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POLICY DEPARTMENT **A**
ECONOMIC AND SCIENTIFIC POLICY

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EU Air Quality Policy and WHO Guideline Values for Health

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Study for the ENVI Committee



DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

EU Air Quality Policy and WHO Guideline Values for Health

STUDY

Abstract

The policy package "A Clean Air Programme for Europe" includes a proposal for a revision of the Directive on National Emission Ceilings. The objective of the proposal is to further reduce the impact of air pollution on human health, taking into account the latest advice issued by the World Health Organisation. The accompanying impact assessment examined various emission reduction scenarios regarding their impacts and cost effectiveness. These underlying building blocks are qualitatively analysed in this study.

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LIST OF ABBREVIATIONS

4DD	4 th Daughter Directive
AAQD	Ambient Air Quality Directive
AGRI	Agriculture and Rural Development Committee
AQG	Air Quality Guidelines
CAPRI	Common Agricultural Policy Regionalised Impact
CH₄	Methane
CLE	Current Legislation scenario
CO	Carbon monoxide
GAINS	Greenhouse Gas - Air Pollution Interactions and Synergies
GDP	Gross Domestic Product
HDV	Heavy Duty Vehicle
HRAPIE	Health Risks of Air Pollution In Europe
IIASA	International Institute for Applied Systems Analysis
IT	Interim Target
LDV	Light Duty Vehicle
MCE	Maximum Control Effort
MTFR	Maximum Technically Feasible Reduction scenario
NEDC	New European Driving Cycle
NECD	National Emission Ceilings Directive
NH₃	Ammonia
NMVOC	Non-methane volatile organic compounds
NO₂	Nitrogen dioxide

- NO_x** Nitrogen oxides
- PC** Passenger Car
- PEMS** Portable Emission Measurement Systems
- PRIMES** A computable Price-driven equilibrium Model of the Energy System and markets for Europe
- PM** Particulate matter
- RDE** Real Driving Emission
- SO₂** Sulphur dioxide
- TSAP** Thematic Strategy on Air Pollution
- REVIHAAP** Review of evidence on health Aspects of Air Pollution
- WHO** World Health Organisation
- WLTP** World Light vehicles Test Protocol
- YOLL** Years Of Life Lost

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EXECUTIVE SUMMARY

Aim

This study aims at providing an analysis of the World Health Organisation (WHO) air quality guideline values for health in the context of the revision of the National Emission Ceilings Directive. In addition, the challenges of reducing air pollutants are analysed in general and a more detailed analysis is provided in two case studies. The basic scenarios for the proposal of a National Emission Ceilings Directive are analysed in a qualitative way.

Background

Improving air quality has been a major objective of EU environmental policy for more than three decades. Significant progress has been achieved; emissions of some pollutants such as SO₂ have declined by more than 90 %, as a consequence of successful implementation of effective measures.

The European air quality policy includes several interlinked instruments such as source and product related emission rules and standards, Directives on ambient air quality (AAQD) and the National Emission Ceilings Directive (NECD). The effectiveness and the efficiency of these instruments were reviewed in detail in the light of new scientific findings on the impact of air pollution. This included also an analysis of current policies to approach the ultimate goal of EU air quality policy: To achieve levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment. *Achieving levels that do not give rise to significant negative impacts* on health can be translated into attaining WHO air quality guideline levels.

WHO air quality guidelines

WHO develops guidelines for ambient levels of air pollutants which are evidence based and rely on the latest scientific knowledge. It is the aim of these guidelines to provide a basis for protecting public health from adverse effects of air pollutants and to eliminate or reduce exposure to those pollutants that are known or likely to be hazardous to human health or wellbeing. The guidelines are intended to provide background information and guide authorities in making risk assessment and risk management decisions. In establishing pollutant levels below which exposure – for life or for a given period of time – does not constitute a significant public health risk, the guidelines provide a basis for setting standards or limit values for air pollutants.

WHO reviewed its guidelines recently; the review confirmed that exposure to air pollutants is causally linked to significant impacts on human health. Recent studies, which were analysed in depth in the review process, have corroborated this result and identified impacts on human health even below some of the current WHO guidance levels. This conclusion was confirmed for PM_{2.5}, NO₂ and ozone.

Non-compliance with the limit values stipulated in the AAQD can have legal consequences such as the start of infringement proceedings or lawsuits by citizens against the relevant agencies or administrations. Thus the economic, technical, political and social aspects of attaining limit values are usually taken into account when setting the relevant regulatory standards. Therefore, e.g., the numerical value of the current European limit value for PM_{2.5} is 250 % higher than the corresponding WHO guideline value.

Despite success in reducing emissions of air pollutants and lowering ambient concentrations, large parts (for ozone and PM_{2.5} > 90 % of urban population) of the European population are currently exposed to concentrations of air pollutants far above the

existing WHO guideline values. This leads to about 400 000 premature deaths and an average loss of life expectancy of several months per citizen. The percentage of urban EU population exposed to air quality in excess of guideline and limit values is shown in the following table.

Table 1: Percentage of the urban population in the EU exposed to air pollutant concentrations above the EU and WHO reference levels

Pollutant	EU reference value ($\mu\text{g}/\text{m}^3$)	Exposure above reference levels estimate (%)	WHO AQG ($\mu\text{g}/\text{m}^3$)	Exposure above reference levels estimate (%)
PM _{2.5}	Year (20)*	20–31	Year (10)	91–96
PM ₁₀	Day (50)	22–33	Year (20)	85–88
NO ₂	Year (40)	5–13	Year (40)	5–13
O ₃	8-hour (120)	14–18	8-hour (100)	97–98

Even though significant negative impacts of air pollution on human health has been clearly demonstrated, exceedances of current EU limit values will sustain in coming years, exceedances of WHO guideline levels in particular for PM_{2.5} and ozone in coming decades.

Therefore, the Commission concluded that continued and additional efforts are needed to achieve the ultimate goal of European air quality policies: To reduce air pollution until no significant effects on human health and the environment are to be expected. One of the main objectives of the Commission's proposal for a new NEC Directive is therefore to narrow the gap between current air pollution and WHO guideline levels by reducing PM_{2.5} and its precursors (NH₃, NO_x, SO₂) as well as precursors of ozone (NMVOC, NO_x, CH₄) and NO₂.

Challenges in the reduction of air pollutants

Compliance with PM₁₀ and PM_{2.5} air quality limit values is hampered by the need to address a broad spectrum of sources (such as traffic, domestic heating, industry, construction work, agriculture etc.), by contributions from neighbouring countries and natural sources, and by deficiencies in air quality management in Member States and/or on regional/local administrative level. Future compliance with target values for ozone depends on emission reductions of precursors within Europe but also in North America and Asia.

