6.2. Measures considered

Following the **indicative** results of the integrated assessment modelling associated with the three ambition scenarios, the measures described below will be considered by the Commission for further action. These measures are at different stages of consideration and development and generally each will need to be accompanied by a detailed and careful impact assessment before definitive proposals are put forward.

6.2.1. Revision of the National Emissions Ceilings Directive

The Commission will propose revised emission ceilings in the NECD in 2006 based upon the interim objectives identified in this strategy.

The natural instrument for setting emission reduction targets is the NEC Directive, which sets emission ceilings for each Member State. At the moment, this Directive sets emissions ceilings for four pollutants (NO_x, SO_2, NH_3 and VOC) which are to be attained by 2010 but leaves the Member States to decide how. This allows flexibility and reduces costs. The Commission will put forward a proposal to amend this Directive in 2006 and establish new ceilings that are consistent with the interim objectives of the Strategy and Scenario B. The Commission will also review other aspects of the NECD, including simplifying implementation and reporting, using emissions trading schemes and introducing targets for primary particulates

The integrated assessment modelling demonstrated that further measures need to be taken to reduce NO_x and SO_2 emissions from large combustion plant in the power production, industrial and fuel production sectors. Currently the Commission has no plans to amend the existing obligations in the Large Combustion Plant Directive (LCPD) which regulates large boilers with a thermal rating in excess of 50 MWh. However, the Commission will, *inter alia,* pursue the option of introducing regional (including regional transboundary) emissions trading for NO_x and SO_2 when revising the NEC Directive in 2006. This would permit individual plants to trade emissions reductions that go beyond current LCPD limits.

6.2.2. *Revision of vehicle emissions limits*

As specified in Directive 98/69/EC, the “Euro 4” emission limits entered into force for cars and other light-duty vehicles on 1 January 2005. Given the continuing health risks posed by PM and ozone, a number of Member States have announced that they intend to give tax incentives for vehicles that meet even tighter limit values. In this situation, and driven by a desire to prevent fragmentation of the internal market, the

Commission has put forward a framework for fiscal incentives for cleaner diesel vehicles[96] to go beyond the current Euro 4 standard for diesel cars. The integrated assessment modelling shows that further measures on diesel particulates from light-duty and heavy-duty diesel vehicles may be warranted. The Commission will put forward a proposal later in 2005 to revise downwards the current Euro 4 emissions limits for light-duty diesel vehicles. These new limits will be in line with the Commission's previous framework for fiscal incentives, but will be accompanied by a separate impact assessment.

New vehicle emission standards and Nitrogen dioxide

Two ambient air quality standards exist for nitrogen dioxide (NO_2) which enter into force on 1 January 2010. The first is a maximum hourly concentration of 200µgm-3 (not to be exceeded more than 18 times per calendar year) and the second, and probably the most stringent, is a maximum annual average concentration of 40µgm-3.

High temperature combustion results in the emission of a mix of nitrogen oxides (NO_X) in the form of nitric oxide (NO) and nitrogen dioxide. Nitrogen dioxide can also be formed from the atmospheric oxidation of nitric oxide. The amount of directly emitted nitrogen dioxide depends upon the particular combustion conditions such as temperature and oxygen content of the fuel-air mixture.

The concentration of nitrogen dioxide in air that is measured at a particular air quality monitoring station will be influenced by the magnitude of nitrogen dioxide emissions nearby and by the amount of nitric oxide that can be converted locally in the vicinity of the sampling point. This latter contribution depends upon the local availability of oxidants in the air such as ozone. Road vehicles contribute significantly to emissions of nitrogen oxides and to the measured concentrations of nitrogen dioxide in urban areas. Historically, nitric oxide comprised around 90% of the NO_X mixture emitted from road vehicles.

There are currently exceedences of the air quality limit values for nitrogen dioxide in urban areas. Moreover, preliminary indications show that exceedences will remain in 2010 when the limit values enter into force even though emissions of nitrogen oxides are decreasing as a result of European vehicle exhaust standards. In this context, a cause of concern is the increasing proportion of directly emitted nitrogen dioxide[97]. This is because of three factors. First, diesel vehicles comprise an increasing fraction of the vehicle fleet and diesel vehicles emit a greater proportion of nitrogen dioxide. Second, some diesel particulate filters actively convert nitric oxide to nitrogen dioxide in order to destroy soot particles, thereby increasing the proportion of nitrogen dioxide. Thirdly, the proportion of nitrogen dioxide increases in slow moving traffic.

The reported results from the DEFRA study above may have implications for future European vehicle emission standards. More specifically, emission limit values for total NO_X may need to be modified so as to (1) reflect better the proportion emitted as nitrogen dioxide and (2) contribute to attainment of Community air quality objectives for nitrogen dioxide.

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96 SEC(2005) 43 of 12 January 2005 http://www.europa.eu.int/comm/enterprise/automotive/pagesbackground/pollutant_emission/sec_2005_43.pdf

97 "Nitrogen dioxide in the United Kingdom, prepared for the Department for Environment, Food and Rural Affairs by the Air Quality Expert Group, March 2004. http://www.defra.gov.uk/environment/airquality/aqeg

As specified in Directive 88/77/EC, the "Euro 5" emission limit values for heavy-duty vehicles will enter into force from October 2008**.** A proposal for further tightening of the emissions from heavy-duty vehicles will be put forward by the Commission shortly after the proposal for Euro 5 standards for cars and light-duty vehicles.

6.2.3. Emissions from small-scale combustion installations

The integrated assessment modelling demonstrated the potential of measures to reduce $PM_{2.5}$ emissions in the residential and commercial combustion sector, particularly in respect of residential biomass combustion. High-efficiency dedusters were also cost-effective for use in the industrial combustion sector.

Small combustion plants are an increasingly important source of emissions, but they are not regulated at Community level. For industrial combustion sources below 50 MWh the Commission will assess whether it is appropriate to extend the scope of the IPPC Directive when it is reviewed in 2006. Harmonised technical standards will also be developed for domestic combustion appliances and associated fuels, including coal and biomass. Inefficient biomass combustion can emit relatively high amounts of particulate matter and methane, thus diminishing the positive contribution made by biomass as a renewable source. Therefore efforts should be made to ensure that biomass is incinerated under optimal conditions.

Efforts could be also be made to shift away from the use of coal and other solid fossil fuels for domestic heating, particularly in the most polluted areas. In the case of low-income households, the Commission will consider how Community funds could be used to help promote such a shift and cleaner combustion methods, without excluding cleaner use of coal.

More efficient use of energy, greater use of renewable fuels and better use of natural resources can all help to reduce emissions of harmful particulate matter as well as mitigating the impacts of climate change and addressing concerns over the security of energy supplies. To that end, if feasible, small residential and commercial buildings could be included in an extended directive on energy efficiency.

6.2.4. VOC emissions from refuelling of passenger cars

The Commission will examine the scope for, and cost-effectiveness of, Community action to reduce emissions from the refuelling of cars at service stations ("Stage II"). If appropriate, a legislative proposal will be developed in early 2006.

6.2.5. NO_x and SO_2 emissions from ships in European seas

Unless action is taken, emissions of sulphur dioxide and nitrogen oxides from ships in EU seas are projected to be greater than all land-based emissions in 2020. Action is needed, but shipping is a global industry and clearly global solutions are preferable, particularly as the Law of the Sea[98] imposes limits on what can be regulated on a regional or national basis. Mindful of these constraints, the Commission has already taken action on ship emissions, adopting an EU strategy

98 United Nations Convention on the Law of the Sea, to which the Community is a Party.

accompanied by a proposal for a directive on sulphur in marine fuel.[99] The directive will set sulphur limits for fuels used in all EU seas and ports. It was finalised by the European Parliament in April 2005 and will be formally adopted later this year.

A scenario for ship emissions was developed, which applied to all ships irrespective of flag and in all EU seas. This included the existing legislation plus the implementation of relatively straightforward additional measures:

– International Maritime Organisation NO_x emission standards for all ships built since 2000 (as set out in the MARPOL Convention, Annex VI on air pollution);

– limits on marine fuel sulphur, as provided for in the abovementioned proposal for a directive, i.e. 1.5% sulphur fuel oil for all ships in the North Sea and the Baltic Sea; 1.5% sulphur fuel for all passenger ships in the other EU seas; 0.1% sulphur fuel for all ships at berth in ports;

– slide valve retrofit on all slow-speed engines installed before 2000 (later engines already have these) with costs below €50 per tonne of NO_x avoided;

– internal engine adjustments for all new engines after 2010.

Scenario B for all EU sources of air pollution was estimated with and without this package of measures on ship emissions. The additional cost of these measures for ships was estimated by the RAINS model at €28 million per annum. However, application of the measures for ships results in cost savings for land-based sources of €159 million per annum whilst maintaining the same level of environmental and health protection. Clearly, measures for ships can be very cost-effective in reducing emissions and result in net savings of €131 million per annum.

The Commission therefore intends to take the following action:

- pursue negotiations on stricter air emission standards for ships under Annex VI to the International Maritime Organisation's Marine Pollution Convention. The Council has called on the Commission to consider EU regulation for NO_x emissions if no tighter standards are agreed by 2006;[100]

- promote the use of shore-side electricity by developing guidelines and considering energy tax exemptions for ships using such facilities;

- ensure that low-emission operation is applied effectively as a criterion for EU funding (Marco Polo and Motorways of the Sea);

- examine the feasibility of using market-based instruments to promote low-emission shipping, including differentiated port dues in the context of the Commission's forthcoming proposal on maritime infrastructure charging;

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99 Communication from the Commission to the European Parliament and the Council on a European Union strategy to reduce atmospheric emissions from seagoing ships, COM(2002) 595.

100 Council conclusions of 23.12.2003 (16369/03).

- consider whether/how to incorporate international shipping when revising the NEC Directive.

6.3. Integration of air quality concerns into other sectors

6.3.1. Agriculture

Cattle farming, the pig and poultry sector and the use of mineral fertilisers account for the vast majority of ammonia emissions. The recent reform of the Common Agricultural Policy should bring about a reduction in ammonia emissions from agricultural sources following: (1) the removal of the link between financial support and the obligation to retain specific number of animals; (2) the removal of incentives towards intensification which will result in a reduction of mineral fertiliser use; and (3) the introduction of obligatory cross compliance with environmental directives as a condition for granting the full direct payments. Further improvements are also expected to result from an effective implementation of certain environmental Directives, such as the Nitrates Directive, [101] the IPPC Directive, the Environmental Impact Assessment Directive and the Water Framework Directive.

However, these improvements could be insufficient to meet the objectives of the Strategy. Given that nitrogen plays a role in several environmental problems, the Commission will pursue a coherent approach to nitrogen management consistent with the recent Nanjing Declaration[102]. Priority will be attached to measures and policies to reduce "excessive" nitrogen use in agriculture and which simultaneously address nitrates in water, and ammonia and nitrous oxide emissions to air. Such policies could address (1) the nitrogen content of animal feedstuffs; (2) excessive use of nitrogen fertilisers; and (3) the promotion of further research into the nitrogen cycle and its environmental implications.

In order to comply with existing and new emissions ceilings for ammonia when the NECD is revised in 2006, the Member States will have to prepare plans and programmes to demonstrate how they will meet these ceilings. The achievement of reduction objectives may require the development of national actions plans, including obligations applicable at farm level.

The current Rural Development Regulation and the Commission proposals for rural development for 2007-13 provide several possibilities to tackle ammonia emissions from agricultural sources. These include measures related to farm modernisation, meeting standards and agri-environment. The Commission urges the Member States to make full use of these measures. In particular, Member States can design agri-environment schemes which go beyond environmental legislative obligations and minimum requirements for fertiliser use identified in rural development programmes. These could also help towards a more effective compliance with the CLRTAP code of good farming practice.[103]

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101 Directive 91/676/EEC, OJ L 375, 31.12.1991, p.1.

102 3rd International nitrogen conference, October 2004 Nanjing China.

103 As required in Annex IX of the CLRTAP Gothenburg Protocol

6.3.2. Transport

In keeping with the commitments made in the White Paper on a common transport policy,[104] the Commission will further encourage shifts towards less polluting modes of transport, alternative fuels and the internalisation of externalities into transport costs. With regard to infrastructure charging, the Commission has already made proposals as regards the charges for the use of road transport infrastructure applicable to heavy vehicles (Eurovignette) and a common framework for all modes will follow. Other possible measures are presented below and these could be complemented by additional measures when the White Paper is reviewed in 2005".

6.3.2.1. Land transport

The Commission will be considering measures to reduce emissions such as:

- practical guidelines for differentiated charging according to air pollution damage and impacts in environmentally sensitive areas;

- mandatory inclusion of external energy and air pollution costs in public procurement decisions for vehicles and transport services;

- establishment of a common framework for designating low-emission zones.

Moreover, since older road vehicles cause disproportionate levels of pollution, Member States should consider retrofitting and scrapping schemes, particularly for public service vehicles, when drawing up plans and programmes to meet air quality objectives. In its thematic strategy on the urban environment, the Commission is exploring how best to help Member States and local authorities devise and implement sustainable urban transport plans which combine improvements in public transport with demand management in order to ensure a fair contribution of transport activities to the achievement of air quality, noise and climate change objectives".

6.3.2.2. Aviation

Measures offering potential synergies between climate change and air quality[105] will be discussed in a forthcoming communication on the use of economic instruments to reduce the climate change impact of aircraft.

6.3.3. Community Funds

Community funds could be used to support attainment of the environmental objectives described above, notably in connection with the development of sustainable transport systems, sustainable and cleaner energy supplies in urban areas, and for institutional capacity-building to allow more effective implementation of air pollution abatement measures.

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[104] COM(2001) 370 final, 12.9.2001.

[105] The impact of air transport on the air quality in the vicinity of transport is not limited to emissions from airplanes during taxi, take-off and landing, and should take into account those from ground based traffic induced by air transport (transport of passengers, staff and goods to/from airports; busses, trucks and service vehicles on runways)

6.4. Applying effective policy instruments

While preparing the Strategy, in 2004 the Commission, together with the CLRTAP, organised a Conference on Policy Instruments to Reduce Air Pollution. It concluded that both traditional regulation and market-based instruments could be applied successfully to reduce emissions of NO_x and SO_2. In practice, market-based instruments often build on the legislative basis, and are used together with direct regulation as part of policy packages. Recently EU Member States have used various types of market-based instruments affected by different sets of Community rules on taxes, State aid, emission trading and internal market considerations.

Since market-based instruments are still at the pilot stage and not yet applied routinely, experimentation with flexible instruments in the policy mix should be encouraged. Furthermore, additional *ex-post* evaluations of the instruments currently used should be carried out more systematically.

The Commission will propose legislation based on a clear long-term policy framework for air pollution, so that this is compatible with its other objectives, notably those of climate change. In this context, when considering instruments it will be particularly mindful to meet specific objectives. Economic instruments, including NO_x and SO_2 emissions trading both for fixed installations and for ships, are part of such considerations to ensure that the environmental objectives are met at the lowest cost and, thus, with minimum impact on competition. The Commission will analyse the scope for introducing such instruments, *inter alia* during revision of the NECD in 2006.

Looking at the legislation on specific sources, "averaging, banking and trading" schemes could perhaps be used as cost-effective policy instruments. The Commission has already proposed such instruments, first in 2000 for reducing air pollution from non-road machinery and then again in 2003 for phasing out fluorinated greenhouse gases from mobile air conditioners.[106]

Conference on Policy Instruments to Reduce Air Pollution

The Commission hosted a conference on policy instruments to reduce air pollution in Brussels on 11 and 12 November 2004 together with the CLRTAP Network of Experts on Benefits and Economic Instruments. The main objectives were:

(a) to bring together the latest research findings from practical applications of economic and other instruments to reduce air pollution in the EU and ECE countries;

(b) to give policy guidance for finalisation of the Thematic Strategy on Air Pollution; and

(c) to provide input for the forthcoming review of the 1999 Gothenburg Protocol, which will be formally initiated after the Protocol enters into force.

For details, see http://europa.eu.int/comm/environment/air/nebei_workshop/index.htm.

[106] COM(2000) 840 of 18.12.2000 and COM(2003) 492 of 11.8.2003.

7. IMPACT ASSESSMENT FOR DIRECTIVE ON "AMBIENT AIR QUALITY AND CLEANER AIR FOR EUROPE"

A proposal to revise substantially existing Community legislation on ambient air quality accompanies the Thematic Strategy on air pollution. An impact assessment is therefore required to support this proposal. However, rather than create a separate assessment with unnecessary duplication of work, the detailed assessment to support the specific options set out in the proposal has been included here. This is logical given that the same economic modelling framework has been used in both cases and given the transferability of results from the Thematic Strategy to the legislative proposal.

7.1. Better regulation: Streamlining current air quality legislation

In line with the general initiative to streamline existing legislation, the new proposal will aim at revision of (i) the first daughter directive on ambient air quality including the air quality framework directive (96/62/EC), (ii) the second and the third daughter directives (2000/69/EC, 2002/3/EC) and (iii) the Council Decision on the exchange of information related to air quality monitoring in general (97/101/EC). This would lead to one comprehensive Directive covering the abovementioned regulations. In doing this the new proposal will aim at some overall objectives such as:

- Condensing everything into a single legal act and removing obsolete provisions
- Bringing data provision, assessment and reporting into the 21st century
- Reforming and modernising what did not work well enough
- Updating limit values according to the latest science.

Implementation of the current directives would be improved and strengthened. A general provision on natural contributions would be included, so that Member States will be able to discount natural contributions to measured levels of pollutants as Member States have no power to tackle such sources.

In addition, there may be compliance problems in the short term with some ambient air quality standards. The Commission proposes to permit a delay for their attainment. This would be restricted to individual zones or agglomerations, provided a Member State can demonstrate objectively verifiable conditions (including strict compliance with certain Community legislation contributing to an improvement of air quality). As a *quid pro quo,* the Member State would have to develop and implement an air pollution abatement programme to ensure that the limit values are attained upon expiry of the extension. It has not been possible to quantify the impact of this proposal, which is a "safety valve" against unduly high abatement costs in exceptional situations. However, all reasonable measures need to have been taken. Thus, a delay of the attainment date can be regarded as a means of safeguarding against uncertainty between the models that predict air quality and the actual situation in specific locations in the EU.

Due to the proposed regulation, the $PM_{2.5}$ monitoring network needs to be expanded by an estimated 800-1200 stations, given that some 100 $PM_{2.5}$ monitoring stations already exist in the Community.[107] It should be noted that under current air quality legislation there is a requirement to monitor $PM_{2.5}$ concentrations.[108] Thus, the proposed regulation does not in itself increase the monitoring requirements. In other words, the Commission does not consider that the additional monitoring requirements increase the regulatory burden for Member States.

For transparency, the Commission has estimated the costs of establishing and running 1200 additional $PM_{2.5}$ monitoring stations, assuming that 1000 of them would use the existing monitoring infrastructure (Table 26). When modelling is also employed, it may be possible to reduce the required additional number of stations to about 800, with 700 of them using the existing monitoring infrastructure. This needs to be seen in a context where $PM_{2.5}$ will be subject to regulation from 2010 onwards following establishment of the percentage reduction in the average urban background concentrations of $PM_{2.5}$ for the period 2010 and 2020. Thus about half of the costs will be incurred from 2008 onwards as urban background monitoring of $PM_{2.5}$ needs to have been established. To assess progress towards compliance with the concentration cap in 2010, it is required that all $PM_{2.5}$ monitoring stations are in place at the time of transposition of the new Directive.

Table 26: Annualised investment and running costs of $PM_{2.5}$ compliance monitoring in EU-25 by 2010 (thousands of euros). Four options are explored: additional 800 or 1200 stations, with/without 500 SO_2 measurement replacement.

		Cost per station		Total	
	Stations	Option 1	Option 2	Option 1	Option 2
Additional $PM_{2.5}$ measurement points (no infrastructure needed)	700	9.3	5.2	6500	4500
Additional $PM_{2.5}$ measurement points (infrastructure needed)	100	11.8	7.7	1200	800
Total	**800**			**7700**	**5300**
Additional $PM_{2.5}$ measurement points (no infrastructure needed)	1000	9.3	5.2	9280	7250
Additional $PM_{2.5}$ measurement points (infrastructure needed)	200	11.8	7.7	2400	1550
Total	**1200**			**11600**	**8800**

Option 1: Assuming no replacement of SO_2 station monitoring
Option 2: Assuming that 500 SO_2 monitoring stations will be replaced by $PM_{2.5}$ monitoring

107 In comparison, there are about 1000 measurement points for PM_{10} in the EU-25.

108 Article 5 (2) of the 1st daughter directive states that "Member State shall ensure that measuring station to supply data on concentrations of $PM_{2.5}$ are installed and operated. Each Member State shall choose the number and siting of the stations at which $PM_{2.5}$ is to be monitored as representative of concentrations of $PM_{2.5}$ within that Member State." However no minimum requirement for the number of stations has been given, as was the case for PM_{10}.

One specific issue is that Member States seem to have an overcapacity of monitoring points on SO_2 at least when compared with the requirements of the current air quality legislation. Therefore, Table 23 also gives the estimates assuming that 500 monitoring points of SO_2 could be replaced by $PM_{2.5}$ monitoring stations.[109] While there would be no saving in investment costs, there would be a saving as far as recurrent costs (in particular labour costs) are concerned.

In sum, the Commission estimates that the annualised costs of running the additional $PM_{2.5}$ monitoring stations would be between €5.3 and €11.6 million, depending on what extent Member States employ modelling and replace SO_2 monitoring with $PM_{2.5}$ monitoring.

A general scheme for background monitoring will be integrated, following the approach introduced with the fourth daughter directive. It will build upon current monitoring requirements under the CLRTAP and will permit a greater use of models in the assessment of air quality which Member States are obliged to undertake. Thus, in the longer term, the Commission anticipates a shift towards greater use of modelling and less use of more expensive monitoring. In accordance with this general scheme, the current proposal will introduce a requirement for the background monitoring of $PM_{2.5}$ mass concentrations and chemical speciation. It is estimated that monitoring should take place at approximately 40 stations in the EU-25, with estimated annualized[110] investment and running costs of €1 million. It is considered that a minimum of 75% of stations will already be operational under the EMEP programme[111] or to meet the requirements of the fourth daughter directive.[112] New sampling equipment, increased station maintenance costs, labour and especially chemical analysis costs (estimated at an annual cost of €24.000 per station, assuming weekly measurements of major inorganics, elemental and organic carbon) contribute to the final estimate.

