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Policy Scenarios for the Revision of the Thematic Strategy on Air Pollution

TSAP Report #10

Version 1.2

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Executive Summary

This report explores how the European Union could make further progress towards the objectives of the EU's Environment Action Programme, i.e., to achieve 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment'. It confirms earlier findings that there is still large scope for additional measures that could alleviate the remaining damage. This scope prevails despite the significant air quality improvements that emerge from current EU air quality legislation. However, such further environmental improvements require additional efforts to reduce emissions, which are associated with additional costs. It is estimated that in 2025 the full implementation of all currently available technical measures would involve additional emission control costs of up to 0.3% of GDP, compared to 0.6% that are spent under current legislation.

As a rational approach, the report compares marginal costs of further emission reductions against their marginal benefits. Restricted to monetized benefits of adult mortality from exposure to PM2.5, marginal health benefits are found to equal marginal costs of further measures slightly above a 75% 'gap closure' between the current legislation baseline and the maximum feasible reductions. At this level, emission reduction costs (on top of current legislation) amount to 4.5 billion €/yr, while benefits from these measures are estimated at 30.4 billion €/yr.

However, such a narrow focus on health benefits leaves out 'low hanging fruits' for ozone, eutrophication and acidification that could be achieved at little extra cost. A central scenario is analysed further that in 2025 would achieve 75% of the possible health improvements, 65% of the possible gains for acidification, 60% of the potential for less ground-level ozone, and 55% for eutrophication. At costs of 5.8 billion €/yr (0.04% of GDP), these measures would cut SO_2 by 77%, NO_x by 65%, PM2.5 by 50%, NH_3 by 27% and VOC by 54% relative to 2005. In addition, BC emissions would be decline by 33%, particle number emissions by 73% and Hg emissions by 33%.

These measures for 2025 were scrutinized against potential regret investments that would become obsolete in 2030 if the emission source would be phased out as part of economic restructuring. It was found that the emission ceilings of the central scenario do not contain significant regret investments, considering the uncertainties around the baseline projection. Appropriate flexibility mechanisms could avoid such regret investments for specific situations where the energy system would drastically restructure.

Numerous uncertainties affect future levels of baseline emissions and the potential and costs for further measures. A sensitivity case demonstrates the feasibility of the central environmental targets under the assumptions of the earlier TSAP baseline, which was more optimistic about future economic development. However, it was found that not all of the corresponding emission ceilings that have been cost-optimized for the TSAP-2013 scenario would be achievable under the TSAP-2012 assumptions. It has been demonstrated that alternative sets of emission ceilings could be derived that could avoid excessive costs to individual Member States if reality developed differently from what has been assumed in the cost-effectiveness analysis. However, such 'insurance' against alternative developments comes at a certain cost.

With the current assumptions on costs for low sulphur fuels, the additional costs of packages of SECAs and NECAs in the 200 nm zones of the EU Member States (with the exception of a SECA in the Mediterranean Sea) could be almost compensated by cost-savings at land-based sources.

Europe-wide regulations of agricultural emission control measures such as those outlined in the Draft Annex IX of the revised Gothenburg Protocol could be part of a cost-effective solution for achieving the environmental targets of the A5 scenario.

List of acronyms

BAT	Best Available Technology
BC	Black Carbon
bbl	barrel of oil
boe	barrel of oil equivalent
CAFE	Clean Air For Europe Programme of the European Commission
CAPRI	Agricultural model developed by the University of Bonn
CO_2	Carbon dioxide
CCS	Carbon Capture and Storage
EC4MACS	European Consortium for Modelling Air Pollution and Climate Strategies
EU	European Union
GAINS	Greenhouse gas - Air pollution Interactions and Synergies model
GDP	Gross domestic product
Hg	Mercury
IED	Industrial Emissions Directive
IIASA	International Institute for Applied Systems Analysis
IPPC	Integrated Pollution Prevention and Control
kt	kilotons = 10^3 tons
LCP	Large Combustion Plants
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NEC	National Emission Ceilings
NECA	NO_x Emissions Control Area
NH_3	Ammonia
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen oxides
O_3	Ozone
PJ	Petajoule = 10^{15} joule
PM10	Fine particles with an aerodynamic diameter of less than 10 µm
PM2.5	Fine particles with an aerodynamic diameter of less than 2.5 µm
PRIMES	Energy Systems Model of the National Technical University of Athens
SECA	Sulphur Emissions Control Areas
SNAP	Selected Nomenclature for Air Pollutants; Sector aggregation used in the CORINAIR emission inventory system
SO_2	Sulphur dioxide
SULEV	Super Ultra-Low Emission Vehicles; a terminology used for the Californian vehicle emission standards
TSAP	Thematic Strategy on Air Pollution
VOC	Volatile organic compounds

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More information on the Internet

More information about the GAINS methodology and interactive access to input data and results is available at the Internet at http://gains.iiasa.ac.at/TSAP.

1 Introduction

The European Commission is currently reviewing the EU air policy and in particular the 2005 Thematic Strategy on Air Pollution. It is envisaged that in 2013 the Commission will present proposals for revisions of the Thematic Strategy.

As analytical input to these forthcoming policy proposals, IIASA developed baseline emission projections in the TSAP Report #1 (Amann et al. 2012a), explored their environmental impacts in TSAP Report #6 (Amann et al. 2012b), and presented an initial screening of cost-effective additional emission control measures in TSAP Report #7 (Amann et al. 2012d). This information offers now a solid basis for more refined policy analyses to identify practical packages of measures that could achieve further air quality improvements in cost-effective ways.

1.1 Objective of this report

To provide an analytical basis for the Commission proposal on the review of the Thematic Strategy, this report explores options for further improvements of air quality in Europe beyond current legislation.

The report reviews the potential for environmental improvements offered by emission control measures that are not yet part of current legislation, and compares costs and benefits of cost-effective packages of measures to reduce negative health and vegetation impacts.

The central analysis relies on the new draft TSAP-2013 scenario that incorporates the draft PRIMES-2012 energy projection that has been recently presented to Member States. Key findings are cross-checked against alternative energy futures, i.e., against the TSAP-2012 Baseline that employed the PRIMES-2010 scenario, which assumed, inter alia, significantly higher economic growth.

1.2 Methodology

This report employs the model toolbox developed under the EC4MACS (European Consortium for Modelling of Air pollution and Climate Strategies) project, which was funded under the EU LIFE programme (www.ec4macs.eu).

The EC4MACS model toolbox (Figure 1.1) allows simulation of the impacts of policy actions that influence future driving forces (e.g., energy consumption, transport demand, agricultural activities), and of dedicated measures to reduce the release of emissions to the atmosphere, on total emissions, resulting air quality, and a basket of air quality and climate impact indicators. Furthermore, through the GAINS optimization tool (Amann 2012), the framework allows the development of cost-effective response strategies that meet environmental policy targets at least cost.

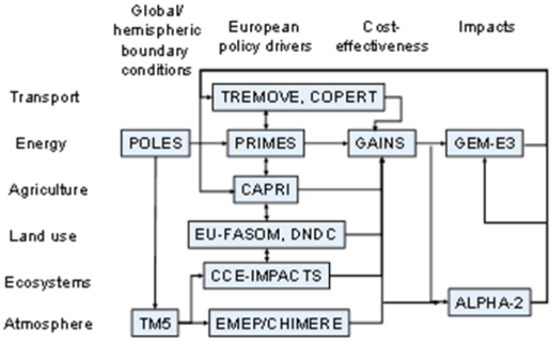

Figure 1.1: The EC4MACS model suite that describes the full range of driving forces and impacts at the local, European and global scale.

1.3 Structure of the report

Section 2 of this report provides a brief summary of the changes that have been introduced to the modelling methodology and databases. Section 3 introduces the new draft TSAP-2012 Baseline projection, and Section 4 discusses the scope for further air quality improvements beyond the baseline projections. Section 5 explores costs and benefits of additional measures, while Section 6 assesses alternative ways for implementation of some of the optimized scenarios. Sensitivity analyses are carried out in Section 7, and conclusions drawn in Section 8.

2 Changes since the last report

This analysis constitutes #10 of a series of reports that assess various aspects that are relevant for a strategic review of the current EU legislation on air quality. All reports are accessible on the Internet[1].

Since the last TSAP Report #6 report, (Amann et al. 2012b), the following changes have been implemented in the GAINS database and to the GAINS methodology.

2.1 Updates of GAINS databases to reflect new national information

In the second half of 2012, bilateral consultations were held with 15 countries (Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Sweden, Switzerland, UK).

After validation and consistency checks, the new information provided by national experts on energy statistics, emission inventories, emission factors and the penetration of emission controls has been incorporated into the GAINS databases. As the new PRIMES-2012 scenario was not yet available at the time of these consultations, the new information has been applied to the draft TSAP-2012 Baseline that relies on the PRIMES-2010 baseline energy projection. Thus, the draft TSAP-2012 Baseline presented in this report is different from the version introduced in the TSAP report #6. The new information has also been used for the conversion of the new PRIMES-2012 Reference scenario into the GAINS TSAP-2013 Baseline.

Stationary energy use

The, GAINS database was revised to better reproduce recent national emission inventories for 2005 and 2010 as reported to EMEP in 2012. This revision took into account the results of bilateral consultations as well as consultations with industrial stakeholders (EURELECTRIC, CONCAWE). Better match was achieved through adjustments of control strategies and emission factors.

In addition, new information allowed a better classification of gas use in the power sector, so that GAINS distinguishes now four types of plants (i.e., plants with boilers, turbines, gas combined cycle plants, and gas engines). These categories differ in their emission factors and the potential for further emission controls. In addition, emission factors for gas fired power plants have been updated to better reflect features of individual countries, such as age and operating regimes. Also, emission factors for stationary combustion engines in the power sector (generators) have been revised based on data provided by CITEPA.

Investment costs for refinery boilers and furnaces using heavy fuel oil have been revised to reflect higher capital investments for co-fired units due to larger flue gas volume). Information was provided by experts from the refining industry (CONCAWE).

The description of legislation on national maritime activities has been refined to include the IMO MARPOL Annex VI emission and fuel standards as well as the compromise agreement between the EU Member States, the European Parliament and the European Commission. The latter requires implementation of the general sulphur limit 0.5% S already in 2020. SECA legislation has been included for the Baltic and the North Sea with the English Channel.

In addition, numerous changes for individual countries were implemented. Some examples include:

- Belgium: inclusion of waste fuels in chemical industry, which are not reported in the EUROSTAT statistics; corrections of control strategies; update of applicabilities of control technologies.
- Finland: inclusion of country-specific emission factors for black liquor, modifications of PM emission factors for boilers to align with the Finnish national inventory.
- Germany: revision of data on (bio-)gas engines, changed structure of brown coal used

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[1] http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP-review.en.html

for power generation according to the recent statistics (high vs. low sulphur lignite).

- Estonia: inclusion of characteristics of oil shale combustion technologies and shale oil refineries (unique technologies, not used in other countries).
- France: revision of emission factors and activity data for combustion and process sectors based on detailed inventory by CITEPA.
- Netherlands: changed structure of liquid fuels consumption for power generation in CHP plants in refineries (less heavy fuel oil, more other liquid fuels with lower sulphur content); inclusion of emissions from processes in mineral products industry previously not properly covered in the GAINS database).

Residential combustion

Activity data for non-commercial wood and/or structure of installations, i.e., shares of stoves, boilers, etc. in fuel (both wood and coal) use for past years and future have been provided by Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, Italy, Poland, Slovak Republic, Slovenia, and Sweden.

Local measurements of emission factors provided by Denmark, Finland, Italy, Slovak Republic, UK helped to update national emission factors.

Austria, Denmark, Estonia, Finland, Italy, Slovak Republic, Sweden, and the UK provided new assessments about the penetration of more advanced combustion technologies in this sector, their future evolution following existing legislation (certification of new installations), and expected replacement rates due to retirement of existing installations.

Mobile sources

For transport, major improvements relate to fuel allocation (diesel/gasoline) across vehicle categories (heavy/light duty vehicles), emission factors and the penetration of Euro-standards. This now brings the GAINS emission estimate for the year 2010 in very close agreement with national inventories.

Most importantly, (diesel) fuel has been re-allocated between different road vehicle categories as well as between non-road categories for Austria, Finland, Germany, Ireland, Italy, the Netherlands, Sweden, Switzerland, and the UK. These structural changes have been propagated to the future scenarios. The fleet composition by technology (in GAINS the so-called ‘control strategy’) has been cross-checked with experts from these countries and revised where appropriate. To explore the implications of a slower turnover of passenger diesel car fleets, a sensitivity scenario is presented in this report.

In addition to country comments, the following changes have been implemented:

The PRIMES-2012 Reference scenario has been fully implemented in terms of transport activity and associated changes in the fleet. The previously used PRIMES 2010 BASELINE scenario is now interpreted as a “high economic growth” variant.

PM emission factors for tyre and brake wear have been revised downwards in the light of recent evidence; likewise, NO_x and PM emission factors for non-road mobile machinery have been revised. Real-driving NO_x emissions from Euro-6 light duty diesel vehicles are assumed to decrease in two steps, namely to about 310 mg NO_x/km in a first step and to 120 mg NO_x/km in the second step. Vehicles with these average emissions are assumed to be introduced from 2014 and from 2017 onwards in the baseline scenario.

Agriculture

New data on livestock and fertilizer use have been obtained from several countries and used to update historical data for recent years and 2010 also with respect to number of animals kept on solid and liquid systems and shares of urea in total mineral N fertilizer use. The updated information was also applied to the new CAPRI projections where such distinction is missing. The above was done for Austria, Belgium, Denmark, France, Ireland, Italy, Netherlands, Slovak Republic, Switzerland, UK.

In the last years, more and more countries have started using the Tier2 methodology of the EEA Emission Inventory Guidebook for estimating ammonia emissions. Beyond that, a number of countries committed their own national studies to analyse the local production conditions, efficiency, and resulting losses of ammonia from agriculture.

This new information was used to update ammonia emission factors for Austria, Denmark, France, Ireland, Netherlands, UK.

Accurate estimates of ammonia emissions, as well as other species, require analysis of the policies and their implementation. The implementation of mandatory and voluntary measures in agriculture has been always a challenge and only recently more attention has been given to agricultural emissions to the air.

Several Member States (Austria, France, Ireland, Italy, Netherlands) provided new information on implementation status and management practices that resulted in the development of new emission factors and assumptions on the penetration of specific control measures.

VOC emissions

A number of countries (Austria, Belgium, Estonia, Italy, Netherlands, United Kingdom) provided new information about recent developments in several industries, which was used to update historic activity data in GAINS and adjust projections for future years.

New information on control strategies for solvent use and liquid fuel production and distribution was provided by Austria, Belgium, Estonia, Ireland, Italy, Netherlands, Sweden, United Kingdom.

On-field burning of agricultural residue

Following discussion with national experts, SEG4, groups working on the assessment of open biomass burning (including agricultural fires) with remote sensing techniques (i.e., GFED, FINN, and University of Michigan) were contacted to improve the representation of this activity in GAINS based on latest available knowledge.

Most recent national reporting documented at www.ceip.at has been used to update the GAINS estimates; however, many countries do not report any agricultural burning. This was also confirmed during bilateral consultation where several national experts confirmed. At the same time, however, nearly all experts recognized the fact that most countries have exceptions to the rules and issue occasional permits. Furthermore, the emission inventory community often did not investigate the enforcement efficiency of the ban. As a consequence, the most recent reporting from Austria, Switzerland and Finland includes now agricultural burning. Based on this information and drawing on results from remote sensing, the GAINS database has been revised for Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, UK.

2.2 The TSAP-2013 Baseline

Compared to TSAP Reports #1 and 6, a new draft TSAP-2013 Baseline has been developed. It employs the most recent draft PRIMES-2012 Reference energy and CAPRI agricultural projections that have been presented for comments to Member States in late 2012. Details of the PRIMES-2012 scenario are provided in Section 3.

2.3 Downscaling methodology

The new downscaling methodology that has been developed under the EC4MACS project to estimate the impacts of future emission scenarios on compliance with air quality limit values for PM10 and NO_2 has now been fully implemented in the GAINS model. The methodology is documented in TSAP Report #9 (Kiesewetter et al. 2013).

After the initial assessment presented in TSAP report #6, the AIRBASE monitoring stations have been allocated to the air quality management zones established under the Air Quality Daughter Directive, so that compliance statistics can now be evaluated and presented for these zones across Europe.

2.4 Impact assessment methodologies

The HRAPIE (Health risks of air pollution in Europe) project conducted by the European Centre for Environment and Health of the World Health Organization has provided specific recommendation of concentration-response functions for core input into the GAINS model for mortality from PM2.5 and ozone to be used in cost-effectiveness analysis (WHO 2013). The recommendations consider specific conditions of

EU countries, in particular in relation to the range of PM2.5 and ozone concentrations expected to be observed in EU in 2020 and availability of baseline health data.

For fine particulate matter, it is recommended that the core cost-effectiveness analysis includes estimates of impact of long term (annual average) exposure to PM2.5 on all-cause (natural) mortality in adult populations (age >30), based on a linear concentration-response function, with relative risk of 1.062 (95% CI 1.040 – 1.083) per 10 µg/m^3. The impacts are to be calculated at all levels of PM2.5.

The central relative risk factor of 1.062 emerges from the most recently completed meta-analysis of all cohort studies published until January 2013 by Hoek et al (Environmental Health 2013, prov. accepted). 13 different studies conducted in adult populations of North America and Europe contributed to estimation of this coefficient. This factor is slightly higher compared to the factor of 1.06 that has been used for earlier GAINS analysis based on Pope III et al. 2002.

It is recommended to explore the implications of alternative, more refined approaches (e.g., cause-specific mortality estimates, non-linear relative risk functions, etc.) in the context of benefit analyses.

For ozone, the core cost-effectiveness analysis should be based on estimates of impact of short term (daily maximum 8-hour mean) exposure to ozone on all-ages all-cause mortality. The impacts of ozone in concentrations above 35 ppb (70 µg/m^3), i.e., using SOMO35, should be calculated with a linear function with a risk coefficient of 1.0029 (95%CI 1.0014-1.0043) per 10 µg/m^3 These new coefficients are based on data from 32 European cities included in the APHENA study (Katsouyanni et al. 2009). Earlier GAINS analysis employed a factor of 1.003.

It is noted that after 2005 several cohort analyses have been published on long-term ozone exposure and mortality. There is evidence from the most influential study, the American Cancer Society (ACS) study, for an effect of long-term exposure to ozone on respiratory and cardiorespiratory mortality, which for the latter is less conclusive. Also, there is some evidence from other cohorts for an effect on mortality among persons with potentially predisposing conditions (chronic obstructive pulmonary disease, diabetes, congestive heart failure, and myocardial infarction). However, these effects should be treated in sensitivity analyses of the cost-benefit assessment.

The above-mentioned modifications, i.e., the new relative risk factors, have been introduced into the GAINS framework that is used for this report. The calculations employ now the most recent mortality numbers provided in the WHO 'Health for All' database[2].

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[2] http://www.euro.who.int/en/what-we-do/data-and-evidence/databases/mortality-indicators-by-67-causes-of-death,-age-and-sex-hfa-mdb.

3 Projections of energy use and agricultural activities

3.1 The draft TSAP-2013 Baseline

A draft version of a baseline projection has been developed that employs the latest projections of economic growth, energy use, transport activities and agricultural production developed by the European Commission. This draft TSAP-2013 Baseline combines energy projections of the PRIMES-2012 Reference scenario and the corresponding projections of agricultural activities produced by the CAPRI model.

3.1.1 The draft PRIMES-2012 Reference energy projection

The draft PRIMES-2012 Reference energy projection has been presented to Member States in late 2012. This projection assesses the impacts of all EU policies that have been adopted given current energy, transport, overall economic and climate trends.

Key assumptions

One major difference to earlier scenarios emerges for the assumed future economic development (Figure 3.1).

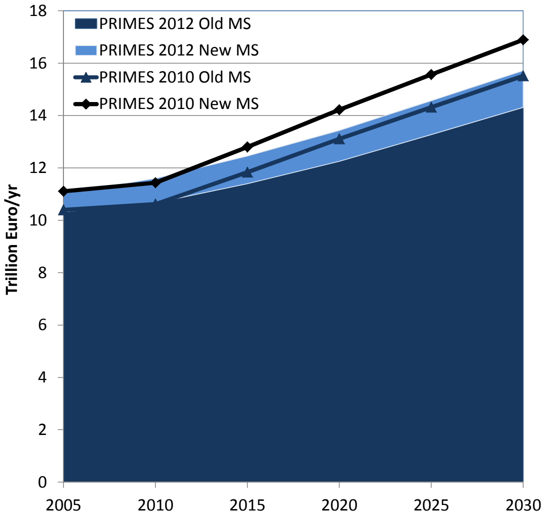

Figure 3.1: Projections of GDP up to 2030; the PRIMES-2012 scenario (shaded area) compared to the assumptions of the PRIMES-2010 case (lines) (EU-28, in €2005)

While the earlier PRIMES-2010 projection has assumed fast recovery after the economic downturn in 2008, the 2012 scenario considers the prolonged stagnation period that has occurred since then, and is less optimistic about future growth rates. Thus, in the recent scenario GDP in 2030 is 7% lower than in the earlier projection.

Additional differences apply to assumptions on energy and climate policies. The draft PRIMES-2012 Reference projection considers all EU policies that were adopted by the Commission under energy, transport, overall economic and climate trends. It assumes in particular that the national targets for renewable energy for 2020 are met.

Energy use

The assumptions in the draft PRIMES-2012 scenario on economic development, enhanced energy efficiency and renewable energy policies and climate strategies lead to almost 10% lower fuel consumption in 2030 compared to 2005 (Figure 3.2, Table 3.1).

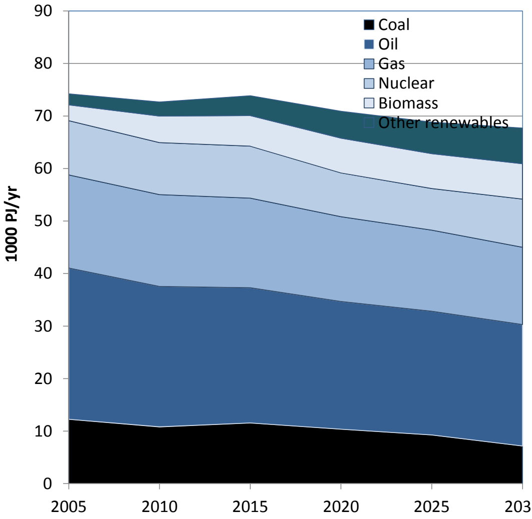

Figure 3.2: Energy consumption by fuel of the PRIMES-2012 projection, EU-28

The adopted policies for renewable energy sources are expected to increase biomass use by more than a factor of two thirds in 2030 compared to

2005, and to triple energy from other renewable sources (e.g., wind, solar). In contrast, coal consumption is expected to decline by 40% by 2030, and oil and natural gas consumption is calculated to be 20% lower than in 2005.

On a sectorial basis, the rapid penetration of energy efficiency measures maintains constant or slightly decreasing energy consumption despite the assumed sharp increases in production levels and economic wealth (Figure 3.3, Table 3.2).

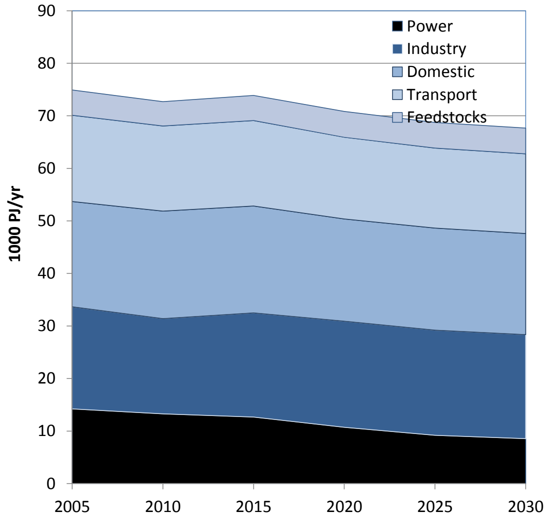

Figure 3.3: Energy consumption by sector of the PRIMES-2012 projection, EU-28

New legislation on fuel efficiency should stabilize the growth in fuel demand for total road transport despite the expected increases in travel distance and freight volumes.

The projected evolution of energy consumption by Member State is summarized in Table 3.3. Implications for future emissions and the scope for further emission reductions are explored in Section 4.

3.1.2 The 2012 CAPRI scenario of agricultural activities

The CAPRI model has been used to project future agricultural activities in Europe coherent with the macro-economic assumptions of the draft PRIMES-2012 Reference scenario and considering the likely impacts of the most recent agricultural policies. The evolution of livestock is summarized in Figure 3.4.

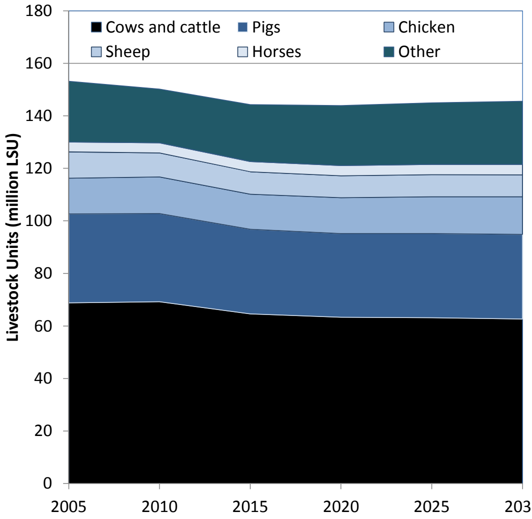

Figure 3.4: CAPRI projection of agricultural livestock in the EU-28 for the PRIMES-2012 Baseline scenario (million livestock units)

Table 3.1: Baseline energy consumption by fuel in the EU-28 (1000 PJ, excluding electricity trade)

	2005	2010	2015	2020	2025	2030
Coal	12.2	10.8	11.6	10.4	9.3	7.2
Oil	28.8	26.7	25.7	24.3	23.6	23.1
Gas	17.7	17.5	17.1	16.1	15.4	14.7
Nuclear	10.3	9.9	9.9	8.3	7.9	9.2
Biomass	3.0	5.1	5.8	6.6	6.6	6.7
Other renewables	2.1	2.7	3.8	5.1	6.0	6.8
Total	74.2	72.7	73.9	70.9	68.8	67.7

Table 3.2: Baseline energy consumption by sector in the EU-28 (1000 PJ)

	2005	2010	2015	2020	2025	2030
Power sector	14.2	13.3	12.7	10.7	9.2	8.6
Households	19.4	18.1	19.8	20.2	20.0	19.8
Industry	20.0	20.5	20.4	19.5	19.4	19.3
Transport	16.4	16.2	16.2	15.6	15.2	15.2
Non-energy	4.8	4.6	4.8	4.9	4.9	4.9
Total	74.9	72.7	73.9	70.8	68.7	67.7

Table 3.3: Baseline energy consumption by country (Petajoules)

	2005	2010	2015	2020	2025	2030
Austria	1440	1449	1584	1529	1486	1446
Belgium	2673	2522	2501	2417	2131	2047
Bulgaria	852	766	774	777	794	721
Cyprus	109	115	123	109	107	108
Czech Rep.	1875	1863	1840	1820	1852	1914
Denmark	826	844	830	784	770	747
Estonia	218	218	225	219	224	190
Finland	1652	1576	1700	1695	1735	1776
France	11661	11246	11394	10614	10538	10500
Germany	14140	14301	14032	12678	11652	10959
Greece	1319	1180	1160	1181	1017	935
Hungary	1168	1089	1092	1085	1120	1172
Ireland	595	568	613	620	617	636
Italy	7149	6605	6428	6262	6086	6084
Latvia	193	202	203	201	204	206
Lithuania	360	288	292	289	323	360
Luxembourg	198	197	176	188	188	188
Malta	40	38	39	31	30	30
Netherlands	3450	3430	3624	3495	3363	3251
Poland	3927	4282	4749	5092	5116	5181
Portugal	1139	1034	1011	1006	999	992
Romania	1641	1483	1557	1620	1596	1605
Slovakia	773	761	818	862	884	906
Slovenia	306	305	324	318	325	339
Spain	5964	5388	5647	5571	5791	5893
Sweden	2204	2156	2279	2331	2317	2313
UK	8680	8424	8495	7680	7124	6796
EU-27	74552	72332	73512	70473	68389	67295
Croatia	376	360	368	367	359	367
EU-28	74928	72692	73880	70841	68749	67662

3.2 The revised TSAP-2012 Baseline

As a sensitivity case, this report employs a slightly revised version of the TSAP-2012 Baseline scenario, which is discussed in detail in TSAP Reports #1 and #6 (Amann et al. 2012c, Amann et al. 2012b). Since then, revisions have been implemented to reflect new information on emission factors and energy statistics that has emerged from the bilateral consultations between IIASA and experts from Member States.

The TSAP-2012 employs the reference energy projection that has been developed for the 2009 update of the 'EU energy trends to 2030' report of DG-Energy (CEC 2010). Dating back to 2009, this scenario assumes higher economic growth than the most recent projection (Figure 3.1) and does not fully reflect the recent EU targets on energy efficiency and renewable energy.

Energy use

The 'PRIMES-2010' energy scenario suggests the total volume of energy consumption to remain at today's level, while the structural composition of fuels and energy sources is anticipated to change Figure 3.5).

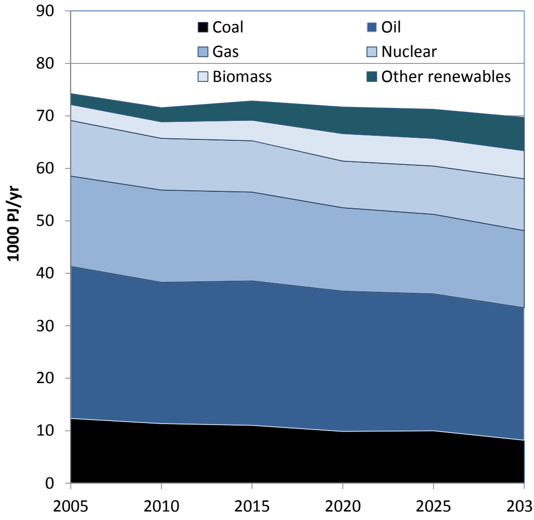

Figure 3.5: Energy consumption of the PRIMES-2010 Baseline scenario, by fuel in the EU-28

Most importantly, policies for renewable energy sources were expected to increase biomass use by two thirds in 2030 compared to 2005, and to triple energy from other renewable sources (e.g., wind, solar). In contrast, coal consumption was expected to decline by 18% by 2030, and oil consumption is calculated to be 13% lower than in 2005.

Agricultural activities

The CAPRI projection coherent with the PRIMES-2010 energy scenario predicted significant changes in the livestock sector as a consequence of the EU agricultural policy reform. In this scenario, dairy cow numbers in the EU would increase, and productivity would improve. As a consequence, also the number of other cattle grow further in this scenario, while pig and poultry numbers, which are not strongly influenced by new policies, are expected to continue their increase (Figure 3.6).