The current NEC Directive addresses both PM and ozone (and also eutrophication, acidification) and regulates national emissions of NO_x, SO₂, NH₃ and NMVOC. However, even full compliance with the existing NEC Directive would not lead to compliance with existing air quality limit and target values, let alone WHO guidelines.

Compliance with national emission ceilings for NO_x and NH₃ by 2010 (as specified in the NECD) proved to be difficult for several Member States. The main reasons include: less effective than expected regulations for diesel vehicles, new sources of emissions, and inadequate or late implementation of emission reduction measures.

Case studies in Member States

The countries showing the largest relative discrepancy between NO_x ceilings and actual emissions are Luxembourg and Austria; the largest absolute discrepancy has been found in Germany. The chosen case studies for these countries are: an analysis of NO_x emissions in Germany and policies which have led to an increased use of diesel vehicles in Luxembourg. The main reasons for non-compliance in Germany are the differences between type approval and real world emissions from diesel vehicles, the fuel consumption by heavy duty vehicles which has been higher than projected, the inclusion of previously not estimated emissions from specific sources in agriculture, and an increase in the use of biomass combustion.

Luxembourg has comparatively low rates for diesel fuel excise duties and fuel prices. This has led to a much higher (than previously projected) consumption of diesel by cars, light and heavy duty vehicles. As the NO_x emissions from diesel vehicles are higher than those from gasoline vehicles, the NO_x ceiling has been exceeded. Reducing CO₂ emissions from passenger cars has been stated as a reason for fuel price policies. The effect on CO₂ is, however, not directly visible given the average passenger car emissions in Luxembourg.

Analysis of the basic scenarios

The Commission's proposal for the air policy package was developed on the basis of model calculations of the International Institute for Applied Systems Analysis (IIASA). The main model outputs are baseline emissions and impact scenarios as well as information on the effects of different emission reduction scenarios for 2020 and 2030 for sulphur dioxide (SO₂), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), PM_{2.5}, methane (CH₄) and ammonia (NH₃). The main purpose of the proposal is to accelerate the improvement of air quality. To achieve this goal, several different scenarios are analysed, starting from a Current Legislation scenario (CLE), which assumes that current regulations have been fully implemented in Member States. In this scenario, health impacts of PM_{2.5} would be reduced by 39 % in 2030 compared to 2005. In contrast, the Maximum Technically Feasible Reduction (MTFR) scenario assumes that all technically feasible emission reduction potentials are implemented. Even though the cost of implementing the measures indicated in this scenario would amount to an additional EUR 47 billion per year in 2025, it would not be sufficient to attain WHO guidelines values, in particular those for PM_{2.5} and ozone: Health impacts from PM_{2.5} would decline by 56 % compared to 2005, but still be substantial.

The analysis of the impact assessment spans the range between the CLE and the MTRF scenarios. Not only the impact of further reductions on human health and the environment has been analysed, but also the cost-effectiveness of such reductions has been investigated. The costs of additional measures increase in a non-linear form, rising rapidly near the MTRF effort.

The Commission proposal achieves about 70 % of positive effects on health in the MTRF scenario in 2030. The pollution control costs of EUR 3.3 billion per year in 2030 are over-compensated by the health benefits, which are estimated at EUR 40 billion per year and provide a strong argument for the proposed additional efforts to reduce air pollution. However, even full implementation of the new proposal (and of the more ambitious MTRF) in 2030 would still leave significant parts of Europe in non-compliance with WHO guideline values.

1. BACKGROUND

KEY FINDINGS

- European air quality policy includes several interlinked instruments to protect human health and the environment.
- At the end of 2013 a review was finalised that resulted in a proposal for new directives to further limit national emissions in the Member States.

On 18 December 2013 the European Commission adopted and published the clean air policy package "A Clean Air Programme for Europe"¹. The pollutants that are most relevant from a public health perspective in Europe today include PM_{2.5}, PM₁₀, O₃ and NO₂. These are the pollutants on which most of the emphasis was laid in the review process by the European Commission. The main element of the policy package is a proposal for a new National Emission Ceilings Directive (named "new NECD" in this study). The main driving force for further emission reductions is the protection of human health, which is to be achieved in particular by lowering the exposure to particulate matter (PM₁₀ and PM_{2.5}). The Ambient Air Quality Directive (AAQD) will currently not be changed as several Member States struggle to comply with existing standards. Therefore source related regulations will be strengthened and Member States will be supported in achieving compliance.

According to the 7th Environmental Action Programme² air quality levels should not exceed World Health Organisation (WHO) air quality guidelines in the long-term. The overall objective of this study therefore is to provide an in-depth analysis of the WHO air quality guideline values for health in the context of the revision of the National Emission Ceilings Directive. It also describes recent additional findings on the impact of air pollutants and analyses to what extent WHO guidelines will be achieved under different scenarios.

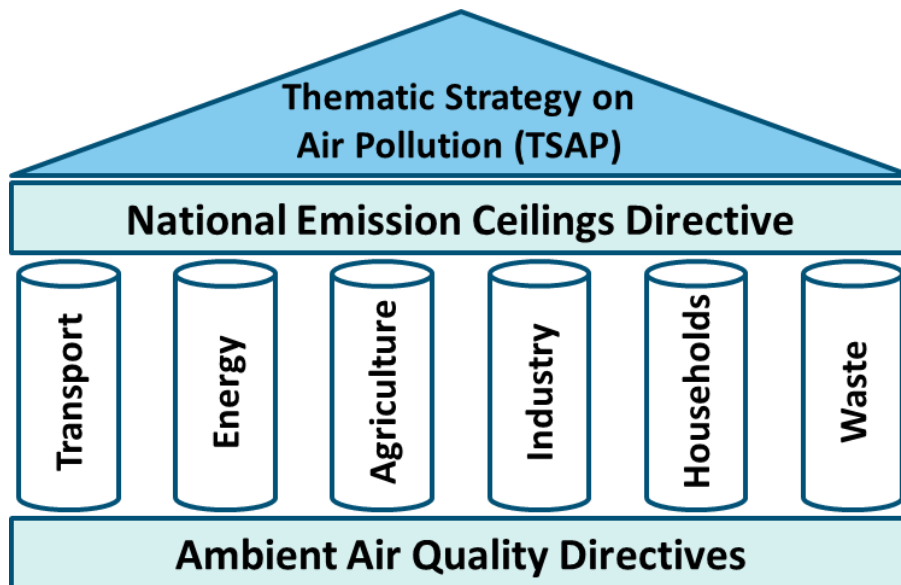
1.1. European air quality policy

European policies for air quality comprise the following (strongly interlinked) elements (Figure 1):

- Source related emission regulations (e.g. for transport, industrial installations, power plants);
- Product related regulations (e.g. for solvents, fuels, appliances);
- Ambient Air Quality Directives to protect human health on the one hand and the environment on the other;
- National emission ceilings to achieve environmental targets in a cost effective way.