The reporting obligations based on the Exchange of Information Decision and under the air quality legislation (framework and daughter directives) will be amended in such a way that all information will eventually feed into a shared information system to be established under the INSPIRE directive when adopted.[113] The shared information system will be used for public information, for the state of environment assessments, and for checking compliance with the environmental objectives. The provisions for reporting will be prepared so as to allow a smooth shift towards future requirements under the INSPIRE Directive. It is also important to ensure that air

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109 Estimation of overcapacity explicitly refers only to comparison with the requirements of the European air quality legislation. Member States might have additional reasons to continue with monitoring. In addition, the geographical distribution of overcapacity is very non-uniform across EU-25. However, the continuation of certain monitoring programmes on ‘historical grounds’, rather than current and future information needs, has been acknowledged to have important potential to streamline environmental monitoring in general.

110 Throughout these estimates investment costs have been annualised using a 4% discount rate. The assumption is that measurement equipment will have a lifetime of 10 years.

111 Protocol on a European Monitoring and Evaluation Programme under the Convention on Long Range Transboundary Air Pollution (www.unece.org)

112 Directive 2004/107/EC OJ L23, 26.1.2005, p. 3 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

113 Proposal for a Directive of the European Parliament and of the Council establishing an infrastructure for spatial information in the Community (INSPIRE) COM(2004) 516 final, SEC (2004) 980.

quality assessment - required to be performed throughout the territory of the Member State - will be made available in the geo-referenced format. This would enable efficient GIS tools to be used for further assessments at European scale, and for enhanced public information. This shared information system is expected to reduce the administrative burden upon the Member States in terms of reducing the numbers of reports that have to be prepared and transmitted to the Commission. Only data needs to be made available, simplifying the tasks of Member States while providing information to citizens faster.

7.2. Health advice

Exposure to particulate matter in ambient air is associated with various impacts on health.

- Increase in lower respiratory symptoms
- Reduction in lung function in children
- Increase in chronic obstructive pulmonary disease
- Reduction in lung function in adults
- Reduction in life expectancy, owing mainly to cardiopulmonary mortality and probably to lung cancer

As previously described, particles can be classified according to their aerodynamic diameter so that, for example, PM_{10} and $PM_{2.5}$ refer to all particles with a diameter less than 10 microns (µm) and 2.5 microns respectively. Fine particulates are those of less than $PM_{2.5}$ while coarse particulates are those in the $PM_{10-2.5}$ fraction. Current Community legislation (Directive 1999/30/EC) has established daily and annual limit values for PM_{10} which came into force on 1 January 2005. The daily limit value is set at $50 \mu g/m^3$ as a 24-hour average not to be exceeded more than 35 times per calendar year. Annual average concentrations shall not exceed $40 \mu g/m^3$. Directive 1999/30/EC also contains indicative limit values for PM_{10} to be attained by 1 January 2010. However, these values would need to be confirmed by the Institutions before becoming legally binding.

In the Summary of its Systematic Review of Health Aspects of Air Pollution in Europe, the WHO commented that[114]

"*Many studies have found that fine particles have serious effects on health, such as increases in mortality rates and in emergency hospital admissions for cardiovascular and respiratory reasons. Thus there is good reason to reduce exposure to such particles. Coarse particles seem to have effects on, for example, hospital admissions for respiratory illness, but their effect on mortality is less clear. Nevertheless, there is sufficient concern to consider reducing exposure to coarse particles as well as to fine particles. Up to now, coarse and fine particles have been evaluated and regulated together, as the focus has been on* PM_{10}*. However, the two types have different sources and may have different effects, and tend to be poorly correlated in*

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114 Systematic Review of Health Aspects of Air Pollution *in Europe*, WHO Regional Office for Europe, June 2004, www.euro.who.int

the air. The systematic review therefore recommended that consideration be given to assessing and controlling coarse as well as fine PM".

The Commission services consulted the Scientific Committee on Health and Environmental Risks (***SCHER***) on some specific questions related to air pollution that had not been addressed in the WHO project "Systematic review of air pollution health aspects in Europe". On 18 March 2005, SCHER adopted its response (see Box). The SCHER specifically stated that there is increasing epidemiological evidence that exposure to $PM_{2.5}$ may be associated with adverse health effects especially in susceptible populations and vulnerable groups. The SCHER also pointed to the fact that at present there is no European study on the exposure-response function for long-term $PM_{2.5}$ effects, so setting a $PM_{2.5}$ standard could be surrounded with uncertainties. However, SCHER acknowledges the evidence of $PM_{2,5}$ as health relevant. It further implied that health impact assessments should be based on the best available exposure response function, *i.e.* derived from U.S. studies to take account of uncertainties.

The Working Group on PM was established as an integral part of the CAFE programme and endorsed by the CAFE Steering Group to assist the European Commission in reviewing Directive 1999/30/EC. The Working Group included experts from Member States, industry, NGOs, CLRTAP, the World Health Organization and the European Environment Agency. In the light of WHO health-related findings, the PM Working Group recommended[115] the use of $PM_{2.5}$ rather than PM_{10} as the principal metric for assessing exposure to particulate matter. The Group further recommended that a $PM_{2.5}$ limit should replace the existing PM_{10} limit values and that the PM_{10} indicative limit values should be reclassified as target values to help control the coarse fraction, $PM_{2.5\text{-}10}$.

[115] http://europa.eu.int/comm/environment/air/cafe/pdf/working_groups/2nd_position_paper_pm.pdf

Opinion of the Scientific Committee on Health and Environmental Risks

This opinion is publicly available at the following web site:
http://europa.eu.int/comm/health/ph_risk/committees/04_scher_opinions_en.htm

"The SCHER agrees, that there is increasing epidemiological evidence that acute $PM_{2.5}$ exposure is related to adverse health effects, especially in susceptible and vulnerable groups. However, there is currently a lack of knowledge on the exposure-response function for health effects in Europe following chronic exposure. Thus the establishment of an air quality standard based upon $PM_{2.5}$ will be surrounded with uncertainties. The major sources of $PM_{2.5}$ and thus the toxicity are different between the USA and Europe, and even within Europe due to different type and level of economic activities. These differences may influence the exposure-response function used for HIA.

The SCHER acknowledges the evidence for $PM_{2.5}$ as health-relevant. The importance of separate guidelines for coarse and fine particles are evident and presently there is not sufficient health effects-related evidence available to exclude PM_{10} as a standard and to favour $PM_{2.5}$ mass based standard as the sole health-relevant indicator. Similar to the US EPA recommendation, SCHER proposes to continue monitoring both $PM_{2.5}$, and the PM_{10}-$PM_{2.5}$ fraction, as the relative importance of these two fractions has not been fully resolved. The sources and chemical composition of coarse and fine particles differ and thus the toxicity of the particles. Furthermore, the ratio between the two types of particles differs greatly with the season and geographic regions.

The SCHER recommends that, in the absence of a robust European E-R function, the E-R function based upon the US data could in general be used for HIA. However, there are uncertainties in applying non-European exposure-response functions to European populations, e.g., differences in monitoring protocols and PM sources. Differences in the sources of PM may have consequences for the toxicity and therefore for the exposure – response function.

The SCHER acknowledges the large difference in toxicity of particles depending on their size and chemical composition. This toxicity will furthermore depend on the source of the particles, and will furthermore show both seasonal and geographical variations. A systematic approach to study the toxicity as a function of these variables is warranted. Integration of toxicological information into epidemiological studies will facilitate the establishment of more accurate exposure-response function.

The SCHER is aware of the emerging evidence of variation in susceptibility, acquired or genetic, to ambient $PM_{2.5}$. This variation should be considered when establishing the air quality guidance values in order to protect the most susceptible and vulnerable groups.

A critical level for ozone to protect the vegetation in Europe has been established within the convention on LRTAP. New experimental studies suggest that a new AOT40 value should be introduced to protect forests from harmful effects due to ozone."

7.3. Reducing exposure to $PM_{2.5}$

The overwhelming evidence that the Commission has received can be summarised as follows: (i) there is a health risk from $PM_{2.5}$, (ii) $PM_{2.5}$ is a better metric to represent the general health risks of ambient levels of particulate matter, and (iii) the risk from the coarse fraction (between $PM_{2.5}$ and PM_{10}) cannot be ignored. Given this, the Commission has considered the following options for revising the existing provisions of Directive 1999/30/EC in relation to particulate matter in ambient air. **Each option assumes that the existing limit values for PM_{10} remain in force.**

(1) Introduce a legally binding requirement to reduce annual average concentrations of $PM_{2.5}$ throughout the territories of the Member States by a given percentage in 2020 relative to the position in 2010 as determined by three years of monitoring of $PM_{2.5}$ concentrations in urban background locations;

(2) Introduce a target to reduce annual average concentrations of $PM_{2.5}$ throughout the territories of the Member States by a given percentage in 2020 relative to the position in 2010 as determined by three years of monitoring of $PM_{2.5}$ concentrations in urban background locations;

(3) Replace the indicative limit values for PM_{10} for the year 2010 by a legally binding limit value for annual average concentrations of $PM_{2.5}$ to be attained by 2010. Such a limit value would be designed to offer a <u>high degree of protection</u> to the population and would apply everywhere in the territory of the Member States;

(4) Replace the indicative limit values for PM_{10} for the year 2010 by a legally binding "cap" for annual average concentrations of $PM_{2.5}$ to be attained by 2010. Such a "cap" or ceiling would be designed to limit <u>unduly high risks</u> to the population and would apply everywhere in the territory of the Member States;

(5) Replace the indicative limit values for PM_{10} for the year 2010 by a non-binding target for the annual average concentrations of $PM_{2.5}$ to be attained as far as possible by 2010. Such a target value would be numerically identical to the limit value in option (2) above;

(6) Do nothing, i.e. do not introduce any requirement to reduce human exposure to $PM_{2.5}$.

Given the overwhelming health evidence and risks from exposure to $PM_{2.5}$, option (6) of doing nothing is not a viable option. This would also be inconsistent with the Community policy on the environment, which urges a precautionary approach.

Integrated assessment modelling has shown that options (1) and (2) are the most cost-effective ways of reducing exposure to $PM_{2.5}$ and also provide the highest net benefits. This has been shown for both the "European-wide" optimisation of health impacts and optimisations using a "gap-closure" approach in each individual grid-cell of the European modelling domain. The difference between (1) and (2) is in the legal characteristic of the requirement to reduce the average urban background concentration. While in (1) the requirement would be legally binding in (2) it would be attained where possible.

Options (1) and (2) is demonstrably more cost-effective than option (3). This is because a stringent limit value has its greatest impact in locations where concentrations are highest. However, these are not necessarily places where most people are exposed to $PM_{2.5}$. Due to the nature of the risk posed by $PM_{2.5}$ (i.e. no threshold for effects) it is more cost-effective to reduce concentrations where most people are exposed. This approach would maximise health benefits for given abatement expenditure. In addition, the uncertainties identified by the SCHER associated with setting a stringent air quality limit value would argue against using this approach at this stage.

One of the underlying principles of current Community policy on ambient air quality is that of equity and guaranteeing a minimum standard of air quality for all EU citizens. One way to achieve this is to implement either option (3), (4) or (5). The main difference between option (3) and (4) would be in the severity of the chosen level. In option (4) the cap would prevent only unduly high risks for the population. Such a cap would be set at a relatively high level to reflect the underlying uncertainties in the use of US risk estimates and to ensure that attainment remained technically feasible. It would not be intended to provide high levels of protection that are associated with the traditional limit value concept embodied in current ambient air quality legislation. Given that the cap is meant to limit unduly high risks to the population, it is appropriate that such a cap apply everywhere in the territory of the Member States. Option (5) would be non-binding, would not necessarily oblige the Member States to take the appropriate measures to reduce levels and so would not guarantee minimum standards of air quality in practice.

The Commission considered whether there would be enough data to determine a legally binding reduction requirement. On balance, it considered it prudent to opt for a target value and establish in 2008-2010 the $PM_{2.5}$ concentrations in urban background stations. Based on these measurements, plus improved modelling data up to 2020, the Commission will propose the legally binding obligation to reduce average urban background concentrations.

Based on the above considerations, the Commission proposes a combination of options (2) and (4) i.e. a relative reduction in annual average concentrations to be attained by 2020 relative to 2010 and a general cap for $PM_{2.5}$ annual average concentrations to be attained in 2010. The current limit values for PM_{10} will remain unchanged whereas the Stage II indicative limit values for 2010 will not be given legal force.

7.3.1. *Reducing average urban background concentration of $PM_{2.5}$*

The Commission proposes that Member States have first a concentration reduction target, which would be later converted to a legal obligation – based on a review of the Directive on Ambiant Air Quality and Cleaner Air for Europe – to reduce the average urban $PM_{2.5}$ background level. The Commission proposes to set this requirement so as to be consistent within the range set between Scenarios A and B.

The Commission has analysed the projected urban background concentration of $PM_{2.5}$ in about 150 European cities. Table 27 shows the projected reductions in $PM_{2.5}$ concentrations between 2010 and 2020 in the baseline and Scenarios A and B.

Table 27: Illustrative calculation of the reduction of annual average urban background concentration of $PM_{2.5}$ in Member States in 2020 compared with the $PM_{2.5}$ concentrations in 2010*)

Member State	Baseline	Scenario A	Scenario B
Austria	6%	17%	20%
Belgium	7%	18%	20%
Cyprus**)	..	..	..
Czech Republic	10%	27%	30%
Denmark	4%	15%	19%
Estonia	7%	13%	15%
Finland	5%	8%	10%
France	7%	19%	22%
Germany	5%	21%	25%
Greece***)	5%	9%	10%
Hungary	8%	27%	30%
Ireland	8%	20%	23%
Italy	11%	20%	23%
Latvia	4%	11%	12%
Lithuania	6%	15%	17%
Luxembourg**)	..	..	..
Malta**)	..	..	..
Netherlands	4%	21%	25%
Poland	14%	29%	30%
Portugal	2%	8%	15%
Slovakia	7%	24%	26%
Slovenia	6%	18%	21%
Spain	5%	13%	15%
Sweden	5%	12%	14%
United Kingdom	7%	24%	27%
EU-25 average	**7%**	**19%**	**22%**

Note: The index has been calculated assuming all Member States comply with the NECD in 2010. EU-25 average is an arithmetic (unweighted) average.
**) Reduced concentrations due to the Directive to reduce sulphur content in marine fuels has not been include. Thus, underestimates to some extent.*
***) No data available*
****) Large transboundary transport from Acceding Countries explains mainly why the reduction percentage is relatively small.*
Source: Calculations for the Commission by RAINS

In Scenario B the unweighted average concentration reduction would be 22% (the population weithted average is somewhat higher, i.e. 25%) while the reduction in Scenario A is a couple of percentage points lower. It can be seen that it would not be cost-effective or equitable to propose that all cities in Member States be required to reduce their concentrations by the same percentage. However, due to data uncertainties, the Commission considers it prudent to wait first for good monitoring data for 2008-2010 before establishing the exact reduction requirement. Therefore, the Commission proposes first to have only a concentration reduction target of 20% for each Member State between 2010 and 2020.

It should be noted that Table 27 uses modelled concentrations of $PM_{2.5}$. Current modelling capabilities are restricted which means that certain contributions to observed concentrations cannot be predicted. These include, for example, the contribution derived from the reactions of organic compounds in the atmosphere and natural contributions from windblown dust, sand and sea spray are not included in the model. As such, an amount of approximately 5µg/m^3 must be added to the modelled results to reflect these additional contributions and the likely increased concentrations in urban hotspots.

The RAINS model demonstrated a clear relationship between the expected reduction in average $PM_{2.5}$ concentrations in urban areas between 2010 and 2020 compared with the estimated concentration in each city in 2010. Although there was significant scatter in the data, a clear trend can be seen which showed that the more polluted the city in 2010 the greater will be the expected reduction in $PM_{2.5}$ concentrations during the 2010-2020 period. Table 28 shows the percentage reductions in average concentrations of $PM_{2.5}$ between 2010 to 2020 for different levels of ambition for the protection of health. This varies from 1.0% to 2.1% per 1µg/m^3 of $PM_{2.5}$ expected in 2010 for the baseline and the MTFR scenarios respectively.

Table 28: Slopes of the relationship between modelled concentrations in European cities in 2010 and the percentage reduction in these concentrations between 2010 and 2020

	Baseline 2020	Scenario A	Scenario B	Scenario C	MTFR
Percentage reduction between 2010 and 2020 per 1µg/m^3 of $PM_{2.5}$ expected in 2010	1.0%	1.6%	1.8%	1.9%	2.1%

Source: Calculations for the Commission by RAINS.

The percentage reductions in Table 28 are based upon modelling results for a limited set of cities and are necessarily subject to uncertainties. These can be mitigated in several ways when developing a proposal for legislation. Firstly, any obligation for Member States to reduce $PM_{2.5}$ concentrations should apply to concentrations measured in urban areas averaged over real measurements undertaken in cities throughout their territory. Hence the national average concentration measured in 2010 will not be unduly influenced by elevated concentrations in particular cities. Secondly, Member States will have flexibility to reduce concentrations where it is most cost effective as there would be no strict requirement to reduce by the same amount in each and every city. Thirdly, one could cap the maximum reduction that any particular Member State will have to undertake. Finally, one can recognise that where air quality is already good it is unfair to require further improvements. These principles need to be as embodied in the relationship to be used to determine each Member State's concentration reduction target for urban $PM_{2.5}$ concentrations.

Specifically, the Commission proposes that the following elements comprise the approach:

1. Each Member State will be obliged to reduce the average urban background concentration of $PM_{2.5}$ in their territory by a specific percentage between 2010 and 2020 measured in the baseline concentration to be established for 2010.

2. This requirement would not be applied for very low concentrations. A lower threshold is proposed to be at 7 $\mu g/m^3$. Below this there is no obligation to reduce average levels further. This would prevent "cleaning of clean air";

3. It could be possible to introduce also an upper threshold above which there is no further increase in the percentage reduction.

Therefore, the Commission proposes a two-stage approach to establish the requirement to reduce annual average urban background concentration of $PM_{2.5}$ between 2010 and 2020. Firstly, each Member State would have a concentration reduction target of 20% for $PM_{2.5}$ between 2010 and 2020. Secondly, once the monitoring data of $PM_{2.5}$ for 2008-2010 are available, the concentration reduction target would be differentiated by Member State and made legally binding for the period between 2010 and 2020.

7.3.2. Establishing a concentration cap for $PM_{2.5}$

In order to establish a concentration cap the Commission used the following methodology: Based upon existing measurements, one can extrapolate or estimate the concentration of $PM_{2.5}$ for a given level of PM_{10}. Given that the air quality limit value for PM_{10} entered into force on 1 January 2005 the Commission proposes to set the cap at a level that is no more stringent that the equivalent limit value for PM_{10}. The current air quality limit value for PM_{10} is 40 $\mu g/m^3$ as an annual average. This would be equivalent to between 24 and 28 $\mu g/m^3$ for $PM_{2.5}$. The current daily (24-hour) air quality limit value for PM_{10} is 50 $\mu g/m^3$ and it cannot be exceeded by more than 35 days. It is estimated that this is a slightly more stringent requirement than the annual limit value, i.e. below 24 to 28 $\mu g/m^3$ for $PM_{2.5}$.

In sum, given the current limit values for PM_{10} and the view that the cap for $PM_{2.5}$ should not itself set a more stringent requirement to Member States, **the Commission proposes that the concentration cap for $PM_{2.5}$ in 2010 be 25 $\mu g/m^3$ expressed as annual average.**

7.4. Costs and benefits of the proposal for regulating $PM_{2.5}$

To calculate the costs of this strategic approach requires a subset of the costs of Scenarios A and B of the Strategy. It is further assumed that by 2010 all Member States will comply with the annual air quality limit values for PM_{10}. As the $PM_{2.5}$ cap for 2010 has been set at a level equivalent to the current PM_{10} annul limit value, this implies that the $PM_{2.5}$ limit value will also be attained with no additional costs. If for some reason a Member State is not able to comply with the limit value, but has made every effort to do so, the proposed "safety valve" (i.e. Article 20 of the proposed

"Directive for Ambient Air Quality and Cleaner Air for Europe") would mean, that for the purposes of compliance costs in 2015 or 2020, no additional cost is estimated.

Given the assumptions outlined above, Table 29 shows the annual compliance costs for $PM_{2.5}$ in 2020. The annual costs of the proposed new approach to regulate $PM_{2.5}$ are estimated to be €2.6 billion lower in 2020 than the total compliance costs of Scenario B of the Strategy (see Table 11 in Chapter 5).

Table 29: Illustrative calculation of compliance costs to reduce the average urban background concentration of $PM_{2.5}$ by an average of 25% (Scenario B) or 20% (Scenario A) in the EU-25 between 2010 and 2020 (million euros)

	Cost of Scenario B with $PM_{2.5}$ only	Cost of Scenario A with $PM_{2.5}$ only	Incremental cost from Scenario A to B
Austria	144.3	66.5	77.8
Belgium	460.6	178	282.6
Cyprus	3.4	3.4	0.0
Czech Republic	169.6	104.4	65.2
Denmark	69.5	28.5	41.0
Estonia	8.8	7.2	1.6
Finland	28.1	22.9	5.2
France	1588.7	874.4	714.3
Germany	1821.5	986.3	835.2
Greece	49.3	42.5	6.8
Hungary	179.5	118.1	61.4
Ireland	44.6	37.5	7.1
Italy	772.8	534.1	238.7
Latvia	11.5	10.3	1.2
Lithuania	39.4	18.1	21.3
Luxembourg	21.5	16.7	4.8
Malta	1.5	1.3	0.2
Netherlands	417.6	200.9	216.7
Poland	603.5	560.8	42.7
Portugal	164.5	136.9	27.6
Slovakia	74.6	51.1	23.5
Slovenia	35.8	25	10.8
Spain	506.5	351.1	155.4
Sweden	87.8	25.7	62.1
UK	774.7	572.7	202.0
EU-25	**8079.6**	**4974.4**	**3105.2**

Source: RAINS

Cost of Scenario A with $PM_{2.5}$ only would be almost €1 billion or almost 20% lower than implementing Scenario A with all measures. The compliance cost of reaching this reduction requirement is likely to be between €5 and €8 billion per annum.