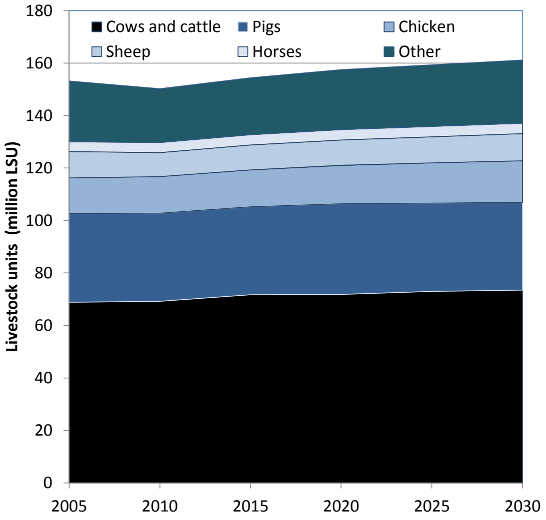

Figure 3.6: CAPRI projection of agricultural livestock in the EU-28 for the PRIMES-2010 Baseline scenario (million livestock units)

3.3 Comparison of activity data

To highlight the different assumptions on activity data of the various emission control scenarios analysed in this report, energy use by fuel type are compared in Figure 3.7, and livestock data in Figure 3.8. Obviously, there are large differences between the scenarios, which provide a solid basis for an assessment of the robustness of the conclusions derived from the cost-effectiveness analysis of further emission control measures.

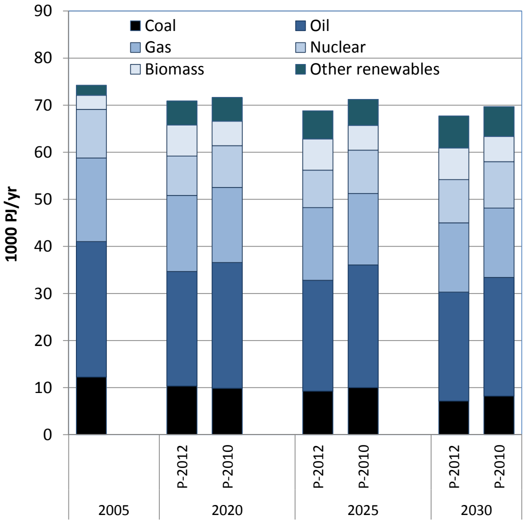

Figure 3.7: Energy consumption in 2005, 2020, 2025 and 2030, of the PRIMES-2012 Reference and the PRIMES-2010 Baseline scenarios that are used in the TSAP-2013 and TSAP-2012 Baseline projections

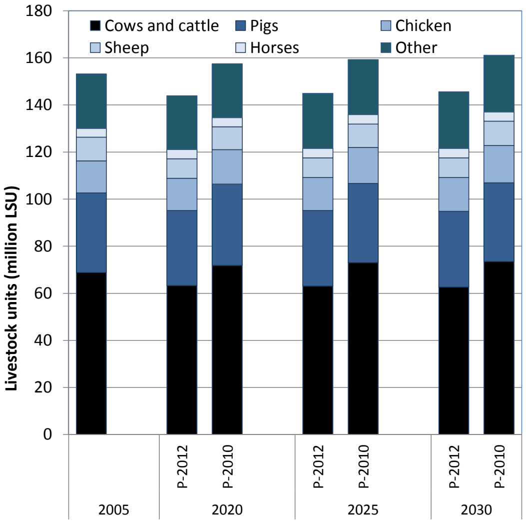

Figure 3.8: Animal numbers (in livestock units) in 2005, 2020, 2025 and 2030 of the CAPRI projection of the TSAP-2013 and TSAP-2012 scenarios

4 The scope for further emission reductions

This section presents emission projections and estimates of emission control costs and air quality impact indicators for the current legislation baseline and the maximum technically feasible emission control cases. As a central case, the analysis is conducted for the draft TSAP-2013 Baseline scenario (based on PRIMES-2012), and results are compared against the TSAP-2012 Baseline (based on PRMES-2010).

In a further step, optimization analyses with the GAINS model explore for the various air quality impact indicators the increase in costs for gradually closing the 'gap' between the current legislation to the maximum feasible reduction cases.

4.1 Assumptions on emission control scenarios

4.1.1 Emission control legislation considered in the 'Current legislation' (CLE) scenarios

In addition to the energy, climate and agricultural policies that are assumed in the different energy and agricultural projections, the baseline projections consider a detailed inventory of national emission control legislation (including the transposition of EU-wide legislation). They assume that these regulations will be fully complied with in all Member States according to the foreseen time schedule. For CO_2, regulations are included in the PRIMES calculations as they affect the structure and volumes of energy consumption. For non-CO_2 greenhouse gases and air pollutants, EU and Member States have issued a wide body of legislation that limits emissions from specific sources, or have indirect impacts on emissions through affecting activity rates.

For air pollutants, the baseline assumes the regulations described in Box 1 to Box 5. However, the analysis does not consider the impacts of other legislation for which the actual impacts on future activity levels cannot yet be quantified. This includes compliance with the air quality limit values for PM, NO_2 and ozone established by the Air Quality directive, which could require, inter alia, traffic restrictions in urban areas and thereby modifications of the traffic volumes assumed in the baseline projection.

Although some other relevant directives such as the Nitrates directive are part of current legislation, there are some uncertainties as to how the measures can be represented in the framework of integrated assessment modelling.

The baseline assumes full implementation of this legislation according to the foreseen schedule. Derogations under the IPPC, LCP and IED directives granted by national authorities to individual plants are considered to the extent that these have been communicated by national experts to IIASA.

Box 1: Legislation considered for SO_2 emissions

- Directive on Industrial Emissions for large combustion plants (derogations and opt-outs are considered according to the information provided by national experts)
- BAT requirements for industrial processes according to the provisions of the Industrial Emissions directive.
- Directive on the sulphur content in liquid fuels
- Fuel Quality directive 2009/30/EC on the quality of petrol and diesel fuels, as well as the implications of the mandatory requirements for renewable fuels/energy in the transport sector
- MARPOL Annex VI revisions from MEPC57 regarding sulphur content of marine fuels
- National legislation and national practices (if stricter)

For NO_x emissions from transport, all scenarios presented here assume from 2017 onwards real-life NO_x emissions to be 1.5 times higher than the NTE Euro-6 test cycle limit value, in line with what has been assumed for the TSAP-2012 Baseline presented in TSAP Report #6. This results in about 120 mg NO_x/km for real-world driving conditions, compared to the limit value of 80 mg/km. As portable emissions measurement systems (PEMS) will only be introduced gradually, between 2014 and 2017 emission factors of new cars are assumed at 310 mg NO_x/km. Also, inland vessels are excluded from Stage IIIB or higher emission controls, and railcars and locomotives not subject to Stage IV controls.

Box 2: Legislation considered for NO_x emissions

- Directive on Industrial Emissions for large combustion plants (derogations and opt-outs included according to information provided by national experts)
- BAT requirements for industrial processes according to the provisions of the Industrial Emissions directive
- For light duty vehicles: All Euro standards, including adopted Euro-5 and Euro-6, becoming mandatory for all new registrations from 2011 and 2015 onwards, respectively (692/2008/EC), (see also comments below about the assumed implementation schedule of Euro-6).
- For heavy duty vehicles: All Euro standards, including adopted Euro-V and Euro-VI, becoming mandatory for all new registrations from 2009 and 2014 respectively (595/2009/EC).
- For motorcycles and mopeds: All Euro standards for motorcycles and mopeds up to Euro-3, mandatory for all new registrations from 2007 (DIR 2003/77/EC, DIR 2005/30/EC, DIR 2006/27/EC). Proposals for Euro-4/5/6 not yet legislated.
- For non-road mobile machinery: All EU emission controls up to Stages IIIA, IIIB and IV, with introduction dates by 2006, 2011, and 2014 (DIR 2004/26/EC). Stage IIIB or higher standards do not apply to inland vessels IIIB, and railcars and locomotives are not subject to Stage IV controls.
- MARPOL Annex VI revisions from MEPC57 regarding emission NO_x limit values for ships
- National legislation and national practices (if stricter)

Box 3: Legislation considered for PM10/PM2.5 emissions

- Directive on Industrial Emissions for large combustion plants (derogations and opt-outs included according to information provided by national experts)
- BAT requirements for industrial processes according to the provisions of the Industrial Emissions directive
- For light and heavy duty vehicles: Euro standards as for NO_x
- For non-road mobile machinery: All EU emission controls up to Stages IIIA, IIIB and IV as for NO_x.
- National legislation and national practices (if stricter)

Box 4: Legislation considered for NH_3 emissions

- IPPC directive for pigs and poultry production as interpreted in national legislation
- National legislation including elements of EU law, i.e., Nitrates and Water Framework Directives
- Current practice including the Code of Good Agricultural Practice

For heavy duty vehicles: Euro VI emission limits, becoming mandatory for all new registrations from 2014 (DIR 595/2009/EC).

Box 5: Legislation considered for VOC emissions

- Stage I directive (liquid fuel storage and distribution)
- Directive 96/69/EC (carbon canisters)
- For mopeds, motorcycles, light and heavy duty vehicles: Euro standards as for NO_x, including adopted Euro-5 and Euro-6 for light duty vehicles
- EU emission standards for motorcycles and mopeds up to Euro-3
- On evaporative emissions: Euro standards up to Euro-4 (not changed for Euro-5/6) (DIR 692/2008/EC)
- Fuels directive (RVP of fuels) (EN 228 and EN 590)
- Solvents directive
- Products directive (paints)
- National legislation, e.g., Stage II (gasoline stations)

4.1.2 The 'Maximum technically feasible reduction' (MTFR) scenario

The GAINS model contains an inventory of measures that could bring emissions down beyond the baseline projections. All these measures are technically feasible and commercially available, and the GAINS model estimates for each country the scope for their application in addition to the measures that are mandated by current legislation.

The 'Maximum technically feasible reduction' (MTFR) scenario explores to what extent emissions of the various substances could be further reduced beyond what is required by current legislation, through full application of the available technical measures, without changes in the energy structures and without behavioural changes of consumers. However, the MTFR scenario does not assume premature scrapping of existing capital stock; new and cleaner devices are only allowed to enter the market when old equipment is retired.

While the MTFR scenario provides an indication of the scope for measures that do not require policy changes in other sectors (e.g., energy, transport, climate, agriculture), earlier analyses have highlighted that policy changes that modify activity levels could offer a significant additional potential for emission reductions. However, due to the complexity of the interactions with many other aspects, the potential for such changes is not quantified in this report. Thus, the analysis presented here should be seen as a conservative estimate of what could be achieved by policy interventions, as the scope is limited towards technical emission control measures.

4.2 Baseline emissions and scope for further reductions

4.2.1 The draft TSAP-2013 Baseline

The TSAP-2013 Baseline employs the PRIMES-2012 Reference scenario together with the most up-to-date projections of agricultural activities that have been developed with the CAPRI model, coherent with the macro-economic assumptions and bio-fuel demand of the PRIMES-2012 scenario. Emission calculations consider new information provided by national experts in the course of the bilateral consultations with IIASA.

Sulphur dioxide

Similar to the earlier baseline projections developed for the TSAP revision, progressing implementation of air quality legislation together with the structural changes in the energy system will lead to a sharp decline of SO_2 emissions in the EU (Figure 4.1), so that in 2025 total SO_2 emissions would be almost 70% below the 2005 level. Most of these reductions come from the power sector (Table 4.1). Full implementation of the available technical emission control measures could bring down SO_2 emissions by up to 80% in 2025 compared to 2005.

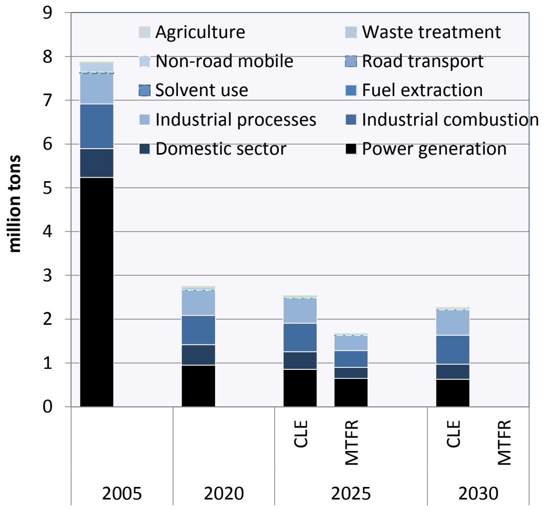

Figure 4.1: SO_2 emissions of the TSAP-2013 Baseline; Current legislation (CLE) and Maximum Technically Feasible Reductions (MTFR), EU-28

Table 4.1: SO_2 emissions of the TSAP-2013 Baseline scenario, by SNAP sector, EU-28 (kilotons)

	2005	2010	2015	2020	2025		2030	
					CLE	MTFR	CLE	MTFR
Power generation	5236	2724	1503	949	847	646	623	451
Domestic sector	659	623	523	470	404	253	341	216
Industrial combust.	1022	695	684	664	645	386	655	384
Industrial processes	692	626	574	574	568	343	574	344
Fuel extraction	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0
Road transport	36	7	6	5	5	5	5	5
Non-road mobile	215	137	109	71	37	29	37	29
Waste treatment	5	5	5	6	6	5	6	5
Agriculture	7	8	8	9	9	0	9	0
Sum	7874	4824	3412	2749	2521	1666	2250	1434

Nitrogen oxides

Also for NO_x emissions, implementation of current legislation will lead to significant declines, and for 2025 a 60% reduction is estimated. These changes emerge from measures in the power sector, and more importantly, from the implementation of the Euro-6 standards for road vehicles (Figure 4.2). Full implementation of additional measures for stationary sources could bring NO_x emissions in 2025 68% down compared to 2005 (Table 4.2).

The sensitivity of these projections towards uncertainties about future real-life emissions from Euro-6 standards as well as the potential for further emission cuts from 'Super Ultra-low Emission Vehicles' (SULEV) is explored in Section 7.

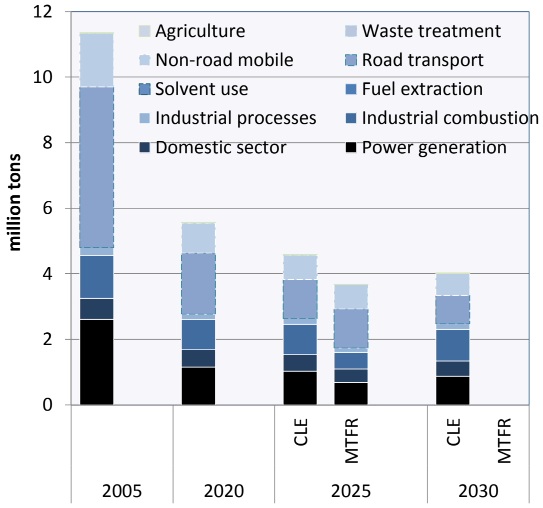

Figure 4.2: NO_x emissions of the TSAP-2013 Baseline

Table 4.2: NO_x emissions of the TSAP-2013 Baseline scenario, by SNAP sector, EU-28 (kilotons)

	2005	2010	2015	2020	2025		2030	
					CLE	MTFR	CLE	MTFR
Power generation	2610	1901	1567	1157	1031	681	872	545
Domestic sector	645	619	576	526	499	413	467	387
Industrial combust.	1310	907	930	914	930	505	961	518
Industrial processes	233	182	169	171	169	135	170	136
Fuel extraction	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0
Road transport	4905	3751	2956	1866	1193	1193	871	871
Non-road mobile	1630	1400	1156	912	747	747	662	662
Waste treatment	9	8	7	8	8	3	8	3
Agriculture	17	17	19	21	21	1	21	1
Sum	11358	8786	7380	5575	4597	3679	4032	3124

Fine particulate matter

Progressing introduction of diesel particle filters will reduce PM2.5 emissions from mobile sources by about two thirds up to 2025; the remaining emissions from this sector will mainly originate from non-exhaust sources. While this trend is relatively certain, total PM2.5 emissions in Europe will critically depend on the development for small stationary sources, i.e., solid fuel use for heating in the domestic sector. The anticipated decline in solid fuel use for heating together with the introduction of newer stoves would reduce emissions from this sector by ~17% in 2025. However, more stringent product standards could cut emissions by up to two thirds.

Overall, total PM2.5 emissions in the EU-28 are expected to decline by 25% in the CLE case, while additional technical measures could cut them by up to 60% compared to 2005 (Figure 4.3, Table 4.3).

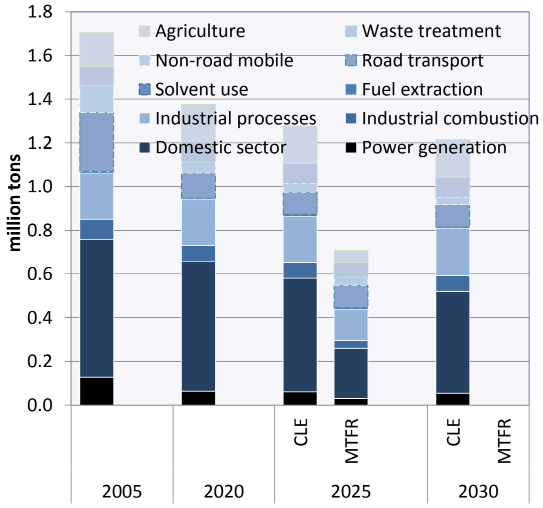

Figure 4.3: PM2.5 emissions of the TSAP-2013 Baseline; Current legislation (CLE) and Maximum Technically Feasible Reductions (MTFR), EU-28

Table 4.3: PM2.5 emissions of the TSAP-2013 Baseline scenario, by SNAP sector, EU-28 (kilotons)

	2005	2010	2015	2020	2025		2030	
					CLE	MTFR	CLE	MTFR
Power generation	129	93	72	63	60	30	54	23
Domestic sector	631	696	654	592	521	229	467	156
Industrial combust.	91	72	74	76	70	36	72	37
Industrial processes	210	199	206	209	209	143	211	145
Fuel extraction	9	8	8	7	7	7	6	6
Solvent use	0	0	0	0	0	0	0	0
Road transport	270	217	148	114	103	103	101	101
Non-road mobile	123	99	74	53	40	40	35	35
Waste treatment	87	89	89	90	91	65	91	65
Agriculture	155	156	164	171	172	53	172	53
Sum	1706	1628	1488	1376	1274	707	1211	623

Ammonia

Although NH_3 emissions are subject to targeted controls in the agricultural sector and will be affected as a side impact of emission legislation for road transport (i.e., by improved catalytic converters), only slight changes in total emissions in the EU-28 are expected up to 2030.

Due to the absence of effective wide-spread legislation on the control of NH_3 emissions from the agricultural sector, the draft TSAP-2013 Baseline shows only little change in NH_3 emissions over time. For 2025, a 5% decline in the EU-28 is estimated. However, EU-wide application of emission control measures that are already implemented in some countries could cut NH_3 by about one third (Figure 4.4, Table 4.4).

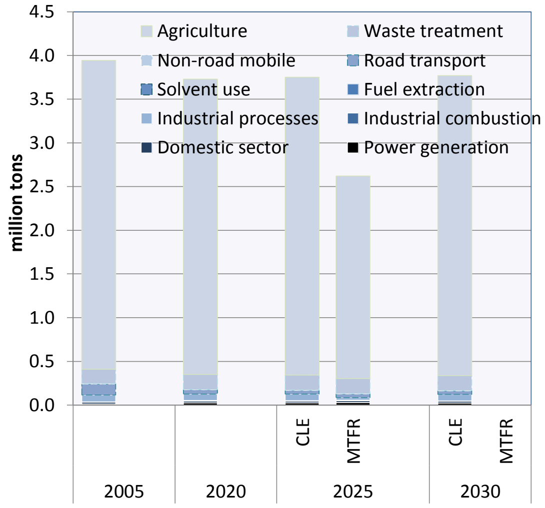

Figure 4.4: NH_3 emissions of the TSAP-2013 Baseline; Current legislation (CLE) and Maximum Technically Feasible Reductions (MTFR), EU-28

Volatile organic compounds

The future trend in VOC emissions is strongly determined by measures for mobile sources and by dedicated controls of solvents emissions (Figure 4.5, Table 4.5).

Further implementation of the Euro-standards will eliminate almost all VOC emissions from road vehicles. Legislation on solvents is expected to cut VOC emissions from this sector by about 20% in 2025 relative to 2005. However, there remains significant potential for further reductions for VOC emissions from solvents. Together with additional measures in households, these could cut total VOC emissions in the EU-28 by two thirds, compared to the 37% reduction in the baseline case.

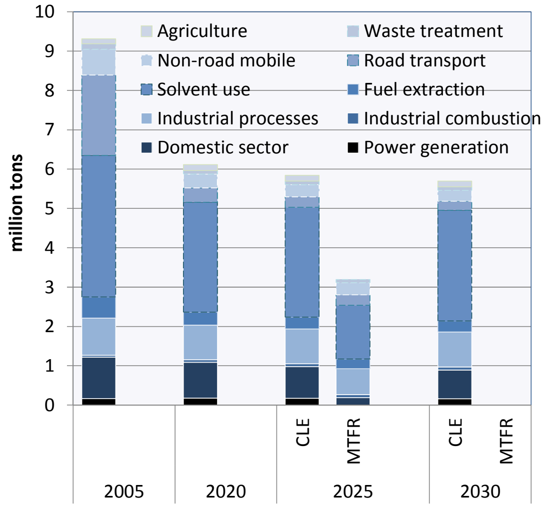

Figure 4.5: VOC emissions of the TSAP-2013 Baseline; Current legislation (CLE) and Maximum Technically Feasible Reductions (MTFR), EU-28

Table 4.4: NH_3 emissions of the TSAP-2013 Baseline scenario, by SNAP sector, EU-28 (kilotons)

	2005	2010	2015	2020	2025		2030	
					CLE	MTFR	CLE	MTFR
Power generation	12	22	23	25	25	30	23	28
Domestic sector	20	22	22	22	20	20	19	18
Industrial combust.	4	4	5	5	5	8	6	8
Industrial processes	78	73	74	75	75	28	75	28
Fuel extraction	0	0	0	0	0	0	0	0
Solvent use	0	0	0	0	0	0	0	0
Road transport	128	88	64	50	43	43	41	41
Non-road mobile	2	2	2	2	2	2	2	2
Waste treatment	166	174	174	174	173	173	173	173
Agriculture	3533	3397	3368	3378	3389	2318	3411	2333
Sum	3942	3782	3733	3730	3733	2621	3750	2632

Table 4.5: VOC emissions of the TSAP-2013 Baseline scenario, by SNAP sector, EU-28 (kilotons)

	2005	2010	2015	2020	2025		2030	
					CLE	MTFR	CLE	MTFR
Power generation	163	196	191	177	173	173	161	161
Domestic sector	1055	1081	1027	909	805	191	731	154
Industrial combust.	50	53	64	69	74	74	81	81
Industrial processes	944	875	879	883	814	659	818	663
Fuel extraction	536	386	358	324	297	248	280	236
Solvent use	3600	3037	2882	2795	2584	1364	2603	1375
Road transport	2047	1100	568	365	267	267	232	232
Non-road mobile	657	538	414	353	311	311	278	278
Waste treatment	136	124	95	91	89	78	88	78
Agriculture	126	126	138	146	146	0	146	0
Sum	9312	7516	6614	6112	5561	3366	5418	3257

4.2.2 Comparison with the TSAP-2012 Baseline

While the draft TSAP-2013 scenario reflects most recent perspectives on future economic development and the implementation of energy, climate and agricultural policies, it can obviously depict only one single realization of the future. All assumptions taken for this scenario are surrounded by uncertainties, which might affect the future evolution of emissions.

The 2012 Baseline, relying on the PRIMES 2010 scenario, embodies more optimistic assumptions on economic growth, as the prolonged phase of economic stagnation after 2009 is not considered in this scenario. It also does not include the full impacts of the energy efficiency and renewable energy targets that have been established by the European Union. Thus, in general, this scenario exhibits higher levels of energy consumption in the future compared to the recent PRIMES-2012 Reference.

Despite these differences, emission projections for all pollutants evolve within a rather narrow corridor up to 2030. Also, there are relatively little differences in the scope for additional measures.

For SO_2, there are only minor differences (Figure 4.6).

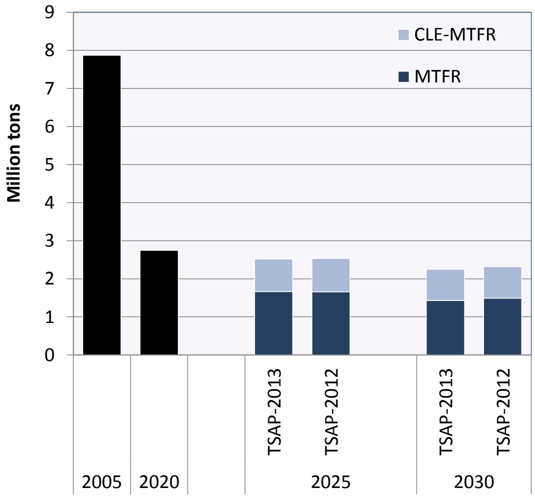

Figure 4.6: Comparison of SO_2 emissions, current legislation (CLE) and maximum technically feasible reductions (MTFR), for the different activity scenarios. The light areas indicate the scope for measures between the CLE and MTFR cases.

NO_x emissions are slightly higher in the TSAP-2012 than in the TSAP-2013 scenario (Figure 4.7), essentially due to different assumptions on road transport and the use of solid and liquid fuels for power generation.

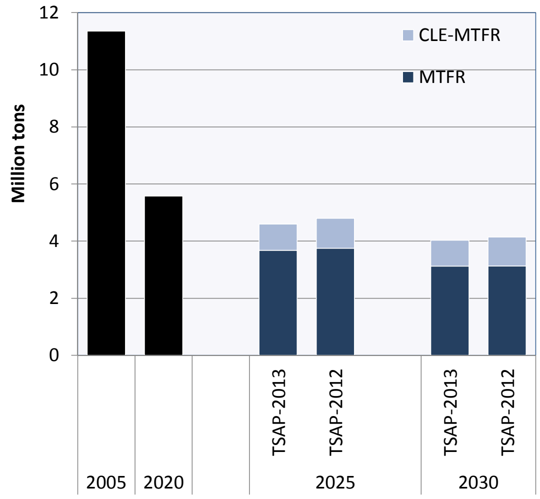

Figure 4.7: Comparison of NO_x emissions, current legislation (CLE) and maximum technically feasible reductions (MTFR), for the different activity scenarios

For PM2.5, the TSAP-2013 scenario suggests more than 8% higher emissions than the 2012 Baseline, mostly as a consequence of enhanced use of renewable energy, inter alia for domestic heating (Figure 4.8).

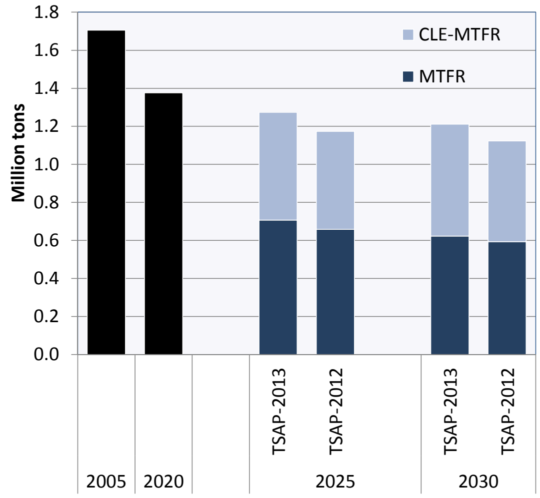

Figure 4.8: Comparison of PM2.5 emissions, current legislation (CLE) and maximum technically feasible reductions (MTFR), for the different activity scenarios

The TSAP-2013 scenario that reflects most recent expectations on the impacts of latest agricultural policy decisions exhibits significantly lower NH_3 emissions than the TSAP-2012 projection that has been developed in 2009 (Figure 4.9).

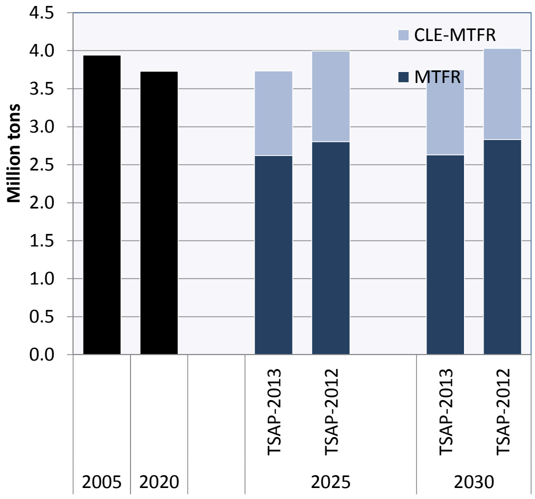

Figure 4.9: NH_3 Comparison of NH_3 emissions, current legislation (CLE) and maximum technically feasible reductions (MTFR), for the different activity scenarios

For VOC, the TSAP-2013 Baseline foresees about 5% lower emissions than the TSAP-2012 case, mainly due much less gasoline consumption in cars and two-strokes engines, which is replaced by diesel fuel. However, part of the 30% lower emissions from mobile sources is compensated by higher emissions from more wood combustion in small residential sources (Figure 4.10).

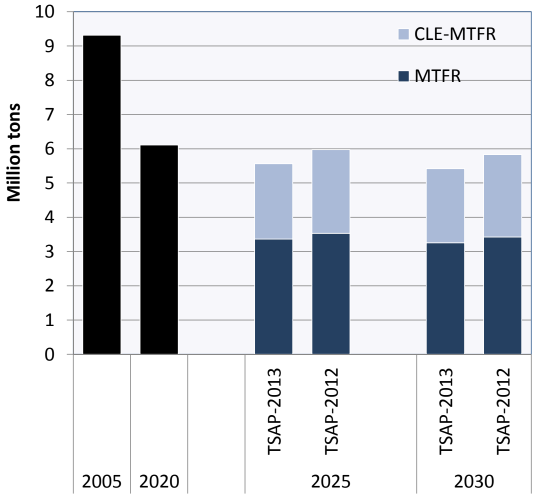

Figure 4.10: Comparison of VOC emissions, current legislation (CLE) and maximum technically feasible reductions (MTFR), for the different activity scenarios

4.3 Emissions of non-EU countries

Due to the long-range transport of air pollutants, air quality within the EU is substantially influenced by emissions outside the territories of EU Member States. While emissions from non-EU countries and marine shipping are not in the focus of this report, the impact calculations for the EU Member States need to consider the likely development of emissions outside the EU and the potential for further emission reductions in these areas.