¹ http://ec.europa.eu/environment/air/clean_air_policy.htm.

² 7th EAP: see: <http://ec.europa.eu/environment/newprg/index.htm>.

Figure 1: Schematic representation of European air quality policy

Source: Environment Agency Austria (Umweltbundesamt) after DG ENV

The Thematic Strategy on Air Pollution³ (“Clean Air For Europe”, CAFE) of 2005 and the policy package “A Clean Air Programme for Europe” of 2013 provide the overarching ambition level for the different directives and regulations. The strategy and the policy package are based on the 6th and 7th Environmental Action Programme⁴, respectively. These programmes aim “to achieve levels of air quality that do not result in unacceptable impacts on, and risks to, human health and the environment”.

1.2. Legal Background for the review

On 18 December 2013 the European Commission adopted and published the clean air policy package “A Clean Air Programme for Europe”. This package includes:

- A Proposal for a Directive of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants and amending Directive 2003/35/EC, COM(2013) 920 final (“new NECD”);
- A Proposal for a Directive of the European Parliament and of the Council on the limitation of emissions of certain pollutants into the air from medium combustion plants, COM(2013) 919 final;
- A Proposal for a Council Decision on the acceptance of the Amendment to the 1999 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone, (COM(2013) 917 final);
- An impact assessment (EC 2013a)⁵.

³ COM(2005) 446 final: Communication from the Commission to the Council and the European Parliament. Thematic Strategy on Air Pollution.

⁴ 6th EAP: COM(2001) 0031 final: see: http://europa.eu/legislation_summaries/environment/general_provisions/l28027_en.htm

7th EAP: see: <http://ec.europa.eu/environment/newprg/index.htm>.

⁵ SWD(2013)531, Commission staff working document. Impact assessment.

This package was the result of a comprehensive review process⁶ which had started in early 2011. The review was a requirement of the Ambient Air Quality Directive⁷ 2008/50/EC (AAQD) which, according to Article 32, requires the Commission to review the provisions for PM_{2.5} and other pollutants if appropriate. The 4th Daughter Directive⁸ 2004/107/EC (4DD) also required a review of the provisions for heavy metals and polycyclic aromatic hydrocarbons. According to the National Emission Ceilings Directive⁹ 2001/81/EC (named "NECD" in this paper), a review should provide the basis for a proposal for further emissions reductions.

⁶ http://ec.europa.eu/environment/air/review_air_policy.htm.

⁷ Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (OJ L 152/1).

⁸ Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (OJ L 23/3).

⁹ Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants (OJ L 309/22).

2. WHO AIR QUALITY GUIDELINES

KEY FINDINGS

- The World Health Organisation develops guidelines for ambient levels of air pollutants which are evidence based and rely on the most recent scientific knowledge. These guidelines are based only on health considerations, whereas for European air quality regulatory standards further aspects have to be taken into account.
- The studies on which the guidelines are based show that exposure to air pollutants (esp. PM_{2.5}, NO₂ and O₃) can be linked to significant impacts on human health.
- Recent studies have corroborated this result and identified impacts on human health even below the current guideline levels.
- Within Europe, large parts of the population are exposed to concentrations of air pollutants far above the guideline values, which leads to about 400 000 premature deaths and a loss of life expectancy of several months.
- Numerous sources contribute to the high levels of air pollution; even under an ambitious scenario (maximum technically feasible reduction), compliance with the guideline values for PM_{2.5} can thus not be expected in large parts of Europe until 2030. Provided substantial structural changes take place in all relevant source sectors, compliance could be largely achieved until 2050.

The World Health Organisation¹⁰ (WHO) published its first air quality guidelines for Europe in 1987, along with health risk assessments for 28 air pollutants (WHO 1987). In 2000, a 2nd edition was published, covering 35 pollutants (WHO 2000). A global update of the guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide was published in 2006 (WHO 2006). For the review of the European air quality policy the European Commission requested WHO to provide answers to a set of questions. The WHO complied with this request within the scope of the REVIHAAP¹¹ and the HRAPIE¹² projects (WHO 2013a, 2013b). For this analysis the focus is on the three most recent WHO publications (WHO 2006, 2013a, 2013b).

2.1. Process of developing WHO guidelines

2.1.1. Understanding of the guidelines

The WHO air quality guidelines (WHO AQGs) aim at providing a basis for protecting humans from adverse effects of air pollution (WHO 2000, 2006). They are usually specified by a concentration level and an averaging period. These values are not standards in themselves but are intended to provide background information and guidance to policy makers. Guidelines are based only on health considerations whereas for regulatory standards further aspects have to be taken into account (see also Section 2.4.1).

¹⁰ World Health Organization Regional Office for Europe: <http://www.euro.who.int/en/home>.

¹¹ Review of evidence on health Aspects of Air Pollution: <http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects>.

¹² Health Risks of Air Pollution In Europe, same web address as REVIHAAP.

Although WHO AQGs are based on health considerations, exposure even below the guideline values may constitute health risks that cannot be excluded. This is especially true for pollutants such as PM for which it has been found that there is no threshold level below which adverse effects can be excluded. Also, mixtures of pollutants might have additive effects; highly sensitive groups might also be affected when exposed to levels at or below the WHO AQG.

The guidelines do not differentiate between indoor and outdoor (ambient) pollution; however, the focus in this study will be on exposure to outdoor sources.

2.1.2. Developing and revising guidelines

The development of WHO AQGs is evidence based and relies on the most recent scientific knowledge from various disciplines, including epidemiology, toxicology, occupational and environmental medicine etc. More than 100 experts contributed to the preparation of the background documents or participated in the scientific discussions that led to the derivation of guideline values for a great number of air pollutants. The pollutants for which guidelines were to be established and revisions to be carried out were selected by working groups on the basis of various criteria, including whether significant health effects might occur and where considerable exposure could be expected. The working groups prepared in-depth reviews of the scientific background documents for each pollutant. Based on these documents, guidelines were discussed and drafted. The draft report was reviewed by a consultancy group.

In addition to the guideline values, a special working group provided guidance for policy makers for setting air quality regulatory standards based on these values.

To account for the attainability of the guideline values in different parts of the world, WHO provided interim targets for PM, O₃ and SO₂ in its global update 2005 (WHO 2006).

2.2. Rationale behind the guideline values recommended for the main pollutants

The pollutants that are most relevant from a public health perspective in Europe today include PM_{2.5}, PM₁₀, O₃ and NO₂. These are the pollutants on which most of the emphasis was laid in the review process by the European Commission.

The current regulatory standards of the Ambient Air Quality Directive (AAQD) are shown in Annex 1 (Section 2.4.1 compares guidelines to regulatory standards, see also Table 2).