Table 30 gives the benefits of the reduction of $PM_{2.5}$ concentration in Member States assuming the reductions in concentrations to be compatible with Scenario B. Table 31 gives the cost/benefit ratios of Tables 29 and 30. Overall the health benefits of reaching the average concentration reduction by 25% in the EU are five times higher than costs when the lowest benefits are used as the basis for estimation. If the highest values were used the benefits would outweigh the costs 17 times. It is also important to see whether moving form Scenario A to Scenario B would bring additional benefits. This is also the case as the benefits of this are still at least 2.5 times higher than costs. However, in two Member States[116] in this incremental analysis the benefits are projected to be slightly lower than costs. However, overall, the benefits are still more than two times higher than costs for these Member States.

Table 30: Illustrative calculation of benefits from increased life expectancy and health of the reduced average urban background concentrations of $PM_{2.5}$ by an average of 25% in the EU-25 between 2010 and 2020 (based on Scenario B)

	VOLY (median)		VSL (median)		VOLY (mean)		VSL (mean)	
	Benefits	Incremental benefits	Benefits	Incremental benefits	Benefits	Incremental benefits	Benefits	Incremental benefits
Austria	730	145	1237	246	1366	272	2313	460
Belgium	1525	281	2581	475	2871	529	4843	892
Cyprus*)	6	1	8	2	11	2	15	3
Czech Rep.	1227	188	2185	336	2292	352	4105	630
Denmark	370	87	672	157	699	163	1269	297
Estonia	31	6	60	11	57	11	114	21
Finland	50	12	86	21	94	23	162	40
France	6435	1361	10288	2176	12148	2570	19219	4065
Germany	10719	2097	19703	3854	20166	3944	37232	7283
Greece	311	44	611	87	583	83	1158	165
Hungary	1452	163	2867	321	2711	304	5435	609
Ireland	213	43	300	61	400	81	551	112
Italy	4738	816	9393	1619	8889	1532	17844	3075
Latvia	108	18	155	27	200	34	285	49
Lithuania	112	15	278	37	209	28	536	71
Luxembourg	84	17	112	23	158	32	203	42
Malta	13	2	21	3	24	4	39	6
Netherlands	2714	525	4401	851	5114	989	8225	1591
Poland	4039	325	6816	548	7519	605	12710	1022
Portugal	484	229	885	419	906	429	1669	789
Slovakia	699	77	1154	127	1301	143	2147	236
Slovenia	198	39	358	70	369	72	673	132
Spain	1739	424	3099	756	3247	792	5818	1419
Sweden	247	56	421	96	465	106	791	180
UK	6442	1071	9894	1646	12099	2012	18355	3053
EU-25	**44685**	**8044**	**77586**	**13968**	**83902**	**15113**	**145712**	**26242**

Source: CAFE Cost-Benefit Analysis. *Note: Incremental benefit means the benefits that accrue when changing from Scenario A to B. VOLY/VSL median and mean are explained in Chapter 2*

*) *The negligible incremental cost data for Cyprus is probably inaccurate because of modelling uncertainties*

116 These were Lithuania and Sweden.

Table 31: Illustrative calculation of cost/benefit ratios from increased life expectancy and health of the reduced average urban background concentration of $PM_{2.5}$ by an average of 25% in the EU-25 between 2010 and 2020.

	VOLY (median)		VSL (median)		VOLY (mean)		VSL (mean)	
	Benefits	Incremental benefits	Benefits	Incremental benefits	Benefits	Incremental benefits	Benefits	Incremental benefits
	Costs	Incremental costs	Costs	Incremental costs	Costs	Incremental costs	Costs	Incremental costs
Austria	5.1	1.9	8.6	3.2	9.5	3.5	16.0	5.9
Belgium	3.3	1.0	5.6	1.7	6.2	1.9	10.5	3.2
Cyprus	1.7	*n.a.*	2.3	*n.a.*	3.2	*n.a.*	4.4	*n.a.*
Czech Rep.	7.2	2.9	12.9	5.2	13.5	5.4	24.2	9.7
Denmark	5.3	2.1	9.7	3.8	10.1	4.0	18.3	7.2
Estonia	3.5	3.7	6.9	6.7	6.5	6.7	13.0	12.8
Finland	1.8	2.3	3.1	4.0	3.3	4.4	5.8	7.7
France	4.1	1.9	6.5	3.0	7.6	3.6	12.1	5.7
Germany	5.9	2.5	10.8	4.6	11.1	4.7	20.4	8.7
Greece	6.3	6.5	12.4	12.8	11.8	12.2	23.5	24.3
Hungary	8.1	2.7	16.0	5.2	15.1	4.9	30.3	9.9
Ireland	4.8	6.1	6.7	8.6	9.0	11.5	12.4	15.8
Italy	6.1	3.4	12.2	6.8	11.5	6.4	23.1	12.9
Latvia	9.4	15.1	13.4	22.7	17.3	28.6	24.7	41.2
Lithuania	2.8	0.7	7.1	1.7	5.3	1.3	13.6	3.3
Luxembourg	3.9	3.6	5.2	4.8	7.3	6.7	9.4	8.8
Malta	8.7	10.5	14.1	15.8	16.1	21.1	26.2	31.6
Netherlands	6.5	2.4	10.5	3.9	12.2	4.6	19.7	7.3
Poland	6.7	7.6	11.3	12.8	12.5	14.2	21.1	23.9
Portugal	2.9	8.3	5.4	15.2	5.5	15.6	10.1	28.6
Slovakia	9.4	3.3	15.5	5.4	17.4	6.1	28.8	10.0
Slovenia	5.5	3.6	10.0	6.5	10.3	6.7	18.8	12.3
Spain	3.4	2.7	6.1	4.9	6.4	5.1	11.5	9.1
Sweden	2.8	0.9	4.8	1.5	5.3	1.7	9.0	2.9
UK	8.3	5.3	12.8	8.1	15.6	10.0	23.7	15.1
EU-25	**5.5**	**2.6**	**9.6**	**4.5**	**10.4**	**4.9**	**18.0**	**8.5**

Source: CAFE Cost-Benefit Analysis *Note: Incremental benefit means the benefits that accrue when changing from Scenario A to B. VOLY/VSL median and mean are explained in chapter 2.*

The social and other economic implications of the proposed cap and reduction in urban background concentration of $PM_{2.5}$ are very similar to those presented in Chapter 5. As the annual compliance cost for $PM_{2.5}$ is €2.6 billion (i.e. about 25%) less than the total compliance cost of the Strategy, the general equilibrium effects were modelled[117] only for $PM_{2.5}$ (Table 32).

117 Analysis of macroeconomic and competitiveness effects with GEM-E3 of CAFE Scenarios (AEAT, August, 2005)

Table 32: Illustrative calculation of macroeconomic impacts of Scenarios A and B – $PM_{2.5}$ only compared to baseline in 2020

Macroeconomic Aggregates EU-25	Scenario A for $PM_{2.5}$	Scenario B for $PM_{2.5}$
Gross Domestic Product	-0.03%	-0.06%
Employment	0.00%	0.00%
Private Consumption	-0.06%	-0.11%
Investment	-0.01%	-0.01%
Final Energy Consumption	-0.11%	-0.17%
Exports to RW	0.00%	0.02%
Imports	0.04%	0.09%
Real Wage Rate	-0.04%	-0.08%
Relative Consumer Price	0.00%	0.01%
Real Interest Rate	0.01%	0.02%
Terms of Trade	0.03%	0.05%

Source: GEM-E3

In summary, the Commission proposes a cap of 25 micrograms per cubic metre to be attained by 2010, and proposes that a concentration reduction target of 20% between 2010 and 2020, which would be converted – based on a review of the Directive on Ambiant Air Quality and Cleaner Air for Europe – to a legally binding reduction requirement once the monitoring data are available. The benefits of the proposal are estimated to be between €37 billion and €145 billion per annum in 2020. These are between 6 and 18 times higher than the estimated costs ranging between €5 and €8 billion per annum. (Table 33).

Table 33: Illustrative summary of the annual costs and benefits from increased life expectancy and health of the reduced average urban background concentration of $PM_{2.5}$ by 20% (Scenario A) of $PM_{2.5}$ and by 25% (Scenario B) in the EU-25 between 2010 and 2020 (billions of euros)

	Total costs and benefits		Incremental costs and benefits from Scenario A to B
	Scenario A	Scenario B	
Cost (€bn)	5.0	8.1	3.1
Benefits (€bn)			
VOLY (median)	36.7	44.7	8.0
VSL (median)	63.6	77.6	14.0
VOLY (mean)	68.8	83.9	15.1
VSL (mean)	119.5	145.7	26.2
Benefit/Cost ratio			
VOLY (median)	6.3	5.5	2.6
VSL (median)	11.7	9.6	4.5
VOLY (mean)	12.8	10.4	4.9
VSL (mean)	22.9	18.0	8.5

This conclusion is further strengthened by the fact that the incremental benefits between Scenarios A and B are between 3 and 9 times higher than the incremental costs. In other words, the impact of the proposed manner to regulate $PM_{2.5}$ on human health is clearly beneficial.

8. MONITORING AND EVALUATION

8.1. Evaluation and review of policies

Given the expected advances in our understanding of the adverse health and environmental impacts likely in the future, it is appropriate that the targets and policies described in this strategy be reviewed on an ongoing basis. Such reviews should also take account of advances in our knowledge of pollution abatement costs and assess retrospectively the effectiveness of existing measures. This Strategy will be reviewed in five year policy cycles and will feed into the final evaluation of the EAP. Ongoing assessment of policies will also continue on the basis of existing indicators and reported information. In the coming years, however, more work will be required to inform such a review.

The EEA and Eurostat have developed indicators to monitor the impacts of air emissions on human health and the environment. Long-term monitoring of environmental effects of air pollution will be undertaken in association with the UNECE Convention on Long-range Transboundary Air Pollution. Activities under CAFE will link with the established structures of the effects-oriented activities under the Convention in order to assist and support cooperation in monitoring and assessment activities. Monitoring, modelling, assessment and mapping will follow agreed methodologies and focus on status and trends in: forests, including soils and ground vegetation; (semi-)natural ecosystems and protected areas;[118] agricultural receptors; aquatic ecosystems including coastal and marine waters;[119] materials including cultural heritage. Eutrophication, acidification and ozone effects and their trends will be monitored; related biodiversity and effects of climate change will receive specific attention. The results of monitoring together with detailed reports on emissions and air quality from the Member States will provide the basis for assessing the effectiveness of Community and Member States´ policies.

To carry out the review effectively, the Commission needs to ensure that the scientific and economic knowledge is systematically collected, updated and analysed by the modelling tools that have been developed during the CAFE programme. Thus, it will make specific call for proposals in the Preparatory Action of the LIFE programme for this task.

8.2. Consultative arrangements

Following adoption of the Strategy, the next major task will be revision of the National Emissions Ceilings Directive and the ongoing implementation of air quality legislation. The institutional framework will need to be adapted accordingly.

The CAFE Steering Group, or a similar group, will continue to be the main forum for future stakeholder participation and consultation. In addition, a Working Group on "National Emission Ceilings and Policy Instruments" was created in May 2005 to help out with the technical work on revising the National Emissions Ceilings

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[118] Protected areas are not currently separately assessed under the Convention

[119] Coastal and marine waters are not currently monitored under the Convention

Directive. AQUILA[120] network of national reference laboratories, hosted by JRC, already now monitors implementation of the air quality directives with regard to quality of assessments of ambient air quality and assists the Commission in efforts of further harmonisation and better comparability of data between the Member States. Greater use is also likely to be made of the Regulatory Committee on air pollution particularly for monitoring and reporting on implementation of existing legislation. Data Exchange Group has been created in 2004, consisting of air quality data handling experts from the Member States and the EEA, which will assist in drafting of the Implementing provisions on reporting to be adopted through Comitology. The committee will also be used to coordinate Community views on technical issues, which may arise in international *fora*.

8.3. Research needs including financial implications

Community air pollution policy is built on robust scientific and technical knowledge and the first review of policies about five years will require new scientific and technological information on:

– Emission sources, atmospheric chemistry and pollutant dispersion, particularly on the hemispheric scale, and a better understanding of the origin of air pollutants to support policy development

– The effects of air pollution on health and the environment including the risks of nutrient nitrogen and the recovery of ecosystems

– The costs, effectiveness and benefits of measures actually deployed.

In addition, the structural and societal changes occurring in Europe after the accession of new Member States will need to be addressed, including changes in trade and industry and the enlarged trans-European networks.

8.3.1. Emission sources, atmospheric chemistry and pollutant dispersion

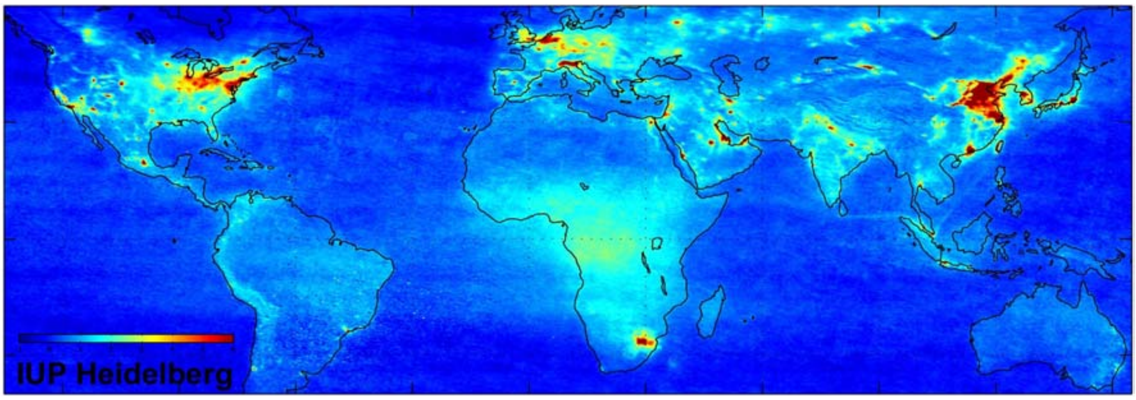
The emissions of air pollutants depend on both the activities in the different sectors of society and the emission control technologies applied. Emissions may change over time, particularly as a result of global changes in trade and industry. To some extent these changes are covered by the present analysis and policy development, but there is a need to improve understanding. Research needs should be geared towards better integration of multi-scale processes from the global scale to the local scale. Such integrated approaches should be included into the framework of risk analysis and risk management, and capable of addressing changes in important sectors like transport, trade, energy and agriculture. Methods to account for emerging technologies also need to be developed.

Looking at global scale, it needs to be recognised that air pollution is emitted in different parts of the world. As an example, a global atmospheric map of nitrogen dioxide pollution has been produced by the European European Space Agency (ESA), based on the recent observations of Envisat, the world's largest satellite for

[120] http://ies.jrc.cec.eu.int/Units/eh/Projects/Aquila/

environmental monitoring (Figure 25). It shows there are three main sources of NO_2 emissions in the Northern hemisphere: Europe, Northern America and Eastern Asia.

Figure 25: Global atmospheric map of nitrogen dioxide pollution, 2003-2004



Source: ESA (http://www.esa.int/esaEO/SEM340NKPZD_index_0.html)

There is an urgent need to better understand how the changing patterns of emissions over the Northern hemisphere impact on air pollution over Europe through the transcontinental transport of air pollutants such as particulate matter, ozone, persistent organic pollutants, and mercury. The UNECE has recently set up a Task Force on hemispheric transport of air pollution, jointly chaired by the Commission and the US EPA. One objective of the Task Force is to assess scientific knowledge on the hemispheric transport of particulate matter of natural and anthropogenic origin, and the chemical and physical characteristics of these emissions.

Long-term monitoring of environmental effects of air pollution will be undertaken in association with the UNECE Convention on Long-range Transboundary Air Pollution. Activities will link to the established structures of the effects-oriented activities under the Convention in order to assist and support cooperation in monitoring and assessment activities. Monitoring, modelling, assessment and mapping will follow agreed methodologies and focus on status and trends in: forests including soils and ground vegetation; (semi-)natural ecosystems and protected areas[121]; agricultural receptors; aquatic ecosystems including coastal and marine waters[122]; materials including cultural heritage. Eutrophication, acidification and ozone effects and their trends will be monitored; related biodiversity and effects of climate change will receive specific attention. The results of monitoring together with detailed reports on emissions and air quality from the Member States will provide the basis for assessing the effectiveness of Community and Member States´ policies. The monitoring activities and the related scientific work will continue to be reviewed regularly.

121 Protected areas are not currently separately assessed under the Convention
122 Coastal and marine waters are not currently monitored under the Convention

Other research priorities include

- the formation of secondary organic aerosols and how different emission sources contribute to the particulate mass and appropriate EU-wide monitoring (see below)

- the links between air pollution and climate change, and climate impact on air pollution.

- improved methods for assessing air pollution, at local and regional level, including the integrated use of monitoring data from the ground and space instruments and assessment models.

8.3.2. Effects of air pollution on health and the environment

In order to develop and refine strategies to avoid health impact we need new research or updated information on:

- how the changing sources and composition of air pollution in Europe impact on the human population; health-related studies are needed on exposure patterns and the effects of air pollution abatement and policies (*ex post* evaluations).

- the exposure routes, sensitivity and vulnerability of the population and different population groups, which may also change with time.

- the health effects of long-term exposure to ozone, nitrogen oxides and particulate matter (and their different size fractions) relevant for present and future air pollution. For airborne particles, we are specifically concerned by fuel-source specific risk. Further research is also needed to understand the specific composition effects of particulate matter (e.g. secondary organic and inorganic aerosols, metals). The research would include both air pollution epidemiology and toxicology.

- Specifically it is necessary to start long-term studies on the impact of air pollution on different European population groups including children, and to follow these groups (cohort) over a long period of time. This is also very closely linked with the Environment and Health Strategy of the Commission (a joint initiative by DG ENV, DG SANCO and DG RTD).

- The environmental effects of air pollution are considerable, through acidification and eutrophication of waters and soils and high concentrations of ground-level ozone. Priority areas for further research would include improved methods to quantify ozone damage to crops and other vegetation and improved understanding of the dynamic effects of ecosystem recovery (including biodiversity) from pollution damage. Nitrogen in the ecosystems and as a pollutant plays a key role in many environmental processes, but better understanding is needed to address the nitrogen issue in a more integrated way.

8.3.3. *Costs, effectiveness and benefits of measures*

Present pollution policy is a main driver for further development of abatement technologies for those sectors and sources that contribute such as energy, transport, industry and agriculture. This is a continued effort for research and technology development, but is also closely linked with economic aspects. It is therefore also important to give support for the introduction of new technologies (demonstration programmes) and abatement techniques for bench and feasibility testing, pilot scale and early full-scale introduction.

– For new vehicles and other mobile sources, future on-board diagnostics and emissions monitoring equipment would be required to assess and further control emissions. As an example, the ERTRAC network investigates the medium term research needs in the transport sector.

– Other combustion sources also give rise to high emissions of nitrogen oxides and particulate matter and cost-effective technologies are needed to reduce these emissions. A major research effort is needed to develop integrated approaches to facilitate the development and implementation of the effective emission abatement strategies that exist in EU Member States. This requires extensive knowledge of the origins and interplay of all major pollution sources, taking into account the associated costs and benefits and other possible factors arising from the adoption of these abatement strategies.

Risk assessment, risk communication and risk management require comprehensive tools for integrated assessment of air pollution and policy options and these need to be further developed. These tools need to integrate regional and local urban problems, and also the influence between air pollution policy and other sector policies. They should include the use of technical and non-technical measures and tools to evaluate various policy instruments, including market-based instruments, legislation and voluntary agreement.

Integrated assessment tools should be further developed for assessing the effectiveness of measures, and the positive and negative factors for the different sectors of society. They should also be able to assess more in depth the effects of sustainable development of all three aspects (economic, social and environmental). *Ex ante* evaluations also need to be more systematically compared with *ex post* evaluations of policy effectiveness, both for the costs of measures and the assessment of benefits.

Risk communication would include the development of indicators to be used to communicate with non-experts. The indicators should be easy to understand and could be related to long-term and interim objectives. These indicators could be based on monitoring of air pollution and its effects (environment and health monitoring) and complemented by other assessment techniques such as modelling. (One important step in this direction is the development of the health-relevant Strategic Development Indicator.) Also the development of EU-wide air quality indices could be envisaged.

8.3.4. *Financial implications*

The research community should take advantage of EU RTD funding opportunities and the capabilities of the Joint Research Centre of the European Commission to address these issues with the full support of Member States.