For the non-EU countries, calculations assume for 2020 the activity projections and current legislation control measures that have been used for the negotiations of the revised Gothenburg protocol (Amann et al. 2011). Beyond 2020, the energy projections developed within the FP7 EnerGeo project (www.energeo-project.eu) that rely on scenarios developed with the POLES energy model have been employed, together with information on the penetration of already agreed national emission control measures (see Table 4.6 and Table 4.7).

Table 4.6: Baseline emissions of SO_2, NO_x and PM2.5 for non-EU countries (kilotons and change relative to 2005)

	SO_2			NO_x			PM2.5		
	2005	2025	2030	2005	2025	2030	2005	2025	2030
Albania	19	16	19	19	21	23	9	8	8
Belarus	85	87	90	178	167	172	54	53	54
Bosnia-H	225	47	57	33	25	27	20	9	9
FYR Macedonia	104	19	17	35	20	19	12	5	5
R Moldova	7	3	4	27	16	16	10	10	10
Norway	24	20	20	173	134	126	51	43	42
Russia	1923	1634	1691	2979	1766	1765	758	791	810
Serbia-M	454	92	99	165	85	82	71	47	46
Switzerland	17	10	10	94	43	36	10	7	7
Turkey	1462	2124	2316	859	1130	1284	350	446	474
Ukraine	1063	412	532	875	587	643	392	357	423
Non-EU	5383	4463	4856	5438	3992	4192	1740	1776	1886
Change to 2005		*-17%*	*-10%*		*-27%*	*-23%*		*+2%*	*+8%*

Table 4.7: Baseline emissions of NH_3 and VOC for non-EU countries (kilotons and change relative to 2005)

	NH_3			VOC		
	2005	2025	2030	2005	2025	2030
Albania	17	21	22	34	26	25
Belarus	117	161	164	200	152	147
Bosnia-H	18	24	25	44	27	26
FYR Macedonia	9	7	7	23	12	11
R Moldova	16	18	18	30	21	20
Norway	24	25	27	202	100	101
Russia	492	563	575	2678	1644	1629
Serbia-M	64	49	46	169	105	99
Switzerland	62	62	62	120	79	78
Turkey	416	547	583	697	550	539
Ukraine	253	293	303	591	336	325
Non-EU	1488	1769	1833	4788	3051	3000
Change to 2005		*19%*	*23%*		*-36%*	*-37%*

4.4 Emissions from marine shipping

For marine shipping activities, this report uses historic and future emissions of air pollutants as provided by the recent VITO report to DG-ENV (Campling et al. 2012) (see Table 4.8). The VITO inventory and projections distinguish activities of 11 vessel categories in 8 Sea regions (Figure 4.11), as well as within the Territorial Seas of the EU Member States, i.e., within 12 nm from the coast, and in the 200 nm Exclusive Economic Zones.

In 2005, ships emitted about 1.7 million tons of SO_2, which was about 20 % of the emissions from land-based sources in the EU-27. Emissions of NO_x (2.8 million tons) were equivalent to 25% land-based emissions. About 30% of these emissions occurred within 12 nm from the coast. Emissions from the Exclusive Economic Zones (200 nm) were approximately 75% of the total.

Under baseline assumptions, emissions of SO_2 from the European seas will decrease by 82% in

2020 compared to 2005. Emissions of NO_x will drop by 13%. After 2020, emissions increase due to growing transport volume, and by 2030 will be 12-13% higher than in 2020.

The cost-effectiveness of further measures to reduce emissions from marine sources is discussed in Section 6.3.

Table 4.8: Baseline emissions of SO_2, NO_x and PM2.5 for sea regions (kilotons)

	SO_2			NO_x			PM2.5		
	2005	2025	2030	2005	2025	2030	2005	2025	2030
Baltic Sea	130	6	7	220	193	202	14	9	10
Bay of Biscay	282	71	78	474	457	488	34	25	27
Black Sea	27	7	8	47	42	44	3	2	2
Celtic Sea	14	2	2	22	19	20	2	1	1
Mediterranean Sea	764	183	198	1294	1186	1255	87	62	67
North Sea (+ English Channel)	309	16	17	518	476	503	37	24	26
Rest of NE Atlantic (within EMEP grid)	31	8	9	54	51	54	4	3	3
Rest of NE Atlantic (TNO grid outside EMEP)	112	28	30	192	184	196	14	10	11
Non-EU	1668	321	349	2821	2606	2762	194	137	148
Change to 2005		*-81%*	*-79%*		*-8%*	*-2%*		*-29%*	*-24%*

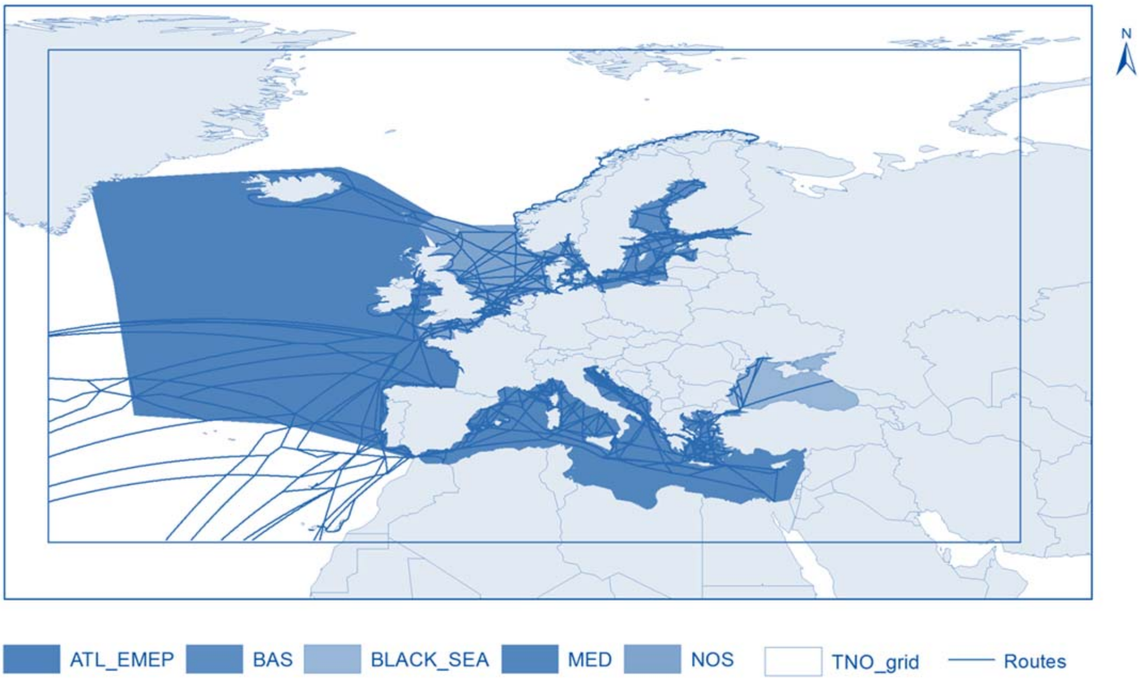

Figure 4.11: Sea regions distinguished in the VITO emission study, and main shipping routes

4.5 Air quality impacts

As a starting point for the cost-effectiveness analysis of measures to improve air quality in Europe, this section reviews the baseline evolution of the quality impacts along a selected set of indicators and outlines the scope for further improvements that could be achieved through implementation of the measures contained in the MTFR scenario.

While this assessment explores the impacts of emission changes within the EU-28, it assumes for non-EU countries and for marine shipping the baseline emissions that are outlined in Sections 4.3 and 4.4. Implications of additional measures in these regions on air quality within the EU as well on cost-effective portfolios for improvements are analysed in Section 6.3.

4.5.1 Health impacts from PM2.5

The decrease in the precursor emissions of ambient PM2.5 of the TSAP-2013 Baseline projection suggests a decline of the loss of statistical life expectancy attributable to the exposure to fine particulate matter (PM2.5) from 8.5 months in 2005 to 5.3 months in 2025. However, in Belgium, Poland, the Czech Republic, Hungary and Romania people would still lose more than six months even in 2030 (Figure 4.12).

It is noteworthy that the TSAP-2013 Baseline results in larger future health impacts compared to the TSAP-2012 scenario, mainly due to higher primary emissions of PM2.5 from expanded biomass combustion in small installations. Thereby, higher primary PM2.5 emissions compensate the benefits from lower precursor emissions of secondary PM2.5, i.e., SO_2, NO_x, NH_3 and VOC.

With the additional technical measures that could be implemented within the EU, life shortening could be further reduced by up to 1.4 months, or by 2030 down to about 3.6 months on average.

Overall, despite implementation of current emission control legislation, population in the EU-28 would still lose between 200 and 220 million years of life after 2020 (Figure 4.13). The additional measures could gain approximately 60-70 million life years.

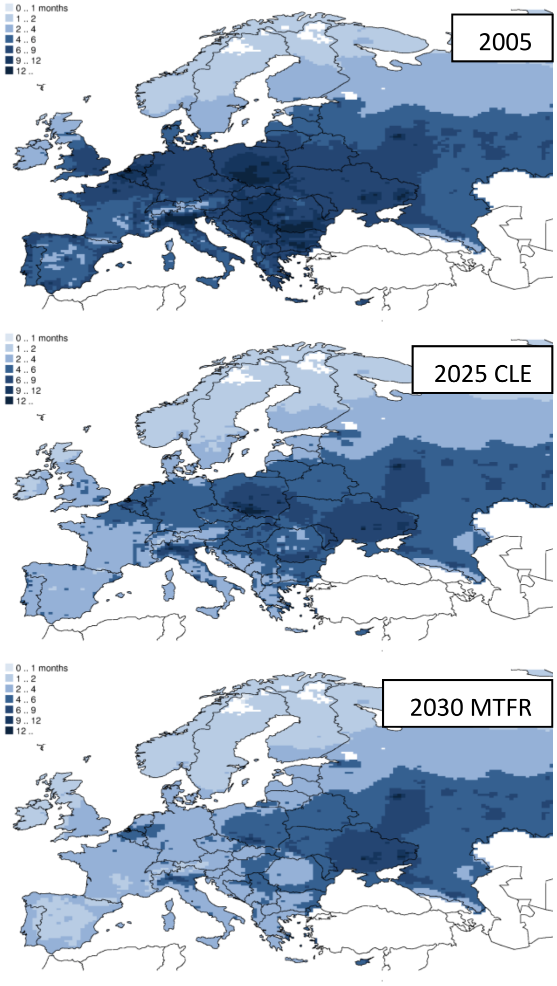

Figure 4.12: Loss in statistical life expectancy from exposure to PM2.5 from anthropogenic sources; top: 2005, mid: 2025 CLE, bottom: MTFR 2030

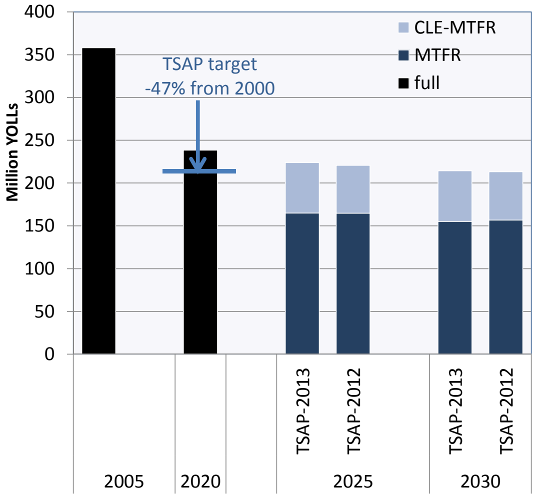

Figure 4.13: Years of life lost (YOLLs) due to exposure to fine particulate matter, EU-28

Despite progress, the TSAP-2013 Baseline would not meet the environmental target for health impacts from PM that has been established in the 2005 Thematic Strategy on Air Pollution for 2020. Instead of the 47% improvement in years of life lost (YOLL) relative to 2000, the current legislation case of the TSAP-2013 would reach only a 45% reduction.

4.5.2 Health impacts from ground-level ozone

The TSAP-2013 Baseline suggests for 2025 approximately 18,000 cases of premature deaths from exposure to ground-level ozone in the EU-28 (Figure 4.14). This is safely below the 10% reduction target (25,000 cases) that was established by the 2005 Thematic Strategy on Air Pollution for 2020 relative to 2000, mainly due to more optimistic expectations on the development of hemispheric background ozone levels.

Additional emission reduction measures within the EU-28 could save another 2,500 cases of premature deaths.

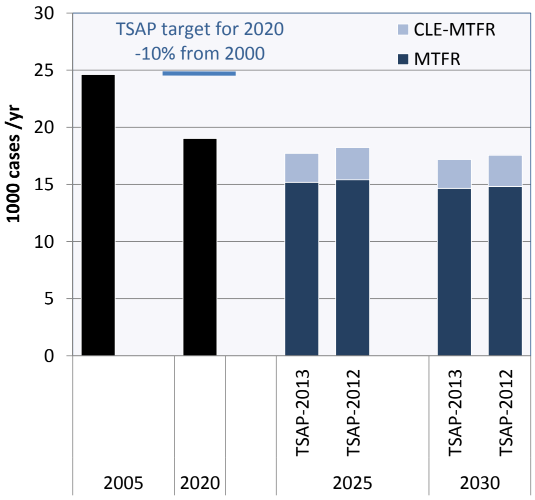

Figure 4.14: Cases of premature deaths due to exposure to ground-level ozone, EU-28

The spatial pattern of the health-relevant SOMO35 indicator, and how this will be influenced by the different emission reduction scenarios, is presented in Figure 4.15.

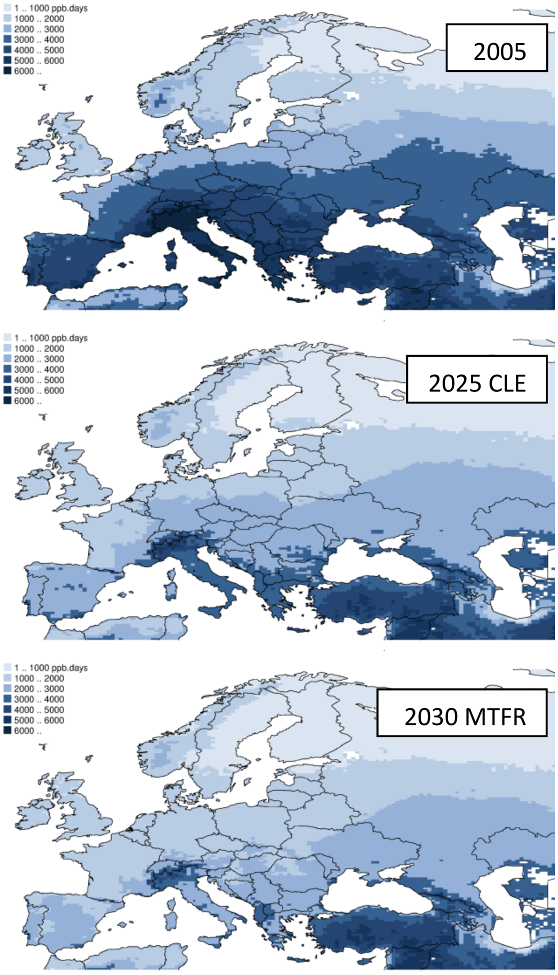

Figure 4.15: The SOMO35 indicator that is related to premature mortality from ground-level ozone

4.5.3 Eutrophication

Threat to biodiversity of Natura2000 areas

In addition to fragmentation and climate change, excess nitrogen deposition constitutes an important threat to biodiversity in areas that are protected under the Birds Directive and the Habitat Directive (i.e., Natura2000 areas).

For 2005, it is calculated that biodiversity was under threat from excess nitrogen deposition in 77% (423,000 km^2) of the protected zones. By 2025, the expected declines in NO_x emissions would reduce the threatened area to 62%, leaving 343,000 km^2 unprotected. By 2030, full application of the available reduction measures, especially for ammonia emissions, could provide protection to another 95,000 km^2 of the nature protection areas in Europe (Figure 4.16).

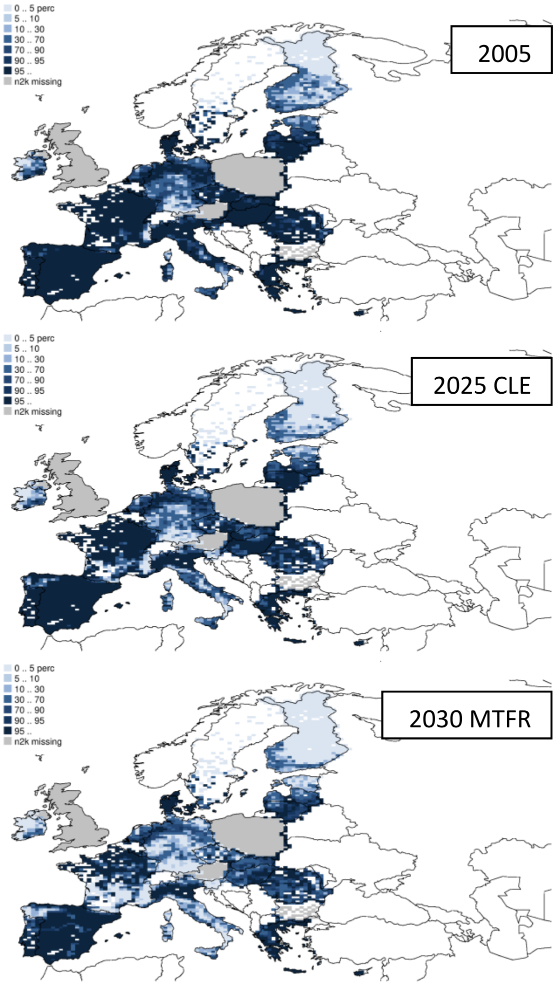

Figure 4.16: Percentage of Natura2000 areas with nitrogen deposition above their critical loads for eutrophication. Top: 2005, mid: 2025 CLE, bottom: MTFR 2030

As this assessment is a new feature of GAINS that has been only recently developed within the EC4MACS[3] project of the EU LIFE program, no targets for Natura2000 areas have been established in the 2005 TSAP.

Threat to biodiversity of all ecosystems

In 2005, more than 1.1 million km^2 (i.e., 66%) of the European ecosystems were exposed to nitrogen deposition that exceeded their critical loads for eutrophication. The future development will be mainly influenced by the fate of NH_3 emissions. In 2025, the TSAP2013 Baseline would reduce the area under threat to about 0.9 million km^2, while higher NH_3 emissions in the TSAP-2012 Baseline would leave about 0.94 million km^2 unprotected. The available additional emission reduction measures could safeguard another 180,000 to 200,000 km^2 (Figure 4.18).

Due to lower progress in the reduction of NH_3 emissions than anticipated, the TSAP-2013 Baseline would fail to meet the environmental targets for eutrophication that have been established in the 2005 Thematic Strategy on Air Pollution for 2020. Instead of the 31% improvement in ecosystems area with nitrogen deposition above critical loads for eutrophication relative to 2000, the current legislation case of the TSAP-2013 would achieve only a 24% reduction (Figure 4.17).

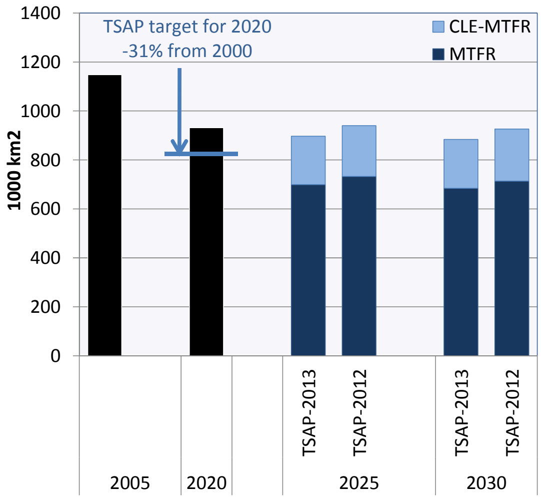

Figure 4.17: Ecosystems area with nitrogen deposition in excess of the critical loads for eutrophication, EU-28

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[3] www.ec4macs.eu

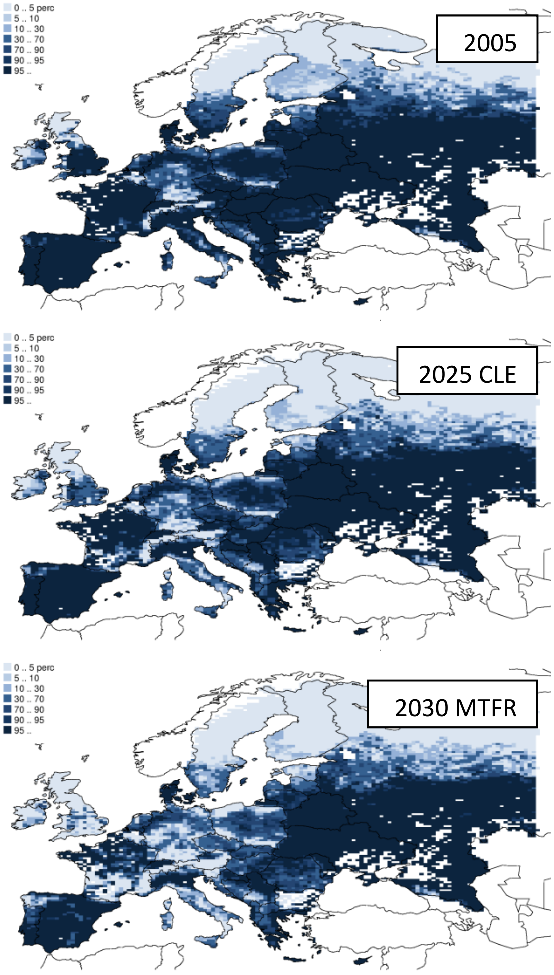

Figure 4.18: Percentage of ecosystems area with nitrogen deposition above their critical loads for eutrophication.

4.5.4 Acidification of forest soils

With the 2012 data set on critical loads (Posch et al. 2011), it is calculated that in 2005 critical loads for acidification have been exceeded in a forest area of 160,000 km^2, i.e., in about 12% of the forests within the EU-28 for which critical loads have been reported.

Especially the anticipated further decline in SO_2 emissions will resolve the threat for another 110,000 km^2 up to 2025. Additional measures could provide sustainable conditions for another 30,000 km^2 up to 2030, and leave only 0.45% of European forests threatened by acidification (Figure 4.19). These measures would especially benefit the former ‘black triangle’ (i.e., in Poland, Czech Republic and the eastern parts of Germany), while residual problems would remain in the Netherlands due to high ammonia density.

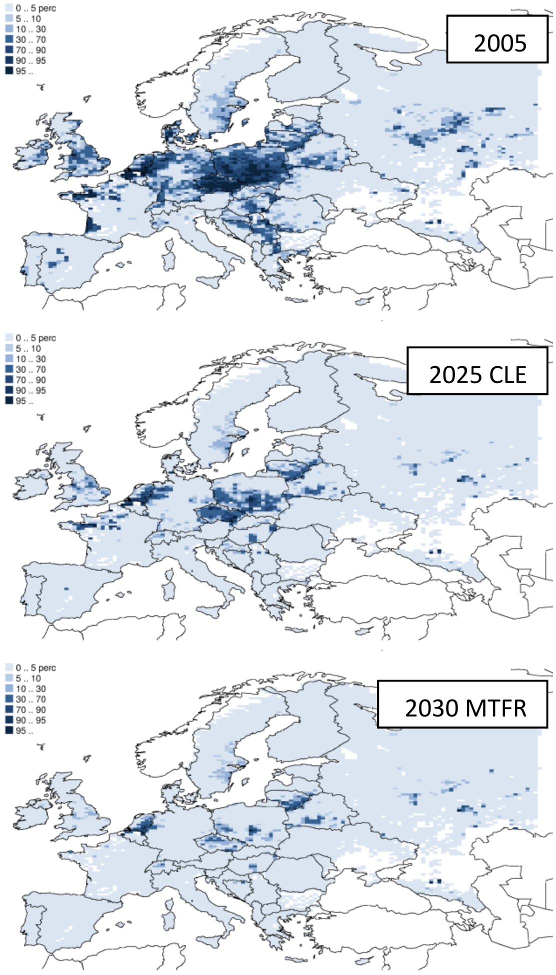

Figure 4.19: Percentage of forest area with acid deposition above the critical loads for acidification. Top: 2005, mid: 2025 CLE, bottom: MTFR 2030

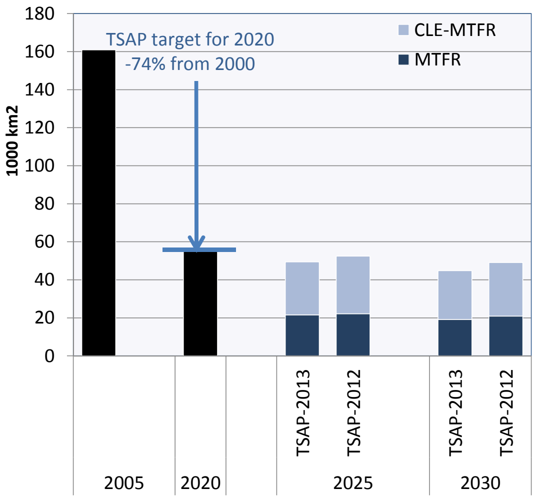

Figure 4.20: Forest area with acid deposition in excess of the critical loads for acidification, EU-28

Thereby, in 2020 the TSAP-2013 Baseline would achieve the 74% target for acidification of the TSAP 2005 (Figure 4.20).

4.5.5 Compliance with NO_2 limit values

The decline in NO_x emissions projected by the TSAP-2013 Baseline should significantly improve future compliance with NO_2 air quality limit values.

A new methodology has been developed to estimate with the GAINS model future NO_2 concentrations at traffic stations (Kiesewetter et al. 2013). This enables the assessment of the impacts of the Europe-wide emission reduction scenarios on compliance with the air quality limit values for each of these stations.

However, due to data gaps, this approach could not be implemented for all monitoring sites in Europe, but is restricted for NO_2 to 2000 sites for which sufficient monitoring data have been provided to AIRBASE, and for PM10 for 1900 sites. Obviously, this sub-set of stations is not necessarily representative, and there are large differences in station numbers across Member States. To facilitate representative conclusions, stations have been allocated to their respective air quality management zones established under the Air Quality Daughter Directive. The analysis presented here determines the compliance status of each zone along the highest concentration modelled at any AIRBASE monitoring site located within the zone.

It has been shown for NO_2 that achievement of the annual limit value of 40 $\mu g/m^3$ is more demanding than compliance with the hourly limit value of 200 $\mu g/m^3$. Thus, modelling for NO_2 is restricted to the annual limit value.

To reflect unavoidable uncertainties in monitoring data, modelling techniques and future meteorological conditions, three compliance categories with the annual limit value are distinguished.

Computed annual mean concentrations of NO_2 below 35 $\mu g/m^3$ indicate likely compliance. If concentrations are computed in the range between 35 and 45 $\mu g/m^3$, compliance is possible but uncertain due to the factors mentioned above. This is also the range where additional local measures (e.g., traffic management) have a realistic chance to achieve safe compliance, even under unfavourable conditions. In contrast, compliance is unlikely if computed NO_2 concentrations exceed 45 $\mu g/m^{3.}$

On this basis, it is estimated that the number of air quality management zones in the EU-28 where compliance with the current limit values is unlikely will decline from about 100 zones (21%) in 2010 to 38 zones (8%) in 2020 under baseline conditions (for this, 500 zones have been considered). However, this estimate is conservative as it does not consider benefits from local measures (e.g., traffic management or low emission zones), which could be quite effective for reducing the large share of NO_2 from near-by emission sources.

Conversely, in 2020 safe compliance will be achieved in 80% of the zones, compared to 63% in 2010 (Table 4.9). Obviously, by 2020 Europe will not fully reach the ultimate target of bringing all Europe in compliance. However, as shown in Figure 4.21, Europe will be pretty much on the right track towards such a target, with non-compliances rapidly decreasing following fleet renewal. For the baseline projection, which does not consider additional local measures, the number of non-compliance zones is estimated to decline to 13 in 2025 and five in 2030 (Figure 4.22). The additional measures of the MTFR scenario could eliminate 99% of the robust non-compliance cases.

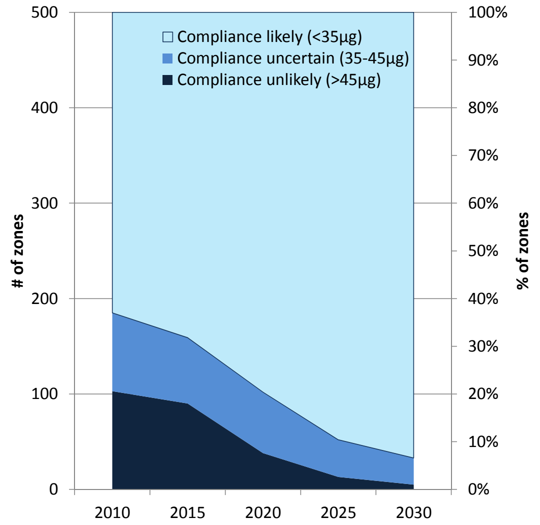

Figure 4.21: Compliance with air quality limit values for NO_2 in the air quality management zones

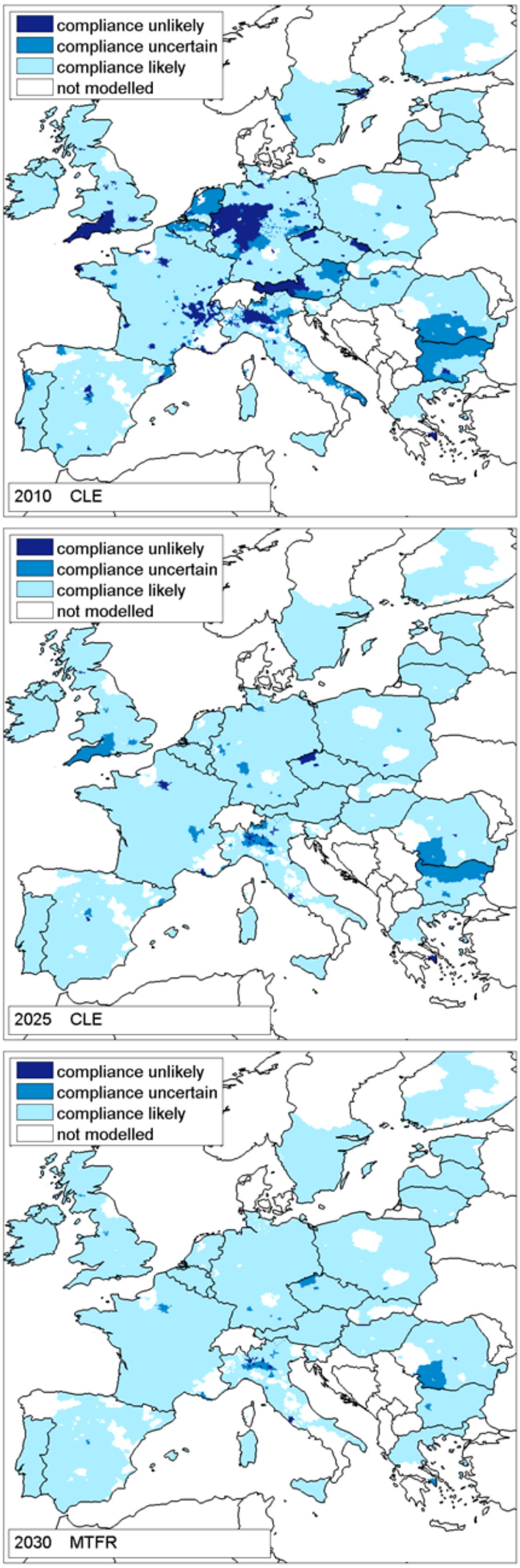

Figure 4.22: Compliance with air quality limit values for NO_2 in the air quality management zones

Table 4.9: Compliance with NO_2 limit values (number and % of zones). Note that this calculation does not include effects of additional local policies, such as low-emission zones.