2.2.1. Particulate matter <2.5 µm (PM_{2.5})

There is widespread evidence throughout the world on adverse health effects associated with exposure to ambient PM_{2.5} (WHO 2006). These health impacts include effects on the respiratory and cardiovascular system for large groups of the general population, leading to an increased risk of premature mortality and thus a reduced life expectancy. There is little evidence that suggests a threshold; health effects have been found to occur at fairly low levels, which were only a little above low background concentrations. Thus, it has not been possible to propose guidelines that provide complete protection. The epidemiological evidence shows that effects are possible after both short-term and long-term exposure. Therefore, both annual mean and 24-hour mean targets and guideline values have been proposed.

2.2.2. Particulate matter <10 µm (PM₁₀)

In general, WHO assumes similar effects for both PM₁₀ and PM_{2.5}. As the numerical guideline value is mainly based on PM_{2.5}, the targets for PM₁₀ were derived from an average PM₁₀:PM_{2.5} ratio. A ratio of 0.5 was chosen, which is at the lower end of the ratios observed in Europe¹³. This should be taken into account when setting the regulatory standards. Short-term (24-hour) and long-term (annual mean) guidelines were proposed for PM₁₀ as well (see tables in Annex 1).

2.2.3. Ozone

Based on newly accumulated evidence from epidemiological time series studies, WHO lowered the guideline value in the global update for the daily maximum 8-hour mean for ozone from 120 µg/m³ to 100 µg/m³. Effects on daily mortality were observed at ozone concentrations below the previous guideline but without clear evidence of a threshold. Therefore, health effects might occur in some sensitive individuals even below the guideline level.

2.2.4. Nitrogen dioxide

Adverse health effects (mainly respiratory symptoms) were observed even below the NO₂ annual mean guideline level of 40 µg/m³. However, as NO₂ is associated with other complex combustion-generated air pollutant mixtures, these effects could not be unambiguously attributed to NO₂ only. Therefore, there was not enough evidence to suggest lower guideline levels.

Also, there was no evidence that challenged the 1-hour mean guideline level. Therefore, no interim targets were proposed.

2.3. New scientific evidence on health risks

To support the review of the European air policy, the European Commission requested WHO to answer 25 questions on new scientific evidence on the adverse effects of air pollution on human health. WHO answered these questions within the scope of the REVIHAAP¹¹ and the HRAPIE¹² projects. The questions covered all pollutants of the AAQD and the 4th DD; and small PM fractions¹⁴, specific constituents¹⁵ and source types¹⁶ were also addressed. The focus in this study is on PM (different fractions, sources and constituents), O₃ and NO₂.

2.3.1. New evidence on PM_{2.5}

The studies analysed by WHO clearly strengthen the conclusions about the adverse health effects of PM_{2.5} presented in the global update of the guidelines (WHO 2006, 2013a). These conclusions are as follows:

- long-term exposure to PM_{2.5} is a cause of both cardiovascular mortality and morbidity (there is a clear causal relationship);
- there is additional support for the effects of short-term exposure on mortality and morbidity;
- there are additional studies that link long-term exposure to atherosclerosis, adverse birth outcomes and childhood respiratory disease;

¹³ In general, the ratio is about 0.65 (based on 2012 data from AirBase).

¹⁴ Ultrafine particles.

¹⁵ Black carbon, metals, organics, inorganics, crustal material and PM of natural origin, primary or secondary.

¹⁶ Road traffic including non-tailpipe emissions, industry, waste processing.

- there is emerging evidence for possible links between long-term exposure and neurodevelopment and cognitive function as well as diabetes;
- associations between long-term PM exposure and mortality have been observed at levels well below the current WHO guideline.

WHO therefore concluded that the WHO guideline levels should be updated. The scientific evidence also supports the need for regulating short-term (24-hour average) exposure (currently not regulated under EU legislation).

2.3.2. New evidence on small PM fractions, specific constituents and source types

There is new evidence that short-term exposure to coarse particles (PM_{10-2.5}) is associated with respiratory and cardiovascular health effects in addition to the health effects of PM_{2.5}.

There is increasing evidence that short-term exposure to ultrafine particles (< 0.1 µm) has an impact on cardiorespiratory health and the central nervous system.

WHO has found clear new evidence linking exposure to black carbon and cardiovascular health effects and premature mortality. Both short-term (24 hours) and long-term (annual) exposures are of importance here. It is therefore suggested that black carbon is used as an additional indicator for evaluating the health risks of combustion related particles, in particular from traffic.

With respect to source types, most evidence on adverse health effects has been found for carbonaceous particles from traffic. There is some evidence that abrasion particles from traffic also contribute to the health effects. Coal and shipping oil combustion are also relevant sources for the health effects, as is the metal industry. Particles from biomass combustion may be associated with respiratory and cardiovascular effects.

2.3.3. New evidence on ozone

There is evidence from cohort studies for an effect of long-term exposure to ozone on respiratory and cardiorespiratory mortality. Also, adverse effects on asthma incidence and lung function growth have been reported.

Short-term exposure (1-hour, 8-hour mean) has been shown to have adverse effects on all-cause, cardiovascular and respiratory mortality.

The available data does not allow for an identification of a threshold below which impacts can be ruled out. Several studies have shown evidence for effects below the current short-term threshold (both 1-hour and 8-hour mean) of the EU Air Quality Directive (2008/50/EC).

WHO therefore concluded that the development of guidelines for the long-term average ozone concentrations should be considered.

2.3.4. New evidence on nitrogen dioxide

There are many new studies showing associations between short-term and long-term exposure to NO₂ and mortality and morbidity. These effects were found in areas where concentrations were at or below the current standard values.

Even though NO₂ is often associated with other pollutants (e.g. black carbon, particulate matter), there is some evidence that NO₂ (both short-term and long-term exposure) has direct effects as well.

Hence it is suggested that the WHO air quality guidelines for NO₂ should be updated.

2.4. Criteria for the attainability of guideline values

2.4.1. Understanding WHO guideline values (vs. EU limit values)

WHO air quality guideline values have a different role than European air quality regulatory standards as laid down in the Ambient Air Quality Directive (AAQD) and the 4th Daughter Directive (4DD). WHO guidelines are based solely on scientific conclusions about public health aspects of air pollution; however, they do not consider the technical feasibility or the economic (such as cost benefit analysis), political and social aspects of the achievement of these levels. The WHO AQG levels can thus be considered as a recommendation.

In contrast, limit values as laid down in the European Directives have to be attained within a given period of time and are not to be exceeded once they have been attained. Non-compliance with the limit values stipulated in the AAQD can have legal consequences such as the start of infringement proceedings¹⁷ or lawsuits by citizens against the relevant agencies or administrations. Thus the economic, technical, political and social aspects of attaining limit values are usually taken into account when setting the relevant regulatory standards. In addition, the technical details of compliance (e.g.: Where do the standards have to be met? At urban background sites or at hot spots like street canyons?) have to be specified.