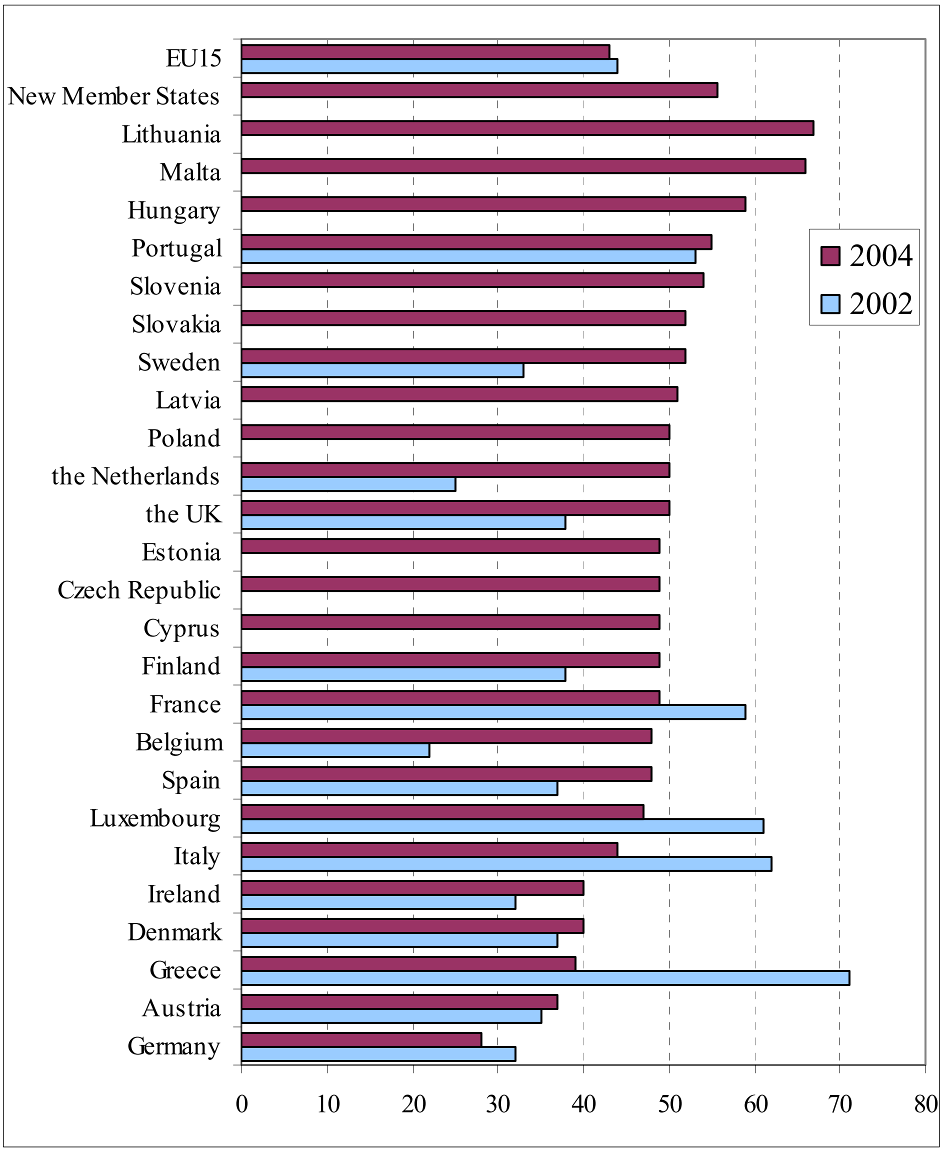
It is vital to address the gaps in knowledge on the nature and impacts of particulate matter. Additional efforts are therefore required to obtain enhanced chemical, temporal and size-resolved measurement data, not captured by regulatory monitoring throughout the EU. Research infrastructure which will provide such data is often referred to as '*superstations*'. An integrated European-wide research project will, through an elaborate assessment, combine the data from '*superstations*' with the data from surrounding 'satellite' stations (regular network stations, enhanced for the duration of the contract), additional measurement campaigns, detailed emission inventories and a comprehensive monitoring of the impacts on the human health. The Commission estimates that the annualized investment and running costs of this research network of '*superstations*' would be about five times higher than the normal background monitoring. Thus, the annualised costs of '*superstations*' are estimated at €5 million. An important share of these costs is due to the investment on research infrastructure. This needs would be covered by the budget already allocated to this purpose in the 7th Research Framework Programme as proposed by the Commission for the financial perspectives 2007-2013.

9. STAKEHOLDER AND PUBLIC CONSULTATION

9.1. Public consultation

According to Eurobarometer – a survey based on a random sample in each Member State – EU citizens have rated air pollution as one of the five environmental problems of most concern in 2002 and 2004. Overall almost 50% of Europeans are "very worried" about air pollution (see Figure 26), while there are differences between Member States. It is striking that the share of "very worried" about air pollution was higher in the new Member States than in the EU-15 in 2004.

Figure 26: Percentage of the population "very worried" by air pollution in 2002 and 2004 in EU-25



Source: Eurobarometer

The Commission launched a public consultation on air pollution in December 2004 and January 2005. This consultation should be seen against the background of general public concern about air pollution in Europe. The consultation was held in the form of a questionnaire, available on the internet to anyone to fill in. In view of the setup, the results should not be seen as the opinions of the EU population at large, but as a representation of the views of those interested in air pollution, aware of the consultation and able to fill in the questionnaire. The response - 11587 questionnaires filled in - was larger than received in any previous consultation of this kind.

The response was far from evenly distributed over the countries; half was from Portugal. Most respondents (89%) were 'individuals', 6% labelled themselves as 'experts' (from research bodies or public authorities), 2% represented business and 2% were from NGOs. There were differences between categories, with representatives of NGOs tending to be somewhat more concerned and in favour of ambitious reduction measures than individuals, and representatives from business even less so. Experts from research and public authorities were on average somewhat less concerned than other individuals.

Several conclusions relevant for this Strategy were drawn from the consultation. There are good reasons for the Commission to continue its policy of pushing for air quality information to be available to the public. Very many respondents were concerned about air quality, particularly about the impacts on environment and health. They attach high priority to improving air quality and called for Scenario C. The international and European levels were seen as the most appropriate competence level for taking action. Industrial production and traffic were given as the main targets for measures, and respondents were also prepared to take individual action themselves to improve air quality.

These results were taken into account in the Strategy when defining the ambition level, focusing on health and environment objectives and identifying the possible and acceptable measures to be taken to reduce air pollution. Measures to simplify legislation and to improve public information will also meet the concerns raised in the public consultation.

9.2. Stakeholder consultation

A **Clean Air for Europe (CAFE) Steering Group**[123] composed of representatives of the Member States, industry, and non-governmental and some international organisations was set up to advise the Commission on the environmental ambition concerning the Strategy. It met 14 times over the time frame of the preparation of the Strategy.

A **Working Group on Target-Setting and Policy Assessment**[124] (***WG TSPA***), representing a mosaic of European stakeholders and invited experts, was set up with the purpose of assisting the Commission in the development of air quality related targets for the protection of human health and the environment, and giving advice on issues related to policies and measures and their effect on air quality and other

[123] http://europa.eu.int/comm/environment/air/cafe/meetings/steering_group.htm

[124] http://europa.eu.int/comm/environment/air/cafe/working_groups/wg_target_setting.htm

aspects of economic, societal and environmental development. Its main task was to assist in the initial setting of policy-relevant air quality indicators for the Baseline scenarios and initial targets for Integrated Assessment Modelling (***IAM***), to support the qualitative and quantitative assessment of the results of IAM, including Cost-Benefit Analysis, to make recommendations for alternative model runs ("scenarios") for the IAM, to assist in the analysis of the policies and measures related to the development of the Thematic Strategy and to recommend the most appropriate options for the CAFE work programme, and the final report of the CAFE programme. The WG TSPA met 12 times in all during preparation of the Thematic Strategy on Air Pollution.

Since the issue of particulate matter was identified at the onset of the CAFE programme a **Working Group on Particulate Matter**[125] (***WG on PM***) was set up with national experts. The main objective of the WG on PM was to give support to the Commission in its review of the Air Quality Directive 1999/30/EC relating to airborne PM and its preparation of the Thematic Strategy on Air Pollution. With respect to the Directive, the main tasks were to assess the air quality situation with regard to the PM limit values and to review the Position Paper on PM published in 1997 with regard to information obtained since, and also to collect together information on predictive studies on the attainability of the limit values, considering contributions from long-range transport and local sources. With the aim of supporting preparation of the Thematic Strategy, the WG on PM had the task of considering the WHO work on health effects of PM and to give recommendations for concrete targets for integrated assessment. A further task was to review the results of the integrated assessment modelling work on PM, which took place in a joint meeting between the WG TSPA and experts from the WG on PM. In all the WG on PM had seven meetings with the full group. Most importantly it reviewed the Position paper on PM from 1997, and undertook far-reaching consultation on its content with experts and stakeholders, *inter alia* through a consultation workshop in Stockholm in 20 and 21 of October 2003. The final report is available on the web.[126]

The Commission has set up a **Working Group on Implementation**[127] (***WGI***) with experts from Member States and some other stakeholders. The main objective of the group is to assist in collecting experiences of implementation of air quality legislation in the Member States, to make assessments of the implementation and effectiveness of air quality legislation and to assist the Commission in preparing amendments to directives. The WGI has, *inter alia*, the tasks of:

– identifying and listing problems in implementing the legislation in Member States;

– developing, as appropriate, specific guidance to support Member States in implementing the legislation;

125 http://europa.eu.int/comm/environment/air/cafe/working_groups/wg_particulate_matter.htm
126 http://europa.eu.int/comm/environment/air/cafe/pdf/working_groups/2nd_position_paper_pm.pdf
127 http://europa.eu.int/comm/environment/air/cafe/working_groups/wg_implementation.htm

– investigating possibilities of streamlining and harmonising reporting requirements within the air quality frame work directives, its daughter directives and the directive on national emission ceilings;

– examining particular problems in Accession Candidate Countries in implementing the *aquis*.

The WGI has also organised workshops on implementation, "Meeting the Limit Values", held in Bruges on 17 and 18 September 2001. The WGI will also continue its work on the follow-up to the Thematic Strategy on Air Pollution, but with a revised mandate.

The Commission has also organised a large number of workshops and other meetings to consult with stakeholders, such as Member States experts and NGOs. The Commission has actively participated in meetings organised by others, giving presentations of policy relevance and seeking various stakeholders' views on key issues. In many cases too our consultants and Member State representatives have presented key issues to their stakeholders.

9.3. Consultation within the Commission

In addition to DG ENV consultations with European stakeholders internal consultations with other Commission departments have been a regular feature of the preparation of the Thematic Strategy. Throughout the CAFE programme 10 Inter-Service meetings were held. Five of them were informal meetings, between 2001 and 2003, and the other five were formal during 2004-2005, and focused on the impact assessment of the Thematic Strategy.

10. COMMISSION PROPOSAL AND GROUNDS

10.1. Selection of the interim objectives for the Thematic Strategy up to 2020

The previous sections analysed in detail the environmental and health impacts of three possible sets of interim objectives. They also tested the robustness and analysed the impact of scenarios in wider contexts, whether economic (e.g. competitiveness and sectoral implications) social (e.g. employment and social inclusion) or environmental (e.g. climate change, water and soil policies). Overall, the foregoing analysis has demonstrated that an interim objective beyond Scenario C would be justified only if the higher end of the statistical values for life years lost were used in the benefit assessment. Given the uncertainties concerning the benefit estimates, it would be prudent to conclude that the case for selecting an interim objective beyond Scenario C would be rather weak.

It was also demonstrated that while costs would increase quite rapidly from Scenario A to Scenario C, the environmental and health benefits would increase relatively modestly. The impact on competitiveness – estimated by a general equilibrium model – would be generally similar, albeit somewhat lower than the direct sectoral costs estimated by the RAINS integrated assessment model. Also the overall macroeconomic impact was shown to be fairly small. For instance, the impact of Scenario B on gross domestic product was projected to be 0.08% in 2020. It should be noted that between 2000 and 2020 gross domestic product is projected to increase by over 50%.

Another point to note is that the analysis assumed that the rest of the world would not reduce air pollution while the EU implements the Thematic Strategy on Air Pollution. However, key competing economies (e.g. the USA[128] and China) are making efforts similar to the action proposed in the Strategy. In other words, as countries outside the EU are also reducing their air pollution, the impact of air pollution policies in the EU on competitiveness will be mitigated. Consequently, the costs – in terms of competitiveness – shown in this impact assessment are overestimated because the impact of the air pollution abatement policies of other economies in the world has been excluded from the analysis.

It was also shown that the overall impact on employment was negligible. In some sectors employment would increase while in others it would decrease. The sectors where employment seems likely to increase would be those where the educational requirements are relatively high. This would be compatible with the Lisbon strategy of increasing competitiveness in the EU by raising the skill levels of the labour force.

To sum up, all three scenarios were shown to pass the cost-benefit test and their wider economic and social impacts were demonstrated to be compatible with the EU's Lisbon and sustainable development strategies. Consequently, all that remains to be done is to select the interim objectives for the Strategy up to 2020.

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128 For instance, the recently announced Clean Air Interstate Rule programme in the USA will induce an annual abatement cost to the power generation sector of $5 billion.

Scenario C has the advantage of delivering high environmental and health benefits. However, at the same time the annual costs of Scenario C are about €4 billion higher than in Scenario B. A cautious marginal analysis approach, taking into account the uncertainties, shows that the optimum level of ambition for PM health benefits is between B and C. Regarding the other targets for ecosystems and ozone for which a monetary valuation is not fully available, additional ecosystem benefits between Scenarios A and B are relatively small compared with the increase in costs. Therefore, it seems justified to select a final scenario which represents a combination of Scenarios A and B, i.e. a level of ambition for human health protection from PM close to Scenario B with a level of protection for ecosystems based on Scenario A. This delivers the lowest levels of air pollution that can be justified in terms of benefits and costs whilst attempting to prevent undue risks for the population. This strategy would yield monetised benefits for human health and crop damage of €42.7 billion per annum with associated costs of € 7.1 billion per annum. Table 34 summarises the alternative ambition levels and shows the chosen combination labeled as "Strategy".

Table 34: Alternative environmental ambition levels up to 2020

		Baseline		Policy Scenarios			
		2000	2020	A	B	C	**Strategy**
Emissions (relative to year 2000)	SO2		-68%	-80%	-82%	-83%	**-82%**
	NOx		-49%	-60%	-63%	-65%	**-60%**
	VOC		-45%	-50%	-54%	-55%	**-51%**
	NH3		-4%	-25%	-32%	-35%	**-27%**
	PM2.5		-45%	-57%	-59%	-61%	**-59%**
Impacts of particulate matter on health							
Premature mortalities		348,000	272,000	218,000	206,000	200,000	**210,460**
Months of life expectancy lost		8.1	5.5	4.4	4.1	4.0	**4.2**
Total PM Damage costs to human health per annum		€268bn	€184bn	€147bn	€139bn	€136bn	**€142bn**
Cost per annum (*Particulate Matter & human health*)		-	-	+ €5.0	+ €8.1bn	+€11.4	**+€6.6bn**
Health Benefits (PM) per annum		-	-	+ €37bn	+ €45bn	+ €49bn	**+€42bn**
Environment & ozone impacts on health							
Monetised ozone damage costs per annum (*health, crops, materials*)		€13.3bn	€7.5bn	€6.8bn	€6.6bn	€6.4bn	**€6.8bn**
Cost per annum (*health (ozone) and Environment*)		-	-	+€0.5bn	+€2.6bn	+€3.4bn	**€0.5bn**
Ozone monetised benefits for health		-	-	+€0.4bn	+€0.5bn	+€0.6bn	**€0.4bn**
Ozone monetised benefits to agricultural crops		-	-	+€0.3bn	+€0.4bn	+€0.5bn	**€0.3bn**
Area of ecosystems at risk to acidification (000 km^2)	Forests	243	119	67	59	55	**63**
	Semi-natural	24	8	4	3	3	**3**
	Freshwaters	31	22	19	18	17	**19**
Area of ecosystems at risk to eutrophication (000 km^2)		733	590	426	375	347	**416**
Area of ecosystems at risk from ozone (000 km^2)		827	764	699	671	652	**699**

Note: Ecosystem benefits have not been monetised but still need to be considered. Depending on the type of ecosystem and type of function valued, research has shown that each hectare improved could be worth between €250 and €155,000. In addition, damage to buildings and materials will also be reduced.

The strategy presented in Table 34 appears to present a more optimal balance between economic and environmental dimensions and is more consistent with the Lisbon Strategy objectives and the Community's Sustainable Development Strategy. However, the Commission will look again at this issue when reviewing this Strategy in about five years and may adjust the basis on which the following challenging interim health and environmental objectives are set.

By 2020 emission reductions would be required in the EU-25 of 82% for SO_2, 60% for NOx, 51% for VOCs, 27% for NH_3 and 59% for $PM_{2.5}$ relative to the position in 2000.

The strategy would, on average, reduce loss of life expectancy due to exposure to $PM_{2.5}$ to 4.2 months instead of 5.5 months in the baseline for 2020. Based on the calculations from RAINS further analysis within the CBA framework allowed an assessment of the number of people dying prematurely every year. The Strategy would correspond to a reduction of premature deaths by about 61,500 people per year compared with the baseline for 2020.

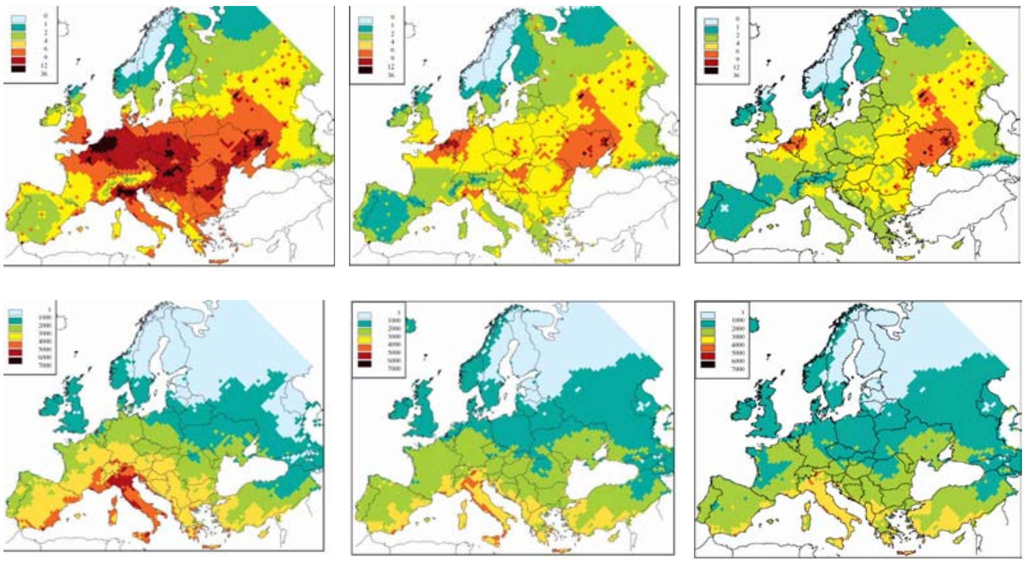
The number of deaths brought forward due to ozone exposure[129] all over the EU would be reduced by about 1000 people (Figure 27). At the same time, other health-related impacts due to ozone would also be reduced. However, some regions would still have elevated levels of ozone in 2020.

Figure 27: Maps on air quality health impact of the Thematic Strategy

2000 | **Baseline 2020** | **Strategy**

Loss in life expectancy attributable to anthropogenic $PM_{2.5}$ (months)

Health effects attributable to exposure ground-level ozone (ppb.days)



[129] above a cut-off of 35 ppb

Table 35: Change in annual health impacts over baseline in 2020

End point	Poll.	Unit	**2000**	**Baseline 2020**	Strategy 2000	% Change over baseline
Chronic mortality (years)	PM	thousand	3619	2467	1911,5	-23%
Chronic mortality (premature deaths)	*PM*	*thousand*	*695,8*	*271,6*	210,9	-22%
Infant mortality (0-1 years) (premature deaths)	PM		680	350	270	-23%
Chronic bronchitis (over 27 years)	PM	thousand	163,8	128,1	99,4	-22%
Respiratory hospital admissions (all ages)	PM	thousand	62	42,3	32,8	-22%
Cardiac hospital admissions (all ages)	PM	thousand	38,3	26,1	20,2	-23%
Restricted activity days (15-64 years)	PM	million	347,7	222	172	-23%
Respiratory medication use (children 5-14 years)	PM	million	4,2	2	1,55	-23%
Respiratory medication use (adults over 20 years)	PM	million	27,7	20,9	16,2	-22%
Lower respiratory symptom (LRS 5-14 years)	PM	million	192,8	88,9	68,9	-22%
LRS among adults (over 15years) with chronic symptoms	PM	million	285,3	207,6	160,9	-22%
Acute mortality (premature deaths)	O3	thousand	21,4	20,8	19,2	-8%
Respiratory hospital admissions (over 65years)	O3	thousand	14	20,1	18,5	-8%
Minor restricted activity days (MRADs 15-64 years)	O3	million	21,4	12,9	9,7	-25%
Respiratory medication use (5-14 years)	O3	million	8,8	8,2	7,2	-12%
Respiratory medication use (over 20 years)	O3	million	53,9	42,4	41,8	-1%
Cough and lower respiratory symptom (LRS 0-14 years)	O3	million	108,1	65,3	60,4	-8%

Source: CAFE Cost-Benefit Analysis

Table 36: Change in annual health impacts over baseline in 2020 (millions of euros)

Endpoint	Pollutant	Strategy
Chronic mortality – VOLY – (median value)	PM	29,041
Chronic mortality – VSL – (median value)	*PM*	59,500
Chronic mortality – VOLY – high (mean value)	PM	65,186
Chronic mortality – VSL – high (mean value)	*PM*	122,416
Infant mortality (0-1 years) – (median value)	PM	112
Infant mortality (0-1 years) – (mean value)	*PM*	224
Chronic bronchitis (over 27 years)	PM	5,392
Respiratory and cardiac hospital admissions	PM	31
Restricted activity days (RADs 15-64 years)	PM	4,173
Respiratory medication use	PM	5
Lower respiratory symptoms	PM	2,563
Acute mortality (VOLY median)	O_3	83
Acute mortality (VOLY mean)	O_3	186
Respiratory hospital admissions and medication use	O_3	5
Minor restricted activity days (MRADs 15-64 years)	O_3	124
Cough and lower respiratory symptoms (0-14 years)	O_3	189
Total with mortality – VOLY – (median value)		41,718
Total with mortality – VSL – (median value)		72,177
Total with mortality – VOLY –(mean value)		78,078
Total with mortality – VSL – (mean value)		135,308

Source: CAFE Cost-Benefit Analysis

The contribution of the Strategy to ecosystem and non-health benefits can be estimated as follows:

– The Strategy would reduce the forest area receiving acid deposition above the critical load further by about 56,000 km^2. The area of freshwater ecosystems (Figure 28) in these EU Member States receiving a deposition of acid above the critical load is estimated to be further reduced by decrease by 3,000 km^2.