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	103	82	315	*21%*	*16%*	*63%*
2020	38	64	398	*8%*	*13%*	*80%*
2025	13	39	448	*3%*	*8%*	*90%*
2030	5	28	467	*1%*	*6%*	*93%*
2030 MTFR	4	22	474	*1%*	*4%*	*95%*

Table 4.10: Population living in air quality management zones with different compliance with the NO_2 limit values (million people, % of European population)

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	124.6	63.3	238.6	*29%*	*15%*	*56%*
2020	68.7	55.6	302.1	*16%*	*13%*	*71%*
2025	30.8	49.7	345.9	*7%*	*12%*	*81%*
2030	8.9	48.0	369.5	*2%*	*11%*	*87%*
2030 MTFR	8.1	33.5	384.7	*2%*	*8%*	*90%*

4.5.6 Compliance with PM10 limit values

For PM10, the limit on 35 allowed daily exceedances of 50 µg/m^3 is more difficult to attain than the annual mean limit value of 40 µg/m^3. However, there is a strong linear correlation between the 36th highest daily values and the annual mean concentrations, both in observations and model results. As an annual mean of 30 µg/m^3 corresponds well to the 36th highest daily concentration of 50 µg/m^3, this threshold is used as the criteria for the GAINS modelling, which is conducted on an annual mean basis. As for NO_2, uncertainty ranges of ±5 µg/m^3 are employed.

For the 516 zones for which sufficient monitoring data are available, it is calculated that in 2010 about 60 zones (12%) did not comply with the PM10 limit value. The decrease in precursor emissions of the TSAP-2013 Baseline should halve this number to about 30 by 2020 (Figure 4.23). As for NO_2, this estimate does not consider additional measures at the urban scale, which could achieve further improvements.

However, in contrast to NO_2, the TSAP-2012 baseline does not suggest additional reductions beyond 2020. Remaining problems will prevail in the new Member States where, due to continued reliance of solid fuels for domestic heating, only little further declines in the emissions from the domestic sector are anticipated.

Technical emission control measures, together with the switch to cleaner fuels and/or to centralized heating systems could bring down PM10 concentrations below the limit value also in urban areas in the new Member States. The bottom panel in Figure 4.24 illustrates the MTFR case that does not assume additional expansion of central heating systems.

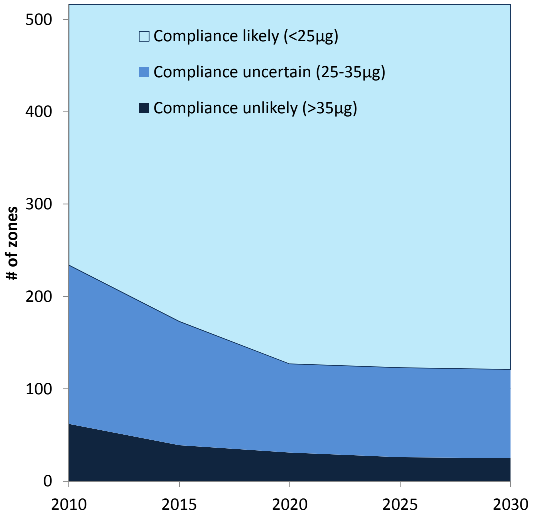

Figure 4.23: Compliance of the air quality management zones with air quality limit values for PM10

Table 4.11: Compliance with PM10 limit values in 2025 (number and % of zones)

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	62	172	282	12%	33%	55%
2020	31	96	389	6%	19%	75%
2025	26	97	393	5%	19%	76%
2030	25	96	395	5%	19%	77%
MTFR	17	56	443	3%	11%	86%

Table 4.12: Population living in air quality management zone with different compliance with PM10 limit values (million people, % of European population)

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	81.3	132.0	213.5	19%	31%	50%
2020	48.8	85.3	292.7	11%	20%	69%
2025	39.5	92.6	294.6	9%	22%	69%
2030	40.3	86.8	299.7	9%	20%	70%
MTFR	21.4	74.1	331.3	5%	17%	78%

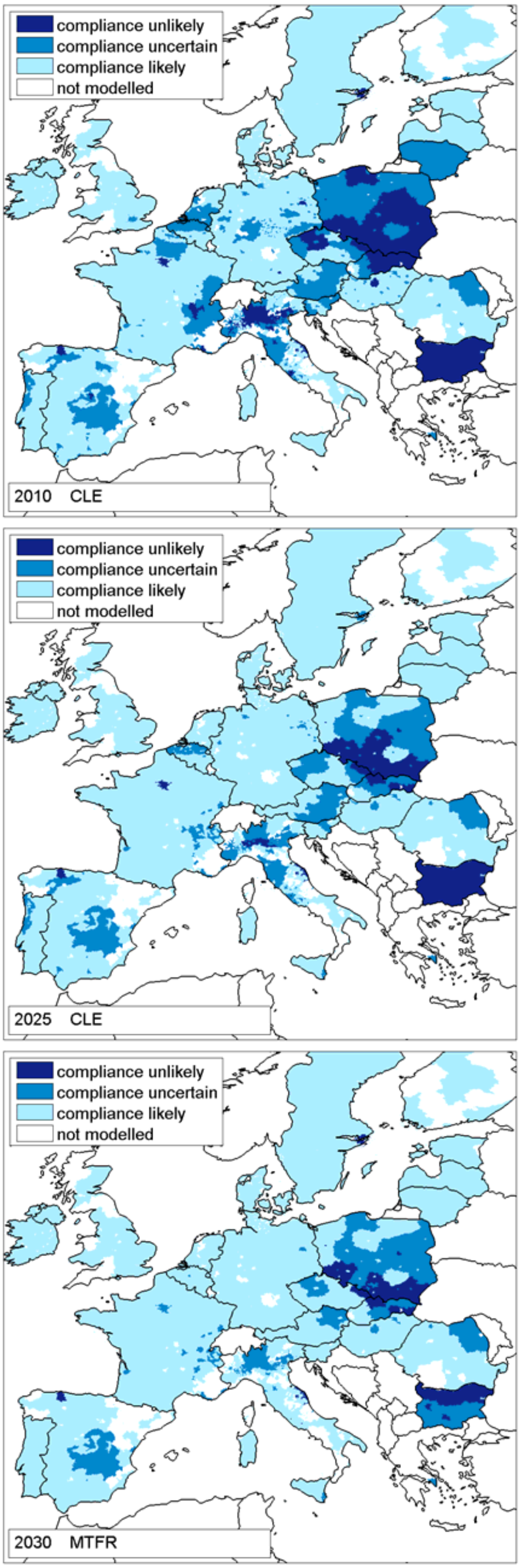

Figure 4.24: Compliance with the air quality limit values for PM10 in the air quality management zones

5 Costs and benefits of further emission reduction measures

As discussed before, despite the significant improvements from the implementation of the current EU air pollution legislation, there is clear evidence that the objectives of the Sixth Environment Action Programme (EC 2002) will not be met by the baseline scenarios up to 2030. It is also clear that there is scope for additional improvements of air quality in Europe (Table 5.1). As further measures involve additional costs, the question arises about meaningful and balanced interim targets towards the achievement of the objectives of the Sixth Environment Action Programme. The European Commission plans to propose such interim targets in the forthcoming revision of the Thematic Strategy.

To inform the Commission on the choice of appropriate interim targets, this report examines costs and benefits of additional measures between the current legislation (CLE) and the maximum feasible emission reduction (MTFR) cases.

Following the practices of the 2005 Thematic Strategy on Air Pollution, emission control scenarios are evaluated along their impacts on four air quality impact indicators:

- Premature mortality (life shortening) from exposure to fine particulate matter (with Years of Life Lost (YOLLs) as quantitative metric),
- premature mortality from exposure to ground-level ozone (with cases of premature deaths as a quantitative metric),
- the area of ecosystems where biodiversity remains threatened by nitrogen deposition in excess of the critical loads (km^2 of ecosystems),
- forest area threatened by acidification, i.e., receiving acidifying deposition above their critical loads (km^2 of forests).

The scope for improvements of these impact indicators from further emission reductions is summarized in Table 5.1.

The subsequent sections explore costs of cost-effective emission control strategies for progressively ambitious targets for these indicators between the CLE and the MTFR cases and compare these with estimates of the monetary benefits.

Table 5.1: Summary of impact indicators for the CLE and MTFR scenarios

	2005	2025		2030	
		TSAP-2013	TSAP-2012	TSAP-2013	TSAP-2012
	Health impacts PM (million years of life lost – YOLLs)				
CLE	358	224	221	214	213
MTFR		165	165	155	157
	Premature deaths from O_3 (cases/yr)				
CLE	24614	17735	18221	17188	17571
MTFR		15189	15408	14670	14812
	Eutrophication (Ecosystems area with nitrogen deposition above critical loads, km^2)				
CLE	1148097	897483	940209	883855	926306
MTFR		699467	733102	684111	714053
	Acidification (Forest area with nitrogen deposition above critical loads, km^2)				
CLE	160900	49407	52517	44825	49110
MTFR		21610	22184	19136	20903

5.1 Costs and benefits of measures to improve human health

5.1.1 Cost-effective emission reductions

As a first step, the GAINS optimization has been employed to determine least-cost packages of measures that reduce the gap in years of life lost (YOLL) between CLE and MTFR for the central TSAP-2013 scenario. With costs of MTFR of approximately 45 billion €/yr, a large share of the feasible improvement in YOLLs can be achieved at comparatively little costs. For instance, the cost-optimization suggests that 80% of the feasible health improvements could be achieved for approximately 10% of the total MTFR costs (Table 5.2).

Table 5.2: Emissions (kilotons) and emission control costs (million €/yr) of the optimized scenarios for 2025. Changes in emissions refer to 2005, changes in costs to the costs of current legislation.

Gap	*2005*	CLE	A1	A2	A3	MTFR
closure		*0%*	*25%*	*50%*	*75%*	*100%*
SO_2	7874	2521	2256	1971	1764	1666
		-68%	-71%	-75%	-78%	-79%
NO_x	11358	4597	4526	4475	4164	3679
		-60%	-60%	-61%	-63%	-68%
PM2.5	1706	1274	1063	972	860	707
		-25%	-38%	-43%	-50%	-59%
NH_3	3942	3733	3467	3187	2814	2621
		-5%	-12%	-19%	-29%	-34%
VOC	9312	5561	5300	5142	4625	3366
		-40%	-43%	-45%	-50%	-64%
Costs		87673	222	1195	4470	45014
			+0.3%	+1.4%	+5.1%	+51.3%

Table 5.3: Impact indicators of the optimized scenarios for 2025. [YOLLs million, ozone: cases of premature deaths/yr, eutrophication and acidification: 1000 km^2 of forests/ecosystems] Changes refer to 2005.

Gap	*2005*	CLE	A1	A2	A3	MTFR
closure		*0%*	*25%*	*50%*	*75%*	*100%*
YOLLs	358	224	209	194	179	165
		-38%	*-42%*	*-46%*	*-50%*	*-54%*
Ozone	24614	17735	17491	17300	16589	15189
		-28%	*-29%*	*-30%*	*-33%*	*-38%*
Eutro.	1148	897	860	822	757	699
		-22%	*-25%*	*-28%*	*-34%*	*-39%*
Acidif.	161	49	39	33	25	22
		-69%	*-76%*	*-80%*	*-84%*	*-87%*

However, there is no obvious point at which (total or marginal) costs would start increasing steeply (Figure 5.1). Thus, by just analysing emission control costs there is no strong hint towards a plausible ambition level for further emission reductions.

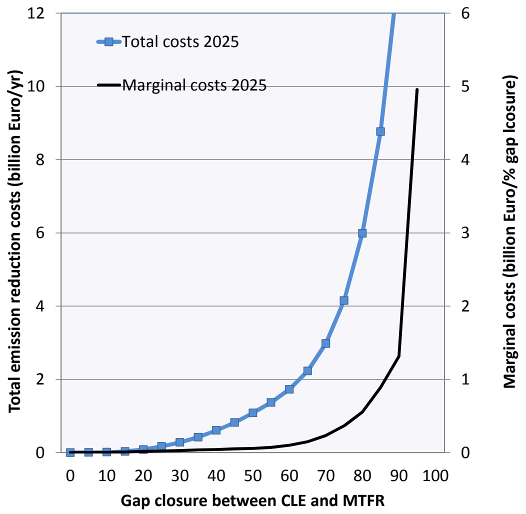

Figure 5.1: Emission control costs (total and marginal) for improvements of health impacts from PM2.5 between CLE and MTFR. Note that for better readability the y-axis is limited to 12 billion €/yr and does not cover the full range of the MTFR costs of about 45 billion €/yr.

To provide a rational approach towards target setting, the following sections compare marginal benefits from further measures against their marginal costs.

5.1.2 Health benefits

For this purpose, health benefits have been determined. Based on the benefit methodology described in (Holland et al. 2008), health benefits for particulate matter and ozone have been calculated for the CLE and MTFR scenarios. Thereby, this analysis quantifies incremental monetary health benefits from the additional measures of the MTFR scenario (Table 5.4). The morbidity category covers a range of effects including hospital admissions, chronic bronchitis, days of restricted activity (including work loss days) and respiratory medication use. More details on the approach and results are described in the companion TSAP Report #11.

As shown in Table 5.4, in 2025 total health benefits range from 47 billion €/yr to more than 250 billion €/year, depending on the valuation concept.

Table 5.4: Monetization of health benefits, differences between the CLE and the MTFR scenario (€million/year). Total health benefits include ranges based on different variants for values of life year lost (VOLY) and values of statistical life (VOSL)

Endpoint	2025	2030
Particulate matter		
Chronic Mortality (All ages) LYL median VOLY	41,231	40,730
Infant Mortality (0-1yr) median VSL	194	180
Morbidity (core functions)	17,949	18,063
Morbidity (sensitivity functions)	2,292	2,497
Ozone		
Acute Mortality (All ages) median VOLY	147	145
Morbidity (core functions)	299	290
Morbidity (sensitivity functions)	1,386	1,392
Total health benefits		
Best estimate	41,378	40,875
Best estimate: Mortality and morbidity	59,800	59,400
Range	47,100 – 248,000	46,900 – 259,000

In order to take a conservative approach, the further comparison of benefits against emission control costs employs the low valuation of health benefits from the Clean Air For Europe (CAFE) program (the best estimate shown in the Table). Thus, the further analysis presented in this report excludes benefits from reduced mortality and infant mortality, as well as all non-health related benefits, e.g., for ecosystems, agricultural crops and materials.

To estimate benefits for intermediate 'gap closure' scenarios, it is possible to scale the benefits computed for the additional measures of the MTFR scenario relative to the progress in YOLLs achieved in these scenarios. Consistency is maintained as the finally used benefit quantification of the MTFR is limited to changes of exactly these YOLLs.

5.2 Comparison of marginal costs and benefits

In essence, the proposal of an appropriate ambition level that balances costs and benefits of further measures remains a political choice and has to reflect implicit value judgements of decision makers.

It is noteworthy that even for the maximum feasible emission control scenario total health benefits exceed total emission control costs by a large margin. However, in order to offer a rational basis for the revision of the Thematic Strategy, following economic theory the marginal costs of further emission reductions are compared against the marginal benefits. As mentioned above, the benefit quantification is deliberately cautious, as it is limited to adult mortality from PM only and applies the most conservative valuation concept.

With this conservative perspective on benefits, marginal benefits (i.e., 412 million €/% gap closure) equal marginal costs at a 76.2% gap closure between CLE and MTFR in 2025 (Figure 5.2).

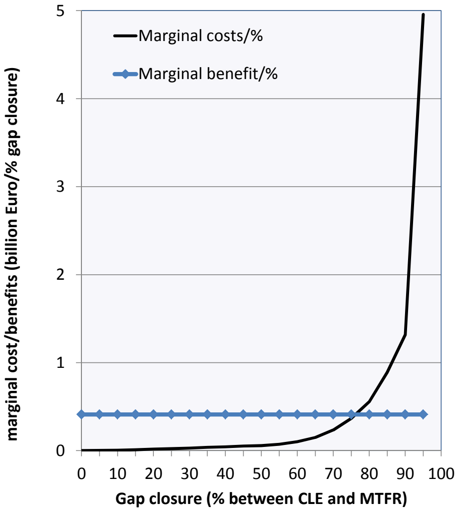

Figure 5.2: Marginal costs and marginal benefits of the cost-effective emission control scenarios targeted at the improvement of health impacts from fine particulate matter

As the next lower round number, a 75% gap closure has been assumed for the following analyses as the central ambition level for health impacts from fine particulate matter.

It should be noted that this calculation is based on the most conservative assessment, as it is restricted to adult mortality from PM using the low CAFE Value of Life Year Lost. Benefits from lower infant mortality, morbidity, associated health impacts from ozone as well as co-benefits for agricultural crops, ecosystems and materials are not included in this calculation.

5.3 Additional targets for non-health impacts

As mentioned above, the 75% gap closure target was established with a conservative perspective limited to mortality impacts of PM that can be monetized with sufficient robustness. However, reductions of air pollutant emissions yield a wide range of additional air quality benefits, although these are more difficult to quantify in monetary terms. The inability to quantify monetary benefits, e.g., to ecosystems, does not imply that improvements for these impacts are without value, and additional emission control measures could be justified for such non-quantifiable benefits.

Given this situation, the analysis presented in this report examines how emission control costs would increase if additional targets were introduced, in addition to the 75% YOLL gap closure target for the health impacts from PM2.5.

A further complication relates to the nature of the targets that have been established in the 2005 Thematic Strategy on Air Pollution for ozone, eutrophication and acidification. While for health impacts the 'gap closure' in terms of YOLLs was considered on an EU-wide basis, in the interest of protection of local ecosystems a trading of environmental improvements across countries was excluded. Thus, the cost-effective solution had to achieve a minimum gap closure for the ecosystems-related targets (i.e., for ozone, eutrophication and acidification) in all countries.

Maintaining this principle, the GAINS cost optimization explored the response of emission control costs to additional targets for the other impacts. As shown in Figure 5.3, costs increase most rapidly for improvements of ozone, both for the human health indicator (related to the SOMO35 metric) and an indicator for crop damage from ozone (based on the ozone flux concept quantifying the phytotoxic ozone dose POD6). Additional costs for a 50% gap closure of the ozone indicator exceed for instance 0.5 billion €/yr, while for eutrophication and acidification measures for the same budget could achieve around 85% of the possible improvements.

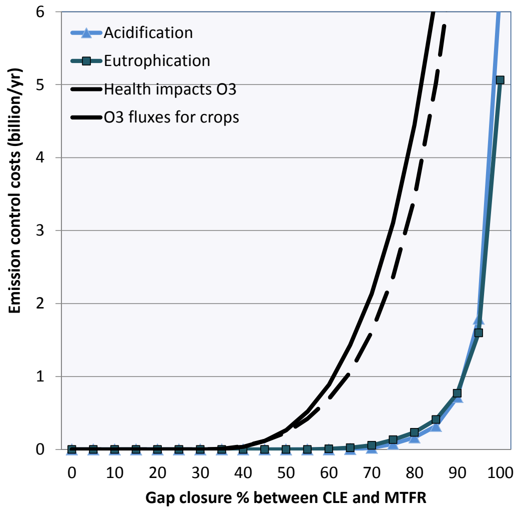

Figure 5.3: Emission control costs (on top of the costs of the 75% gap closure scenario for YOLL (A3) for additional improvements of the ozone and ecosystems effects indicators

While the lack of monetized benefits prohibits a quantitative cost-benefit analysis that could guide the choice of policy option scenarios, the scope for additional measures was explored through three optimization scenarios with different ambition levels for ozone, eutrophication and acidification. Ambition levels were chosen to yield round numbers in gap closure percentages with additional costs at roughly 5%, 20% and 50% of the costs of the 75% YOLL scenario A3 (Table 5.6).

Table 5.5: Ambition levels for ozone, eutrophication and acidification (minimum gap closures between CLE and MTFR, to be achieved in each country in 2025)

Target	*YOLL*	*Ozone*	*Eutrophication*	*Acidification*
A4	75%	50%	50%	55%
A5	75%	60%	55%	65%
A6	75%	70%	60%	75%

It is noteworthy that, due to the cost-optimizing approach, these environmental improvements do not result in additional health benefits for PM, as further emission reductions that are necessary to meet the additional targets release other measures that are cost-effective only for the YOLL target (Table 5.7)

Table 5.6: Emissions (kilotons) and emission control costs (million €/yr) of the optimized scenarios with additional non-PM targets for 2025. Changes in emissions refer to 2005, changes in costs to the costs of CLE or to the 75% gap closure scenario for YOLL (A3).

	2005	*CLE*	*A4*	*A5*	*A6*	*MTFR*
SO_2	7874	2521	1766	1773	1780	1666
		-68%	*-78%*	*-77%*	*-77%*	*-79%*
NO_x	11358	4597	4035	3943	3846	3679
		-60%	*-64%*	*-65%*	*-66%*	*-68%*
PM2.5	1706	1274	859	861	859	707
		-25%	*-50%*	*-50%*	*-50%*	*-59%*
NH_3	3942	3733	2842	2864	2872	2621
		-5%	*-28%*	*-27%*	*-27%*	*-34%*
VOC	9312	5561	4459	4310	4100	3366
		-40%	*-52%*	*-54%*	*-56%*	*-64%*
Costs		87673	4733	5362	6675	45014
cf. CLE			+5%	+6%	+8%	+51%
Costs			263	892	2205	
cf. A3			*+6%*	*+20%*	*+49%*	

Table 5.7: Impact indicators of the optimized scenarios for 2025. [YOLLs million, ozone: cases of premature deaths/yr, eutrophication and acidification: 1000 km^2 of forests/ecosystems]. Changes refer to 2005.

	2005	CLE	A4	A5	A6	MTFR
YOLLs	358	224	179	179	179	165
		-38%	*-50%*	*-50%*	*-50%*	*-54%*
Ozone	24614	17735	16352	16124	15872	15189
		-28%	*-34%*	*-34%*	*-36%*	*-38%*
Eutro.	1148	897	755	755	751	699
		-22%	*-34%*	*-34%*	*-35%*	*-39%*
Acidif.	161	49	25	25	25	22
		-69%	*-85%*	*-84%*	*-84%*	*-87%*

5.4 Feasibility under the TSAP-2012 assumptions

While the above analysis has attempted to identify balanced sets of emission reductions that emerge as cost-effective under the draft TSAP-2013 Baseline, it is important to examine their robustness for alternative activity projections, which alter baseline emissions and costs for further control measures.

To examine the feasibility and implications of the different environmental ambitions under different future scenarios, a series of cost-optimizations explored emission reductions and associated control costs for achieving the environmental targets of the A4-A6 scenarios in absolute terms (i.e., in absolute YOLLs, km^2, etc.) for the TSAP-2012 scenarios. Obviously, under this sensitivity scenario the targets constitute different gap closure percentages, as they involve different CLE and MTFR emissions.

For the TSAP-2012 scenario, emission control costs to achieve the A4 targets amount to 5.7 billion €/yr (on top of the costs for the TSAP-2012 Current legislation), (Table 5.8). They increase to 13.2 billion €/yr for the A5 target, while the A6 targets are not achievable under this scenario.

Table 5.8: Emissions (kilotons) and emission control costs (million €/yr) of the A4-A6 targets optimized for the TSAP-2012 Baseline for 2025. Changes in emissions refer to 2005, changes in costs to the costs of current legislation for the TSAP-2012 Baseline.

	2005	CLE	A7	A8	MTFR
Targets			*A4*	*A5*	
SO_2	7874	2532	1835	1899	1661
		-68%	*-77%*	*-76%*	*-79%*
NO_x	11358	4802	3962	3761	3752
		-58%	*-65%*	*-67%*	*-67%*
PM2.5	1706	1173	802	851	658
		-31%	*-53%*	*-50%*	*-61%*
NH_3	3942	3993	3078	2950	2802
		1%	*-22%*	*-25%*	*-29%*
VOC	9312	5977	4280	3862	3531
		-36%	*-54%*	*-59%*	*-62%*
Costs		93366	5713	13217	42435
cf. CLE			*+6%*	*+14%*	*+45%*

Table 5.9: Impact indicators of the A4-A6 targets optimized for the TSAP-2012 Baseline, for 2025. [YOLLs million; ozone: cases of premature deaths/yr; eutrophication and acidification: 1000 km^2 of forests/ecosystems]. Changes refer to 2005.

	2005	CLE	A7	A8	MTFR
Targets			*A4*	*A5*	
YOLLs	358	221	179	179	165
		-38%	*-50%*	*-50%*	*-54%*
Ozone	24614	18221	16114	15637	15408
		-26%	*-35%*	*-36%*	*-37%*
Eutro.	1148	940	787	761	733
		-18%	*-31%*	*-34%*	*-36%*
Acidif.	161	53	27	26	22
		-67%	*-83%*	*-84%*	*-86%*

5.5 Comparison of emission control costs

For the 'YOLL only' target A3, additional emission control costs (on top of those for current legislation) amount to 4.5 billion €/yr for the TSAP-2013 scenario, and to 3.8 billion € for the TSAP-2012. This is a consequence of the higher use of biomass in the domestic sector in TSAP-2013, which causes more emissions of primary PM2.5. Controlling emissions from these small sources is more expensive than the larger emission reductions of precursor emissions of secondary PM2.5 (i.e., SO_2, NO_x, etc.) in the TSAP-2012 case.

However, costs increase faster for additional improvements of ozone, eutrophication and acidification under TSAP-2012 (Table 5.10). For the TSAP-2013 Baseline, costs for further improvements rise by 0.2, 0.9 and 2.2 billion €/yr for the A4, A5 and A6 targets, respectively. For the TSAP-2012 scenario, additional costs (on top of the YOLL-only case) increase from 1.9 for the A4 case to 9.4 billion €/yr for the A5 case.

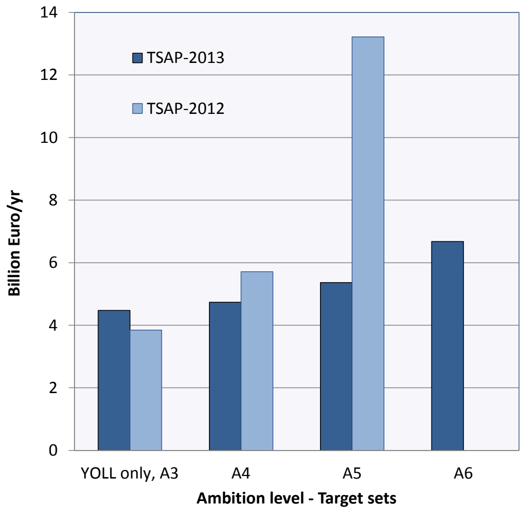

Figure 5.4: Variation of emission control costs (on top of the costs for the CLE scenarios) for achievements of the A3-A6 targets under the TSAP-2013 and TSAP-2012 scenarios

Table 5.10: Emission control costs for the different targets under different activity scenarios (million €/yr)

	Targets					
	CLE	A3	A4	A5	A6	MTFR
TSAP-2013	87673	92142	92406	93034	94347	132687
TSAP-2102	93366	97211	99079	106583		135800

Table 5.11: Additional emission control costs (on top of CLE) for the different targets under different activity scenarios (million €/yr)

	Targets					
	CLE	*A3*	*A4*	*A5*	*A6*	*MTFR*
TSAP-2013		4470	4733	5362	6675	45014
TSAP-2102		3845	5713	13217		42435

Table 5.12: Additional emission control costs (on top of the YOLL target) for the different targets under different activity scenarios (million €/yr)

	Targets					
	CLE	*A3*	*A4*	*A5*	*A6*	*MTFR*
TSAP-2013			263	892	2205	40544
TSAP-2102			1868	9372		38590

5.6 Analysis of regret investments

The Sixth Environment Action Programme has established the objective of achieving 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment'. While this objective is long-term, the analysis in this report examines meaningful interim targets for 2025 on the way towards the long-term objective. Thus, the cost-effectiveness analyses A1 to A6 presented above identify additional measures that could achieve the specified environmental targets at least cost in 2025. The chosen target year 2025 should provide sufficient time for a well-staged implementation of additional measures while not allowing for too much delay in the implementation strategies that would move the air quality agenda beyond the current policy cycle.

However, it is important that measures that are necessary for meeting emission ceilings proposed for 2025 will not require investments into long-lived pollution control that would emerge as superfluous in subsequent years, especially if – according to the baseline projection - activity rates would decline in the course of the envisaged restructuring process of the European economy.

For this purpose, an analysis was carried out for the A5 scenario to determine to what extent additional measures that are implied by the least-cost emission ceilings for 2025 would emerge as regret investments thereafter because of a decline in activity that is projected in the TSAP-2013 Baseline for the year 2030. For instance, to meet emission ceilings in 2025 could require investments into emission controls for plants that would retire in the Baseline projection within the following five years, i.e., until 2030.

Such potential regret measures, and their associated costs, have been identified in the following way:

First, for each activity-sector combination in the GAINS model the amount of activity data was calculated for which the optimized A5 scenario foresees additional control measures in 2025 that are incremental to the current legislation baseline. By definition, only such additional investments that are not implied by current legislation for 2025 could become regret investments.

Subsequently, the survival rate of these investments up to 2030 was estimated, taking into account typical life times of such investments and assuming that these additional measures would be gradually phased in from 2015 until 2025. Thus, only the share of the additional investments that would not have retired by 2030 has been considered further.

In a third step, for 2030 the surviving capacity of the additional emission controls that are imposed by the A5 scenario was compared against the potential for additional measures in 2030. This potential is determined by the baseline activity level as well as the level of activities for which long-lived control measures have been implemented already before as part of the current legislation. Surviving capacities of additional A5 control measures that exceed the uncommitted potential for new measures in 2030 constitute regret investments, as they would need to retire in 2030 prematurely before the end of their life time due to the decline in baseline activity levels.

As this analysis is carried out for more than 2000 source categories in each country, it is impractical to present detailed results. As a pragmatic solution, (annualized) costs of these regret measures have been calculated, which can then be easily summed up and compared to the total additional (annualized) costs implied by the A5 scenario.