A comparison of the WHO guidelines (see Table 9 to Table 14 in Annex 1) with European regulatory standards (Table 15 to Table 22 in Annex 1) is shown in Table 2 below.

Table 2: Comparison of WHO air quality guidelines and European regulatory standards

Pollutant	AQG ($\mu\text{g}/\text{m}^3$)	EU-Dir ($\mu\text{g}/\text{m}^3$)	Averaging period	Remark
PM ₁₀	20	40	Annual mean	
PM ₁₀	50	50	Daily mean	3 days a year in WHO AGQ, 35 days in AAQD
PM _{2.5}	10	25*	Annual mean	
PM _{2.5}	25	-	Daily mean	3 days a year in WHO AGQ
NO ₂	40	40	Annual mean	
NO ₂	200	200	1-hour mean	18 exceedances allowed in AAQD
O ₃	100	120	8-hour daily max. mean	AAQD: not to be exceeded on more than 25 days per calendar year averaged over three years

* Limit value; there is also an exposure concentration obligation of 20 $\mu\text{g}/\text{m}^3$

Source: WHO 2006, Ambient Air Quality Directive

¹⁷ When comparing limit values in different regions outside the EU, an exact definition of the respective limit values needs to be provided, including the legal consequences of non-compliance and the relevant assessment regime.

2.4.2. Observed pollutants levels (compared to WHO guidelines)

The European Environment Agency has estimated the percentage of the urban population in Europe that is exposed to levels above EU regulatory standards and WHO guidelines for the years 2009 to 2011.

For ozone and PM_{2.5} more than 90 % of the European urban population is exposed to levels above the WHO guidelines; for PM₁₀ this percentage is close to 90 % (Table 3).

Table 3: Percentage of the urban population in the EU exposed to air pollutant concentrations above the EU and WHO reference levels

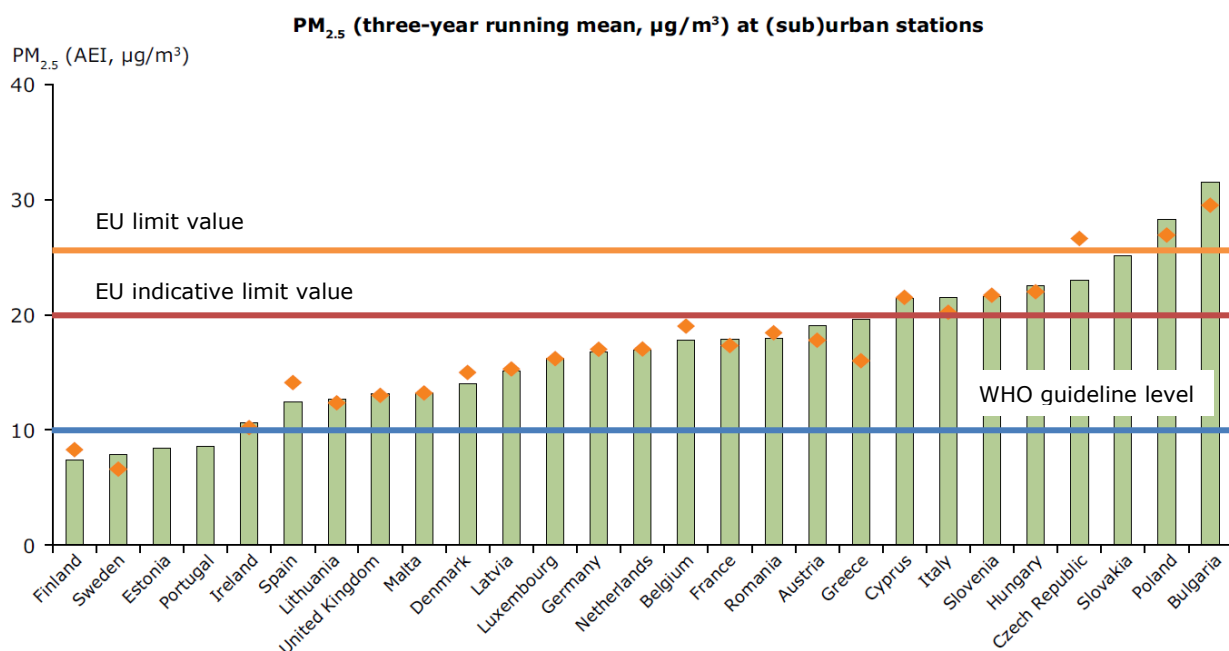
Pollutant	EU reference value (µg/m ³)	Exposure estimate (%)	WHO AQG (µg/m ³)	Exposure estimate (%)
PM _{2.5}	Year (20)*	20–31	Year (10)	91–96
PM ₁₀	Day (50)	22–33	Year (20)	85–88
NO ₂	Year (40)	5–13	Year (40)	5–13
O ₃	8-hour (120)	14–18	8-hour (100)	97–98

* 2020 indicative annual limit value (20 µg/m³).

Source: EEA 2013b

Figure 2 and Figure 3 show that exposure levels are highest in eastern and central European countries. Levels at or below the WHO AQGs are found only in five Member States.

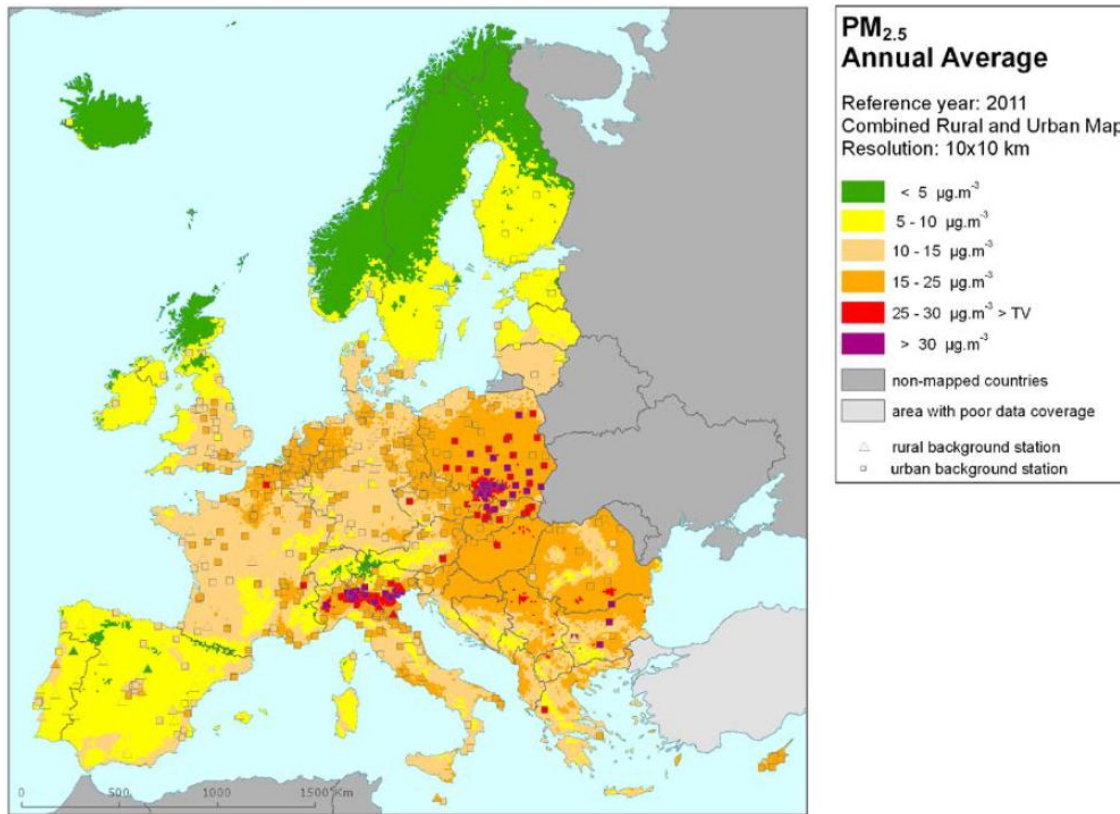
Figure 2: Urban PM_{2.5} concentrations presented as multi-annual average in EU, 2009–2011