– The Strategy would reduce the area with excess deposition of nitrogen above the critical load by a further 174,000 km^2, but substantial and severe eutrophication problems would remain in many Member States (Figure 28).

– The area of ecosystems at risk from ozone would further decrease by 65,000 km^2. The overall damage to crops (mainly wheat yield loss, Figure 28) would be further reduced by about 330 million euros in 2020.

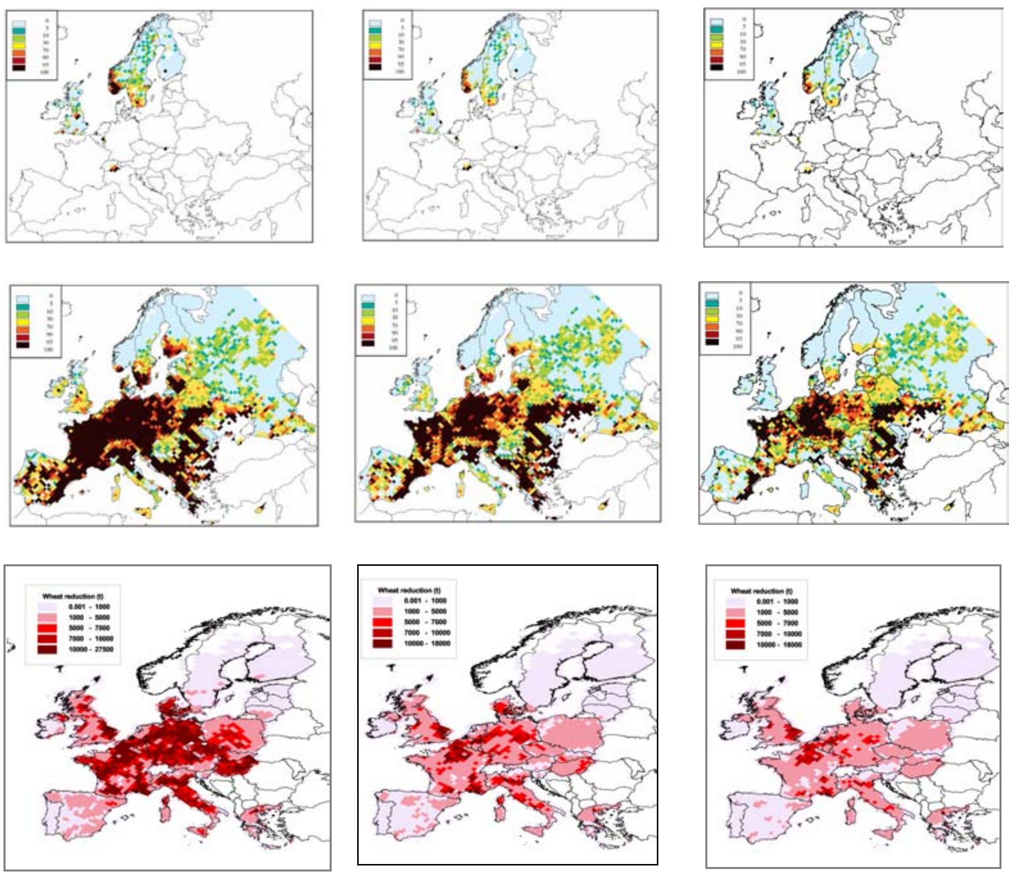
Figure 28: Maps on air quality impact on ecosystems of the Thematic Strategy

2000 | **Baseline 2020** | **Strategy**

Percentage of freshwater ecosystems area receiving acid deposition above the critical loads

Percentage of total ecosystems area receiving nitrogen deposition above the critical loads

Reduction of impacts of ozone on wheat yields



Source: RAINS. Note: Calculation results are based on meteorological conditions of 1997.

To sum up, the Strategy would trigger by 2020 improvements of (relative to 2000):

– 47% in life expectancy lost from exposure to particulate matter

– 10% fewer cases of acute mortality from exposure to ozone

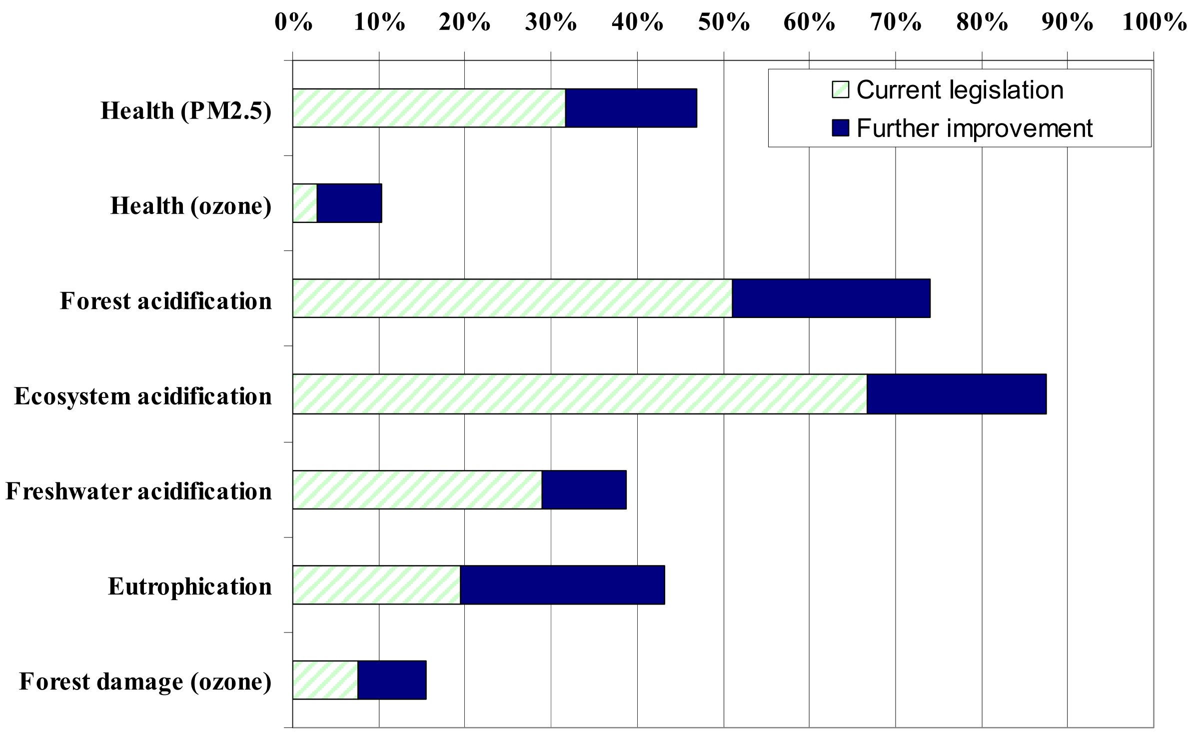
– 74% less forest area and 39% less freshwater area where acidification critical loads are exceeded

– 43% less area where critical loads for eutrophication are exceeded

– 15% less forest area where critical levels are exceeded due to ozone

These improvements include both the effect of this Strategy and the cumulative effect of current legislation. Figure 29 demonstrates how these improvements are divided.

Figure 29: Improvement of health and environment due to the Thematic Strategy



Source: RAINS and CAFE Cost-Benefit Analysis

Annual abatement costs of the measures included in the Thematic Strategy are estimated at €7.1 billion. Table 37 and Figure 30 disaggregate the costs by pollutant and major source. As explained in Chapter 6, this is a preliminary estimate that does not take into account substantial issues, such as:

– For transport, the costs forecast relate to one emission reduction scenario based on a single source of data. Future emissions standards will be defined on the basis of a more detailed impact assessment (See Section 5.5.2.). Accompanying and non-technological measures may also influence in a positive way the cost-effectiveness of these standards.

– For energy, additional measures of energy efficiency could trigger additional emissions reduction.

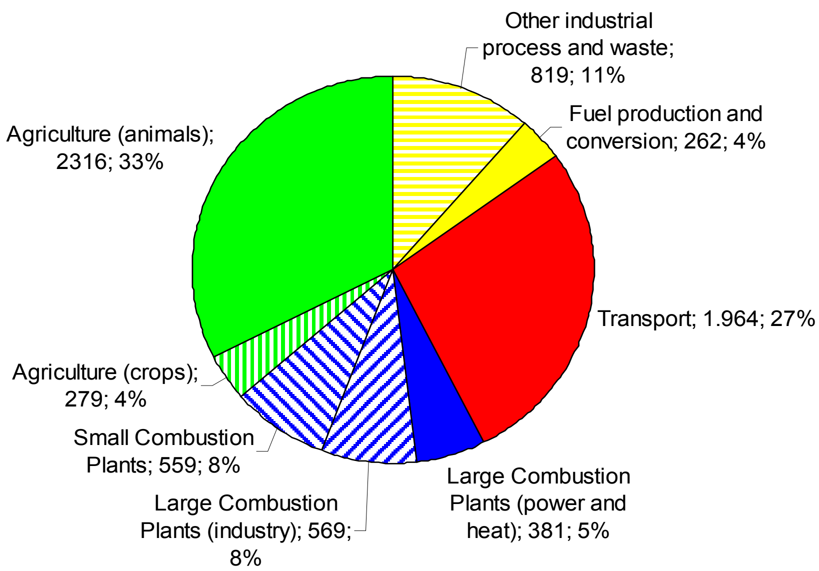
– For agriculture, estimates do not take into account the impact of the Common Agricultural Policy reform or the implementation of the nitrate and IPPC directives (see section 5.5.1). Moreover, the decrease in ozone damage to crops has to be taken into account (see section 5.7.5.). It would amount to €0.3 billion in 2020, corresponding to more than 13% of the direct cost of the measures for Agriculture.

Table 37: Annual abatement cost per pollutant for the Thematic Strategy by 2020 (millions of euros)

Ambition level	Annual Cost (€ million)
SO_2	934
NO_x	998
NH_3	2.595
Primary $PM_{2.5}$	636
VOC	118
Road transport (both $PM_{2.5}$ and NO_x)	1.868
Total	**7.149**

Source: RAINS.

Figure 30: Sectoral distribution of the cost of the measures associated with the Thematic Strategy (millions of euros and % total).



Source: RAINS

All these elements will be analysed in depth during the review of the National Emission Ceilings Directive. The objective will be to promote measures which are synergistic for the various environmental media and at the same time to help achieve various environmental objectives with cost effective measures.

Attainment of these targets is estimated to cost about 0.05% of the EU-25 GDP in 2020. No net change in employment is expected to result. Production lost through ill health would also be reduced whilst those in lower income groups may be expected to benefit most as these groups are generally exposed to the highest levels of air pollution.

Although the effect on GDP is slighly negative, it is known that high environmental standards can be an engine for business growth and innovation. The EU can also gain competitive advantages and create opportunities by focusing research and development on resource-efficient and less polluting technologies that other countries will eventually need to adopt. Whilst developed countries, like the USA and Japan, already have similar air pollution policies in place, it is clear that developing countries like China and Korea are also increasingly concerned about air pollution, are taking positive steps to limit emissions and are looking for policy and technical inspiration from Europe.

10.2. Better regulation — cutting red tape and streamlining current air quality legislation

In order to improve the regulatory framework on air quality in line with the Commission's strategic objectives for 2005-2009 calling for better regulation, it is indispensable to modernise and simplify the current air quality legislation – and to reduce its volume – in order to improve the competitiveness of the European economy.

The Commission therefore proposes to combine the Framework Directive, the First, Second and Third Daughter Directives, and the Exchange of Information Decision into a single Directive on "Ambient Air Quality and Cleaner Air for Europe". This will cut red tape, clarify and simplify ambiguous provisions, repeal obsolete provisions, modernise and reduce reporting requirements and introduce new provisions on fine particulates. The Fourth Daughter Directive will be merged later by means of a simplified "codification" process. While the impact of this modernisation and simplification exercise cannot be quantified in monetary terms, it is certain to have positive effects on competitiveness by reducing bureaucracy and increasing transparency.

It is necessary to address certain problems which have occurred with implementation of the current air quality legislation. The Commission proposes to allow Member States to extend the deadline for compliance in affected zones if objectively verifiable conditions are met, including information about compliance with certain Community legislation contributing to improvement of air quality. As a *quid pro quo* the Member States would have to develop and implement an air pollution abatement programme to ensure that the limit values are attained by the time the extension expires. It has not been possible to quantify the impact of this proposal, which is a "safety valve" against unduly high abatement costs in exceptional situations.

It is also necessary to bring the reporting requirements for air quality into the 21st century by using the Internet as the main means of delivery and making this compatible with INSPIRE.

The costs and benefits of cutting red tape and of modernising air quality legislation could not be quantified in monetary terms. However, the changes are clearly beneficial in terms of lower implementation costs and faster, more accurate information. The Commission therefore considers the simplification and better regulation approach justified.

10.3. Proposal for regulating particulate matter and other air pollution

In the light of recent health evidence, the Commission considers it justified to adopt the following approach:

No change in current limit values

Based on the advice received from the scientific community – the WHO *'Systematic review on air pollution health aspects in Europe'* and the Commission's Scientific Committee on Health and Environmental Risks – the Commission is not proposing to revise the current limit and target values for air pollutants set by the European air quality legislation. However, the Commission proposes to repeal the indicative limit value for PM_{10} for 2010 and – on the basis of scientific advice and health evidence – to start regulating fine particulate matter below 2.5 microns ("$PM_{2.5}$") differently.

Reducing annual average urban background concentrations of $PM_{2.5}$ between 2010 and 2020

The latest scientific evidence confirms that $PM_{2.5}$ is responsible for significant negative effects on human health and leads to substantial loss of life amongst European citizens. What is more, there is no identifiable threshold below which particulate matter would pose no risk to human health. Because of this evidence, it is vital to regulate fine particulate matter differently from certain other air pollutants. The Commission proposes an effective and proportionate approach: setting a concentration reduction target of 20% between 2010 and 2020 for all Members States, and – as part of the review of the Directive on Ambient Air Quality and Cleaner Air for Europe - revise this into a legally binding reduction of the average annual urban background concentration of $PM_{2.5}$ once the monitoring data for 2008-2010 of urban background monitoring stations has established the baseline.

The Commission proposes to require each Member State to reduce average annual urban background concentrations of $PM_{2.5}$ between 2010 and 2020 by a specific percentage per cubic metre measured in the baseline concentration. This would start in 2010. It also proposes that average annual urban background concentrations be calculated as a three-year running average – starting from the period between 2008 and 2010 – thus moderating the impact of meteorological variability. The reduction would be based on the arithmetic (or population weighted) mean of all measurements of $PM_{2.5}$ concentrations made in urban background locations in the territory of the individual Member State. This reduction requirement should be set to be consistent to the ambition level proposed in the Thematic Strategy on Air Pollution.

Benefits and costs of regulating $PM_{2.5}$ at EU level

The benefits of the Commission's proposal for a two-staged approach to reduce the average urban background concentration between 2010 and 2020 will total between €37 billion and €119 billion per annum in 2020. This is between seven and 24 times higher than the estimated costs of between €5 and €8 billion per annum.

As the benefits demonstrably outweigh the costs of regulating $PM_{2.5}$ the Commission considers that it has demonstrated that the proposed method to regulate $PM_{2.5}$ justified. However, the exact definition of the reduction requirement will be made after the monitoring data from 2008-2010 will be available.

Capping unduly high risk

The Commission also proposes a concentration cap of 25 micrograms per cubic metre, expressed as an annual average, to be attained by 2010. The cap is set at a level entirely consistent with the existing limit value for PM_{10} and is therefore expected to place no additional burden on Member States. The cap will apply throughout the territory of the Member States.

This approach is expected to entail no additional implementation costs apart from certain costs to monitor $PM_{2.5}$ concentrations. These costs are estimated at between €5 million and €12 million per annum depending how much less monitoring Member States would carry out for SO_2.

The main reason for proposing the concentration cap is to make sure that reducing average $PM_{2.5}$ concentrations will have no unintended consequences, which would expose some Europeans to unduly high $PM_{2.5}$ concentrations.

ANNEXES

ANNEX 1

CAFE reference documents

The forthcoming Thematic Strategy on Air Pollution and its Impact Assessment are based on other relevant documents produced by the Commission in the framework of the CAFE Programme[130]:

Strategy, Orientation

- 6th Environment Action Programme
- Communication "The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality" COM(2001)245

Methodology

- Methodology for the Integrated Assessment Modelling

– Review of the Rains Integrated Assessment Model

– Documentation of the RAINS model approach prepared for the RAINS peer review 2004

- Methodology for the Cost-Benefit Analysis of the CAFE Programme (AEAT, March 2005):

– Volume 1: Overview of Methodology

– Volume 2: Health Impact Assessment

– Volume 3: Uncertainty : Methods and First Analysis

– Peer review Cost-Benefit Analysis of the CAFE Programme report

- Health Effects of Air Pollution

– Systematic review of health effects of air pollution in Europe (WHO, June 2004)

– Second Position Paper on Particulate Matter (CAFE Working Group on Particulate Matter, December 2004)

Integrated Assessment Modelling and Cost-Benefit Analysis

- Baseline

– Energy Baseline Scenarios for the Clean Air for Europe (CAFE) programme. (NTUA, December 2004)

130 All the documents are available on Europa website at : http://europa.eu.int/comm/environment/air/cafe/general/keydocs.htm

- CAFE Scenario Analysis Report 1, "Baseline Scenarios for the Clean Air for Europe (CAFE) Programme" (IIASA, February 2005)
- CAFE Cost-Benefit Analysis: Baseline Analysis 2000 to 2020 (AEAT, April 2005)

• Scenarios

- CAFE Scenario Analysis Report Nr. 2, "The “Current Legislation” and the “Maximum Technically Feasible Reduction” cases for the CAFE baseline emission projections" (IIASA, November 2004)
- CAFE Scenario Analysis Report Nr. 3, "First Results from the RAINS Multi-Pollutant/Multi-Effect Optimization including Fine Particulate Matter" (IIASA, January 2005)
- CAFE Scenario Analysis Report Nr. 4, "Target Setting Approaches for Cost-effective Reductions of Population Exposure to Fine Particulate Matter in Europe" (IIASA, February 2005)
- CAFE Scenario Analysis Report Nr. 5, "Exploratory CAFE scenarios for further improvements of European air quality" (IIASA, March 2005)
- CAFE Scenario Analysis Report Nr. 6, "A final set of scenarios for the Clean Air For Europe (CAFE) programme" (IIASA, June 2005)
- Cost-Benefit Analysis of Policy Option Scenarios for the CAFE programme (AEAT, August 2005)

Measures

• Review and ex-Post Evaluation of current policies and measures:

- Recommendations on the review of Directive 1999/30/EC (WG on Implementation, June 2004)
- Review of the National Emission Ceiling Directive
- Assessment of the Effectiveness of European Air Quality Policies and Measures (DMU, 2004):
- *Shell report*,
- *Case Studies on EU and US Approaches (Acidification, Eutrophication and Ground-Level Ozone*,
- *Air Quality Standards and Planning Requirements*,
- *Controlling Emissions from High-Emitting Vehicles*,
- *Approaches towards Particulate Matter*,

– *Survey to assess successes and failures of the EU Air Quality Policies*,

– *Study on transparency and public participation*,

– *Report on databases*,

– *Lessons learned and Recommendations*,

– *"Ex-post" Evaluation of Short-term and Local Measures in the CAFE Context (AEAT, January 2005*

- New Measures:

– Assessment of Air Emission impact of emerging technologies (DFIU/IFARE, November 2004)

– Small scale combustion installations (AEAT, November 2004)

– Evaluation of the Potential Scope for and Costs of Further Reductions of Emissions of VOCs from Refuelling Operations at Service Stations ("Stage II") in an Enlarged European Union (ENTEC, to be published)

– Report of the conference on policy instruments on air pollution (November 2004)

Stakeholder and Public Consultation

- Public views on air pollution in the European Union, Results of the European Commission's public consultation on air pollution (TNO, April 2005)
- CAFE Steering group
- Working Group on Target Setting and Policy Assessment
- Working Group on Particulate Matter
- Working Group on Implementation

ANNEX 2

Methodology and models for the impact assessment

This annex describes the methodologies developed for the construction of the CAFE baseline and the tools used by DG Environment during the CAFE Programme to develop the Strategy, including assessment of policy options, namely the PRIMES, RAINS, CBA and GEM-E3 models.

BUILDING THE CAFE BASELINE

A baseline of future energy consumption, emissions and air pollution is required in order to make an assessment of the effectiveness of current policies and to propose a strategy to address remaining problems and to make progress towards the Community air pollution objectives. This baseline must be as realistic as possible and incorporate the full effects of current policies to combat air pollution. An extensive dialogue therefore took place between the Commission, its contractors, Member States and stakeholders to ensure that a robust and consistent baseline was developed.

A consistent EU-wide baseline was constructed that built upon economic projections from DG ECFIN, agricultural projections from DG AGRI and information from the Member States. An EU-wide baseline was preferred in order to avoid inconsistencies in methodologies and to take into account the facts that market integration makes it more and more difficult to construct a national baseline in isolation from other Member States and that national baselines may include some strategic behaviour.

The baseline takes into account:

– what changes are likely in the output of the pollution sources (i.e. how much more energy and emissions are likely to be required given the most plausible GDP growth rate);

– what autonomous technological development might induce (e.g. new plants tend to be more efficient and cleaner than old ones);

– what legislation will be in place to control emissions; and

– what role external factors could play (e.g. movements in world market prices of coal, gas and oil).

The approach taken to construct the baseline was first to develop a consistent EU-wide energy scenario using the PRIMES model for all of the EU-25 Member States. These energy balances were then used as exogenous input to the RAINS model which gave estimates of emissions up until 2020 and also predicted the environmental damage caused by those emissions for the EU-25 region. Emissions projections are built upon a thorough knowledge of current emissions and corresponding air pollution levels. These have been established on the basis of emission inventories and air quality measurements reported by Member States under Community legislation or to the CLRTAP.