For the rapid capital turnover assumed in the draft PRIMES-2012 energy scenario, a small share of the additional measures of the A5 scenario could turn out as regret investments in 2030. In total, these questionable measures affect 7 kt of SO_2 (i.e., 1.2% of the additional reductions of the A5 scenario), with 5 kt in the UK, 0.5 kt NO_x (0.4% of the A5 reductions) and 2.3 kt PM2.5 (2.5% of the A5 improvements). Costs associated with these regret measures account to 0.6% of the costs of the A5 scenario. However, 50% of these costs emerge in one country, i.e., the UK, where the draft PRIMES-2012 Reference scenario suggests an almost complete phase-out of coal from power generation between 2025 and 2030. For the remaining 27 Member States, regret measures account on average for 0.3% of the costs of all A5 measures (country-specific results are provided in the Annex).

In conclusion, the emission ceilings of the A5 scenario do not lead to significant regret investments, considering the uncertainties around the baseline projection. Appropriate flexibility mechanisms could avoid regret investments for specific situations with drastic restructuring measures of the energy system.

6 Options for achieving the environmental targets

Based on the line of arguments presented above, this report adopts the Scenario A5 as the central case for further analyses. These explore the implications on total emission reductions for individual Member States, the emission control measures implied by the emission ceilings, the distribution of emission control costs, and the evolution of the various air quality indicators across Europe.

6.1 The central case (Scenario A5)

6.1.1 Emissions in 2025

Table 6.1 to Table 6.5 provide more details on cost-effective emission ceilings that achieve the central ambition level in 2025.

As discussed above, in 2025 the cost-effective allocation of emission reduction measures to achieve the A5 targets would reduce in the EU-28 SO_2 by 77% below the 2005 level (Figure 6.1). NO_x would decline by 65%, PM by 50%, NH_3 by 27% and VOC by 54%.

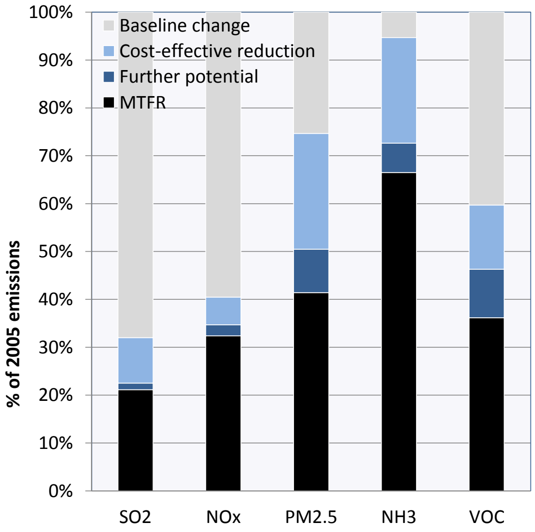

Figure 6.1: (Cost-effective) changes of 2005 emissions in 2025 (EU-28)

It is interesting that, despite their largest decline in the baseline case, SO_2 emissions would be reduced most in such a cost-effective solution. There are also significant and cost-effective potentials for reductions of primary PM2.5 and NH_3 emissions, although they would show the least changes compared to 2005.

Table 6.1: SO_2 emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	*CLE 2025*		*A5 2025*		*MTFR 2025*	
Austria	27	15	*-44%*	12	*-54%*	12	*-55%*
Belgium	154	66	*-57%*	51	*-67%*	51	*-67%*
Bulgaria	774	142	*-82%*	85	*-89%*	83	*-89%*
Cyprus	39	2	*-95%*	2	*-95%*	1	*-98%*
Czech Rep.	199	93	*-53%*	77	*-61%*	74	*-63%*
Denmark	20	11	*-47%*	10	*-50%*	9	*-54%*
Estonia	78	28	*-64%*	26	*-67%*	23	*-70%*
Finland	68	63	*-6%*	63	*-7%*	59	*-13%*
France	467	130	*-72%*	107	*-77%*	103	*-78%*
Germany	538	344	*-36%*	307	*-43%*	302	*-44%*
Greece	486	59	*-88%*	49	*-90%*	37	*-92%*
Hungary	128	35	*-73%*	25	*-81%*	24	*-81%*
Ireland	72	19	*-73%*	14	*-80%*	14	*-81%*
Italy	390	131	*-66%*	86	*-78%*	67	*-83%*
Latvia	5	3	*-47%*	3	*-52%*	2	*-56%*
Lithuania	47	26	*-45%*	12	*-75%*	10	*-79%*
Luxembourg	2	1	*-27%*	1	*-48%*	1	*-60%*
Malta	11	0	*-96%*	0	*-97%*	0	*-99%*
Netherlands	66	34	*-49%*	31	*-53%*	29	*-57%*
Poland	1270	534	*-58%*	334	*-74%*	320	*-75%*
Portugal	115	53	*-54%*	28	*-75%*	23	*-80%*
Romania	670	101	*-85%*	58	*-91%*	54	*-92%*
Slovakia	91	46	*-49%*	22	*-76%*	21	*-77%*
Slovenia	40	8	*-80%*	7	*-83%*	7	*-83%*
Spain	1291	237	*-82%*	164	*-87%*	149	*-88%*
Sweden	37	31	*-15%*	31	*-15%*	30	*-18%*
UK	722	286	*-60%*	159	*-78%*	155	*-79%*
EU-27	7807	2500	*-68%*	1762	*-77%*	1657	*-79%*
Croatia	67	21	*-68%*	10	*-85%*	8	*-88%*
EU-28	7874	2521	*-68%*	1773	*-77%*	1666	*-79%*
Power gen.	5236	847	*-84%*	699	*-87%*	646	*-88%*
Domestic	659	404	*-39%*	258	*-61%*	253	*-62%*
Ind. comb.	1022	645	*-37%*	428	*-58%*	386	*-62%*
Ind. process	692	568	*-18%*	346	*-50%*	343	*-50%*
Fuel extract.	0	0		0		0	
Solvent use	0	0		0		0	
Road transp.	36	5	*-86%*	5	*-86%*	5	*-86%*
Non-road	215	37	*-83%*	31	*-85%*	29	*-87%*
Waste	5	6	*18%*	5	*-14%*	5	*-14%*
Agriculture	7	9	*24%*	0	*-100%*	0	*-100%*
Sum	7874	2521	*-68%*	1773	*-77%*	1666	*-79%*

Table 6.2: NO_x emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	CLE 2025		A5 2025		MTFR 2025	
Austria	229	76	-67%	70	-69%	67	-71%
Belgium	300	147	-51%	128	-57%	120	-60%
Bulgaria	154	71	-54%	58	-62%	54	-65%
Cyprus	21	7	-69%	5	-76%	5	-78%
Czech Rep.	291	134	-54%	114	-61%	103	-65%
Denmark	183	72	-61%	63	-65%	60	-67%
Estonia	41	23	-44%	17	-60%	16	-62%
Finland	194	109	-44%	104	-46%	94	-51%
France	1374	496	-64%	422	-69%	402	-71%
Germany	1413	615	-56%	518	-63%	513	-64%
Greece	396	139	-65%	130	-67%	115	-71%
Hungary	159	61	-62%	52	-67%	44	-72%
Ireland	142	65	-54%	52	-64%	50	-65%
Italy	1216	489	-60%	431	-65%	412	-66%
Latvia	36	21	-40%	19	-47%	18	-51%
Lithuania	64	31	-51%	27	-58%	25	-61%
Luxembourg	48	12	-74%	12	-74%	12	-75%
Malta	11	1	-86%	1	-87%	1	-90%
Netherlands	374	159	-57%	154	-59%	141	-62%
Poland	804	438	-46%	383	-52%	346	-57%
Portugal	263	107	-59%	79	-70%	74	-72%
Romania	305	142	-54%	116	-62%	99	-67%
Slovakia	98	51	-48%	42	-57%	36	-63%
Slovenia	50	19	-61%	18	-64%	17	-66%
Spain	1476	488	-67%	400	-73%	365	-75%
Sweden	216	82	-62%	73	-66%	72	-67%
UK	1425	506	-65%	428	-70%	397	-72%
EU-27	11283	4561	-60%	3916	-65%	3656	-68%
Croatia	76	36	-53%	27	-64%	23	-69%
EU-28	11358	4597	-60%	3943	-65%	3679	-68%
Power gen.	2610	1031	-60%	783	-70%	681	-74%
Domestic	645	499	-23%	479	-26%	413	-36%
Ind. comb.	1310	930	-29%	578	-56%	505	-61%
Ind. process	233	169	-28%	159	-32%	135	-42%
Fuel extract.	0	0		0		0	
Solvent use	0	0		0		0	
Road transp.	4905	1193	-76%	1193	-76%	1193	-76%
Non-road	1630	747	-54%	747	-54%	747	-54%
Waste	9	8	-16%	3	-64%	3	-64%
Agriculture	17	21	25%	1	-95%	1	-95%
Sum	11358	4597	-60%	3943	-65%	3679	-68%

Table 6.3: PM2.5 emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	CLE 2025		A5 2025		MTFR 2025	
Austria	24	17	-30%	11	-54%	10	-60%
Belgium	29	19	-33%	16	-46%	14	-51%
Bulgaria	35	27	-23%	14	-59%	11	-68%
Cyprus	3	1	-69%	1	-73%	1	-75%
Czech Rep.	41	35	-14%	24	-41%	18	-55%
Denmark	29	16	-45%	11	-60%	9	-68%
Estonia	24	14	-40%	8	-65%	5	-77%
Finland	29	21	-27%	17	-40%	13	-56%
France	284	185	-35%	157	-45%	126	-55%
Germany	124	88	-29%	75	-40%	69	-45%
Greece	61	33	-46%	19	-68%	17	-72%
Hungary	29	20	-30%	12	-58%	10	-67%
Ireland	14	13	-8%	10	-24%	9	-32%
Italy	177	123	-31%	81	-54%	72	-59%
Latvia	19	13	-28%	8	-55%	5	-75%
Lithuania	14	12	-15%	7	-53%	4	-68%
Luxembourg	3	2	-44%	2	-48%	2	-53%
Malta	1	0	-75%	0	-79%	0	-82%
Netherlands	24	16	-32%	15	-38%	14	-43%
Poland	240	220	-8%	157	-35%	126	-47%
Portugal	64	42	-34%	19	-69%	17	-73%
Romania	112	91	-19%	44	-61%	30	-73%
Slovakia	32	20	-36%	12	-61%	8	-74%
Slovenia	9	6	-31%	3	-68%	3	-73%
Spain	154	127	-18%	64	-59%	54	-65%
Sweden	32	25	-20%	22	-30%	14	-55%
UK	86	75	-13%	45	-47%	41	-52%
EU-27	1691	1262	-25%	856	-49%	703	-58%
Croatia	15	11	-25%	5	-64%	4	-74%
EU-28	1706	1274	-25%	861	-50%	707	-59%
Power gen.	129	60	-53%	37	-71%	30	-77%
Domestic	631	521	-17%	354	-44%	229	-64%
Ind. comb.	91	70	-23%	45	-51%	36	-61%
Ind. process	210	209	-1%	152	-28%	143	-32%
Fuel extract.	9	7	-21%	7	-21%	7	-21%
Solvent use	0	0		0		0	
Road transp.	270	103	-62%	103	-62%	103	-62%
Non-road	123	40	-67%	40	-67%	40	-67%
Waste	87	91	4%	65	-26%	65	-26%
Agriculture	155	172	10%	57	-63%	53	-66%
Sum	1706	1274	-25%	861	-50%	707	-59%

Table 6.4: NH_3 emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	*CLE 2025*		*A5 2025*		*MTFR 2025*	
Austria	63	69	*9%*	52	*-17%*	48	*-24%*
Belgium	74	73	*-1%*	62	*-17%*	61	*-18%*
Bulgaria	65	65	*-1%*	59	*-9%*	57	*-12%*
Cyprus	6	6	*-6%*	5	*-20%*	4	*-33%*
Czech Rep.	80	65	*-19%*	53	*-33%*	53	*-34%*
Denmark	76	52	*-32%*	47	*-38%*	40	*-47%*
Estonia	12	12	*6%*	11	*-11%*	8	*-30%*
Finland	34	31	*-9%*	28	*-16%*	24	*-29%*
France	675	659	*-2%*	490	*-27%*	440	*-35%*
Germany	593	578	*-2%*	334	*-44%*	306	*-48%*
Greece	57	50	*-12%*	45	*-22%*	41	*-28%*
Hungary	78	70	*-9%*	53	*-32%*	50	*-35%*
Ireland	103	103	*-1%*	96	*-7%*	88	*-15%*
Italy	434	407	*-6%*	327	*-25%*	316	*-27%*
Latvia	13	15	*16%*	13	*2%*	12	*-5%*
Lithuania	44	48	*8%*	40	*-8%*	31	*-31%*
Luxembourg	6	6	*-10%*	5	*-23%*	5	*-26%*
Malta	2	3	*3%*	2	*-8%*	2	*-15%*
Netherlands	144	113	*-22%*	112	*-22%*	111	*-23%*
Poland	344	340	*-1%*	256	*-26%*	234	*-32%*
Portugal	73	71	*-2%*	58	*-20%*	49	*-33%*
Romania	161	138	*-14%*	119	*-27%*	109	*-32%*
Slovakia	28	23	*-18%*	17	*-42%*	16	*-43%*
Slovenia	19	17	*-9%*	15	*-21%*	14	*-25%*
Spain	366	360	*-2%*	264	*-28%*	216	*-41%*
Sweden	53	47	*-12%*	43	*-19%*	38	*-29%*
UK	310	279	*-10%*	236	*-24%*	230	*-26%*
EU-27	3913	3700	*-5%*	2841	*-27%*	2602	*-34%*
Croatia	29	32	*10%*	23	*-23%*	19	*-34%*
EU-28	3942	3733	*-5%*	2864	*-27%*	2621	*-34%*
Power gen.	12	25	*105%*	19	*53%*	30	*146%*
Domestic	20	20	*1%*	20	*1%*	20	*-2%*
Ind. comb.	4	5	*23%*	7	*76%*	8	*90%*
Ind. process	78	75	*-4%*	73	*-7%*	28	*-64%*
Fuel extract.	0	0		0		0	
Solvent use	0	0		0		0	
Road transp.	128	43	*-66%*	43	*-66%*	43	*-66%*
Non-road	2	2	*11%*	2	*11%*	2	*11%*
Waste	166	173	*4%*	173	*4%*	173	*4%*
Agriculture	3533	3389	*-4%*	2527	*-28%*	2318	*-34%*
Sum	3942	3733	*-5%*	2864	*-27%*	2621	*-34%*

Table 6.5: VOC emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	*CLE 2025*		*A5 2025*		*MTFR 2025*	
Austria	169	106	*-37%*	80	*-52%*	54	*-68%*
Belgium	161	99	*-39%*	80	*-50%*	70	*-57%*
Bulgaria	138	73	*-47%*	54	*-61%*	35	*-74%*
Cyprus	9	4	*-54%*	4	*-56%*	3	*-69%*
Czech Rep.	250	144	*-42%*	98	*-61%*	73	*-71%*
Denmark	130	64	*-51%*	50	*-62%*	40	*-69%*
Estonia	44	33	*-24%*	19	*-56%*	15	*-67%*
Finland	176	100	*-43%*	77	*-56%*	53	*-70%*
France	1141	613	*-46%*	541	*-53%*	414	*-64%*
Germany	1236	853	*-31%*	640	*-48%*	547	*-56%*
Greece	282	120	*-57%*	88	*-69%*	65	*-77%*
Hungary	142	84	*-41%*	62	*-56%*	47	*-67%*
Ireland	64	44	*-31%*	34	*-46%*	24	*-63%*
Italy	1263	652	*-48%*	520	*-59%*	429	*-66%*
Latvia	69	39	*-43%*	26	*-63%*	16	*-77%*
Lithuania	81	43	*-47%*	32	*-60%*	19	*-77%*
Luxembourg	12	6	*-55%*	5	*-60%*	4	*-67%*
Malta	4	3	*-31%*	2	*-47%*	1	*-64%*
Netherlands	204	139	*-32%*	121	*-41%*	108	*-47%*
Poland	621	413	*-34%*	277	*-55%*	207	*-67%*
Portugal	226	137	*-40%*	117	*-48%*	92	*-59%*
Romania	459	255	*-44%*	170	*-63%*	104	*-77%*
Slovakia	77	54	*-30%*	45	*-41%*	29	*-62%*
Slovenia	41	31	*-26%*	16	*-61%*	12	*-71%*
Spain	933	592	*-37%*	474	*-49%*	359	*-61%*
Sweden	208	134	*-36%*	121	*-42%*	99	*-52%*
UK	1093	678	*-38%*	522	*-52%*	421	*-61%*
EU-27	9233	5511	*-40%*	4274	*-54%*	3339	*-64%*
Croatia	79	50	*-36%*	36	*-54%*	27	*-66%*
EU-28	9312	5561	*-40%*	4310	*-54%*	3366	*-64%*
Power gen.	163	173	*6%*	131	*-20%*	173	*6%*
Domestic	1055	805	*-24%*	350	*-67%*	191	*-82%*
Ind. comb.	50	74	*48%*	74	*48%*	74	*48%*
Ind. process	944	814	*-14%*	767	*-19%*	659	*-30%*
Fuel extract.	536	297	*-45%*	281	*-48%*	248	*-54%*
Solvent use	3600	2584	*-28%*	2051	*-43%*	1364	*-62%*
Road transp.	2047	267	*-87%*	267	*-87%*	267	*-87%*
Non-road	657	311	*-53%*	311	*-53%*	311	*-53%*
Waste	136	89	*-35%*	78	*-43%*	78	*-43%*
Agriculture	126	146	*17%*	0	*-100%*	0	*-100%*
Sum	9312	5561	*-40%*	4310	*-54%*	3366	*-64%*

Aerosol particle number emissions

With the exception of source-specific emission limit values for particle numbers from new vehicles, current European legislation on PM addresses mainly the total mass concentrations of particles with diameters (d_P) below 2.5 µm (PM2.5) or below 10 µm (PM10).

However, in addition to the above mass-based metrics, there is increasing information that adverse health effects of aerosols are partly associated with the number concentration of ultrafine particles (UFP) with $d_P < 0.1$ µm (WHO 2013). In addition, climate effects of aerosol particles are strongly dependent on the number concentrations of particles with approximately $d_P > 0.1$ µm, due to their capability to form cloud droplets and thus cool the climate by causing negative radiative forcing (IPCC 2001).

However, neither of these number concentrations is directly comparable to PM2.5 or PM10, because mass concentrations are dominated by particles with $d_P > 0.5$ µm and the number concentrations by those with $d_P < 0.5$ µm. The sources of particles in these size ranges are often different: the larger are directly emitted into the atmosphere, whereas a significant fraction of the smaller particles is formed from vapours through nucleation process e.g. in the exhaust plumes (secondary particles).

Within the last year, the GAINS model has been extended to estimate particle numbers. Emission factors and particle size distributions are based on studies conducted by TNO during the EUCAARI-project (Kulmala et al. 2011), with some modifications.

Ultra-fine particles are responsible for roughly 90% of the total anthropogenic particle number emissions. The health effects of aerosol number emissions from their largest sources can be estimated based on the total number emissions. The analysis suggests that in 2010 more than 75% of total particle numbers originated from road transport, and 12% from combustion in the domestic sector (Table 6.6). This is in strong contrast to PM2.5 mass emissions, which are dominated by the domestic sector. It is estimated that current legislation would reduce the total number of emitted particles in Europe by almost 70% between 2010 and 2025, mainly by an 85% cut in particle number emissions from road transport. However, even with these decreases the road transport remains as the largest source for aerosol numbers.

The additional measures in the A5 scenario would lead to a 73% decrease in the emissions of ultrafine particles, mainly by decreasing emissions from industrial processes and by banning open burning of agricultural residuals.

While this estimate presents a first outlook into current and future emissions, there are important uncertainties in the current numbers. For instance, road transport emissions calculated with an earlier version of emission factors and size distributions were lower by almost a factor three, though still being the dominant source in 2010 (the current version is based on emission factors from the TRANSPHORM database gathered under FP7, the earlier on PARTICULATES data from FP5). One of the main reasons for these uncertainties is that secondary ultrafine particles, formed from nucleating vapours and mostly responsible for total particle numbers, are not solid and thus their stability depends on several factors, including air temperature.

It is important to better quantify emissions of the secondary non-solid particles in the future. Although the upcoming regulations for Euro-VI heavy duty diesel vehicles limit the number emissions of solid particles to $6x10^{11}$ #/kWh, the simultaneous increase in the emissions of UFP is estimated to result in total particle emissions of the order of 10^{14} #/kWh., This brings the total number emissions roughly back to the Euro-IV level.

The increase in UFP emissions with advancing technologies is mainly caused by the decrease in the emissions of larger (solid) particles, which act as an efficient filter for the nucleating vapours and freshly nucleated non-solid particles. This effect is not limited to the transport sector, but is visible also, e.g., in the emission factors for domestic wood combustion. As a consequence, further reductions in solid particle number and PM2.5 mass emissions from some of the major sources are likely to increase emissions of ultra-fine particles that are of concern for human health.

More detailed results of size-segregated particle number emissions, addressing the estimated changes in number emissions of particles in the climatically-beneficial size range >0.1 µm, are provided in Paasonen et al. (forthcoming).

Currently, particle number emissions and related size distributions from several sources cannot be accurately estimated because of the scarcity of the available data. More experiments on the particle number emissions are needed for reducing the current uncertainties and for optimizing the reductions in particle mass and number emission in order to maximize the health benefits.

Table 6.6: Particle number emissions, by country and by sector (10^{23} and change to 2010). Particle numbers are most relevant for health impacts

	2010	*CLE 2025*		*A5 2025*		*MTFR 2025*	
Austria	547	112	*-80%*	101	*-81%*	98	*-82%*
Belgium	572	90	*-84%*	82	*-86%*	82	*-86%*
Bulgaria	173	82	*-53%*	62	*-64%*	58	*-67%*
Cyprus	36	7	*-81%*	7	*-82%*	7	*-82%*
Czech Rep.	428	252	*-41%*	231	*-46%*	212	*-50%*
Denmark	292	77	*-74%*	76	*-74%*	74	*-75%*
Estonia	46	19	*-59%*	18	*-61%*	15	*-68%*
Finland	239	89	*-63%*	90	*-63%*	77	*-68%*
France	3481	690	*-80%*	604	*-83%*	563	*-84%*
Germany	2199	514	*-77%*	452	*-79%*	447	*-80%*
Greece	379	207	*-45%*	170	*-55%*	169	*-56%*
Hungary	174	84	*-52%*	77	*-56%*	74	*-58%*
Ireland	306	160	*-48%*	121	*-61%*	112	*-63%*
Italy	2526	700	*-72%*	608	*-76%*	601	*-76%*
Latvia	94	34	*-63%*	31	*-67%*	27	*-71%*
Lithuania	111	67	*-40%*	59	*-46%*	55	*-50%*
Luxembourg	114	21	*-82%*	21	*-82%*	21	*-82%*
Malta	5	2	*-68%*	2	*-70%*	2	*-71%*
Netherlands	457	99	*-78%*	91	*-80%*	91	*-80%*
Poland	2496	1309	*-48%*	1200	*-52%*	1111	*-56%*
Portugal	480	73	*-85%*	57	*-88%*	54	*-89%*
Romania	387	223	*-42%*	134	*-65%*	117	*-70%*
Slovakia	152	62	*-59%*	54	*-65%*	50	*-67%*
Slovenia	78	31	*-60%*	27	*-65%*	26	*-66%*
Spain	2679	886	*-67%*	699	*-74%*	688	*-74%*
Sweden	314	105	*-67%*	98	*-69%*	76	*-76%*
UK	1860	406	*-78%*	383	*-79%*	376	*-80%*
EU-27	20624	6400	*-69%*	5556	*-73%*	5283	*-74%*
Croatia	74	34	*-54%*	26	*-65%*	24	*-68%*
EU-28	20698	6434	*-69%*	5583	*-73%*	5307	*-74%*
Power gen.	176	139	*-21%*	78	*-56%*	68	*-62%*
Domestic	2503	1967	*-21%*	1878	*-25%*	1632	*-35%*
Ind. comb.	109	104	*-5%*	66	*-40%*	49	*-55%*
Ind. process	515	512	*-1%*	162	*-69%*	160	*-69%*
Fuel extract.	0	0	*-14%*	0	*-14%*	0	*-14%*
Solvent use	0	0	*0%*	0	*0%*	0	*0%*
Road transp.	16048	2560	*-84%*	2560	*-84%*	2560	*-84%*
Non-road	1039	801	*-23%*	801	*-23%*	801	*-23%*
Waste	38	39	*3%*	30	*-22%*	30	*-22%*
Agriculture	270	311	*15%*	8	*-97%*	7	*-97%*
Sum	20698	6434	*-69%*	5583	*-73%*	5307	*-74%*

Table 6.7: Emissions of particles larger than 0.1 µm of the optimized A5 scenario, by country and by sector (10^{23} and change to 2010). Particles larger than 0.1 µm act as cloud nuclei and have climate impacts

	2010	*CLE 2025*		*A5 2025*		*MTFR 2025*	
Austria	52	17	*-68%*	13	*-75%*	12	*-77%*
Belgium	48	11	*-78%*	8	*-83%*	8	*-84%*
Bulgaria	30	18	*-39%*	7	*-76%*	6	*-78%*
Cyprus	4	1	*-77%*	1	*-80%*	1	*-81%*
Czech Rep.	55	33	*-39%*	25	*-54%*	23	*-57%*
Denmark	29	9	*-68%*	8	*-72%*	8	*-74%*
Estonia	10	5	*-46%*	3	*-69%*	2	*-75%*
Finland	33	15	*-54%*	14	*-58%*	11	*-68%*
France	306	83	*-73%*	72	*-77%*	64	*-79%*
Germany	227	58	*-75%*	50	*-78%*	48	*-79%*
Greece	48	27	*-43%*	14	*-71%*	14	*-71%*
Hungary	29	11	*-60%*	8	*-72%*	8	*-74%*
Ireland	27	15	*-44%*	13	*-53%*	12	*-56%*
Italy	262	72	*-72%*	54	*-80%*	52	*-80%*
Latvia	13	8	*-39%*	5	*-61%*	4	*-68%*
Lithuania	19	12	*-34%*	7	*-63%*	6	*-66%*
Luxembourg	10	1	*-86%*	1	*-86%*	1	*-87%*
Malta	1	0	*-80%*	0	*-85%*	0	*-86%*
Netherlands	44	11	*-76%*	9	*-79%*	9	*-79%*
Poland	232	139	*-40%*	112	*-52%*	103	*-56%*
Portugal	55	17	*-69%*	7	*-87%*	6	*-89%*
Romania	80	61	*-24%*	21	*-74%*	18	*-78%*
Slovakia	21	10	*-54%*	7	*-69%*	6	*-73%*
Slovenia	11	5	*-55%*	3	*-75%*	3	*-74%*
Spain	277	149	*-46%*	60	*-78%*	57	*-79%*
Sweden	39	18	*-54%*	18	*-54%*	9	*-76%*
UK	163	45	*-72%*	29	*-82%*	28	*-83%*
EU-27	2123	852	*-60%*	568	*-73%*	520	*-76%*
Croatia	14	8	*-39%*	4	*-74%*	3	*-77%*
EU-28	2137	861	*-60%*	571	*-73%*	523	*-76%*
Power gen.	42	34	*-19%*	11	*-75%*	3	*-93%*
Domestic	346	287	*-17%*	244	*-29%*	210	*-39%*
Ind. comb.	24	25	*6%*	10	*-59%*	5	*-78%*
Ind. process	25	27	*6%*	13	*-47%*	12	*-52%*
Fuel extract.	0	0	*-14%*	0	*-14%*	0	*-14%*
Solvent use	0	0	*0%*	0	*0%*	0	*0%*
Road transp.	1342	199	*-85%*	199	*-85%*	199	*-85%*
Non-road	159	64	*-60%*	64	*-60%*	64	*-60%*
Waste	28	29	*3%*	22	*-23%*	22	*-23%*
Agriculture	170	195	*15%*	8	*-95%*	7	*-96%*
Sum	2137	861	*-60%*	571	*-73%*	523	*-76%*

Emissions of Black Carbon

A further extension of the GAINS model provides now estimates of black carbon (BC) emissions, calculated as a special fraction of PM2.5 with source-specific emission factors. Emission factors are taken from the literature and are consistent with those used for PM2.5; however, results have not yet been consulted with Member States.

Compared to 2005, the baseline is expected to reduce BC by 50% until 2025. The A5 scenario would enhance this decline to ~60%, while the MTFR scenario could eliminate almost three quarters of current BC emissions. In 2005, mobile (road and non-road) sources emitted about 50% of total BC emissions, and domestic small-scale combustion about 40%. BC emissions from road transport will decline by about 90%, and from non-road mobile machinery by about 70%. The A5 scenarios would double the reduction of BC from the domestic sector, from 10% in the baseline to 20% (Table 6.8).

Table 6.8: BC emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	CLE		A5		MTFR	
Austria	7.4	2.5	-67%	1.6	-79%	0.9	-88%
Belgium	7.6	2.1	-72%	1.8	-76%	1.5	-80%
Bulgaria	5.9	3.8	-36%	2.7	-54%	1.4	-76%
Cyprus	0.5	0.1	-83%	0.1	-85%	0.1	-87%
Czech Rep.	8.9	6.6	-26%	5.3	-41%	3.5	-61%
Denmark	5.5	2.1	-61%	2.0	-63%	1.3	-77%
Estonia	2.4	2.5	5%	2.2	-9%	1.3	-47%
Finland	6.8	3.3	-51%	2.7	-61%	1.6	-77%
France	63.4	26.8	-58%	23.6	-63%	11.8	-81%
Germany	31.2	10.0	-68%	8.7	-72%	6.2	-80%
Greece	10.6	4.5	-57%	3.1	-70%	2.2	-79%
Hungary	5.4	2.6	-51%	2.1	-61%	1.2	-78%
Ireland	3.1	2.0	-36%	1.9	-39%	1.7	-46%
Italy	39.2	17.0	-57%	14.7	-62%	12.6	-68%
Latvia	4.1	2.7	-35%	2.4	-41%	0.9	-78%
Lithuania	2.9	2.4	-15%	1.9	-34%	0.9	-68%
Luxembourg	1.4	0.2	-85%	0.2	-86%	0.1	-90%
Malta	0.2	0.0	-90%	0.0	-93%	0.0	-93%
Netherlands	7.5	1.8	-75%	1.8	-76%	1.6	-78%
Poland	50.6	43.6	-14%	39.8	-21%	28.7	-43%
Portugal	9.3	2.9	-68%	1.8	-80%	1.0	-89%
Romania	18.2	14.5	-21%	10.7	-41%	4.3	-76%
Slovakia	3.4	2.7	-21%	2.4	-31%	0.9	-73%
Slovenia	1.8	1.3	-27%	0.3	-81%	0.2	-89%
Spain	36.4	17.7	-51%	10.3	-72%	6.8	-81%
Sweden	5.9	2.0	-67%	1.4	-77%	0.8	-86%
UK	24.3	8.6	-64%	6.9	-72%	5.3	-78%
EU-27	363.7	186.5	-49%	152.3	-58%	98.9	-73%
Croatia	2.8	1.7	-40%	1.1	-59%	0.7	-77%
EU-28	366.5	188.1	-49%	153.4	-58%	99.5	-73%
Power gen.	6.0	1.0	-83%	0.5	-92%	0.3	-95%
Domestic	146.5	130.9	-11%	115.9	-21%	62.7	-57%
Ind. comb.	2.1	1.2	-43%	0.5	-78%	0.1	-96%
Ind. process	2.2	1.0	-52%	0.2	-92%	0.1	-95%
Fuel extract.	0.0	0.0		0.0		0.0	
Solvent use	0.0	0.0		0.0		0.0	
Road transp.	137.1	15.1	-89%	15.1	-89%	15.1	-89%
Non-road	50.2	14.5	-71%	14.5	-71%	14.5	-71%
Waste	9.4	9.4	0%	6.9	-27%	6.9	-27%
Agriculture	13.1	15.1	16%		-100%		-100%
Sum	366.5	188.1	-49%	153.4	-58%	99.5	-73%

Emissions of mercury (Hg)

Another extension of the GAINs model addresses emissions of mercury (Hg), fully consistent with the estimates of historic and future emissions of the other air pollutants and greenhouse gases (Rafaj et al., forthcoming). This extension makes it possible to estimate, in addition to the other pollutants, the (side) impacts of different climate and air pollution strategies on Hg emissions.