Note: The Average Exposure Indicator (AEI), which is the three-year running mean of PM_{2.5} concentrations (2009–2011), is calculated as the average over all operational (sub) urban background stations within a Member State in the period 2009–2011. The orange dots correspond to AEI-values as provided by the EU Member States in the air quality questionnaire (reporting year 2011; reference period 2009–2011 except Poland: reference period 2010–2011).

Source: EEA 2013b

Figure 3: Combined rural and urban concentration map of PM_{2.5} – annual average, year 2011. Spatial interpolated concentration field and the measured values in the measuring points (Units: µg/m³)



Source: ETC/ACM 2014a

2.4.3. Main sources of elevated levels

The sources of elevated PM levels vary considerably across Europe. In addition to primary particles (e.g. from combustion or mechanically generated) particles are formed by chemical reactions from gaseous precursors or they come from natural sources.

However, there is no recent Europe-wide analysis of PM sources in different regions. From annual air quality reports and time extension notifications¹⁸ the following main sources of primary particles can be deduced:

- road traffic (both exhaust and non-exhaust emissions);
- domestic heating in particular in central, eastern and northern Europe;
- industry in various locations and regions;
- construction work (and off-road traffic in general);
- shipping (close to large harbours);
- Saharan dust events in southern Europe;
- winter sanding in northern and partly in central Europe;
- forest fires;
- agriculture.

¹⁸ http://ec.europa.eu/environment/air/quality/legislation/time_extensions.htm.

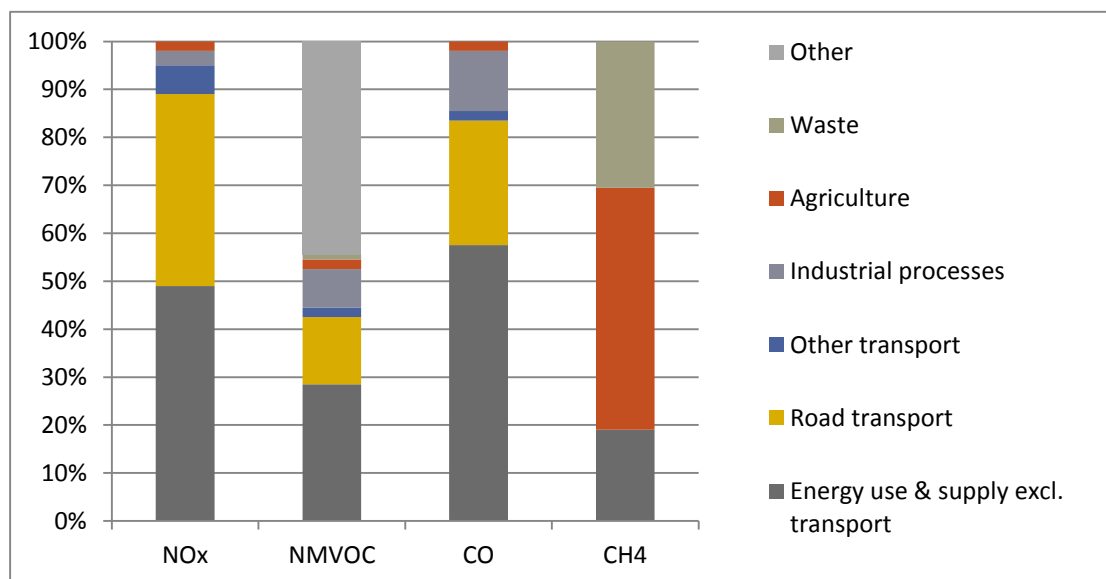
The main sources of secondary inorganic particles are traffic and other combustion sources (NO_x), energy use and supply (SO_2) and agriculture (NH_3) (EEA 2013a; see also Figure 4).

Exceedances of NO_2 limit values are almost exclusively caused by road traffic, in particular by diesel driven vehicles. Unfortunately, Euro standards for diesel vehicles have not been as effective in reducing NO_x emissions as originally anticipated. Due to high real world emissions from diesel passenger cars and light duty vehicles, there is not much difference in emissions between the Euro standards up to Euro 5 (EC 2013a, see also Annex 3).

Ozone is a secondary pollutant that is formed through complex atmospheric chemical reactions of precursor gases. The main precursor gases are nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), and methane (CH_4). The relationship between precursor emissions and the formation of ground-level ozone is highly non-linear. Due to the long atmospheric lifetime of some of the ozone precursors, pollutants transported from both North America and Asia contribute substantially to the mean ozone levels observed in Europe (UNECE 2010).

NO_x emissions are dominated by traffic and energy use, NMVOCs by other sources (solvent use), CO by energy use and transport, CH_4 by agriculture and waste (Figure 4).