Demographic and economic hypothesis

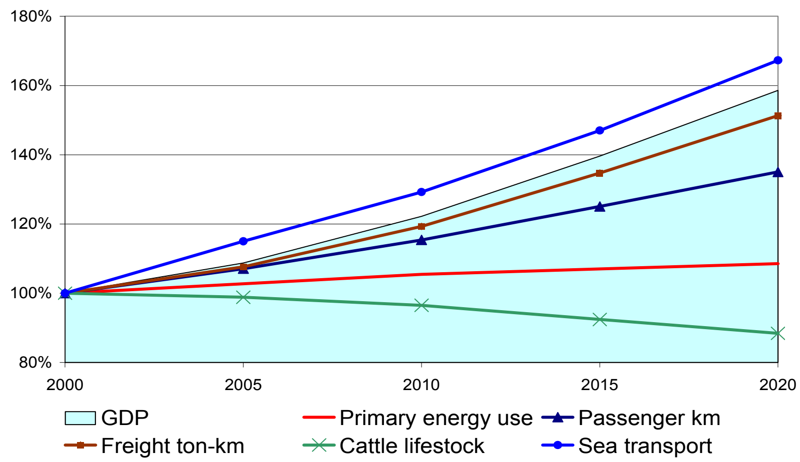
The starting point for the CAFE baseline is the "Long-Range Energy Modelling" (LREM) study from DG Energy and Transport, finalised in December 2002[131]. CAFE has taken the LREM base case and used revised demographic and macroeconomic assumptions which reflect the latest information and trends.

The EU-25 population remains fairly stable at 2000 levels, according to EUROSTAT historical data and projections for population and the projections of the United Nations Global Urban Observatory and Statistics Unit of UN-HABITAT for household size.

The current situation in each country, together with clearly identifiable trends and the identifiable driving forces of growth for each economy, were used to determine the growth rates in individual branches of industry. As a result, GDP growth in the EU averaging 2.3% per annum in 2000-2030 was used. This is modest compared to the ambitions of the Lisbon strategy, but high compared with the current weak state of the EU economy. Faster economic growth was assumed in the new Member States (3.5% per annum in 2000-2030) combined with gradual convergence of the EU economies throughout the projection period. However, even in 2030 per capita GDP in the acceding countries will remain more than 30% below the EU average (from 55.5% lower in 2000).

Economic modernisation will also continue throughout the projection period - on the one hand in the form of restructuring away from primary and secondary sectors towards services and on the other hand through dematerialisation of industrial production (a trend driven by a shift away from energy-intensive processes and an increasing proportion of new industrial activities with high value added and a lower material base).

Economic development assumptions for EU-25 for the CAFE baseline



Source: Baseline Scenarios for the Clean Air for Europe (CAFE) Programme - Final Report

131 This assessment covered the EU Member States (PRIMES model), the 13 EU candidate countries (ACE model), Norway and Switzerland (ACE model). For a detailed analysis of the assumptions and results see the publication by DG Energy and Transport: "European Energy and Transport – Trends to 2030".

Sectoral developments

In order to construct the baseline, assumptions had to be made on how firms will innovate (because of competition, change of production methods, replacement of old equipment, etc.) and how this innovation relates to changes in GDP and then to emissions. The following sectors are considered particularly important in the air quality context: energy production, transport, industry and agriculture.

Energy and transport projections are produced by the PRIMES energy market model for EU-25. LREM was taken as the basis for the CAFE baseline; however, this baseline assumed explicitly that no further climate policy measures would be taken. It was important to know the implications for air pollution assuming EU-25 were to meet its Kyoto Protocol obligations. After consulting the Climate Change Unit of DG Environment it was decided that – for the purposes of the CAFE baseline scenario – all measures to comply entailing a marginal cost of up to €12/tCO_2 would be taken in EU-25. Above this cost it was implicitly assumed that Joint Implementation or Clean Development Mechanism measures plus other means of compliance (e.g. carbon sequestration) would be used.

It was also assumed that by 2020 the carbon constraint would increase slightly. For the purposes of the CAFE baseline it was assumed that the compliance cost in the EU would be €20/tCO_2. Again, the implicit assumption was that measures along the lines of Joint Implementation, the Clean Development Mechanism or carbon sequestration would be undertaken where compliance costs were higher. For 2015 it was assumed that the compliance cost would be in between the 2010 and 2020 levels. This means that the compliance cost was assumed to be €16/tCO_2 in 2015. All other assumptions (e.g. about demographics, economic growth and its sectoral composition) were kept constant. However, within sectors the increasing cost per tonne of CO_2 would shift the patterns of consumption of energy and transport fuels towards greater fuel efficiency and lower CO_2 emissions.

In addition to the two modified LREM projections (i.e. without and with climate measures), two further scenarios were developed in the CAFE Programme:

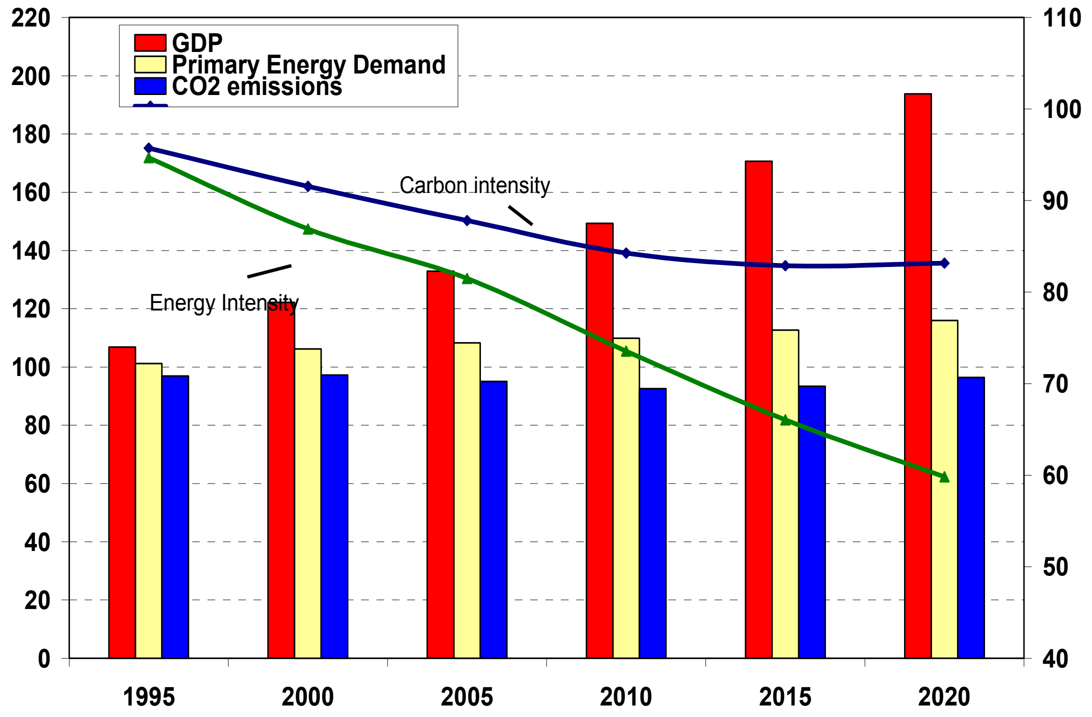
– National projections for energy use up to 2020. These were submitted by some 10 Member States but not all of the projections gave complete sectoral coverage and it was therefore not always possible to compare them fully with the CAFE baseline.

– An "illustrative climate" scenario, assuming a 20% reduction in CO_2 emissions in 2020 compared to 1990 corresponding to a compliance cost in 2020 of €90 per tonne of CO_2. It was considered important to see what the implications of such a scenario would be for air pollution.

The CAFE baseline scenario incorporates updated energy, economic and financial information (taking 2000 as the base year). It reflects recent trends and policies in place, such as the fuel efficiency agreement with the car industry, the liberalisation of the electricity and gas markets, existing policies on energy efficiency and renewable energy sources, ongoing infrastructure projects and current nuclear policies.

The projected trend for the EU-25 energy system in the CAFE baseline scenario shows that despite the evidence of further de-linking of economic growth from energy demand in EU-25, energy demand is expected to continue to grow. During the period 2000 to 2020 primary energy demand in EU-25 is set to increase by 9.2% compared to GDP growth of 58.6%, implying that energy intensity in EU-25 (expressed as primary energy demand per unit of GDP) will improve at a rate of 1.85% per annum. Improvements in energy efficiency (on both the demand and the supply sides), changes in the structure of EU industry, saturation in demand for some important energy needs and the policies already in place are some of the key drivers for the projected intensity gains.

EU-25 primary energy indicators 1995-2020 (1990 = 100)



Source: PRIMES, Energy Baseline Scenarios for the CAFE Programme

Significant changes will also occur in the demand-side fuel mix as a result of the projected shifts towards the use of more efficient and less carbon-intensive energy sources. Solid fuels will decline continuously over the projection period accounting for just 2.5% of energy needs on the demand side in EU-25 by 2020 (down from 5.3% in 2000 and 11.7% in 1990). Liquid fuels will remain the main energy carrier in demand sectors in EU-25 over the projection period, but will grow at rates well below average, constantly losing market share. By 2020 some 76% of demand for liquid fuels is projected to come from the transport sector, compared to 67% in 2000.

Following the introduction of an EU-wide CO_2 emissions trading scheme, CO_2 emissions are projected to decline further than observed in the recent past, falling to 7.4% below 1990 levels in 2010 (from 1990 to 2000 CO_2 emissions fell by 2.8% whereas the corresponding primary energy needs grew by 6.2%). However, beyond 2010 once more and more use has been made of the options available for shifting the fuel mix towards less carbon-intensive energy sources, carbon intensity is projected to deteriorate with CO_2 emissions in 2020 down by 3.6% on 1990 levels.

The transport baseline used for the CAFE integrated assessment is derived from the PRIMES energy projection. This ensures consistency with the energy baseline, and the projections include trends in emissions from international transport. The transport baseline is supplemented by the outcome of an upgraded version of the TREMOVE[132] model, an integrated simulation tool developed within the framework of the Auto-Oil II Programme for strategic analysis of the costs and effects of a wide range of policy instruments applicable to local, regional and European transport markets.

The ammonia emissions from agriculture are taken from the CAPRI[133] model specifically constructed for modelling agricultural production (and emissions).

Effect of legislation

In order to convert economic activity into air pollution and air quality it is necessary to know how current environmental and other legislation – both in EU-15 and in the new Member States[134] – will affect emissions in the future. A large number of directives lay down minimum requirements to control emissions from specific sources. These are listed below:

132 http://www.tremove.org

133 For a description of the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system see http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm

134 It has been assumed that all new Member States will have fully implemented the 'acquis' by 2015 to 2020.

Measures considered for the CAFE baseline
Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants[135]
Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control[136]
Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC[137]
Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC[138]
European Parliament and Council Directive 94/63/EC of 20 December 1994 on the control of volatile organic compound (VOC) emissions resulting from the storage of petrol and its distribution from terminals to service stations[139]
Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations[140]
Directive 2004/42/EC of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC[141]
Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste[142]
Directive 2002/51/EC of the European Parliament and of the Council of 19 July 2002 on the reduction of the level of pollutant emissions from two- and three-wheel motor vehicles and amending Directive 97/24/EC[143]
Directive 1998/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Council Directive 70/220/EEC[144]
Directive 2002/88/EC of the European Parliament and of the Council of 9 December 2002 amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery[145]
Council Directive 88/77/EEC of 3 December 1987 on the approximation of the laws of the Member States relating to the measures to be taken against the emission of gaseous pollutants from diesel engines for use in vehicles[146]

135 OJ L 309, 27.11.2001, p. 1.
136 OJ L 257, 10.10.1996, p. 26.
137 OJ L 121, 11.5.1999, p. 13.
138 OJ L 350, 28.12.1998, p. 58.
139 OJ L 365, 31.12.1994, p. 24.
140 OJ L 85, 29.3.1999, p. 1.
141 OJ L 143, 30.4.2004, p. 87.
142 OJ L 332, 28.12.2000, p. 91.
143 OJ L 252, 20.9.2002, p. 20.
144 OJ L 350, 28.12.1998, p. 1.
145 OJ L 35, 11.2.2003, p. 28.
146 OJ L 36, 9.2.1988, p. 33.

The baseline of future emissions includes all of those known measures, both national and Community, which have a direct impact on emissions. The baseline projections take no account of caps imposed on total national emissions by the National Emission Ceilings Directive, nor of compliance with the Air Quality Framework and Daughter Directives to avoid local pollution "hot spots". The NECD and the ambient air quality legislation only have an indirect impact on emissions because they establish environmental quality standards or emissions caps. Member States must adopt specific direct measures in order to comply with their provisions. It is these direct measures and policies which are modelled in the RAINS integrated assessment model. It is not capable of handling/estimating the impact of indirect measures such as NECD.

The annual emissions ceilings in the NECD come into force in 2010. Currently, several Member States may have difficulty in attaining their ceilings for nitrogen oxides. This is not a widespread problem however. If ceilings for particular pollutants are met after the attainment date of 2010, then our current analyses will have over-estimated the costs associated with the policy scenarios. This is because costs associated with attainment of the NECD should be associated with existing legislation rather than the thematic strategy. Member States will take the same measures either before or after 2010, the issue of whether the costs should be attributed to the thematic strategy or implementation of existing legislation.

Other legislation could have a significant indirect impact on air quality. For instance, changes in the common agricultural policy could have an impact on ammonia emissions. Implementation of the Landfills Directive (which shifts waste from landfills to incinerators) could change air emissions as well. As mentioned above, the legislation to reduce energy-related CO_2 emissions is included[147] and an alternative scenario without additional climate change measures beyond the "Kyoto Protocol" has been introduced so that the specific impact of these measures on air quality can be assessed.

METHODOLOGY FOR QUANTIFYING THE HEALTH IMPACT OF AIR POLLUTION

The methodology followed in the impact assessment aimed neither systematically to over-estimate nor under-estimate the health effects. The impact assessment is consistent with the WHO's *"Systematic Review of Health Aspects of Air Quality in Europe"*[148] and with the advice of the UNECE WHO Joint Task Force on Health. Health impacts have been estimated for both particulate matter and ozone for short-term (acute) and long-term (chronic) exposure.

Particulate matter

The figures for particulate matter are based on the health evidence on the fine fraction ($PM_{2.5}$) based on long-term exposure. The WHO proposed using the risk factors derived from the epidemiological studies carried out in the USA, because of the shortage of such studies in the EU to date.

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147 See report on Energy Baseline Scenarios for the CAFE Programme.

148 See http://www.euro.who.int/document/e79097.pdf and answers to follow-up questions http://www.euro.who.int/document/e82790.pdf

The RAINS model and the health impact assessment are based on the advice from the WHO Joint Task Force on Health. The RAINS model has been extended to include the additional effect of urban air pollution (through the City Delta project[149]). WHO advice has been drawn on to estimate the changes, in terms of loss of statistical life expectancy, attributable to changes in the anthropogenic fraction of $PM_{2.5}$ emissions. The Joint Task Force recommended applying a linear concentration-response function associating changes with health impacts (6% change in mortality hazard per 10 µg/m^3 $PM_{2.5}$). This excludes the health impacts of particulate matter from natural sources and of secondary organic aerosols. Secondary organic aerosols have not been included in the RAINS model for lack of information. A substantial fraction of the secondary organic aerosols could be of anthropogenic origin; the impact of anthropogenic emissions is underestimated in the RAINS model. In the cost-benefit analysis the RAINS assessment of the health impact due to particulate matter was supplemented by specific quantification of infant mortality and assessment of morbidity due to particulate matter. Using life-table methods, the analysis expresses health impacts in terms of years of life lost because of air pollution. However, there are methodological difficulties with estimates of the value of a life year (VOLY). Therefore, an alternative method to estimate the effect of air pollution has been used, in the form of estimation of premature mortality. The value of statistical life (VSL) has been applied to premature mortality. However, the methods used to derive the number of premature deaths are approximate and to some extent over-estimate the true fraction attributable.

The analysis of mortality from long-term exposure applies only to adults. There is now substantial evidence that higher levels of air pollution are associated with a wide range of adverse effects on foetal and infant health, including mortality. In this impact assessment, the cases attributable have been estimated, rather than life-years. This is consistent with the approach used in the USA.

149 http://rea.ei.jrc.it/netshare/thunis/citydelta/

City-Delta project

The objective of the City-Delta project is to explore systematic differences (deltas) between rural and urban background air quality, how these deltas depend on urban emissions and other factors, how they vary across cities and how they vary across models. In the first phase of the project general differences were explored for numerous cities and over a cross-section of European models. In the second phase (City-Delta II) a limited number of models on regional and urban scale and a limited number of cities (Berlin, Milan, Paris and Prague) were selected to derive *functional relationships* between air pollution at regional level and the urban background levels detected.

The functional relationships derived are relevant for the situation in European cities and depend on key parameters such as wind speed and emission densities at low and high sources. So far functional relationships have been developed for the annual average urban background $PM_{2.5}$ concentration in European cities. The calculated values for urban background concentrations have been compared to the data obtained on $PM_{2.5}$ from monitoring in a wide range of European cities and are generally within the 30 percent difference band. Intercomparison shows systematic underestimation by the calculated values compared to the monitored values. Other discrepancies remain for some cities due to topography (e.g. valleys or basins) which have not been properly resolved and represented in large-scale models along with issues linked with the cities effectively divided into several grids in the large-scale EMEP model.

The functional relationships for the annual averages for $PM_{2.5}$ have been used to assess more accurately the exposure and health impact on the European urban population. The same functional relationships are used for assessment of the future urban increment of $PM_{2.5}$ and to assess the effects of implementation of Community-wide emission control measures.

Further development of the methodology and validation of the functional relationships are expected later. This would include functional relationships for annual urban background ozone levels and measures to improve the parameterisation of the functional relationships for $PM_{2.5}$ and to validate the relationships.

Ozone

Effects of daily ozone exposure on 'acute' mortality have been calculated at concentrations greater than 35ppb (parts per billion, which is equivalent to 70 $\mu g/m^3$) as a maximum 8-hour mean. A risk estimate of a 0.3% increase in daily mortality per 10 $\mu g/m^3$ ozone has been used. This factor is based on the meta-analysis from European studies on the health impact of ozone and part of the WHO systematic review. The health impacts here can best be described as "deaths brought forward" because of ozone. This signifies that people whose deaths are brought forward by higher air pollution belong largely (but not exclusively) to a group of sensitive people with cardio-respiratory conditions. Some people affected by ozone have a disease or are elderly. In at least some of these cases, the actual loss of life expectancy is likely to be small – the death might have occurred within the same year and, for some, might only be brought forward by a few days. In this impact assessment it has been assumed that, on average, each death has been brought forward by 12 months.

The quantifiable impact on morbidity included major effects, such as hospital admissions and the development of chronic respiratory disease, plus effects which are less serious, but are likely to affect a greater number of people, for example changes in frequency of use of medicines to control asthma and days of restricted activity. When the impact and the values were combined in the analysis the most important health-related issues to emerge were mortality, restricted activity days and chronic bronchitis.

Atmospheric modelling

Detailed baseline reports on quantification of the environmental impacts and health effects have been published separately (see Annex 1). The full EMEP atmospheric model (to predict air concentrations and deposition) using the average for the 1997, 1999, 2000 and 2003 meteorological years has been calculated to assess the impact of air pollution on human health and the environment. However, as the EMEP model takes several months to calculate the impacts of different RAINS scenario runs covering all the meteorological years, in this impact assessment the most typical of the four years, i.e. 1997, was selected and all the model calculations made consistently assumed 1997 meteorological conditions.

While for the EU as a whole 1997 was a relatively normal meteorological year, this is not necessarily the case in any particular Member State. However, these differences between meteorological years do not matter much as long as the impact assessment is not carried out on measures that would affect a single particular Member State. As the Thematic Strategy on Air Pollution imposes no direct obligations on specific Member States the choice of 1997 as the reference year seems justifiable.

Consequently, the output from the RAINS model for the 1997 meteorological year was used for the cost-benefit analysis for this impact assessment. 1997 is the only year for which source-receptor relationships are available for use in the RAINS integrated assessment model. Although the RAINS model is an approximation of the full EMEP model, it has been used to provide a consistent data set for the baseline years of 2000 and 2020 and for the different levels of ambitions. This allows sensible analysis of incremental costs and benefits for each of the policy scenarios compared to the baseline years (see table below).

Differences in quantification of the mortality effects of $PM_{2.5}$ between the full EMEP atmospheric model and RAINS

	RAINS (1997 only)			*Full EMEP model (four meteorological years)*		
	2000	2020	Differ-ence	2000	2020	Differ-ence
Average loss in statistical life expectancy	8.1	5.0	-3.1	8.6	5.4	-3.2
Thousand life years lost	3.6	2.5	-1.1	3.1	1.9	-1.2

However, because the 1997 meteorological year is used throughout the impact assessment, the baseline impacts presented in this impact assessment are slightly different to those indicated in the CAFE baseline report (2004)[150]. However, as can be seen in the above table, the difference between the reference year (2000) and the baseline for 2020 is very small.

Throughout this impact assessment, mortality due to PM can be expressed on the basis of four different metrics (see table below). The RAINS integrated assessment model can optimise the cumulative reduction in life years lost. In addition, RAINS can produce an estimate of the average statistical life expectancy as a result of different measures to reduce air pollution. The CBA model annualises the cumulative life years lost. The advantage of the annual figure for life years lost is that it can be compared with the annual costs of reducing air pollution. Finally, as it is difficult to communicate statistical life expectancies or life years lost to the general public, the CBA methodology gives an alternative metric of mortality due to particulate matter. This is the number of premature deaths. These two metrics can be used to calculate the monetised benefits of reducing air pollution.