A first implementation suggests for the TSAP-2013 Baseline a decline of Hg emissions of 25% in the EU-28 between 2005 and 2025, mainly as a consequence of lower coal use in the power sector (Table 6.9). Measures of the A5 scenario targeted at stricter control of PM emissions, especially in smaller units in the power sector and for industrial processes, would lead to a further decline of Hg, so that in 2025 Hg release in the EU-28 would be one third lower than in 2005.

Table 6.9: Hg emissions of the optimized A5 scenario by country and by sector (kilotons and change to 2005)

	2005	CLE		A5		MTFR	
Austria	1.41	0.96	-32%	0.89	-37%	0.76	-46%
Belgium	2.43	1.28	-47%	1.18	-51%	1.06	-56%
Bulgaria	3.21	3.74	17%	3.36	5%	1.85	-42%
Cyprus	0.08	0.04	-50%	0.04	-50%	0.04	-50%
Czech Rep.	5.00	3.37	-33%	3.26	-35%	2.32	-54%
Denmark	0.83	0.74	-11%	0.70	-16%	0.31	-63%
Estonia	0.61	0.86	41%	0.85	39%	0.15	-75%
Finland	1.07	1.08	1%	1.01	-6%	0.83	-22%
France	5.93	3.81	-36%	3.22	-46%	2.63	-56%
Germany	20.52	14.69	-28%	14.28	-30%	11.65	-43%
Greece	2.75	1.37	-50%	1.18	-57%	0.95	-65%
Hungary	2.41	1.80	-25%	1.67	-31%	1.48	-39%
Ireland	0.58	0.55	-5%	0.52	-10%	0.48	-17%
Italy	9.13	6.70	-27%	4.24	-54%	3.15	-65%
Latvia	0.13	0.14	8%	0.12	-8%	0.10	-23%
Lithuania	0.16	0.16	0%	0.12	-25%	0.10	-38%
Luxembourg	0.09	0.09	0%	0.09	0%	0.09	0%
Malta	0.01	0.00	-100%	0.00	-100%	0.00	-100%
Netherlands	1.35	1.52	13%	1.47	9%	1.04	-23%
Poland	18.11	15.30	-16%	14.81	-18%	9.38	-48%
Portugal	1.56	1.27	-19%	1.03	-34%	0.75	-52%
Romania	4.21	2.87	-32%	2.56	-39%	2.22	-47%
Slovakia	1.17	1.02	-13%	0.94	-20%	0.82	-30%
Slovenia	0.51	0.43	-16%	0.40	-22%	0.17	-67%
Spain	8.71	5.21	-40%	4.62	-47%	3.40	-61%
Sweden	0.96	0.97	1%	0.95	-1%	0.87	-9%
UK	6.36	3.56	-44%	3.12	-51%	2.41	-62%
EU-27	99.27	73.53	-26%	66.64	-33%	49.01	-51%
Croatia	0.29	0.26	-10%	0.16	-45%	0.12	-59%
EU-28	99.56	73.79	-26%	66.80	-33%	49.13	-51%
Power gen.	60.0	38.3	-36%	36.1	-40%	23.9	-60%
Domestic	4.2	3.5	-17%	3.4	-20%	3.2	-24%
Ind. comb.	3.4	2.9	-14%	2.9	-16%	2.8	-17%
Ind. process	25.1	22.4	-11%	21.1	-16%	18.2	-27%
Fuel extract.	0.0	0.0		0.0		0.0	
Solvent use	0.0	0.0		0.0		0.0	
Road transp.	0.8	0.5	-40%	0.5	-40%	0.5	-41%
Non-road	0.4	0.4	-6%	0.4	-6%	0.3	-11%
Waste	5.4	5.5	0%	2.6	-52%	0.2	-96%
Agriculture	0.3	0.4	16%	0.0	-100%	0.0	-100%
Sum	99.6	73.8	-26%	66.8	-33%	49.1	-51%

6.1.2 Emission reductions by source sector

For each country, the GAINS optimization model considers costs and impacts of about 2000 individual emission reduction measures, and determines cost-effective portfolios of emission control measures that achieve the prescribed environmental quality targets at least cost. In the GAINS cost-minimization approach, the application rates of all 2000 measures serve as decision variables, and thus the cost-optimal solution specifies the implementation rates for each measure, between the current legislation baseline and the maximum feasible reduction cases (Wagner et al. 2013).

Figure 6.2 to Figure 6.6 summarize for each country the contribution of the various source sectors to the cost-effective emission reductions of the A5 scenario, on top of measures that are already required by the current legislation.

For readability, these graphs present group measures by sector. Detailed measures that are included for each sector in each country are available on the Internet at http://gains.iiasa.ac.at.

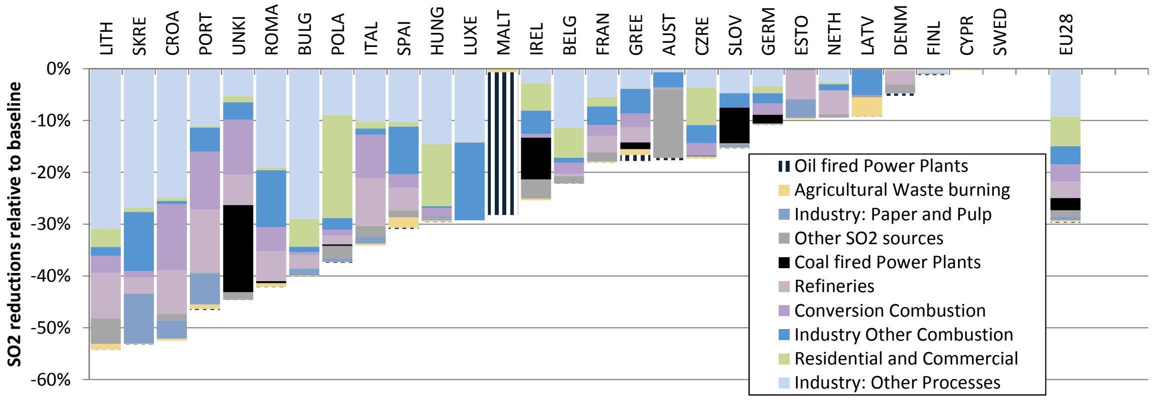

Figure 6.2: Further reductions of SO_2 emissions (beyond the baseline) for the A5 scenario, relative to national baseline emissions

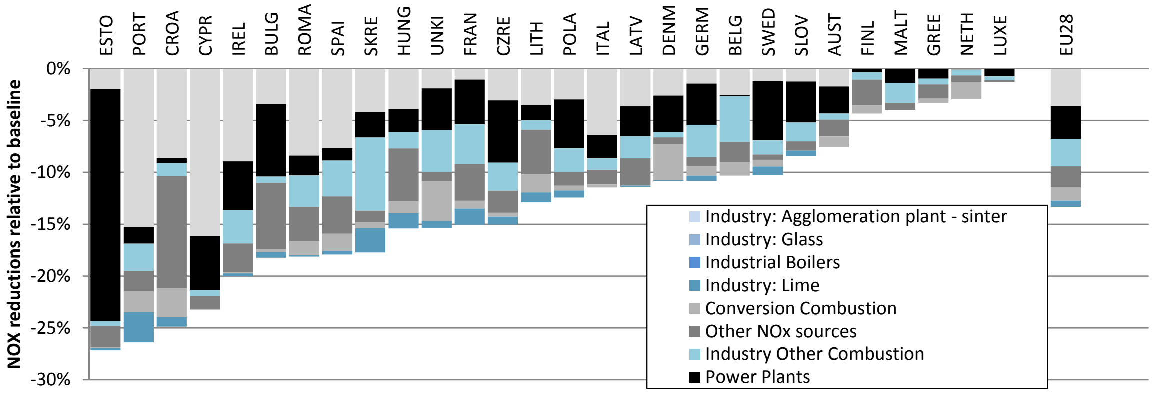

Figure 6.3: Further reductions of NO_x emissions (beyond the baseline) for the A5 scenario, relative to national baseline emissions NO_x

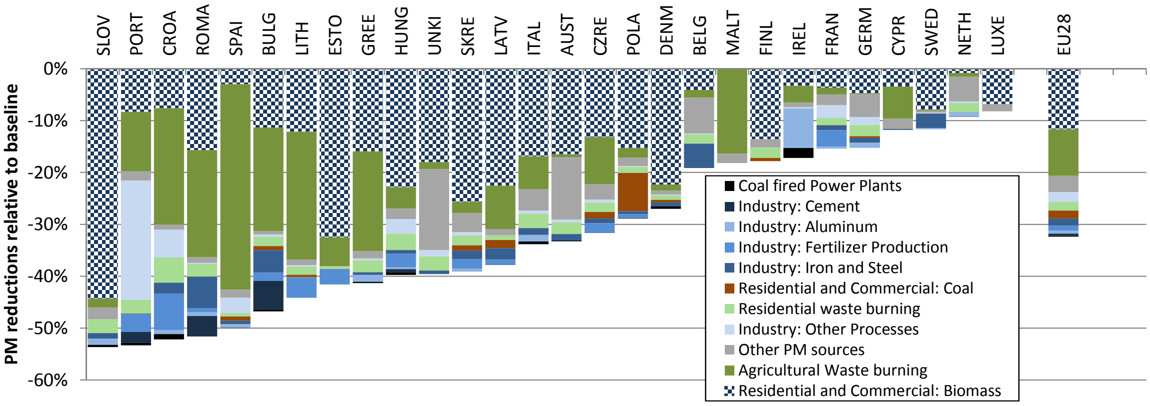

Figure 6.4: Further reductions of PM2.5 emissions (beyond the baseline) for the A5 scenario, relative to national baseline emissions

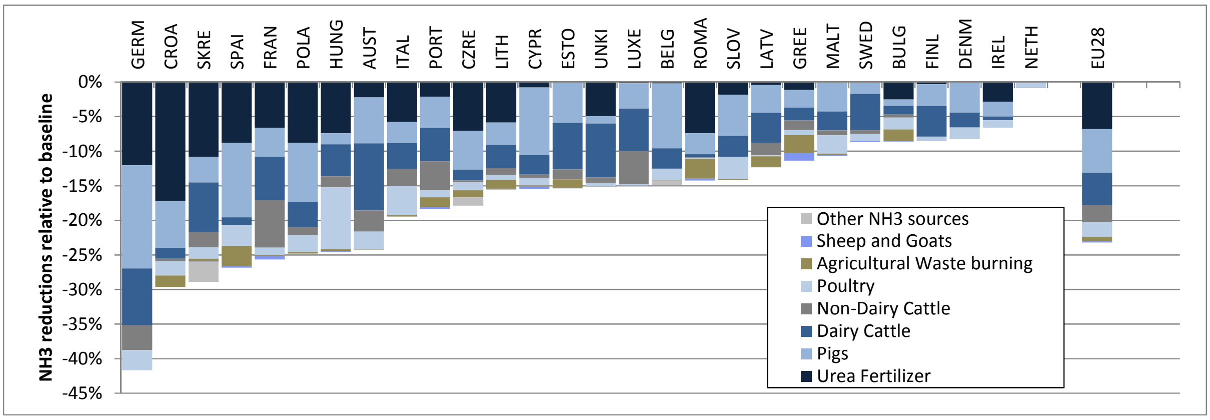

Figure 6.5: Further reductions of NH_3 emissions (beyond the baseline) for the A5 scenario, relative to national baseline emissions

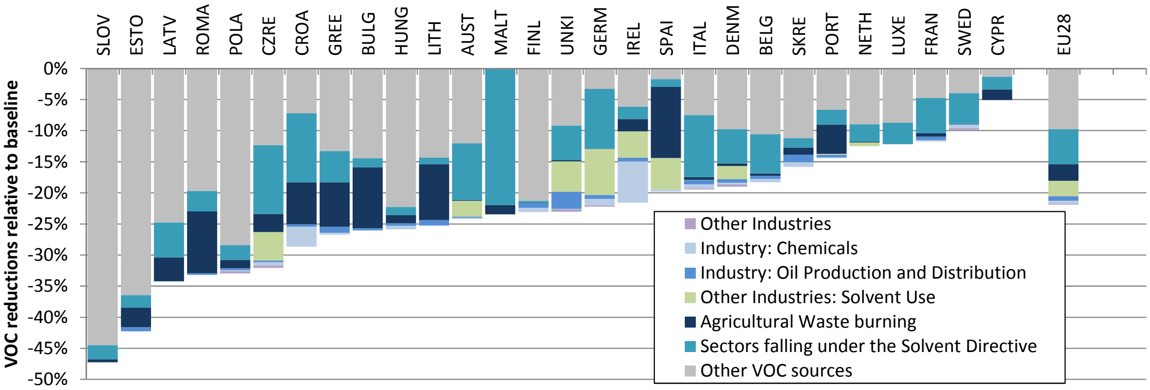

Figure 6.6: Further reductions of VOC emissions (beyond the baseline) for the A5 scenario, relative to national baseline emissions

6.1.3 Emission control costs

The A5 scenario involves emission control costs of 5.4 billion €/yr, which represents an increase of about 6% compared to the costs for implementing current legislation in 2025 (Table 6.10).

These 5.4 billion € constitute about 0.04% of the GDP in the EU-28 that is assumed for 2025. However, this share varies widely across Member States, essentially due to differences in economic wealth. While the additional measures would require up to 0.28% in Bulgaria and Estonia, they account for only 0.01% of the GDP in Luxembourg, the Netherlands and Sweden.

In earlier analyses, e.g., for the CAFE programme, modified scenarios have been developed where costs (on a % per GDP basis) have been restricted for all Member States to remain below a certain upper limit. Such an approach could be certainly applied to refine the current analysis.

Table 6.10: Emission control costs in 2025 of the optimized A5 scenario, by country and by sector

	CLE		*A5*		*MTFR*	
Costs by country (million €/yr, % of GDP)						
Austria	1899	0.57%	113	0.03%	962	0.29%
Belgium	2334	0.59%	171	0.04%	755	0.19%
Bulgaria	1377	4.14%	94	0.28%	710	2.13%
Cyprus	139	0.31%	5	0.01%	45	0.10%
Czech Rep.	2027	1.32%	146	0.10%	1190	0.77%
Denmark	1158	0.45%	41	0.02%	761	0.30%
Estonia	352	2.11%	41	0.25%	332	1.99%
Finland	1350	0.65%	34	0.02%	950	0.46%
France	11941	0.52%	561	0.02%	7638	0.33%
Germany	14124	0.50%	968	0.03%	5152	0.18%
Greece	2035	0.96%	82	0.04%	877	0.41%
Hungary	1067	1.02%	89	0.08%	661	0.63%
Ireland	1054	0.45%	48	0.02%	458	0.20%
Italy	10072	0.61%	599	0.04%	3566	0.21%
Latvia	367	1.99%	26	0.14%	574	3.11%
Lithuania	353	1.16%	43	0.14%	604	1.99%
Luxembourg	193	0.44%	3	0.01%	40	0.09%
Malta	97	1.42%	0	0.01%	18	0.26%
Netherlands	3833	0.56%	101	0.01%	809	0.12%
Poland	9839	2.18%	741	0.16%	5788	1.28%
Portugal	1480	0.84%	89	0.05%	801	0.46%
Romania	2501	2.05%	205	0.17%	2855	2.34%
Slovakia	781	1.11%	85	0.12%	766	1.09%
Slovenia	474	1.18%	45	0.11%	139	0.35%
Spain	7675	0.61%	284	0.02%	4232	0.34%
Sweden	1422	0.34%	61	0.01%	585	0.14%
UK	7309	0.30%	650	0.03%	3373	0.14%
EU-27	87257	0.60%	5323	0.04%	44638	0.31%
Croatia	415	0.83%	39	0.08%	376	0.75%
EU-28	87673	0.60%	5362	0.04%	45014	0.31%
Costs by SNAP sector (million €/yr, increase compared to CLE)						
Power gen.	10241		650	*6.3%*	*2825*	*28%*
Domestic	9256		1723	*18.6%*	*17874*	*193%*
Ind. comb.	2739		801	*29.2%*	*1985*	*72%*
Ind. process	5060		311	*6.1%*	*3964*	*78%*
Fuel extract.	660		6	*0.9%*	*562*	*85%*
Solvent use	1176		734	*62.5%*	*12054*	*1025%*
Road transp.	47970		0	*0.0%*	*0*	*0%*
Non-road	8763		31	*0.4%*	*45*	*1%*
Waste	6		9	*148.3%*	*9*	*148%*
Agriculture	1801		1096	*60.9%*	*5696*	*316%*
Sum	87673		5362	*6.1%*	*45014*	*51%*

6.1.4 Air quality impacts

Premature mortality from PM2.5

Together with the current legislation, the additional measures in the A5 scenario would reduce the loss in statistical life expectancy in the EU from 8.5 months in 2005 to 4.3 months, i.e., by almost 50% (Table 6.11). Thus, life shortening will exceed five months in the old Member States only in a few areas in the Benelux countries and northern Italy. In the new Member States, the anticipated prevalence of solid fuel use for domestic heating will prohibit further reductions (Figure 6.7). Overall, these measures will gain about 180 million life years to the European population.

A fuller assessment of health impacts, including infant mortality and morbidity, is presented in the accompanying TSAP Report #11.

Table 6.11: Loss of statistical life expectancy from exposure to PM2.5 from anthropogenic sources (months)

	2005	*CLE*		*A5*		*MTFR*	
Austria	7.4	4.6	*-37%*	3.7	*-50%*	3.5	*-53%*
Belgium	10.2	6.2	*-39%*	5.2	*-49%*	4.9	*-52%*
Bulgaria	11.1	5.9	*-47%*	4.8	*-56%*	4.5	*-59%*
Cyprus	6.4	5.8	*-9%*	5.7	*-11%*	5.6	*-12%*
Czech Rep.	9.1	6.2	*-31%*	4.9	*-45%*	4.5	*-50%*
Denmark	6.4	3.7	*-42%*	3.1	*-51%*	2.9	*-55%*
Estonia	4.8	3.9	*-18%*	3.3	*-30%*	3.0	*-37%*
Finland	3.7	2.9	*-24%*	2.6	*-30%*	2.4	*-35%*
France	8.8	4.8	*-45%*	4.1	*-54%*	3.6	*-59%*
Germany	7.9	5.1	*-35%*	4.2	*-47%*	4.0	*-49%*
Greece	12.3	6.5	*-47%*	5.4	*-56%*	5.0	*-59%*
Hungary	10.1	6.2	*-38%*	4.9	*-52%*	4.5	*-55%*
Ireland	3.6	2.4	*-33%*	2.1	*-41%*	2.0	*-44%*
Italy	10.2	6.3	*-39%*	4.9	*-52%*	4.5	*-56%*
Latvia	5.9	4.4	*-24%*	3.8	*-35%*	3.4	*-42%*
Lithuania	6.3	5.0	*-21%*	4.2	*-34%*	3.9	*-39%*
Luxembourg	9.2	5.5	*-40%*	4.6	*-50%*	4.3	*-53%*
Malta	7.1	3.9	*-45%*	3.6	*-49%*	3.5	*-51%*
Netherlands	8.8	5.2	*-41%*	4.5	*-49%*	4.3	*-51%*
Poland	11.6	9.1	*-21%*	7.0	*-40%*	6.3	*-46%*
Portugal	9.2	4.2	*-55%*	3.1	*-66%*	2.9	*-69%*
Romania	11.3	6.5	*-42%*	5.0	*-55%*	4.4	*-61%*
Slovakia	8.3	6.1	*-27%*	4.7	*-44%*	4.2	*-49%*
Slovenia	8.5	5.1	*-40%*	3.8	*-55%*	3.6	*-58%*
Spain	7.4	4.3	*-43%*	3.4	*-55%*	3.1	*-59%*
Sweden	3.4	2.4	*-31%*	2.2	*-37%*	2.0	*-40%*
UK	5.8	3.8	*-34%*	2.9	*-49%*	2.8	*-52%*
EU-27	8.5	5.3	*-37%*	4.3	*-50%*	3.9	*-54%*
Croatia	8.1	4.7	*-42%*	3.8	*-53%*	3.5	*-56%*
EU-28	8.5	5.3	*-38%*	4.3	*-50%*	3.9	*-54%*

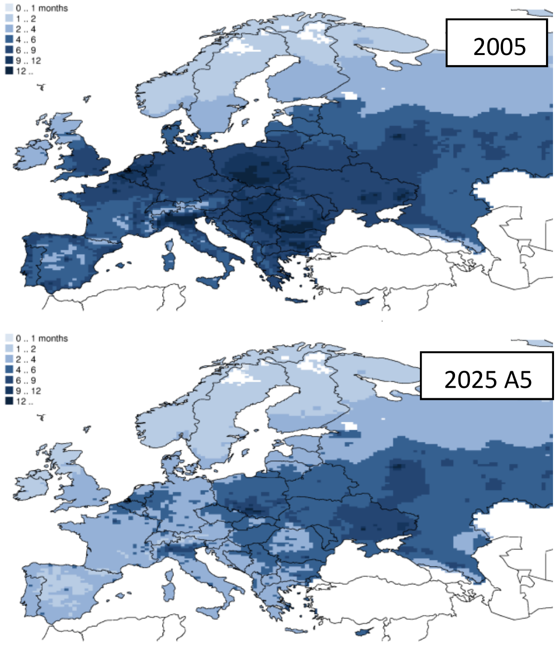

Figure 6.7: Loss in statistical life expectancy from exposure to PM2.5 from anthropogenic sources

Premature mortality from ground-level ozone

With the measures of the A5 scenario, the number of premature deaths attributable to exposure to ground-level ozone is computed to decline by 34% between 2005 and 2025 (Table 6.12).

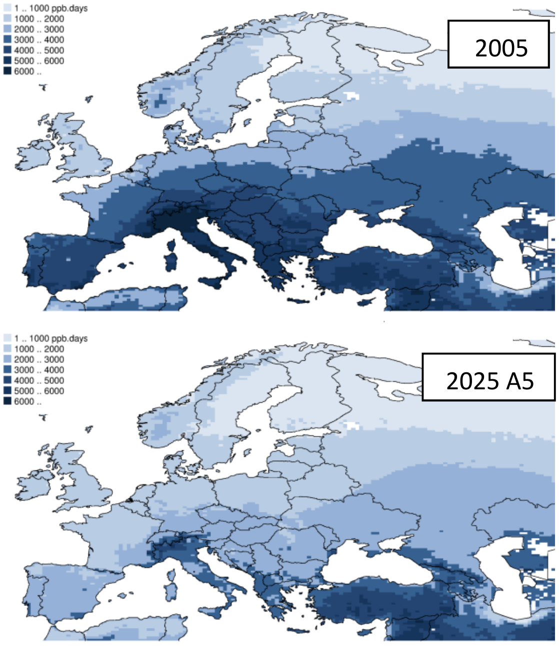

Figure 6.8: The SOMO35 indicator that is related to premature mortality from ground-level ozone

Larger improvements (up to 40%) occur in central Europe (Austria, Hungary, Slovakia), while changes in the UK will be limited to below 10% as a consequence of high NO_x emission densities and the non-linear ozone chemistry.

Table 6.12: Premature deaths attributable to exposure to ground-level ozone (cases/yr)

	2005	*CLE*		*A5*		*MTFR*	
Austria	469	312	*-33%*	280	*-40%*	262	*-44%*
Belgium	316	264	*-16%*	239	*-24%*	224	*-29%*
Bulgaria	814	546	*-33%*	500	*-39%*	473	*-42%*
Cyprus	51	42	*-18%*	40	*-22%*	39	*-24%*
Czech Rep.	547	374	*-32%*	334	*-39%*	312	*-43%*
Denmark	164	127	*-23%*	117	*-29%*	111	*-32%*
Estonia	38	28	*-26%*	26	*-32%*	25	*-34%*
Finland	99	71	*-28%*	67	*-32%*	64	*-35%*
France	2497	1697	*-32%*	1552	*-38%*	1465	*-41%*
Germany	3673	2710	*-26%*	2449	*-33%*	2315	*-37%*
Greece	924	642	*-31%*	595	*-36%*	567	*-39%*
Hungary	828	534	*-36%*	477	*-42%*	443	*-46%*
Ireland	56	50	*-11%*	47	*-16%*	46	*-18%*
Italy	5294	3634	*-31%*	3265	*-38%*	3048	*-42%*
Latvia	93	66	*-29%*	61	*-34%*	58	*-38%*
Lithuania	144	103	*-28%*	96	*-33%*	91	*-37%*
Luxembourg	15	12	*-20%*	11	*-27%*	10	*-33%*
Malta	26	19	*-27%*	17	*-35%*	16	*-38%*
Netherlands	380	336	*-12%*	305	*-20%*	287	*-24%*
Poland	1669	1172	*-30%*	1056	*-37%*	993	*-41%*
Portugal	591	449	*-24%*	419	*-29%*	401	*-32%*
Romania	1597	1076	*-33%*	977	*-39%*	915	*-43%*
Slovakia	307	203	*-34%*	181	*-41%*	168	*-45%*
Slovenia	135	85	*-37%*	75	*-44%*	69	*-49%*
Spain	2085	1604	*-23%*	1485	*-29%*	1408	*-32%*
Sweden	240	172	*-28%*	160	*-33%*	153	*-36%*
UK	1207	1187	*-2%*	1098	*-9%*	1045	*-13%*
EU-27	24256	17514	*-28%*	15929	*-34%*	15009	*-38%*
Croatia	358	221	*-38%*	195	*-46%*	180	*-50%*
EU-28	24614	17735	*-28%*	16124	*-34%*	15189	*-38%*

Eutrophication

Natura2000 areas

With the emission reductions of the A5 scenario, the area of Natura2000 nature protection zones where biodiversity is not threatened by excess nitrogen deposition will increase by 149,000 km^2 compared to 2005. Thus, these measures would push improvement from 20% in the baseline case to more than one third.

Table 6.13: Natura2000 area with nitrogen deposition above their critical loads for eutrophication (1000 km^2 and change to 2005)

	2005	*CLE*		*A5*		*MTFR*	
Austria							
Belgium							
Bulgaria							
Cyprus	*0.8*	0.8	*0%*	0.8	*0%*	0.8	*0%*
Czech Rep.	*1.0*	0.7	*-26%*	0.5	*-50%*	0.4	*-58%*
Denmark	*1.6*	1.6	*-1%*	1.6	*-1%*	1.6	*-3%*
Estonia	*3.3*	1.7	*-49%*	1.3	*-61%*	1.0	*-71%*
Finland	*2.1*	0.7	*-68%*	0.5	*-75%*	0.5	*-78%*
France	*116.8*	91.5	*-22%*	64.0	*-45%*	53.3	*-54%*
Germany	*54.3*	41.6	*-23%*	27.5	*-49%*	25.3	*-53%*
Greece	*17.1*	16.5	*-3%*	16.3	*-4%*	16.2	*-5%*
Hungary	*13.0*	10.8	*-17%*	8.9	*-31%*	8.9	*-32%*
Ireland	*0.1*	0.0	*-55%*	0.0	*-69%*	0.0	*-76%*
Italy	*58.9*	33.2	*-44%*	22.6	*-62%*	20.6	*-65%*
Latvia	*5.1*	4.3	*-16%*	3.7	*-27%*	3.4	*-35%*
Lithuania	*5.5*	5.4	*-3%*	5.2	*-7%*	4.9	*-12%*
Luxembourg	*0.3*	0.3	*-7%*	0.3	*-9%*	0.3	*-14%*
Malta							
Netherlands	*4.1*	3.9	*-5%*	3.6	*-12%*	3.5	*-15%*
Poland							
Portugal	*9.3*	9.2	*0%*	8.7	*-6%*	8.3	*-10%*
Romania	*22.3*	20.3	*-9%*	19.2	*-14%*	18.2	*-18%*
Slovakia	*10.8*	9.4	*-13%*	8.7	*-20%*	8.5	*-22%*
Slovenia	*6.3*	1.6	*-75%*	0.4	*-94%*	0.3	*-95%*
Spain	*91.5*	88.0	*-4%*	83.7	*-9%*	77.7	*-15%*
Sweden	*2.5*	1.1	*-57%*	0.9	*-66%*	0.7	*-71%*
UK							
EU-27	*426.8*	342.6	*-20%*	278.3	*-35%*	254.3	*-40%*
Croatia							
EU-28	*426.8*	342.7	*-20%*	278.3	*-35%*	254.3	*-40%*

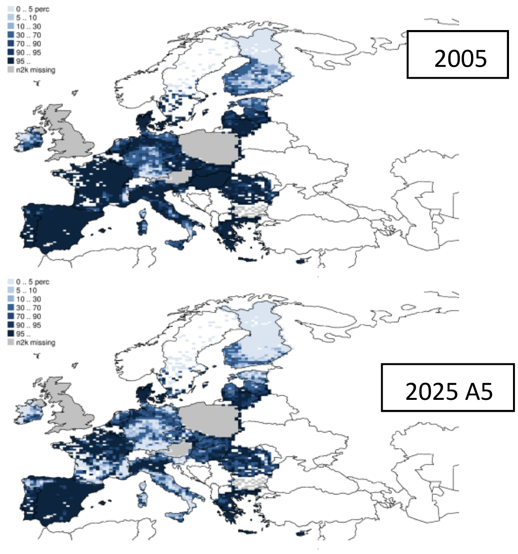

Figure 6.9: Percentage of Natura2000 area with nitrogen deposition above their critical loads for eutrophication.

All ecosystems

Lower nitrogen deposition will not only benefit biodiversity in the protected Natura2000 estimates, but will bring benefits to all ecosystems in Europe (Figure 6.9).