Figure 4: Emissions of ozone precursors by sector in 2011 in EU 27



Note: "Other" source in the case of NMVOC: solvent use

Source: EEA 2013a

2.4.4. Perspective for attaining the guideline levels in the future

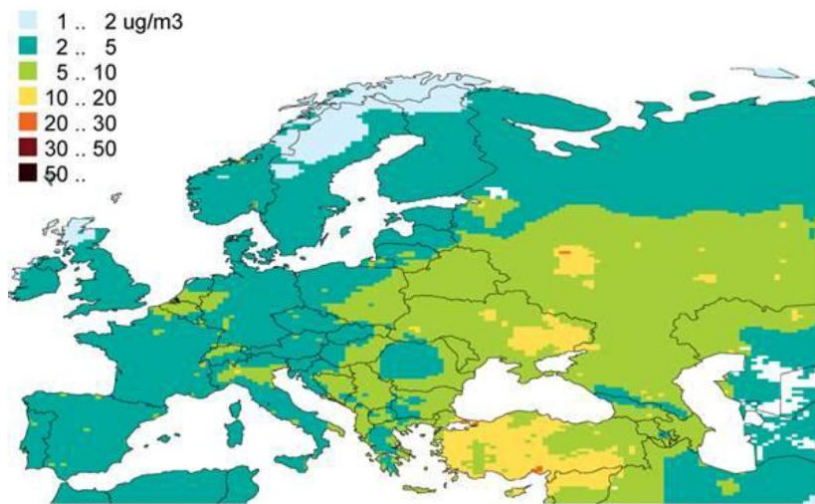
In the impact assessment that accompanied the clean air policy package¹⁹ "A Clean Air Programme for Europe" the European Commission analysed the long term perspective of meeting the current WHO $\text{PM}_{2.5}$ guideline for the annual mean of $10 \mu\text{g}/\text{m}^3$ (see Section 2.2.1). A "maximum control effort" (MCE²⁰) scenario was developed for 2050. This scenario includes all technical measures and in addition structural changes in the energy, transport and agriculture sectors to meet the 2050 objectives of the low-carbon

¹⁹ http://ec.europa.eu/environment/air/clean_air_policy.htm.

²⁰ The MCE scenario combines decarbonisation, air pollution control measures and partly a hypothetical behavioural change and thus would lead to reductions beyond the Maximum Technically Feasible Reduction (MTFR) scenario (see Section 5.2.3).

economy roadmap²¹ (phasing out of coal, an increase in electrification, energy efficiency gains) (SEC(2011) 289 final, EC 2013a). Under these assumptions, background PM_{2.5} concentration would be below the guideline almost everywhere in Europe (Figure 5). This would require further substantial emission reductions after 2025 (on average by 80 % from 2005 levels²²); however, this would require far reaching political decisions in all relevant sectors.

Figure 5: Anthropogenic PM_{2.5} concentrations across Europe in the 2050 maximum control effort scenario



Source: EC 2013a

This analysis relates to background concentrations. A further analysis was carried out for the monitoring sites and shows that the levels would be below the WHO guideline at 90 % of the stations. Local measures would thus be necessary to comply with the WHO guidelines at these locations.

An analysis for PM₁₀ is only available for compliance with the daily mean limit value of the AAQD in 2030. Compliance is predicted to be unlikely mainly in southern Poland (Figure 6).

For 2050, the analysis for PM_{2.5} as described above can be used, based on the average PM₁₀ to PM_{2.5} ratio in Europe. Under these assumptions compliance with the WHO guideline for PM_{2.5} should result in compliance with PM₁₀ in 2050 as well, at least for the background concentrations.

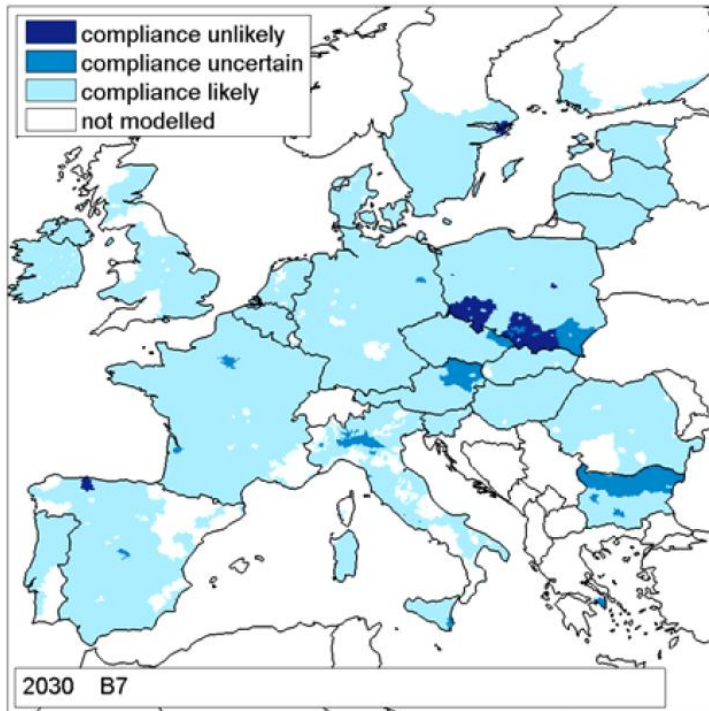
For NO₂ the current WHO guideline for the annual mean equals the limit value of the AAQD. Model calculations by IIASA²³ based on emission reductions according to the Commission's proposal predict compliance in 2030 in all but one Italian air quality zone, (and uncertain compliance in some additional ones for which further local measures would be required, Figure 7). However, there is some uncertainty as to whether the NO_x emissions from vehicles, which are the main source of elevated NO₂ levels, will be reduced as expected, see Section 3.4 and Annex 3.

²¹ Commission Staff Working Document impact assessment accompanying document to the communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions a Roadmap for moving to a competitive low carbon economy in 2050 {COM(2011) 112 final} {SEC(2011) 289 final}.

²² Emission reductions between 2005 and 2030 of the new NECD compared to the MCE scenario for 2050: PM_{2.5}: -51 % vs. -72 %, SO₂: -81 % vs. -91 %, NO_x: -69 % vs. -83 %; NH₃: -27 % vs. -48 %, VOC: -50 % vs. -71 %.

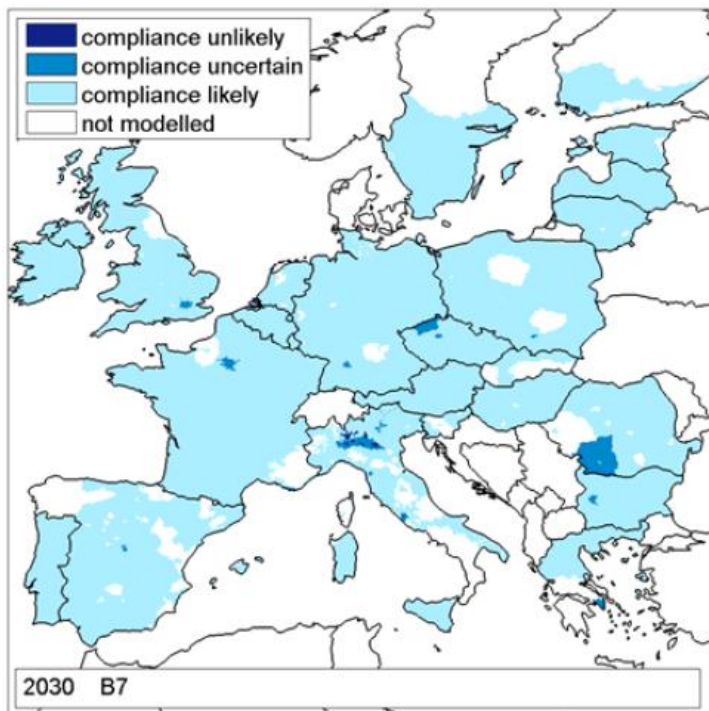
²³ International Institute for Applied Systems Analysis: <http://www.iiasa.ac.at/>.