Correspondence between different $PM_{2.5}$ metrics used in the impact assessment

	Average loss in statistical life expectancy (months)	*Cumulative life years lost (million years)*	*Annual life years lost (million years)*	*Annual premature deaths (thousands)*
(Source)	*(RAINS)*	*(RAINS)*	*(CBA)*	*(CBA)*
2000	8.07	203	3.62	348
Baseline 2020	5.46	137	2.47	272
Scenario A	4.37	110	1.97	218
Scenario B	4.14	104	1.87	206
Scenario C	4.02	101	1.81	200
MTFR	3.82	96	1.72	190

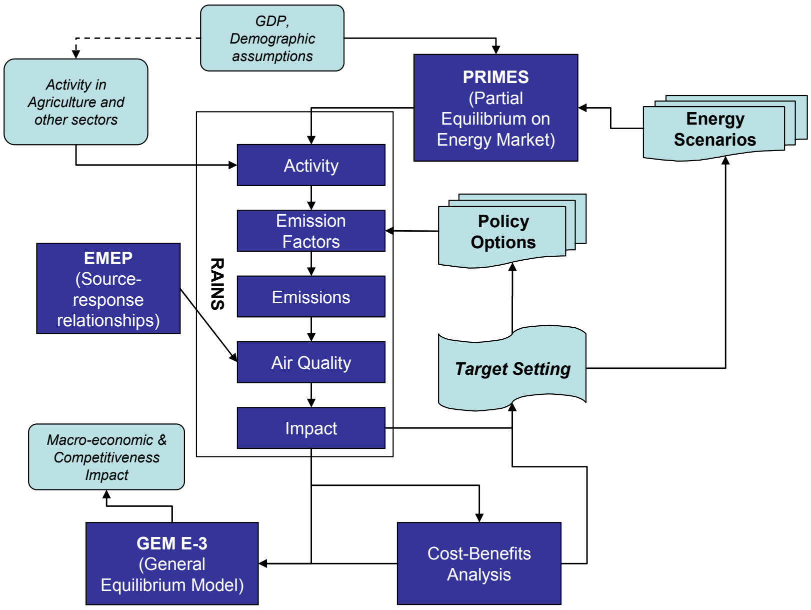
Source: RAINS and CAFE CBA.
Note: All calculations are based on the 1997 meteorological year.

MODELLING FRAMEWORK USED FOR CAFE INTEGRATED ASSESSMENT

The models are used to understand, on the one hand, what the situation is likely to be in the future if no (further) action is taken (the "baseline") and, on the other hand, the environmental and economic implications of policies and measures to reduce emissions (scenarios/policy options). The modelling framework was made up of RAINS, PRIMES, the cost-benefit analysis and GEM-E3 and is used for multi-sectoral assessment of policy to improve air quality, including an optimisation procedure in the RAINS model.

150 Baseline Scenarios for the Clean Air for Europe (CAFE) Programme (IIASA, October 2004 – Corrected February 2005) available at http://europa.eu.int/comm/environment/air/cafe/general/pdf/cafe_lot1.pdf

Modelling framework used in the impact assessment



RAINS integrated assessment model

The Regional Air Pollution Information and Simulation (RAINS) model[151] has been developed by the International Institute for Applied Systems Analysis (IIASA). RAINS has been used, for example, for calculation of the ceilings in the National Emissions Ceilings Directive as well as analysis of the Large Combustion Plants Directive. In the CAFE Programme, RAINS is used to develop (1) a robust baseline scenario; (2) an operational integrated assessment modelling (IAM) framework allowing a large number of scenarios to be analysed within CAFE; (3) scenarios reflecting the various options for improving air quality in the enlarged EU for the period up to 2020.

The model combines information on economic and energy development, emission control potential and costs, atmospheric dispersion characteristics and environmental sensitivities towards air pollution. It quantifies the contributions of the main air pollutants[152] to threats to human health posed by fine particulates and ground-level ozone as well as to the risk of damage to ecosystems from acidification, excess nitrogen deposition (eutrophication) and exposure to high ambient levels of ozone. The model has been subjected to a peer review in the context of CAFE[153].

151 A detailed description of the RAINS model, on-line access to certain parts of the model as well as all input data to the model are available on the Internet (http://www.iiasa.ac.at/rains/review/index.html).

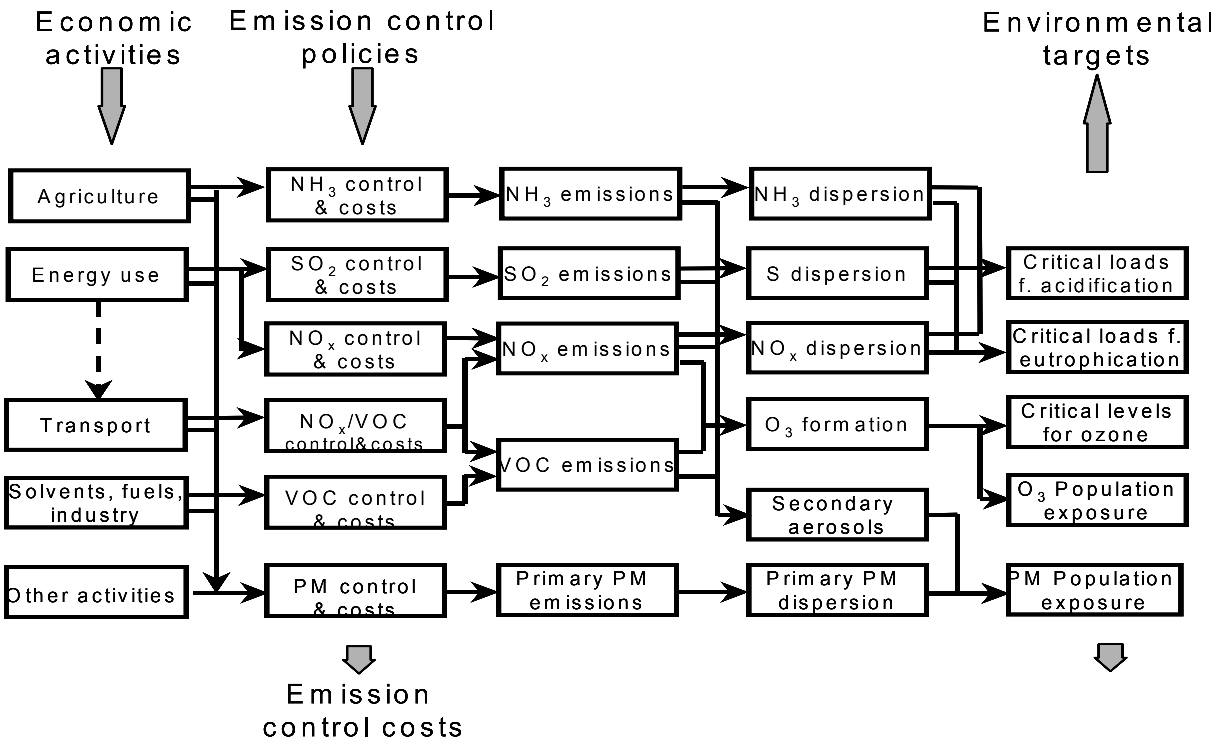
152 RAINS includes the following pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), non-methane volatile organic compounds (VOC) and primary emissions of fine ($PM_{2.5}$) and coarse (PM_{10} - $PM_{2.5}$) particles. It also includes estimates of emissions of relevant greenhouse gases such as carbon dioxide (CO_2) and nitrous oxide (N_2O). Work is in progress to add methane (CH_4), as another direct greenhouse gas, as well as carbon monoxide (CO) and black carbon (BC) to the model framework.

153 http://europa.eu.int/comm/environment/air/cafe/activities/rain_model.pdf

RAINS distinguishes 21 categories of fuel use in six economic sectors. The time scale extends from 1990 to 2020. Emission estimates are based on national data reported to relevant international organisations such as the Convention on Long-range Transboundary Air Pollution and the UN Framework Convention on Climate Change (UNFCCC).

Future economic trends – and more specifically the development of the energy supply system, of the transport sector and of agriculture – are exogenous input to the RAINS model. Data on transport and energy activity were derived from "European Energy and Transport – Trends to 2030" based on the PRIMES model, while transport emission factors were taken from the sources shared by TREMOVE. Agricultural projections came from the CAPRI model.

Flow of information in the RAINS model



The RAINS model covers a variety of technical means for reducing emissions of the pollutants considered. The model estimates the potential rate of utilisation of the available technologies and the specific costs for each country, taking into account the most important country-specific parameters. The description of the emission control options comes from the RAINS databases, updated in collaboration with the Centre of the CLRTAP's Expert Group on Techno-Economic Issues (EGTEI).

The RAINS model uses functional relationships characterising the link between annual emissions and the specific metric of exposures[154] relevant to the individual

154 For instance, deposition of acidifying and eutrophying compounds is expressed as annual deposition rates, reflecting the cumulative nature of acidification and eutrophication. For fine particles, mortality

environmental end points considered in RAINS. These relationships are derived from the EMEP Eulerian atmospheric dispersion models[155] which describe chemical formation and pollutant transport in the atmosphere between the sources of emissions and the receptor sites, using a grid system with 50 km x 50 km spatial resolution for calculating rural background concentrations and deposition of pollutants. The RAINS model includes grid-specific information on the share of urban and rural population, the age structure, the population trend up to 2050 and age-specific mortality rates.

Health impacts of PM and ozone

The EMEP model used by RAINS has certain drawbacks, such as not taking into account high pollution peaks, over-estimating PM and ozone levels in winter and not describing the daily variance in PM and ozone levels. For nitrates, one important point to note is that EMEP uses the highly uncertain monitoring data as there are currently no measurements for total nitrate. Consequently, winter values for total nitrate are overestimated in EMEP as well as values for NH_3 and NH_4^+. The problems with wet deposition of sulphate in EMEP can be summed up as: it rains too often and too little in the model. In the case of NO_x, concentrations are underestimated, especially for ground-level sources, as the EMEP model starts to work from 19 m on. For PM, seasonal variations in emissions are always underestimated (but less in winter) and unaccounted masses (i.e. measurement artefacts) or particles bound to water droplets are only partly taken into account. Up to now RAINS has improved on some of these issues but the following points are not yet taken into consideration: (a) secondary aerosols, e.g. from VOC-based emissions; (b) natural background; (c) the PM fraction that is currently not identified by measurements or forms measurement artefacts; (d) seasonal effects in winter and summer in Southern and Northern Europe, which can be improved and on which work is in progress; (e) for NO_x, influences of VOC emissions and vice versa; and (f) non-linearities of effects between $PM_{2.5}$ and the entire nitrogen fraction and SOMO35 changes for ozone in spring (possibly due to the titration of ozone from free troposphere) – these non-linearities are also included.

For PM and ozone no thresholds have been detected. Consequently, a limit approach or an approach based on cutting '*bad issues*' or peak concentration would not be suitable. Here, it should be noted that on the one hand these data are mostly based on epidemiological studies which naturally have a lower sensitivity for detecting such a threshold compared to detailed toxicological studies either *in vivo* or *in vitro*. On the other hand, it is important to recognise that these conclusions are also based on *in vivo* animal studies and cohort studies (where a defined population group is followed over a long period of time, e.g. 5 to 10 years or even longer – these cohorts are difficult to establish and even more difficult to maintain, which means that ongoing financial support is needed). PM exposure is linked to arrhythmia (i.e. a deviation from or disturbance of the normal heart rhythm). Mortality is linked primarily to PM

impacts are estimated on the basis of long-term cohort studies, which were originally regressed against annual mean concentrations of fine particles. For ground-level ozone, vegetation-relevant exposure will be expressed in terms of an AOTx, i.e. hourly ozone concentrations in excess of a certain threshold accumulated over the vegetation period.

155 For a description of the EMEP model and its results see http://www.emep.int.

and not to ozone, while cardiovascular diseases are another major effect (e.g. linked to black smoke (soot)). In addition, most effects will occur at '*normal concentrations*' for $PM_{2.5}$, such as ~5-20µg/m^3, although another important point to note is that different types of $PM_{2.5}$ are not equally hazardous – more work is essential here, including more detailed monitoring. Moreover, the chronic effects of PM on mortality seem to outweigh all the acute effects and so far $PM_{2.5}$ is seen as an appropriate indicator for these effects.

RAINS does not address compliance in local short-term hot-spots reporting exceedance in terms of air pollution. RAINS uses the evidence from cohort studies. It also uses the data from the US cancer society together with the life tables from EUROSTAT. Amongst the critical assumptions made in the model, no threshold together with a linear dose response curve is assumed for its methodology and the impact linked to anthropogenic PM is extrapolated beyond 35µg/m^3 $PM_{2.5}$. Moreover, no effects are assumed from natural PM despite the fact that these are used positively to help patients with pulmonary-based diseases. Also, no effects for younger population groups below 30 years old and infant mortality are included in RAINS. Nor are secondary organic aerosols and natural sources for PM included. For PM, a loss of life expectancy of between 3 and 13 months is estimated and for EU-25 from 6 to 9 months have been included. Finally in relation to PM, it must be remembered that the accuracy of the output from the RAINS model on health depends on the accuracy of the dispersion calculation and the significant meteorological impacts. For ozone, much smaller effects are taken into account in RAINS than for PM. A relative risk factor of an 1.003/10 µg/m^3 increase in the daily maximum 8-hours mean together with a '*cut-off*' value of 35 ppb from WHO (i.e. SOMO 35) is incorporated in RAINS. Also, a premature death by 6 months due to ozone is assumed. The peer review concluded that RAINS is following the WHO approach and recommended further improvements relating to its underestimation of the health effects from both ozone and PM – in urban areas only in the case of PM.

On ozone-related health effects, the model's description of the regional concentration of ozone and its relationship with emissions within Europe is acknowledged as reliable, although no spatial resolution is given in the urban-scale ozone exposure assessment, and non-linearities in response to NO_x and VOC controls remain to be resolved. (The importance of background ozone will be addressed in the course of further development of the EMEP/RAINS framework.) RAINS has followed the WHO recommendations and health effects are underestimated by not including other health outcomes (only short-term effects on mortality are estimated) and the use of the 35 ppb cut-off (no effects below 35 ppb are quantified).

On PM, RAINS has followed the WHO recommendations. Only WHO exposure-response relationships for mortality in adults were included in RAINS. Emission control is limited to the effects of anthropogenic primary particles and secondary inorganic aerosols, resulting in considerable underestimation of $PM_{2.5}$ concentrations from the EMEP model, as secondary organic and natural aerosols were omitted.

Only exposure-response functions reflecting the effect of urban background exposure may currently be applied in RAINS, resulting in a spatial scale too large for modelling urban air quality to quantify the full magnitude of health effects and in inconsistency between measured and modelled urban air concentrations. RAINS modelling of urban air quality has been improved by incorporating the revised results of the City Delta project[156], i.e. wind speed influences, population density differences and reductions of the EMEP grid cells from 50 km x 50 km to 2, 5 and 10 km. However, the validation was hampered by the shortage of monitoring data from reliable sources. For natural PM, levels of 1-3 $\mu g/m^3$ were used. These were somewhat arbitrary based on literature, which shows values of about 1 $\mu g/m^3$ for Northern Europe and about 3 $\mu g/m^3$ for Southern Europe. For Spanish cities the RAINS model underestimates the $PM_{2.5}$ concentrations compared to actual measurements. It is not yet clear if this is due to the measurements (this seems to be more likely given the current difficulties with PM measurements) or to the modelling. The RAINS peer review also clearly highlighted that these difficulties need to be solved. Local reductions in cities lying in valleys have a dramatic influence on the RAINS scenarios compared to cities located in flat areas.

Impact on ecosystems

For acidification and eutrophication, RAINS relies on the EMEP model. So far comparability has been achieved between the data from actual monitoring and the results from modelling. However, as highlighted by the RAINS peer review, the static modelling approach currently used by the RAINS model will need to be replaced in the future by the dynamic modelling approach, including impacts on biodiversity such as changes in the presence of populations of different species.

– On acidification, atmospheric depositions calculated for coastal areas by EMEP do not reflect the effects of shipping sources. Deposition in complex terrain (hills, forest edges, etc.) is still underestimated, which could lead to underestimation of the need for controls.

– No final agreement has yet been reached on how results from dynamic modelling could be handled in RAINS, but application of the dynamic approach may also be limited by the lack of input data including deposition of base cations.

– On eutrophication, the spatial scale of the reductions in the nitrogen impact (like that of urban air quality) is small in relation to the 50 km x 50 km scale of the RAINS model. Critical loads are probably smaller than in present assessments and this could lead to underestimation of the controls required in order to achieve a certain environmental status.

– The fixed critical loads approach currently used will not be able to pick up the dynamic aspects involved in eutrophication of ecosystems and further development of dynamic models is needed in order to include nitrogen processes in vegetation and soils.

On the effects of ozone on vegetation, the AOT30 or AOT40 are well established for measuring effects and it is recommended that they be used, while the review of the EMEP model concluded that source-receptor matrices can be established for policy purposes. Humidity and climatic conditions such as light and temperature together with nutrient availability are taken into account. RAINS does not yet apply a flux approach for crops. In addition, RAINS needs further improvements on small effects

156 http://rea.ei.jrc.it/netshare/thunis/citydelta/

related to grid-average data such as the sulphur/ammonia co-deposition which actually takes place. However, it must be noted that this is negligible from the overall European point of view but can have a dramatic influence when local emission reduction measures are implemented in different regions in Member States, as shown by national models such as the ASAM model used in the UK. These drawbacks were highlighted in the RAINS peer review.

Emission control

For a given activity scenario, RAINS is used to identify the lowest-cost combination of emission controls meeting user-supplied air quality targets, taking into account regional differences in emission control costs and atmospheric dispersion characteristics. The optimisation function is used to search for the lowest-cost mixes of controls for the six pollutants (SO_2, NO_x, VOC, NH_3, primary $PM_{2.5}$, primary $PM_{10-2.5}$ (=coarse PM)) over the various sectors of the economy in all European countries which would simultaneously achieve user-specified targets for human health impacts (e.g. expressed in terms of reduced life expectancy), ecosystems protection (e.g. expressed in terms of excess acid and nitrogen deposition) and maximum allowed violations of WHO guide values for ground-level ozone, etc.

In the RAINS model, emission control costs are evaluated at the production level, not at the level of consumer prices. Any mark-ups added to production costs by manufacturers or dealers do not represent actual resource use and are therefore ignored. Any taxes added to production costs are similarly ignored as transfers. The same applies to subsidies.

From the three components of expenditure on emission control (investment, fixed operating costs and variable operating costs), RAINS calculates annual costs per unit of activity level. Subsequently, these costs are expressed per tonne of pollutant abated. The annual cost method is applied, taking into account a uniform interest rate of 4% and constant prices for the year 2000.

Some of the parameters are considered common to all countries. These include technology-specific data, such as removal efficiencies, unit investment costs, fixed operating and maintenance costs, as well as parameters used for calculating variable cost components such as the extra demand for labour, energy and materials.

Country-specific parameters characterise the type of capacity operated in a given country and its operating conditions. These parameters include the average size of installations in a given sector, operating hours, annual fuel consumption and vehicle mileage. Costs for labour, electricity, fuel and other materials as well as for waste disposal also fall into that category.

Although based on the same principles, the methodologies for calculating costs for individual sectors need to reflect the relevant differences, e.g. in terms of capital investment. Separate formulas are therefore developed for stationary combustion sources, stationary industrial processes and mobile sources (vehicles).

The peer review highlighted that a sensitivity analysis must be performed at country and sector level in order to gain a better understanding of any possible biases. This work is currently in progress. Also, in the future RAINS should be able to obtain more up-to-date data on technologies and their costs from different data providers, notably EGTEI.

The RAINS model deals mainly with technical measures. This could introduce a bias in the results in that it over-emphasises costly (end-of-pipe) solutions and overlooks less expensive options implied or inherent in structural changes and reactions of the economy to market stimuli. However, if the energy mix includes such changes RAINS would calculate these effects. For example, the inclusion of climate change policies in the impact assessment on the Thematic Strategy on Air Pollution has induced certain structural changes and these have been estimated in the RAINS model.

The inclusion of non-technological measures, in particular in the transport sector,[157] would produce a more accurate estimate of the cost of policy. If non-technical measures are included, environmental benefits could be realised more cost-effectively.

Other basic general drawbacks include the quality of monitoring data (bearing in mind the current problems with PM monitoring, sampling and measurements as inputs; the uncertainties and classifications of different emission data and their aggregation levels such as those from VOCs; incorporation of variability of scenarios based on different meteorological years; and inclusion of improvements in relation to the current 50 km x 50 km grid size.

PRIMES energy market model

The PRIMES[158] model is used in conjunction with the RAINS model to feed in energy production and consumption in different Member States. It was developed by the National Technical University of Athens (NTUA) and has been used, among others, by DG TREN for "European Energy and Transport – Trends to 2030".

The model determines the equilibrium by finding the prices of each energy source at which the quantity producers see fit to supply matches the quantity which consumers in the Member States wish to use. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships. The model represents in detail the available energy demand and supply technologies and pollution abatement technologies. It reflects considerations about market economics, industrial structure (e.g. impact of liberalisation), energy/environmental policies and regulations. PRIMES is designed for forecasting, scenario construction and analysis of policy impact. It covers a medium- to long-term scale (2030).

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157 The original plan was that TREMOVE would provide sectoral input data for RAINS in the context of the CAFE Programme. This proved impossible due to the timetable for the two projects (as the final version of TREMOVE was not scheduled until a point when RAINS was already performing simulations). In the context of the forthcoming review of the NEC Directive, TREMOVE will be recalibrated to ensure consistency with RAINS and will be used to analyse technological measures as well as to introduce elements reflecting the reactions of the economy to market stimuli in the process of optimisation of transport measures.

158 http://www.e3mlab.ntua.gr

Cost-benefit analysis

The methodology has been developed under the *'Service Contract for Cost-Benefit Analysis (CBA) of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme'*. The objective of the service contract was to establish the capability to assess the costs and benefits of air pollution policies and to analyse scenarios generated within the CAFE Programme. The methodology paper:

– defined the overall rationale for the CBA, in particular by demonstrating how it builds on the impact assessment carried out in the RAINS integrated assessment model and the TREMOVE transport model;

– identified a general framework for quantifying impacts, including links to the other models;

– identified the assumptions and data (stock at risk inventories, response functions, unit valuations) that will form the basis for quantification of the benefits;

– set out the approaches for extending the CBA to unquantifiable impacts and for addressing other uncertainties;

– took account of the views expressed by stakeholders during the consultation process from December 2003 to October 2004;

– took account of the suggestions of the independent scientific peer review which was carried out from July to September 2004.