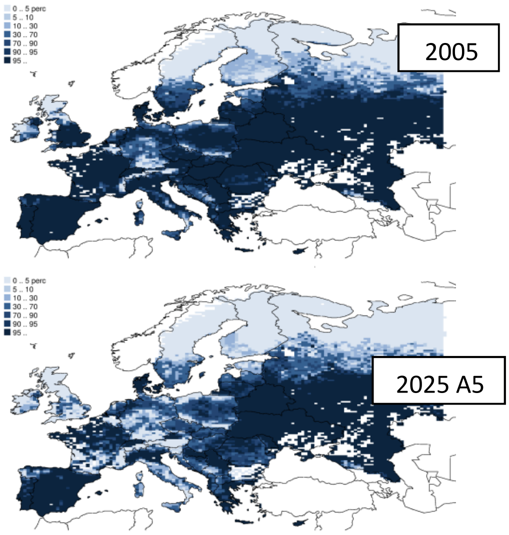

Figure 6.10: Percentage of ecosystems area with nitrogen deposition above their critical loads for eutrophication

The additional measures of the A5 scenario would provide protection against excess nitrogen deposition to 50% more ecosystems area (+140,000 km^2) than the baseline projection (Table 6.14), especially in the central and western parts of Europe.

Acidification

There will also be large reductions in the threat to forests from acidification. The measures of the A5 scenario would achieve sustainable conditions for more than 98% of European forest areas by bringing acid deposition below the critical loads. Compared to 2005, the residual area under threat would shrink by 84% in 2025 (Figure 6.11, Table 6.15).

Table 6.14: Ecosystems area with nitrogen deposition above their critical loads for eutrophication (1000 km^2 and change to 2005)

	2005	CLE		A5		MTFR	
Austria	*29.6*	18.0	*-39%*	9.2	*-69%*	7.0	*-76%*
Belgium	*0.3*	0.0	*-89%*	0.0	*-99%*	0.0	*-100%*
Bulgaria	*32.0*	15.2	*-52%*	12.9	*-60%*	11.6	*-64%*
Cyprus	*2.5*	2.5	*0%*	2.5	*0%*	2.5	*0%*
Czech Rep.	*2.1*	1.7	*-17%*	1.3	*-40%*	1.1	*-47%*
Denmark	*4.3*	4.2	*-1%*	4.2	*-3%*	4.1	*-4%*
Estonia	*10.9*	4.5	*-59%*	3.4	*-69%*	2.7	*-75%*
Finland	*30.0*	7.9	*-74%*	5.4	*-82%*	4.4	*-85%*
France	*157.0*	126.5	*-19%*	91.6	*-42%*	78.8	*-50%*
Germany	*65.7*	51.2	*-22%*	35.0	*-47%*	32.5	*-50%*
Greece	*57.9*	55.3	*-5%*	54.2	*-6%*	53.7	*-7%*
Hungary	*23.8*	19.7	*-17%*	15.9	*-33%*	15.9	*-33%*
Ireland	*1.6*	0.7	*-60%*	0.5	*-71%*	0.4	*-77%*
Italy	*98.1*	58.9	*-40%*	42.2	*-57%*	38.8	*-60%*
Latvia	*32.7*	27.0	*-18%*	22.7	*-31%*	20.4	*-38%*
Lithuania	*19.3*	18.9	*-2%*	18.0	*-7%*	16.9	*-13%*
Luxembourg	*1.2*	1.1	*-3%*	1.1	*-5%*	1.1	*-7%*
Malta	*0.0*	0.0		0.0		0.0	
Netherlands	*4.1*	3.9	*-5%*	3.6	*-12%*	3.5	*-15%*
Poland	*74.1*	60.7	*-18%*	47.1	*-36%*	42.2	*-43%*
Portugal	*32.7*	32.6	*0%*	30.8	*-6%*	28.9	*-12%*
Romania	*94.8*	88.5	*-7%*	84.8	*-11%*	81.9	*-14%*
Slovakia	*22.2*	19.7	*-11%*	18.6	*-16%*	18.2	*-18%*
Slovenia	*9.7*	2.6	*-73%*	0.8	*-92%*	0.5	*-95%*
Spain	*211.6*	202.5	*-4%*	192.7	*-9%*	182.4	*-14%*
Sweden	*91.9*	44.5	*-52%*	32.9	*-64%*	27.3	*-70%*
UK	*8.9*	4.0	*-55%*	1.6	*-82%*	1.2	*-86%*
EU-27	*1119.2*	872.6	*-22%*	733.1	*-35%*	678.0	*-39%*
Croatia	*28.9*	24.9	*-14%*	22.2	*-23%*	21.5	*-26%*
EU-28	*1148.1*	897.5	*-22%*	755.3	*-34%*	699.5	*-39%*

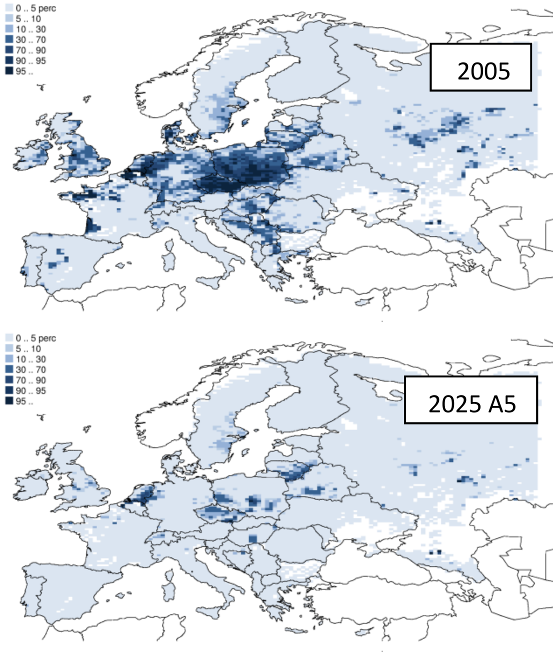

Figure 6.11: Percentage of forest area with acid deposition above the critical loads for acidification.

Table 6.15: Forest area with acid deposition above the critical loads for acidification (1000 km^2 and change to 2005)

	2005	CLE		A5		MTFR	
Austria	*0.1*	0.0	*-100%*	0.0	*-100%*	0.0	*-100%*
Belgium	*0.7*	0.0	*-95%*	0.0	*-97%*	0.0	*-98%*
Bulgaria	*0.0*	0.0		0.0		0.0	
Cyprus	*0.0*	0.0		0.0		0.0	
Czech Rep.	*1.9*	1.0	*-49%*	0.4	*-77%*	0.3	*-82%*
Denmark	*1.4*	0.0	*-97%*	0.0	*-99%*	0.0	*-99%*
Estonia	*0.1*	0.0	*-100%*	0.0	*-100%*	0.0	*-100%*
Finland	*0.0*	0.0	*-100%*	0.0	*-100%*	0.0	*-100%*
France	*15.4*	3.5	*-78%*	0.5	*-97%*	0.2	*-99%*
Germany	*32.6*	4.8	*-85%*	1.0	*-97%*	0.8	*-98%*
Greece	*1.2*	0.2	*-84%*	0.1	*-94%*	0.1	*-94%*
Hungary	*3.3*	1.1	*-67%*	0.5	*-85%*	0.4	*-87%*
Ireland	*0.7*	0.0	*-99%*	0.0	*-100%*	0.0	*-100%*
Italy	*1.1*	0.1	*-92%*	0.0	*-97%*	0.0	*-98%*
Latvia	*5.3*	1.1	*-79%*	0.6	*-89%*	0.5	*-91%*
Lithuania	*6.6*	5.8	*-12%*	5.3	*-19%*	5.0	*-23%*
Luxembourg	*0.2*	0.1	*-28%*	0.0	*-83%*	0.0	*-98%*
Malta	*0.0*	0.0		0.0		0.0	
Netherlands	*4.8*	3.9	*-19%*	3.5	*-28%*	3.4	*-30%*
Poland	*52.3*	20.2	*-61%*	8.1	*-84%*	6.5	*-88%*
Portugal	*1.4*	0.2	*-86%*	0.1	*-90%*	0.1	*-92%*
Romania	*2.9*	0.1	*-97%*	0.0	*-100%*	0.0	*-100%*
Slovakia	*2.1*	0.6	*-70%*	0.1	*-96%*	0.0	*-98%*
Slovenia	*0.2*	0.0	*-98%*	0.0	*-100%*	0.0	*-100%*
Spain	*2.6*	0.1	*-98%*	0.0	*-100%*	0.0	*-100%*
Sweden	*19.4*	5.3	*-73%*	4.2	*-78%*	3.9	*-80%*
UK	*3.3*	1.0	*-71%*	0.4	*-88%*	0.3	*-90%*
EU-27	*159.6*	49.0	*-69%*	25.0	*-84%*	21.6	*-86%*
Croatia	*1.3*	0.4	*-68%*	0.1	*-95%*	0.0	*-97%*
EU-28	*160.9*	49.4	*-69%*	25.0	*-84%*	21.6	*-87%*

Compliance with NO_2 and PM10 limit values

The additional measures in A5 will also benefit compliance with the NO_2 and PM10 limit value (Figure 6.12). For NO_2, the number of zones which are in firm or potential non-compliance will decrease from 52 to 46 in 2025. For PM10, even larger improvements are expected, with the number of zones in firm or potential non-compliance declining by 28% compared to the baseline as a consequence of the additional measures of the A5 scenario.

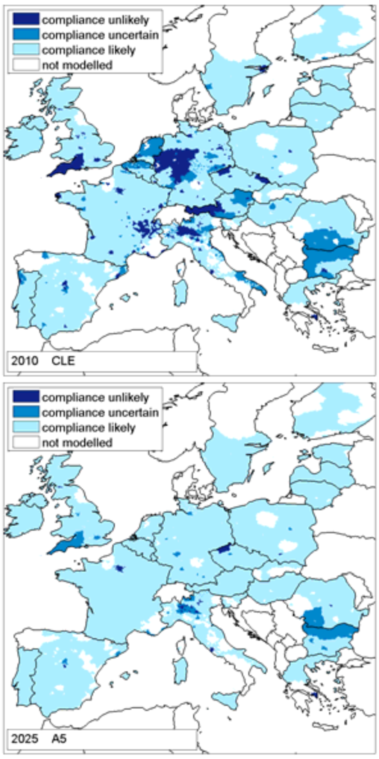

Figure 6.12: Compliance of the air quality management zones with the limit values for NO_2, for 2010 (top panel) and the A5 scenario in 2025 (bottom panel)

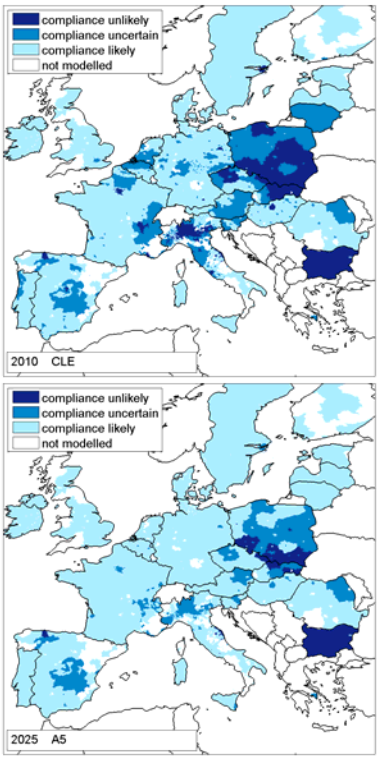

Figure 6.13: Compliance of the air quality management zones with the limit values for PM10, for 2010 (top panel) and the A5 scenario in 2025 (bottom panel)

6.2 Achieving emissions ceilings of the A5 scenario under TSAP-2012 assumptions

The central A5 scenario has been developed for the most recent TSAP-2013 Baseline projection. However, there is uncertainty about numerous assumptions in this scenario, *inter alia,* about future economic development, and energy, transport, climate and agricultural policies. These uncertainties affect future levels of baseline emissions as well as the potential and costs for further emission reductions.

The achievability of the environmental targets of the A5 scenario under the TSAP-2012 Baseline has been established in the A8 scenario that is described in the preceding section. From a different perspective, the question arises whether emission ceilings for individual countries that have been developed for the TSAP-2013 Baseline could be achieved under the TSAP-2012 Baseline.

Table 6.16: Comparison of the optimized emissions for the A5 scenario with the MTFR cases of the TSAP-2012 scenario (kilotons)

	SO_2		NO_x	
	A5	MTFR TSAP-2012	A5	MTFR TSAP-2012
Austria	12	12	70	61
Belgium	51	**61**	128	123
Bulgaria	85	44	58	58
Cyprus	2	2	**5**	7
Czech Rep.	77	76	114	109
Denmark	10	9	63	58
Estonia	26	30	17	17
Finland	63	32	104	83
France	107	**125**	422	407
Germany	307	300	518	482
Greece	49	32	130	118
Hungary	25	**30**	52	52
Ireland	14	18	52	47
Italy	86	80	431	**441**
Latvia	3	3	19	18
Lithuania	12	7	27	23
Luxembourg	1	1	12	**13**
Malta	0	0	1	**3**
Netherlands	31	30	154	128
Poland	334	262	383	330
Portugal	28	20	79	62
Romania	58	**70**	116	103
Slovakia	22	21	42	38
Slovenia	7	7	18	18
Spain	164	**174**	400	**462**
Sweden	31	25	73	65
UK	159	**181**	428	403
EU-27	1762	1652	3916	3728
Croatia	10	9	27	24
EU-28	1773	1661	3943	3752

To shed light on this question, the achievability of the emission ceilings of the A5 scenario under TSAP-2012 assumptions has been examined through a comparison with the MTFR emission levels of the TSAP-2012 scenario.

As shown in Table 6.16 for SO_2 and NO_x, and in Table 6.17 for PM2.5 and NH_3, some of the emission ceilings of the A5 scenario are lower than the MTFR emissions of the TSAP-2012 case. (For VOC, all emission ceilings are higher). Thus, these emission ceilings could not be achieved in a TSAP-2012 world.

Table 6.17: Comparison of the optimized emissions for the A5 scenario with the MTFR cases of the TSAP-2012 scenario (kilotons)

	PM2.5		NH_3	
	A5	MTFR TSAP-2012	A5	MTFR TSAP-2012
Austria	11	10	52	50
Belgium	16	15	62	**66**
Bulgaria	14	11	59	**60**
Cyprus	1	1	5	4
Czech Rep.	24	16	53	**60**
Denmark	11	10	47	44
Estonia	8	5	11	9
Finland	17	14	28	25
France	157	119	490	468
Germany	75	71	334	**339**
Greece	19	17	45	**47**
Hungary	12	11	53	**54**
Ireland	10	7	96	93
Italy	81	57	327	**340**
Latvia	8	5	13	14
Lithuania	7	4	40	33
Luxembourg	2	2	5	5
Malta	0	0	2	2
Netherlands	15	12	112	**113**
Poland	157	97	256	243
Portugal	19	18	58	50
Romania	44	29	119	105
Slovakia	12	8	17	**18**
Slovenia	3	3	15	**16**
Spain	64	61	264	233
Sweden	22	14	43	41
UK	45	41	236	**252**
EU-27	856	655	2841	2783
Croatia	5	4	23	19
EU-28	861	658	2864	2802

Although the TSAP-2013 Baseline reflects latest thinking on future economic performance as well as energy, transport, agriculture and climate policies, a rational approach might hedge against different developments and consider such uncertainties when developing potential emission ceilings. It remains a political judgment of risk management to what extent less likely developments should be considered in the setting of national emission ceilings.

As an illustration of a possible approach that could avoid potentially very expensive action for some Member States, Scenario A9 requires for each Member State all emission ceilings to remain at or above the MTFR levels of the TSAP-2012 projection. As a slight modification of the TSAP-2012 scenario, this sensitivity analysis considers the option for power plants to switch from heavy fuel oil to low sulphur diesel, similar to what is assumed for marine shipping (this option is not considered in the standard MTFR assumptions in GAINS).

Since the TSAP-2013 perspective reflects latest thinking, the cost-minimization is performed for the cost curves of the PRIMES-2013 Baseline.

While the resulting allocation achieves the environmental targets of the A5 scenario, these constraints on emissions let total emission control costs increase by 80%. All Member States face higher costs, even those that are not affected by constraints on their own emissions (Table 6.18 and Table 6.19). However, such a solution would provide certainty that the ceilings of the A5 scenario could be achieved even for rather different economic and political developments as outlined in the TSAP-2012 scenario.

Table 6.18: Comparison of optimized emissions for the A5 scenario with the A9 sensitivity case in which emission reductions are limited to the MTFR level of the TSAP-2012 scenario (kilotons, change relative to 2005)

	SO_2				NO_x				PM2.5			
	A5		A9		A5		A9		A5		A9	
Austria	12	*-54%*	12	*-54%*	70	*-69%*	67	*-71%*	11	-54%	11	-54%
Belgium	51	*-67%*	52	*-66%*	128	*-57%*	123	*-59%*	16	-46%	15	-47%
Bulgaria	85	*-89%*	84	*-89%*	58	*-62%*	58	*-62%*	14	-59%	14	-59%
Cyprus	2	*-95%*	2	*-95%*	5	*-76%*	7	*-69%*	1	-73%	1	-69%
Czech Rep.	77	*-61%*	77	*-61%*	114	*-61%*	109	*-63%*	24	-41%	23	-44%
Denmark	10	*-50%*	10	*-50%*	63	*-65%*	60	*-67%*	11	-60%	11	-60%
Estonia	26	*-67%*	26	*-67%*	17	*-60%*	17	*-59%*	8	-65%	8	-67%
Finland	63	*-7%*	63	*-7%*	104	*-46%*	102	*-48%*	17	-40%	17	-42%
France	107	*-77%*	107	*-77%*	422	*-69%*	418	*-70%*	157	-45%	156	-45%
Germany	307	*-43%*	307	*-43%*	518	*-63%*	481	*-66%*	75	-40%	75	-40%
Greece	49	*-90%*	37	*-92%*	130	*-67%*	118	*-70%*	19	-68%	20	-68%
Hungary	25	*-81%*	25	*-81%*	52	*-67%*	52	*-67%*	12	-58%	12	-59%
Ireland	14	*-80%*	16	*-78%*	52	*-64%*	51	*-64%*	10	-24%	10	-24%
Italy	86	*-78%*	86	*-78%*	431	*-65%*	441	*-64%*	81	-54%	81	-54%
Latvia	3	*-52%*	3	*-52%*	19	*-47%*	18	*-50%*	8	-55%	8	-55%
Lithuania	12	*-75%*	12	*-75%*	27	*-58%*	26	*-59%*	7	-53%	6	-56%
Luxembourg	1	*-48%*	1	*-49%*	12	*-74%*	12	*-74%*	2	-48%	2	-46%
Malta	0	*-97%*	0	*-98%*	1	*-87%*	1	*-86%*	0	-79%	0	-76%
Netherlands	31	*-53%*	31	*-53%*	154	*-59%*	144	*-61%*	15	-38%	15	-38%
Poland	334	*-74%*	334	*-74%*	383	*-52%*	350	*-57%*	157	-35%	155	-35%
Portugal	28	*-75%*	29	*-75%*	79	*-70%*	75	*-71%*	19	-69%	19	-69%
Romania	58	*-91%*	58	*-91%*	116	*-62%*	103	*-66%*	44	-61%	44	-61%
Slovakia	22	*-76%*	22	*-76%*	42	*-57%*	38	*-61%*	12	-61%	11	-65%
Slovenia	7	*-83%*	7	*-83%*	18	*-64%*	18	*-65%*	3	-68%	3	-71%
Spain	164	*-87%*	164	*-87%*	400	*-73%*	461	*-69%*	64	-59%	62	-60%
Sweden	31	*-15%*	31	*-15%*	73	*-66%*	73	*-66%*	22	-30%	23	-28%
UK	159	*-78%*	168	*-77%*	428	*-70%*	420	*-71%*	45	-47%	45	-48%
EU-27	1762	*-77%*	1761	*-77%*	3916	*-65%*	3843	*-66%*	856	-49%	848	-50%
Croatia	10	*-85%*	10	*-85%*	27	*-64%*	24	*-69%*	5	-64%	5	-64%
EU-28	1773	*-77%*	1772	*-78%*	3943	*-65%*	3867	*-66%*	861	-50%	854	-50%

Table 6.19: Comparison of optimized emissions for the A5 scenario with the A9 sensitivity case in which emission reductions are limited to the MTFR level of the TSAP-2012 scenario (emission given in kilotons, change of emissions relative to 2005, costs given in million €/yr and of GDP)

	NH_3				VOC				Emission control costs*)			
	A5		A9		A5		A9		A5		A9	
Austria	52	*-17%*	52	*-17%*	80	*-52%*	59	*-65%*	113	*0.03%*	352	*0.10%*
Belgium	62	*-17%*	66	*-11%*	80	*-50%*	78	*-52%*	171	*0.04%*	179	*0.04%*
Bulgaria	59	*-9%*	60	*-9%*	54	*-61%*	49	*-65%*	94	*0.24%*	123	*0.32%*
Cyprus	5	*-20%*	5	*-22%*	4	*-56%*	3	*-64%*	5	*0.02%*	6	*0.02%*
Czech Rep.	53	*-33%*	60	*-25%*	98	*-61%*	80	*-68%*	146	*0.09%*	319	*0.19%*
Denmark	47	*-38%*	47	*-38%*	50	*-62%*	45	*-65%*	41	*0.02%*	88	*0.03%*
Estonia	11	*-11%*	11	*-11%*	19	*-56%*	17	*-60%*	41	*0.24%*	48	*0.28%*
Finland	28	*-16%*	28	*-16%*	77	*-56%*	65	*-63%*	34	*0.02%*	78	*0.04%*
France	490	*-27%*	491	*-27%*	541	*-53%*	488	*-57%*	561	*0.02%*	1006	*0.04%*
Germany	334	*-44%*	369	*-38%*	640	*-48%*	580	*-53%*	968	*0.03%*	1490	*0.05%*
Greece	45	*-22%*	47	*-18%*	88	*-69%*	72	*-74%*	82	*0.03%*	256	*0.08%*
Hungary	53	*-32%*	54	*-31%*	62	*-56%*	55	*-61%*	89	*0.07%*	126	*0.10%*
Ireland	96	*-7%*	95	*-8%*	34	*-46%*	30	*-52%*	48	*0.02%*	71	*0.03%*
Italy	327	*-25%*	340	*-22%*	520	*-59%*	443	*-65%*	599	*0.03%*	1308	*0.07%*
Latvia	13	*2%*	14	*10%*	26	*-63%*	23	*-67%*	26	*0.14%*	53	*0.27%*
Lithuania	40	*-8%*	40	*-8%*	32	*-60%*	24	*-70%*	43	*0.13%*	115	*0.34%*
Luxembourg	5	*-23%*	5	*-14%*	5	*-60%*	5	*-61%*	3	*0.01%*	4	*0.01%*
Malta	2	*-8%*	2	*-10%*	2	*-47%*	2	*-61%*	0	*0.00%*	5	*0.07%*
Netherlands	112	*-22%*	112	*-22%*	121	*-41%*	113	*-45%*	101	*0.01%*	243	*0.04%*
Poland	256	*-26%*	257	*-25%*	277	*-55%*	241	*-61%*	741	*0.16%*	1272	*0.27%*
Portugal	58	*-20%*	58	*-20%*	117	*-48%*	109	*-52%*	89	*0.04%*	124	*0.06%*
Romania	119	*-27%*	111	*-31%*	170	*-63%*	122	*-73%*	205	*0.14%*	633	*0.42%*
Slovakia	17	*-42%*	18	*-36%*	45	*-41%*	34	*-55%*	85	*0.10%*	216	*0.26%*
Slovenia	15	*-21%*	16	*-16%*	16	*-61%*	12	*-70%*	45	*0.09%*	79	*0.16%*
Spain	264	*-28%*	264	*-28%*	474	*-49%*	417	*-55%*	284	*0.02%*	526	*0.04%*
Sweden	43	*-19%*	43	*-19%*	121	*-42%*	113	*-46%*	61	*0.01%*	106	*0.03%*
UK	236	*-24%*	251	*-19%*	522	*-52%*	493	*-55%*	650	*0.02%*	778	*0.03%*
EU-27	2841	*-27%*	2916	*-25%*	4274	*-54%*	3773	*-59%*	5323	*0.03%*	9600	*0.06%*
Croatia	23	*-23%*	22	*-24%*	36	*-54%*	32	*-60%*	39	*0.06%*	75	*0.12%*
EU-28	2864	*-27%*	2939	*-25%*	4310	*-54%*	3804	*-59%*	5362	*0.03%*	9676	*0.06%*

6.3 Further controls of marine emissions

The TSAP Baseline scenario assumes for marine sources the baseline emission projection of the accompanying VITO report (Campling et al. 2013), see Table 6.20 to Table 6.22.

This section examines whether further reductions of ship emissions could emerge as cost-effective means for achieving the A5 environmental targets, i.e., to what extent they could substitute more expensive measures at land-based sources. For this purpose, two sensitivity cases are calculated: Scenario A10 assumes sulphur and nitrogen emission control areas (SECAs and NECAs) in the 200 nm zones of all EU countries, following Scenario #2 of the VITO report. This would result in a 50% reduction of SO_2 emissions relative to the baseline, and a 24% cut in NO_x. As a variant, Scenario A11 excludes the SECA for the Mediterranean (Scenario #4 of the VITO report). Thereby, SO_2 emissions in the European Sea regions would only be 23% lower than in the baseline.

Table 6.20: SO_2 emission from marine activities in 2005 and 2025; baseline, a scenario with SECAs and NECAs (A10 corresponding to VITO Scenario #2), and the A11 scenario where SECAs and NECAs are applied with the exception of the Mediterranean (VITO Scenario #4), kilotons

		Baseline	*A10*	*A11*
	2005	*2025*	*VITO 2*	*VITO-4*
Baltic Sea	130	7	7	7
Bay of Biscay	282	72	16	16
Black Sea	27	7	6	6
Celtic Sea	14	2	1	1
Mediterranean Sea	764	183	104	183
North Sea	309	16	16	16
Rest of NE Atlantic (within EMEP grid)	31	8	8	8
Rest of NE Atlantic (outside EMEP grid)	112	28	14	14
Total	1668	321	171	249

Table 6.21: NO_x emissions from marine activities in 2005 and 2025; baseline, a scenario with SECAs and NECAs (A10 corresponding to VITO Scenario #2), and the A11 scenario where SECAs and NECAs are applied with the exception of the Mediterranean (VITO Scenario #4), kilotons

		Baseline	A10	A11
	2005	2025	VITO 2	VITO-4
Baltic Sea	220	193	131	131
Bay of Biscay	474	457	311	311
Black Sea	47	42	38	38
Celtic Sea	22	19	13	13
Mediterranean Sea	1294	1186	963	963
North Sea	518	476	323	323
Rest of NE Atlantic (within EMEP grid)	54	51	51	51
Rest of NE Atlantic (outside EMEP grid)	192	184	144	144
Total	2821	2606	1973	1973

Table 6.22: PM2.5 emissions from marine activities in 2005 and 2025; baseline, a scenario with SECAs and NECAs (A10 corresponding to VITO Scenario #2), and the A11 scenario where SECAs and NECAs are applied with the exception of the Mediterranean (VITO Scenario #4), kilotons

		Baseline	A10	A11
	2005	2025	VITO #2	VITO #4
Baltic Sea	14	9	9	9
Bay of Biscay	34	25	24	24
Black Sea	3	2	2	2
Celtic Sea	2	1	1	1
Mediterranean Sea	87	62	60	62
North Sea	37	24	24	24
Rest of NE Atlantic (within EMEP grid)	4	3	3	3
Rest of NE Atlantic (outside EMEP grid)	14	10	10	10
Total	194	137	133	135

In a solution that is cost-optimized for land-based sources, the additional measures for SECAs and NECAs reduce costs for these land-based sources in 2025 by 940 million €/yr in the A10 scenario, and in Scenario A11 without SECAs in the Mediterranean, by 780 million €/yr (Table 6.23). At the same time, the VITO report estimates costs for the NECA of 564 million €/yr in 2025. For SECAs in the 200 nm zones of all EU countries, cost estimates range between 1.3 billion €/yr for FGD use and 2.8 billion €/yr for use of low sulphur fuel. Without the Mediterranean SECA (Scenario A11), sulphur control costs for ships range between 0.9 and 1.6 billion €/yr.

Thereby, compared to the A5 scenario, total emission control costs (of land-based and marine sources) would increase by 6-35% in the A10 case, and by 2-15% in A11 without the SECA for the Mediterranean.

In conclusion, with the current assumptions on costs for low sulphur fuels, packages of SECAs and NECAs in the 200 nm zones of the EU Member States do not appear as cost-effective means for achieving the A5 targets. However, without the SECA for the Mediterranean and assuming sulphur scrubbers (FGD) for ships, total costs are only 2% higher than in the A5 scenario. This difference is likely to be within the uncertainty range of the costs estimates, so that more refined analyses with consolidated cost data seem warranted.

Table 6.23: Comparison of emissions (kilotons) and emission control costs (million €/yr) of the ship scenarios A10 and A11. Changes in emissions refer to 2005, changes in costs to the costs of current legislation for the TSAP-2013 Baseline.

	2005	CLE	A5	*A10*	*A11*
SO_2	7874	2521	1773	1789	1782
		-68%	*-77%*	*-77%*	*-77%*
NO_x	11358	4597	3943	4015	4013
		-60%	*-65%*	*-65%*	*-65%*
PM2.5	1706	1274	861	864	862
		-25%	*-50%*	*-49%*	*-49%*
NH_3	3942	3733	2864	2912	2902
		-5%	*-27%*	*-26%*	*-26%*
VOC	9312	5561	4310	4396	4392
		-40%	*-54%*	*-53%*	*-53%*
Costs for land-based		87673	+5362	+4424	+4581
Costs ships					
Low S fuel			0	+2771	+1627
Total costs			+5362	+7195	+6208
Costs ships					
FGD			0	+1283	+910
Total costs			+5362	+5707	+5491

6.4 Europe-wide measures for agricultural emissions

TSAP Report # 3 (Oenema et al. 2012) reviewed recent developments in the agricultural sector that are potentially relevant for the control of agricultural emissions of air pollutants, in particular ammonia and particulate matter. It highlighted the continuing penetration of well-proven emission abatement techniques in many European countries that, together with learning effects, economy of scale and other synergies, lead to declining costs.

The cost-effectiveness of further emission control measures in the agricultural sector is also highlighted by the optimized scenario A5, which includes additional cuts in agricultural ammonia and PM2.5 emissions as an important element in the cost-effective portfolio of measures. However, as shown in Section 6.1.2, the degree to which such measures are adopted in a cost-effective solution varies greatly across Member States.

While, in principle, the choice of additional measures in the agricultural sector could be left to individual Member States as a means for achieving their emission ceilings, it is of interest to what extent the cost-effectiveness of a country-specific approach would be compromised if such measures were introduced through European legislation.