The role of cost-benefit analysis in the CAFE Programme

The links between different pollutants and the direct effects listed in the table below define the rationale behind the CAFE Programme: the only way to develop the most cost-effective strategies for control of these impacts is through simultaneous reduction of the pollutants covered by CAFE.

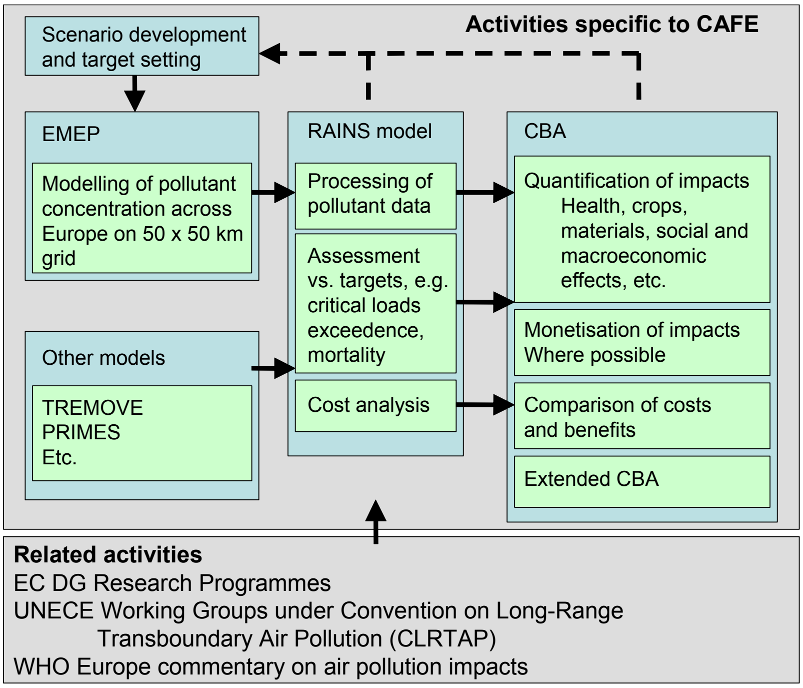
Direct and indirect impacts addressed in the cost-benefit analysis

	$PM_{2.5}$	SO_2	NO_x	VOCs	NH_3
Direct impacts					
Tropospheric ozone formation, leading to effects on health, crops, materials and ecosystems			✓	✓	
Health impacts from primary pollutants and secondary pollutants (ozone and aerosols)	✓	✓	✓	✓	✓
Ecosystem acidification		✓	✓		✓
Ecosystem eutrophication			✓		✓
Damage to building and other materials		✓	✓		
Indirect impacts					
Changes in greenhouse gas emissions as a result of measures employed to control CAFE pollutants	✓	✓	✓	✓	✓
Wider social and economic effects from impacts and the measures recommended for their control	✓	✓	✓	✓	✓

The relationship between the CBA and the other models and activities linked to the CAFE Programme is illustrated in the diagram below. The links from the RAINS and

CBA models to scenario development and target setting are shown by a dashed line to highlight the fact that although these processes will be influenced by model outputs, they are not direct outputs of the models.

It is important to draw a distinction between the roles of the RAINS and CBA models. RAINS identifies a cost-effective set of measures for meeting pre-defined health and environmental quality targets. The CBA model takes this analysis a stage further by assessing the magnitude of benefits and whether the overall benefits are higher or lower than the estimated costs.



Quantification of benefits and comparison with costs

The methodology largely builds on the ExternE[159] methodology called Impact Pathway Analysis that, starting from the sources of pollution and actual emissions of pollutants, identifies concentrations and exposure and finally arrives at the estimation of impacts and their monetary valuation. This approach follows a logical progression through the following stages:

– quantification of emissions (in CAFE, covered by the RAINS model);

– description of pollutant dispersion across Europe (in CAFE, covered by the RAINS and EMEP models);

– quantification of exposure of people, environments and buildings that are affected by air pollution;

159 European Commission, DG Research, ExternE – Externalities of Energy, EC, Luxembourg, Vol. 1 to 10, 1995 and 1999.

- quantification of the impacts of air pollution;
- valuation of the impacts; and
- description of uncertainties (in CAFE, with specific reference to their effect on the balance between the costs of pollution control quantified by the RAINS model and the associated benefits).

The quantification of impacts varies, depending on the availability of data and models:

- For health impacts, damage to crops and damage to building materials, it is generally possible to quantify the impacts including their values. Uncertainties can be addressed using statistical methods and sensitivity analysis.
- For damage to ecosystems and cultural heritage, it is possible to quantify the impacts relative to a measure of risk. However, it is not possible to value these impacts in the analysis. Examples of risk measures include:
  - the rate of deposition of acidifying pollutants relative to the critical load for acidification (as an indicator of the risk of acidification to biodiversity); and
  - the rate of corrosion of building materials as an indicator of risks to historic monuments.
- Other impacts are not currently quantifiable in terms of impact or monetary value, permitting only a qualitative analysis. Examples include reduced visibility due to air pollution and the social dimensions of health impacts.

Given the limits to quantification, an 'extended CBA' has been developed. The purpose is to provide a complete picture of whether the effects that have not been valued or quantified could have a significant effect on the balance of costs and benefits. For each impact a data sheet has been prepared containing the following types of information:

- definition of impact;
- knowledge of the link to air pollution;
- distribution of impacts across Europe;
- contextual information on the scale of associated economic effects;
- consideration of whether the impact seems likely to be important as far as the CAFE Programme is concerned, giving reasons for conclusions drawn.

Assessing the benefits of reduced air pollution for human health

Earlier cost-benefit analysis has shown that health impacts will generate the largest quantified monetary benefits when air pollution is reduced. The pollutants of most concern here are fine particles and ground-level ozone, both of which occur naturally in the atmosphere. Fine particle concentrations close to ground level are increased by emissions from human activity, whether through direct emissions of 'primary' particles or indirectly through the release of gaseous pollutants (especially SO_2, NO_x and NH_3) which react in the atmosphere to form 'secondary' particles. Ozone concentrations close to ground level are increased by anthropogenic emissions, particularly of VOCs and NO_x.

The quantification of health impacts addresses the impacts related to both long-term (chronic) and short-term (acute) exposures. The quantification deals with both mortality (i.e. deaths) and morbidity (i.e. illness). The mortality effects quantified in the CAFE cost-benefit analysis include impacts on infants as well as adults. The morbidity effects that can be quantified include major effects, such as hospital admissions and the development of chronic respiratory disease. They also include less serious effects, which are likely, however, to affect a greater number of people, for example changes in the frequency of use of medicine to control asthma and days of restricted activity. When the impact and the values are combined in the analysis, the most important health-related issues are mortality, restricted activity days and chronic bronchitis.

Major advances have been made in health valuation in recent years. The latest European "willingness to pay" estimates have been included in the CAFE CBA methodology. Accordingly, the most up-to-date information is adopted for a range of morbidity effects and mortality in the context of air pollution. The question of the method which should be used to value mortality is still being debated. The two methods which can be used – value of statistical life (VSL, applied to the change in number of deaths) and value of life year (VOLY, applied to changes in life expectancy) – have contrasting strengths and weaknesses. For the CAFE CBA methodology, the independent external peer reviewers suggested that both the VSL and the VOLY approaches be used to show transparently the uncertainty inherent in these two approaches.

Assessing the benefits of reduced air pollution for the environment

Ozone is recognised as the most serious regional air pollution problem for agriculture in Europe. The literature has linked some air pollutants other than ozone to crop damage (e.g. SO_2, NO_2, NH_3), but generally at higher levels than are currently experienced. When developing the CAFE CBA methodology it was concluded that the direct impacts of these pollutants on agriculture are likely to be small. By contrast, the indirect effects of these pollutants could be significant. This is mainly because air pollution could stimulate the performance of insects and other agricultural pests, which would then have a more severe impact on crop yield than they would have done without air pollution. Development of methods in this area has drawn, in particular, on the Integrated Cooperative Programme (ICP) on Vegetation, and ICP/MM (Mapping and Modelling).

The methods for quantification of damage to materials are based on work carried out by the ICP Materials Europe-wide International Cooperative Programme and quantification under various studies for DG Research, particularly ExternE and associated projects such as GARP (Green Accounting Research Project). The most significant impacts are on natural stone and zinc-coated materials. The 'impact pathway' approach works well for applications in everyday life. This could, in theory, be applied to cultural and historic buildings. However, in practice there is a lack of data at several points in the impact pathway with respect to the stock at risk and valuation. As a result, the effects of air pollution on cultural heritage cannot be quantified and therefore need to be addressed qualitatively through the extended CBA framework.

The effects of acidification, eutrophication and ground-level ozone can be expressed in general terms as ranging from loss of species (e.g. trout and salmon from rivers and lakes in northern Europe) to more subtle effects, for example the relative abundance of different species in grassland or moorland. Stock at risk data for ecosystem impacts have been collated over a period of many years through the Coordination Centre for Effects in the Netherlands. A framework for describing exceedance of critical loads and levels is included in the RAINS model. Valuation of these impacts is not yet possible because of limited research in this area of specific relevance to reductions in air pollutant emissions. The effects of reduced air pollution on ecosystems will therefore be calculated as part of the extended CBA, drawing extensively on the results generated by RAINS.

One major outcome of the process will be an updated BeTa table[160] which shows the value of a reduction of one tonne of pollutant in a specific location.

GEM-E3 general equilibrium model

Macro-economic effects have been assessed with the GEM-E3[161] model, an applied general equilibrium model simultaneously representing world regions or EU Member States linked through endogenous bilateral trade. GEM-E3 aims at covering the interactions between the economy, the energy system and the environment. The model simultaneously calculates the competitive market equilibrium under the Walras law and determines the optimum balance for energy demand/supply and emission/abatement. One major aim of GEM-E3 in supporting policy analysis is consistent evaluation of distributional effects across countries, economic sectors and operators. It implicitly assumes that while the EU implemented, for instance, additional air pollution abatement policies the rest of the world would not do so.

Although global, the model exhibits a sufficient degree of disaggregation concerning sectors, structural features of energy/environment and policy-oriented instruments (e.g. taxation). The model formulates production technologies on an endogenous basis allowing for price-driven derivation of all intermediate consumption and services from capital and labour. On the demand-side the model formulates consumer behaviour and distinguishes between durable (equipment) and consumable goods and services. The model is dynamic, driven by accumulation of capital and equipment. Technological progress is explicitly represented in the production functions and for each production factor.

The model formulates pollution permits for atmospheric pollutants and flexibility instruments allowing for a variety of options, including allocation (grandfathering,

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160 See http://europa.eu.int/comm/environment/enveco/air/betaec02aforprinting.pdf

161 GEM-E3 has been developed as a multinational collaboration project, partly funded by the European Commission, DG Research, 5th Framework programme and by national authorities. Further developments are continuously under way : see http://www.gem-e3.net.

auctioneering, etc.), user-defined bubbles for traders, various exemption schemes, various systems for revenue recycling, etc.

The model evaluates the energy-related emissions of CO_2, NO_x, SO_2, VOC and PM as a function of the energy consumption and abatement level per branch and per pollutant. These emissions are then converted into the concentrations/depositions of pollutants, taking into account the transportation (between countries) and transformation of the pollutants. In the final step, the damage generated by these concentrations/depositions of pollutants is calculated in physical units and valued through the valuation function.

Three types of instruments are formulated: taxes, tradable pollution permits and emission standards (upper bounds on sectors and/or countries). A variety of policy regimes associated with these instruments are considered (burden-sharing rules, limits on trade, recycling mechanism). The possibility for market forces on permit markets is also modelled.

Calibration of GEM-E3 to RAINS

The emissions of the different pollutants (NO_x, SO_2, VOC, PM_{10} and NH_3) have been calibrated to the RAINS baseline scenario associating the RAINS activities with the GEM-E3 sectors. A distinction is drawn between emissions linked to energy consumption and emissions linked to the production of a given sector, depending on the emission source identified in RAINS. Emission coefficients were calculated for 2000 and then an evolution factor for 2000-2020 was applied, based on the evolution in the RAINS data. For the emissions linked to production, only the PM and VOC emissions were adapted.

The marginal abatement cost curves per sector and per country were estimated on the basis of the cost curves from RAINS, after aggregating the data into the GEM-E3 classification. It was not possible to derive abatement cost curves for all pollutants and all sectors, because the number of abatement technologies considered in RAINS was too small for some pollutants and sectors.

The conversion of bottom-up data from RAINS into data for the GEM-E3 aggregate sectors can only be approximate. This increases the margins of error in the results with GEM-E3. The aggregate level of GEM-E3 should give a reasonably accurate initial evaluation of the macroeconomic impact of policies aiming at reducing air pollution. However, the analysis at sector and, in particular, Member State level is surrounded by relatively large uncertainties.

The benefits of reducing air pollution are evaluated with the figures calculated by the cost-benefit analysis for the damage per tonne of pollutant in each EU Member State. This allows calculation of the total EU-wide benefit from the reduction in air pollution but no allocation by country. The evaluations are carried out with the ‘low’ damage figure from AEAT.

The scenarios modelled in GEM-E3

The baseline scenario in the impact assessment assumed that the EU will achieve its Kyoto objective and that it will continue implementing a climate policy beyond

2012. Specifically, it was assumed that a "shadow price" of a climate policy operated in the PRIMES model (i.e. a recyclable CO_2 tax) would ensure some decarbonisation in the EU as a whole up to 2020. The "shadow price" was assumed to be €12/tonne in 2010, €16/tonne in 2015 and €20/tonne in 2020. The revenues from the tax were recycled in GEM-E3 model runs through a reduction in the employers' social security contribution. Also it was assumed that the resource allocation induced by the policy occurs within the EU by imposing the condition that the EU current account remains constant relative to GDP compared to the reference through a flexible interest rate. These assumptions were maintained in all policy scenarios.

The ambition levels, as derived from the aggregation into the sectors covered by GEM-E3 of the reduction imposed by RAINS, have been incorporated as a constraint into GEM-E3 in 2020. The associated costs were calculated in the model, given the marginal abatement cost curves by sector estimated on the basis of the RAINS marginal cost curves. The additional measures on transport going beyond the current legislation have also been implemented. GEM-E3 does not include all the reduction imposed in RAINS[162] but it includes the reduction induced by the decrease in energy consumption or sectoral demand due to the price increase.

UNCERTAINTY

If the costs and benefits of air pollution control were known with absolute confidence there would be no problem in comparing the two. However, costs and benefits are subject to uncertainties, some of which (on both sides of the cost-benefit equation) are significant. Knowledge of these uncertainties and the availability of information to describe them vary. Furthermore, some uncertainties are statistical and continuous in nature, others relate to discrete choices (e.g. selection of approaches for the valuation of air-pollution–related mortality) whilst yet others simply stem from a lack of knowledge. It is clear from this that it will be difficult to develop a fully consistent approach to define uncertainty across the entire CAFE analysis.

Consideration of uncertainty in any comparison of costs and benefits cannot, therefore, be an automatic process. Awareness needs to be raised of the component uncertainties of each part of the analysis. The most important of these component uncertainties should be highlighted and quantified to the extent possible. Account also needs to be taken of how satisfactory the assessment of uncertainty is. Although assessment of uncertainty is complex, it is simplified to an extent by the fact that a small number of issues are likely to dominate any consideration of uncertainty[163]. These are:

– quantification of the mortality impact of exposure to fine particles;

– valuation of mortality impacts from particles and other pollutants;

– assessment of effects of chronic exposure to particles on the prevalence of bronchitis;

[162] For some sectors there are no abatement cost curves (cf. above).

[163] In some situations others may become important, but in general those listed here will dominate.

- attribution of effects to individual species of particle or other pollutants;
- failure to quantify monetary benefits with respect to ecosystems;
- inter-annual variability in meteorology;
- various types of uncertainty in cost estimates.

Uncertainties in RAINS modelling

The RAINS model is used to calculate pollution loadings, environmental impacts and cost-effective strategies. The RAINS peer review team identified four key uncertainties associated with these calculations:

(1) uncertainties in basic scientific understanding;

(2) uncertainties due to assumptions and simplifications in the handling of data or the design of elements of the RAINS model which could introduce biases;

(3) uncertainties due to statistical variance in input data collection;

(4) uncertainties related to socio-economic and technological development.

It is impossible to quantify uncertainties stemming from incomplete scientific information and knowledge gaps. However, sensitivity scenarios can be devised to test the model's robustness against differences in scientific understanding (e.g. health impacts) and also to test different assumptions concerning socio-economic and technological development. For example, one scenario with relatively severe CO_2 reductions and another ignoring health effects due to secondary aerosols have both been tested. In both cases the central scenarios for the Strategy were robust against different underlying assumptions.

A statistical analysis was conducted of the uncertainties associated with key input parameters for the RAINS model using error propagation analysis. When uncertainties in emissions, atmospheric transport, deposition and critical loads are combined, the overall error in critical load exceedances is predicted to be in the order of 5%. This is lower than the estimate error for any of the individual parameters due to the fact that the parameters are independent of each other.

The effects of other potential biases in the RAINS model can also be minimised by the way the model framework is constructed and operated. For example, setting environmental targets on a relative basis ("gap closure") can reduce the effect of absolute biases. In addition, a conservative approach is taken to the selection of cost data and the abatement potential of technologies to avoid overestimating the potential of the control strategies modelled.

The impact assessment includes an additional sensitivity analysis linked with alternative theories on the health impact of PM (primary versus secondary particles) and the implications of post-Kyoto climate regimes. Further sensitivity analyses will be conducted in the context of revision of the NEC Directive, such as taking into account national energy and agricultural projections and inter-annual meteorological variability.

Uncertainties in cost-benefit analysis

A variety of methods for dealing with uncertainties in the CAFE-CBA have been investigated, including[164]:

- statistical techniques, for uncertainties which can be described quantitatively;
- sensitivity analysis, for demonstrating the effect of discrete choices made in the methodology, such as:
  - systematic variation in single parameters;
  - use of different methods for mortality valuation;
  - use of single years to describe meteorology in pollutant modelling;
- bias analysis, frequently linked to gaps in the analysis (e.g. the omission of abatement techniques from the cost assessment or the omission of impacts from the benefits analysis). Given that these uncertainties are by definition unquantifiable, normally they can only be dealt with subjectively. However, sufficient information exists to differentiate between what is and what is not important and to determine the direction of bias introduced to the analysis.

Statistical uncertainties are investigated in depth for the benefits analysis. The report identifies the method to be used, likely ranges in terms of 90% confidence intervals around best estimates for PM and ozone damage, and the parameters which have the greatest effect. Combined assessment of PM and ozone uncertainties is a simple extension of the method and will be carried out during scenario investigation. Given that mortality is the predominant impact in the PM assessment it is not surprising that the most influential uncertainties there concern quantification and valuation of mortality. For ozone, the picture is more mixed, with mortality and minor restrictions on activity both important contributors. When the 'sensitivity' functions are added in, uncertainties on assessment and valuation of respiratory symptoms in adults predominate in the case of ozone. None of the sensitivity functions has any significant effect on uncertainties in PM assessment.

For scenario analysis the quantified variation in benefit estimates can now be used to quantify the probability that benefits will exceed the point estimates of costs generated by the RAINS model. Similar statistical assessment of errors in these cost estimates is not yet possible. However, it is possible to investigate the effect of uncertainty in costs using a stepwise sensitivity analysis. This would involve assessment of the probability of benefits exceeding a series of cost estimates varying by set percentages around the core estimates from RAINS. Turning to sensitivity analysis, the following conclusions have been drawn:

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164 Methodology for the Cost-Benefit Analysis of the CAFE Programme - Part 3: Uncertainty (AEAT, April 2005).

- Statistical analysis shows that variation in results due to different methods for mortality valuation is not as large for PM assessment as originally suspected, with significant overlap in the ranges for VOLY (value of life year) and VSL (value of statistical life) methods. However, it is significant enough to include separate results for the two approaches when reporting.

- Sensitivity to differences in the risks posed by different types of particle will be investigated if and when proposals are made for future policy assessments.

- The effect of the use of a cut-point for the ozone health assessment will be factored into the stratified sensitivity analysis where there is specific concern over the effects of ozone. Where ozone is not a key driver this sensitivity is unlikely to be important.

- The choice of meteorological year is important for modelling pollutant dispersion and chemistry. It can be accounted for by using four different and contrasting meteorological years (1997, 1999, 2000 and 2003). Where this is not done, the effect on health impact assessment can be estimated for each country by reference to figures presented in the report.

- The stratified sensitivity analysis used previously in assessment of the NEC and Ozone Directives and the Gothenburg Protocol should be retained principally for ozone assessments. For scenarios dominated by PM it plays a smaller role because of the higher confidence in quantification of the dominant impact (mortality) and the very limited effect of the functions identified in Volume 2 for sensitivity analysis. These add just a few percent to the total PM damage.

The results of the EMEP, RAINS and CAFE-CBA models are inevitably subject to a number of unquantified biases in addition to the uncertainties already mentioned. The most important of these are:

- EMEP modelling: omission of secondary organic aerosols;

- RAINS modelling: emission starting point bias, omission of some abatement techniques, failure to take account of future technical developments and lack of differentiation of particle species by effect;

- Benefits modelling: omission of impacts on ecosystems and cultural heritage and non-differentiation of particle species by effect.

The analysis undertaken here provides an indication of the direction and potential importance of these biases. It should be noted that the scale of bias can be very substantial and, as such, could affect the conclusions drawn on the balance of costs and benefits, although this is likely to vary considerably between regions and scenarios. Knowledge of these biases, however, opens up the possibility of factoring them into appraisal of the results of the cost-benefit analysis, for example, using stepwise sensitivity analysis. The need to do so depends on the initial outcome of the CBA and the likely direction of the most important biases.

Clearly, these uncertainties should not be considered in isolation. Stakeholders should instead seek to develop an overview of them in order to understand the reliability of any conclusions drawn on the balance of costs and benefits for particular cases. A protocol is being defined so that information on the different uncertainties present can be brought together in a unified assessment.