For this purpose, a series of sensitivity analyses explores how emission control costs of the A5 scenario would increase if certain packages of agricultural measures were introduced in all countries through EU legislation, irrespective of their cost-effectiveness.

The sensitivity analysis distinguishes three alternative packages of measures, with reference to the Draft Annex IX on measures for the control of emissions of ammonia from agricultural sources' prepared for the negotiations of the Gothenburg protocol (ECE/EB.AIR/WG.5/2011/3)[4]:

These packages of measures consist of low nitrogen feed, housing adaptation, covered storage of manure, low-emission application of manure, and low emission application of urea. They differ by the assumed implementation rates of these measures:

Scenario A12: Level A of Annex IX (most stringent):

- Low nitrogen feed applied at all farms with more than 15 livestock units (LSU)
- Housing adaptation for 10% of pigs, 9% of poultry (layers) and 3% of broilers
- Covered storage of manure, also for existing storages
- Low-emission application of manure at large and medium size farms, with stricter measures for large farms.
- Low emission application of urea to the maximum extent (90% in most countries)

Scenario A13: Level B of Annex IX (mid ambition)

- Low nitrogen feed applied at farms with more than 50 LSU cattle, 500 LSU poultry or 100 LSU pigs
- Housing adaptation for 6% of pigs, 7% of poultry (layers) and 3% of broilers
- Low-emission application of manure at large and medium farms
- Low emission application of urea at 60% of the total potential

Scenario A14: Level C of Annex IX (least ambitious)

- Low nitrogen feed applied at farms with more than 50 LSU cattle, 500 LSU poultry or 500 LSU pigs
- Housing adaptation for 4% of pigs, 4% of poultry (layers) and 3% of broilers
- Low-emission application of manure only at large farms
- Low emission application of urea at 40% of the total potential

The rules and measures specified in Annex IX are not fully compatible with the current definition of measures in the GAINS model. A methodology has been developed to translate the Annex IX measures into measures that can be analysed with the GAINS model. A documentation of the methodology and the assumptions behind the interpretation and translation of the three levels defined in Annex IX is provided in Wagner et al. 2011.

In the subsequent three cases of cost-optimizations, implementation of these measures is fixed in each country as described above, considering country-specific factors such as farm sizes, etc. The optimization can then balance remaining measures in such a way that the A5 targets are met in the cheapest possible way.

As a result, the optimization for these sensitivity cases re-arranges only marginally the emission ceilings for NH_3 optimized for the A5 targets without these constraints on NH_3. For individual countries, the adjusted emission ceilings for NH_3

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[4] available at: http://www.unece.org/fileadmin/DAM/env/documents/2011/eb/wg5/WGSR48/ECE.EB.AIR.WG.5.2011.3.E.pdf

differ by less than 1% from the ceilings of the A5 scenario (Table 6.24). Implications for other pollutants are even smaller. At the same time, emission control costs increase slightly (by less than 1%) compared to A5 as a consequence of the additional constraints.

Table 6.24: NH_3 emission and air pollution emission control costs for the three sensitivity cases with the Annex IX measures (Scenarios A12-A14) compared to A5 (EU-28, 2025)

	A5	A12 A	A13 B	A14 C
NH_3 emissions EU-28 (kt)	2864	2855	2859	2861
Costs (million €/yr)	5362	5428	5415	5413
Extra costs (rel. to A5)		+67	+53	+51
Extra costs (% of A5)		*1.2%*	*1.0%*	*1.0%*

This means that in a strict sense a Europe-wide application of none of these packages would be cost-effective for achieving the environmental targets of A5. However, the deviation from the cost-effective solution is marginal (<1% of the costs of A5), so that other arguments could make a community-wide implementation of these measures still an interesting option.

It should be mentioned that the small deviation from the cost-effectiveness is certainly related to the overall environmental ambition level of the A5 scenario, which aims at a 75% gap closure of PM-related health impacts and a 55% gap closure for eutrophication. For such targets, these packages constitute only a sub-set of the necessary (and cost-effective) measures in most countries. Community-wide implementation of these packages could well turn out as a rather cost-ineffective strategy for lower environmental ambitions.

7 Sensitivity analyses

7.1 Impacts of different assumptions on Euro-6 real-world emissions

As shown earlier, future NO_x emissions in the EU-28 and compliance with NO_2 limit values are critically influenced by the performance of the Euro emission standards under real-world driving conditions, especially for light duty diesel vehicles. Sensitivity cases explore how much total NO_x emissions would be affected by different real-driving emissions from light duty diesel vehicles.

The TSAP-2013 Baseline assumes a stepwise decrease of real-driving emissions from the introduction of the Euro-6 emission standards. For the 'second generation' Euro-6b (from 2017 onwards), light duty diesel vehicles are assumed to emit only 120 mg NO_x/km at average real-world driving, compared to the limit value over the type approval cycle of 80 mg/km. Given that Euro-5 vehicles are measured at 700 to 800 mg NO_x/km under real-world driving (Hausberger 2010; Weiss et al. 2011), the assumed reduction requires a step change in technology and notably the test procedure. First measurements on premium-class vehicles have demonstrated the technical feasibility of such low values with SCR technology under real-world driving conditions, although not all vehicles seem to apply a strict control strategy (Demuynck et al.; Hausberger 2012; Weiss et al. 2012).

To span a range of possible developments, the following sensitivity cases are considered.

7.1.1 Assumptions for sensitivity cases

The TSAP-2013 Baseline ("Stepwise lower")

The Baseline scenario employs the latest projections from the PRIMES-2012 Reference scenario. For NO_x, a stepwise reduction of real-driving emissions is assumed, such that a first generation of Euro-6 vehicles (Euro-6a) delivers from 2014 (2015) onwards a reduction over Euro-5 proportional to the reduction in emission limit values, i.e., to about 310 mg/km. The second generation vehicles (Euro-6b) are assumed to emit under real-world driving on average 1.5 times the test cycle limit value from 2017 (2018) onwards, i.e., 120 mg/km. This reduction may result from the introduction of real-drive emission controls, e.g., by on-board PEMS or random cycle testing.

The TSAP-2012 Baseline ("Stepwise lower")

To explore the implications of alternative projections of future transport activity, the same assumptions on the effectiveness of Euro-6, the TSAP-2012 Baseline scenario is analysed. As mentioned above, the TSAP-2012 Baseline relies on the PRIMES-2010 energy projections, which has been developed in 2009 at the beginning of the economic and financial crisis, and does not incorporate recently adopted energy efficiency and renewable energy targets. Compared to the PRIMES-2012 Reference, the PRIMES-2010 projection suggests in general higher transport activities, more than two times higher gasoline consumption in 2030, and 10% lower diesel consumption by cars.

Euro-6 failure

For this sensitivity case, it is assumed that real-world emissions from the first generation Euro-6 diesel light duty vehicles (Euro-6a) remain at the level of Euro-5 vehicles. As the type approval test procedure has not yet changed, there are arguably no provisions to make real-world emissions decrease. With the prospective change in the test procedure it is assumed that real-driving NO_x emissions from second-generation (Euro-6b) would decrease at the same rate as the limit value, i.e., to about 310 mg/km from 2017 (2018) onwards. This scenario could be considered an upper estimate for a case of continued legislation failure.

25% SULEV (Super-Ultra-Low Emission Vehicles)

All diesel car models registered in the US in 2011 and 2012 emit less than 30 mg NO_x/km over the US FTP certification cycle[5].

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[5] US EPA OTAQ: Annual Certification Test Results & Data (http://www.epa.gov/otaq/crttst.htm)

For this sensitivity case, it is assumed that the same technology would be available in Europe from 2017 onwards, and that on average 25% of the newly sold diesel light duty vehicles will be SULEV instead of Euro 6b.

100% SULEV

This scenario assumes that all (100%) new light duty diesel vehicles sold from 2017 onwards would be SULEV (30 mg NO_x/km), at least when driving in urban areas.

Technically this could be achieved with (plug-in) hybrid vehicles that drive mostly electric in urban areas and with conventional engines extra-urban. This scenario is designed to explore consequences on *urban* NO_x emissions and the resulting compliance with NO_2 limit values, assuming some kind of incentive for low-emitting vehicles that would mainly affect the fleet mix *in urban areas*.

7.1.2 NO_x emissions

NO_x emissions from all road vehicles in the EU-28 are projected to decrease further from about 5000 kt in the year 2005.

Under baseline assumptions according to the TSAP-2013 scenario, NO_x emissions decline to less than 1900 kt in 2020 and 870 kt in the year 2030 (Figure 7.1 – upper panel). This means a reduction by more than 60% and 80% respectively. Total NO_x emissions from all sources decrease by 50% in 2020 and by 64% in 2030 from a total of 11'400 kt in the year 2005. Thus, road transport would contribute the biggest reduction.

This reduction is emerges from lower unit emissions of gasoline cars and heavy duty vehicles; however, emissions from light duty diesel vehicles are expected to increase, at least until the year 2015. Light duty diesel vehicles contributed more than one quarter to NO_x emissions from all road vehicles in the EU-28 in 2005. Until 2015, their share in emissions is projected to grow to more than 50%, when they will emit 1550 kt. By then, Euro-6 vehicles will enter the market, and under baseline assumptions emissions from light duty diesel vehicles will gradually decrease to 1100 kt and 550 kt in 2020 and 2030, respectively (Figure 7.1 – lower panel).

The emission trend in the TSAP-2012 Baseline is rather similar. However, it is by coincidence that lower emissions from diesel vehicles (~600 PJ lower consumption by LDDV and ~200 PJ lower consumption by HDV in the year 2030) are compensated by almost three times higher emissions from gasoline cars (~2300 PJ higher consumption in the year 2030). Because of lower consumption and a proportionally lower number of high emitting Euro-5 vehicles, NO_x emissions from light duty diesel vehicles are significantly lower in 2010 and 2015; in 2030, they are 10% lower than in the TSAP-2013 Baseline.

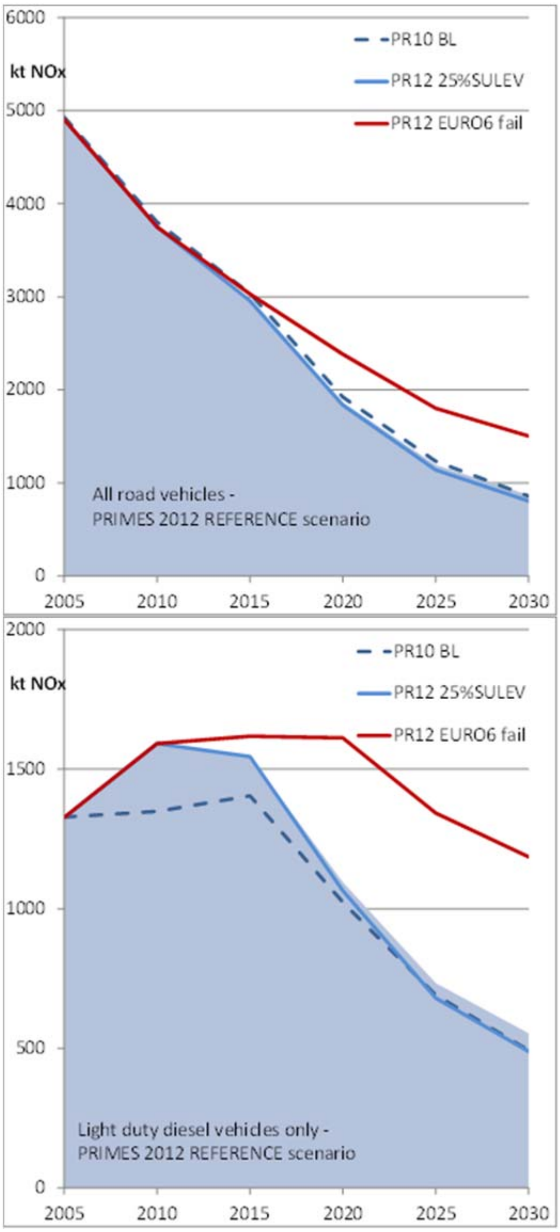

Figure 7.1: Development of NO_x emissions from all road vehicles in the EU-28 (upper panel) in the baseline scenario (shaded area) and under the different assumptions for real-driving emissions from light duty diesel vehicles. Lower panel: Close-up on NO_x emissions from light duty diesel vehicles under the different scenarios.

If real-world emissions from Euro-6 light duty diesel vehicles would not deliver the expected reductions (‘Euro-6 failure’ case), NO_x emissions from road transport would be more than 500 kt 30% higher in 2020 and 600 kt (70%) higher in 2030, compared to the TSAP-2013 Baseline.

The 25% SULEV case would reduce NO_x emissions from road transport by 2% in 2020 and 8% in 2030, compared to the TSAP-2013 Baseline. The 100% SULEV in urban areas case would result in roughly twice as much reduction.

These results clearly indicate that the future level of NO_x emissions and consequently resulting NO_2 ambient concentrations depend strongly on the effectiveness of Euro-6 emission controls under real-world driving conditions. Emissions from light duty diesel vehicles will only decrease by about the same rate as, e.g., those from trucks if the Euro-6 norm proves effective in real driving.

7.1.3 Compliance with NO_2 limit values

Taking into account the impacts of these emission scenarios on background NO_x, O_3 and NO_2 levels and on direct emissions of NO and NO_2 within the near-by street canyons, compliance with the annual NO_2 limit value will greatly improve in the TSAP-2013 Baseline case. It is estimated that the number of air quality management zones in the EU-28 where compliance with the current limit values is unlikely will decline from 103 (20%) in 2010 to 13 (2.5%) in 2025 (Figure 7.2, Table 7.1).

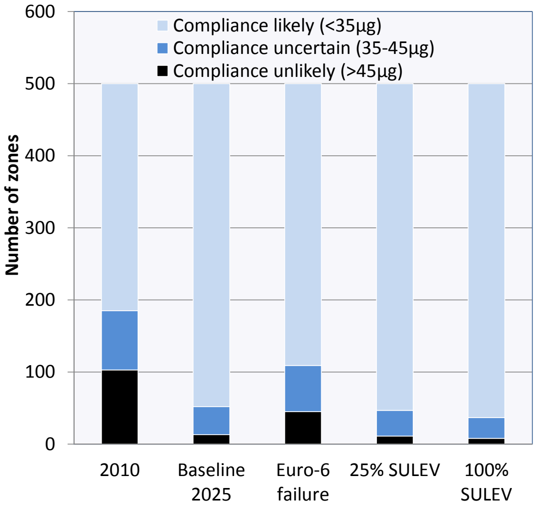

Figure 7.2: Compliance with NO_2 limit values in 2025 for the different sensitivity cases (number of zones)

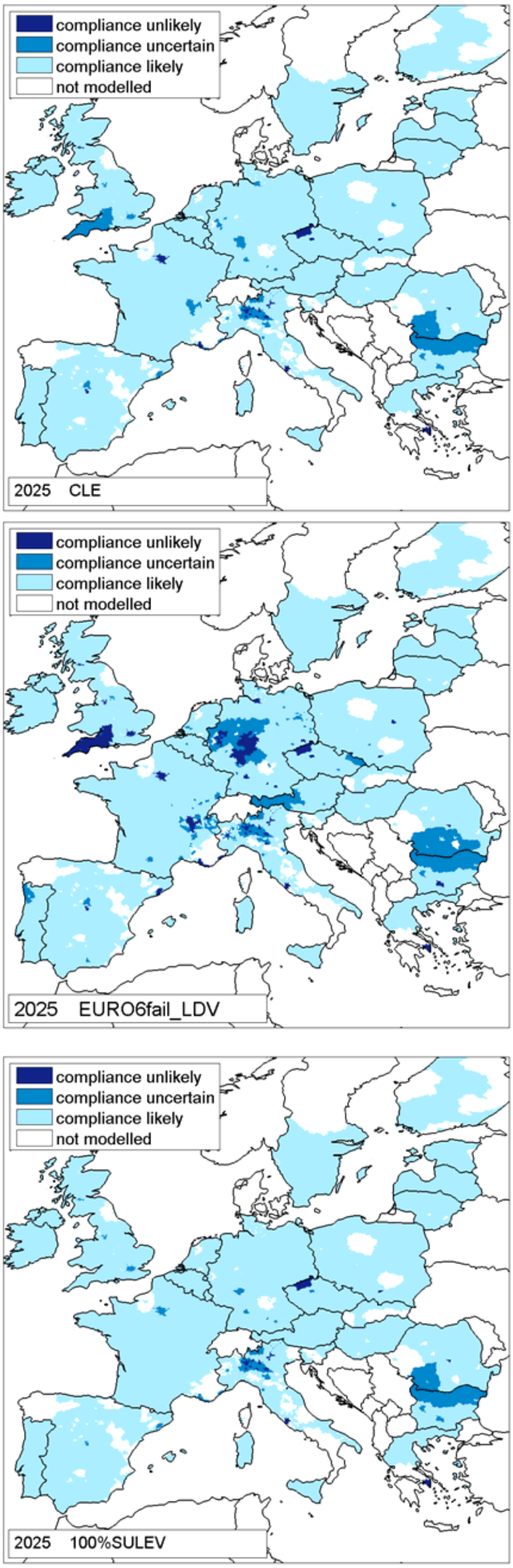

Figure 7.3: Compliance with the NO_2 limit value in the air quality management zones in 2025. Top: TSAP-2013 Baseline, mid: Euro-6 failure case, bottom: 100% SULEV case

If real-world emissions from Euro-6 would not evolve as assumed in the TSAP-2013 Baseline and follow the 'Euro-6 failure' scenarios, the higher NO_x emissions from light duty diesel vehicles would leave 45 zones, i.e., about 9%, in strong non-compliance. 18% of European population for which the assessment was carried out will therefore live in air quality management zones that do not achieve the NO_2 limit values (compared to 6% in the baseline case, Table 7.2).

In the most optimistic case, i.e., in the 100% SULEV scenario where all new light duty diesel vehicles would comply especially in the urban areas with the Californian SULEV standards, only eight air quality management zones with 3% of European population would face serious non-compliance issues.

A partial penetration of SULEV (e.g., as assumed in the 25% SULEV case) will lead to certain improvements compared to the baseline; however benefits are comparably small as within street canyons emissions from non-SULEV vehicles remain still significant.

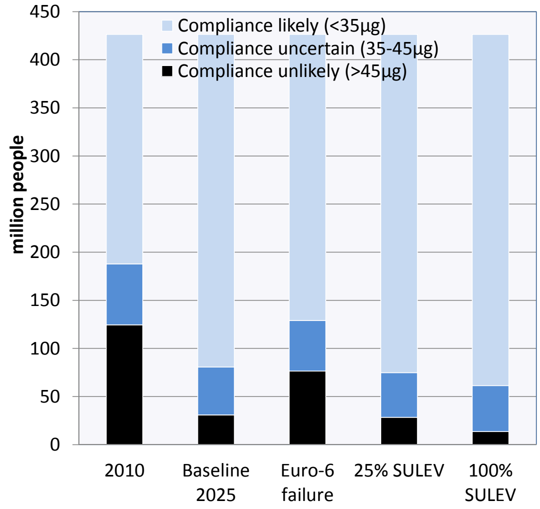

Figure 7.4: Population living in zones with different compliance

Table 7.1: Compliance with NO_2 limit values in 2025 (number and % of zones)

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	103	82	315	*21%*	*16%*	*63%*
Baseline 2025	13	39	448	*3%*	*8%*	*90%*
Euro-6 failure	45	64	391	*9%*	*13%*	*78%*
25% SULEV	11	36	453	*2%*	*7%*	*91%*
100% SULEV	8	29	463	*2%*	*6%*	*93%*

Table 7.2: Population living in air quality management zone with different compliance with NO_2 limit values (million people, % of European population)

	Compliance					
	unlikely	un-certain	likely	unlikely	un-certain	likely
2010	124.6	63.3	238.6	*29%*	*15%*	*56%*
Baseline 2025	30.8	49.7	345.9	*7%*	*12%*	*81%*
Euro-6 failure	76.3	52.7	297.4	*18%*	*12%*	*70%*
25% SULEV	28.3	46.3	351.7	*7%*	*11%*	*82%*
100% SULEV	13.6	47.6	365.2	*3%*	*11%*	*86%*

In summary, it can be stated that the emission performance of Euro-6 light diesel vehicles under real-world driving conditions will have dominant impact on the future compliance with air quality limit values for NO_2. A failure scenario would leave between 45 and 110 of the 500 air quality zones at risk of non-compliance in 2025, with 30% of European population living in these zones. In contrast, when it is ensured that Euro-6 diesel vehicles have as low emissions as intended by the legislation also in real-driving (as assumed in the baseline), only a good dozen zones would remain in serious non-compliance. With additional SULEV vehicles, especially in urban areas for instance, the limit values could be achieved in 98% of all zones, possibly with additional local measures. Obviously, additional measures of the A5 scenario could further alleviate the situation.

8 Conclusions

This report explores how the European Union could progress towards the objectives of the Sixth Environment Action Programme, i.e., to achieve 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment'.

There is significant scope for cost-effective air quality improvements

For the most recent perspectives on future economic growth and energy, transport, agricultural and climate policies (the draft TSAP-2013 Baseline), the report confirms earlier findings that there is still large scope for further measures that could alleviate the remaining damage and move closer to the objectives of the Sixth Environment Action Program. This scope prevails despite the significant air quality improvements that emerge from current EU air quality legislation. Full application of readily available technical emission reduction measures in the EU could reduce health impacts from PM by another 30% and thereby gain more than 70 million life-years in the EU. It could save another 2,500 premature deaths per year because of lower ozone concentrations. Further controls of agricultural emissions could protect biodiversity at another 200,000 km^2 of ecosystems against excess nitrogen deposition, including 95,000 km^2 of Natura2000 areas and other protected zones. It could eliminate almost all likely exceedances of PM10 air quality limit values in the old Member States, while in the urban areas of new Member States additional action to substitute solid fuels in the household sector with cleaner forms of energy would be required. Such Europe-wide emission controls would also eliminate in 2030 all likely cases of non-compliance with EU air quality standards for NO_2 with the exception of a few stations for which additional local measures (e.g., traffic restrictions, low emission zones) would be necessary.

Further emission reductions could require up to 45 billion €/yr

However, these further environmental improvements require additional efforts to reduce emissions, which are associated with additional costs. It is estimated that the full implementation of all currently available technical measures (that achieve the above-mentioned benefits) would involve in2025 additional emission control costs of up to 45 billion €/yr (0.3% of GDP), compared to 88 billion €/yr (0.6%) that are spent under current legislation.

Marginal health benefits justify implementation of 75% of the possible further measures

This report examines the interim targets that could serve for 2025 as milestones towards the long-term objective of the Sixth Environment Action Programme. As a rational approach, it compares marginal costs of further emission reductions against their marginal benefits. To take a conservative perspective, the report limits to monetized benefits of adult mortality from exposure to PM2.5, using the low valuation of the value of a lost life year (VOLY) that has been used for the Clean Air For Europe (CAFE) programme before. Thereby, the comparison ignores benefits of reduced infant mortality, lower premature mortality from less exposure to ground-level ozone, morbidity and all benefits to agricultural crops and natural vegetation.

With such a perspective, marginal health benefits are found to equal marginal costs of further measures slightly above a 75% 'gap closure' between the current legislation baseline and the maximum feasible reductions. At this level, emission reduction costs (on top of current legislation) amount to 4.5 billion €/yr, while benefits from these measures are estimated at 30.4 billion €/yr.

There are additional measures that could also harvest low-hanging fruits for agricultural crops and natural vegetation

While this logic provides a rationale argument for a health-related interim target, it does not account for the other benefits that are more difficult to monetize. Thereby, such a strategy leaves out 'low hanging fruits' for ozone, eutrophication and acidification that could be achieved at little extra cost. As a pragmatic approach, the report assesses the improvements to these impacts that could be achieved for 5%, 20% and 50% higher costs compared to the health-only strategy. It was found that, e.g., for 20% higher costs, 65% of the possible improvements for acidification could be realized, 60% of the potential for ground-level ozone, and 55% for eutrophication.

At costs of 0.04% of GDP, these measures would cut SO_2 by 77%, NO_x by 65%, PM2.5 by 50%, NH_3 by 27% and VOC by 54% relative to 2005

The cost-effective portfolio of measures of the 'central' A5 scenario involves costs of 5.8 billion €/yr for the EU-28. These additional costs constitute about 0.04% of GDP, although this percentage varies greatly across Member States.

This scenario would then cut SO2 emissions in 2025 by 77% relative to 2005 instead of 69% in the current legislation baseline. NOx would be 65% lower instead of 60%, and PM2.5 emission cuts would double (-50% instead of -25%). NH3 would be reduced by 27% compared to 5% in the baseline, and VOC by 54% instead of 40%. In addition, BC emissions would be decline by 33%, particle number emissions by 73% and Hg emissions by 33%.

Optimized emission ceilings do not imply substantial regret investments of emission control equipment

It is important that the measures that are necessary for meeting these emission ceilings in 2025 will not require investments into long-lived pollution control that would emerge as superfluous in subsequent years, especially if – according to the baseline projection - activity rates would decline in the course of the envisaged restructuring process of the European economy. For this purpose, an analysis was carried out for the A5 scenario to determine to what extent additional measures that are implied by the least-cost emission ceilings for 2025 would emerge as regret investments thereafter because of a decline in activity that is projected in the TSAP-2012 Baseline for the year 2030.

While such potential regret measures were found in the A5 portfolio, their share in the total additional emission reductions is below 1.2% for SO_2, 0.5% for NO_x and 2.5% for PM2.5. Costs of such measures constitute 0.6% of the full A5 portfolio. Importantly, 50% of these regret measures and costs emerge in one country, for which the draft PRIMES-2012 energy scenario suggests a complete phase-out of coal from power generation between 2025 and 2030. Thus, the emission ceilings of the A5 scenario do not lead to significant regret investments, considering the uncertainties around the baseline projection. Appropriate flexibility mechanisms could avoid regret investments for specific situations with drastic restructuring measures of the energy system.

At some extra costs, emission ceilings could hedge against alternative baseline development

As demonstrated by the differences between the most recent draft-TSAP-2013 scenario, on which this analysis is based, and the earlier TSAP-2012 projection, there are fundamental uncertainties about the future economic development and energy, transport, agricultural and climate policies. These uncertainties affect future levels of baseline emissions as well as the potential and costs for further measures.

A sensitivity case demonstrates the feasibility of the environmental targets for A5 under the assumptions of the TSAP-2012 Baseline, which was more optimistic about the future economic development than the most recent draft TSAP-2013 case. As the earlier projection assumed higher levels of energy consumption, costs for achieving these targets would be higher.

Although the A5 ambition level could also be achieved in a 'TSAP-2012' world, it was found that not all of the corresponding emission ceilings that have been cost-optimized for the TSAP-2013 scenario would be achievable under the TSAP-2012 assumption. It has been demonstrated that alternative sets of emission ceilings could be derived that could avoid excessive costs to individual Member States if reality developed differently from what has been assumed in the cost-effectiveness analysis. However, such 'insurance' against alternative developments come at a certain costs.

Further analyses should explore the cost-effectiveness of additional emission reductions from marine shipping

The central analysis in this report assumes an evolution of emissions from marine shipping along the projections presented in the accompanying VITO report, taking into account the recent agreements on SO_2 and NO_x reductions that have been reached in MARPOL.

A sensitivity analysis explores to what extent an introduction of sulphur and NO_x control areas (SECAs and NECAs) in the 200 nm zones of the EU countries could alleviate the demand for land-based measures in a cost-effective way. It was found that, with the current assumptions on costs for low sulphur fuels, the additional costs of packages of SECAs and NECAs in the 200 nm zones of the EU Member States (with the exception of a SECA in the Mediterranean Sea) could be almost compensated by cost-savings at land-based sources. More refined analyses with consolidated cost data seem warranted.

Cost-effective further controls of agricultural emissions could include Europe-wide measures

For achieving the environmental targets of the A5 scenario, a Europe-wide application of agricultural emission control measures such as those outlined in the Draft Annex IX of the revised Gothenburg Protocol could be part of a cost-effective solution.

The performance of Euro-6 will have critical influence on future NO_x emissions and the compliance with NO_2 air quality limit values

It has been shown that the future performance of Euro-6 standards for diesel light duty vehicles under real-world driving conditions will have significant impact on the evolution of NO_x emissions in the EU and the compliance with air quality limit values. In a sensitivity case where only modest reductions of real-life emissions are assumed, the anticipated air quality benefits, e.g., on the compliance with NO_2 air quality limit values, would be only half of what has been assumed for the baseline. In contrast, introduction of super ultra-low emission vehicles that comply with current US regulations, especially in urban areas (e.g., plug-in hybrids) could substantially accelerate the anticipated baseline improvement, and eliminate almost all remaining non-compliance cases in 2025.

In summary, to support the revision of the Thematic Strategy on Air Pollution, this report provides a synthesis of the critical factors that determine future air quality in Europe, based on latest expectations on policy developments and best available scientific understanding and most recent input data. It highlights the scope for further cost-effective improvements of air quality in Europe, for which the benefits exceed costs by a high margin. It seems possible to establish meaningful and considerate interim targets for 2025 on the way towards the full achievements of the objectives established by the Sixth Environment Action Programme. Such interim targets could be robustly established, hedging against unavoidable uncertainties of future economic and political development in a rational way. Further analysis will be required to determine the interplay between local, national and community-wide measures, and to arrive at a balanced set of targets that reach fair and equitable distributions of costs and benefits between Member States.

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Annex

Table A-8.1: Costs of regret measures in the A5 scenario (million €/yr), and share of these costs in the total costs of the A5 scenario

	Total costs	Regret costs	% of total costs
Austria	112.6	1.7	1.5%
Belgium	170.9	0.7	0.4%
Bulgaria	93.6	0.1	0.1%
Cyprus	4.6	0.0	0.3%
Czech Rep.	146.1	0.2	0.1%
Denmark	41.0	0.9	2.3%
Estonia	41.0	0.2	0.4%
Finland	34.4	0.0	0.0%
France	560.5	2.9	0.5%
Germany	968.2	1.5	0.2%
Greece	82.4	1.1	1.4%
Hungary	88.6	0.2	0.3%
Ireland	47.9	0.2	0.4%
Italy	599.2	1.3	0.2%
Latvia	26.1	0.0	0.1%
Lithuania	42.7	0.0	0.0%
Luxembourg	3.1	0.0	0.5%
Malta	0.4	0.0	0.0%
Netherlands	100.5	0.0	0.0%
Poland	740.6	0.2	0.0%
Portugal	88.6	2.7	3.1%
Romania	204.9	0.1	0.1%
Slovakia	85.1	0.3	0.3%
Slovenia	44.7	0.3	0.8%
Spain	284.4	0.7	0.3%
Sweden	60.6	0.1	0.1%
UK	649.9	15.7	2.4%
EU-27	5322.5	31.4	0.6%
Croatia	39.3	0.2	0.6%
EU-28	5361.9	31.6	0.6%