Figure 6: Compliance of the air quality management zones with the limit values for PM₁₀ for the Commission proposal scenario (B7) in 2030



Source: IIASA 2014a

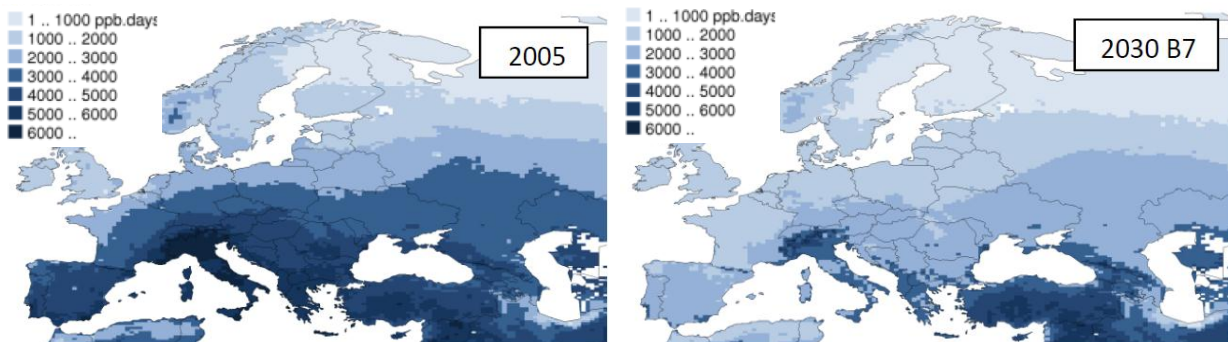
Figure 7: Compliance of the air quality management zones with the limit values for NO₂ for the Commission proposal scenario (B7) in 2030



Source: IIASA 2014a

A reduction in the emissions of precursor gases leads only to a modest reduction in average ozone levels²⁴. This is due to the highly non-linear relationship between emissions and the formation of ozone, as well as to the long-range (including intercontinental) transport of ozone and its precursors. In the scenario proposed by the Commission, the number of premature deaths would decline by 34 % between 2005 and 2030. However, even in 2030 ozone levels will be above the WHO guideline level in all of Europe except some northern regions.

Figure 8: The SOMO35²⁵ indicator (of associations between premature mortality and ground-level ozone) in 2005 and 2030 (B7 scenario)



Source: IIASA 2014a

2.5. Conclusions

Exposure to elevated air pollution levels, in particular PM_{2.5}, NO₂ and ozone, causes negative impacts on human health. Current air pollution levels in some areas of the EU exceed by far the WHO air quality guideline levels. About 400 000 premature deaths are associated with air pollution; the loss of statistical life expectancy amounts to about 9 months on average in Europe. The WHO regards air pollution as one of the major environmental threats to human health (Lim et al. 2012, WHO 2014).

In order to reduce the impact of air pollution on human health the focus should not only be on local or regional hot spots but on reducing air pollution in general. Thereby the health benefits can be maximised, as a consequence of PM being a non-threshold pollutant and the more or less linear PM dose-response relationship (WHO 2013b). It is therefore important to reduce the emissions from the major sources (vehicles, off-road machinery, ships, and appliances for domestic heating, industry) throughout Europe by common source and product related rules and standards. The NECD, in addition, links the necessary emission reductions in the Member States (which cannot be achieved completely by these rules and standards) to environmental objectives in a cost efficient way, leaving a certain amount of flexibility to the Member States on how to achieve these reductions.

²⁴ A 20 % emission reduction of NO_x in Europe reduces average O₃ levels by 1.2 %, the same reduction results from a 20 % of VOC whereas a 20 % CO reduction leads to a 0.3 % of ozone (Wild et al. 2012).

²⁵ Sum of ozone means over 35 ppb (=70 µg/m³; daily maximum 8-hour). This indicator is highly correlated with the number of days above the WHO guideline value of 100 µg/m³ (daily maximum 8-hour mean). A SOMO35 value of about 1000 ppb.days corresponds to zero days with a daily maximum 8-hour mean above 100 µg/m³ (analysis based on Austrian data for 2012).

3. CHALLENGES IN THE REDUCTION OF AIR POLLUTANTS

KEY FINDINGS

- Compliance with PM₁₀ and PM_{2.5} air quality limit values is hampered by the need to address many different sources, as well as by the fact that contributions come from neighbouring countries and from natural sources, and by deficiencies in air quality management. Future PM_{2.5} reductions will mainly rely on the domestic heating sector depending on the implementation of effective legislation on EU and national level, and supported by funding schemes.
- Future compliance with target values for ozone depends on emission reductions of precursors within Europe but also in North America and Asia.
- Compliance with national emission ceilings for NO_x and NH₃ by 2010 proved to be difficult for several Member States. The main reasons are: less effective than expected regulations for diesel vehicles, new sources of emissions, and inadequate emission reduction measures or measures that come too late to account for increased traffic emissions and new sources. Future emission reductions for NO_x will strongly depend on the effectiveness of forthcoming vehicle regulations. Effective emission reduction measures are available for NH₃, but their applicability depends on certain factors which vary considerably across Member States. The implementation of EU-wide regulations on NH₃ will be a challenge.
- For SO₂ the major challenge will be to find a balance between the retrofitting and the phasing out of existing installations (which use a lot of sulphur-containing fuel). NMVOCs are most effectively reduced by replacing old biomass stoves and banning agricultural waste burning; for the latter, compliance checks may prove to be difficult. In the case of methane, the main challenge will be to handle interactions between different climate policies and the uncertainties of future agricultural policies.

This chapter describes the challenges that Member States have faced in achieving their national emission ceilings and ambient air quality levels in the past, as well as the challenges they are likely to face in the future.

3.1. Background

Emissions and impacts of several air pollutants on human health and ecosystems are strongly interlinked (Figure 9). Whereas most of the air pollutants are emitted directly to air, some are formed through the reaction of precursors. Directly emitted pollutants that impact on human health and/or ecosystems are:

- ammonia (NH₃);
- carbon monoxide (CO);
- nitrogen oxides (mainly nitrogen oxide NO and nitrogen dioxide NO₂);
- polycyclic aromatic hydrocarbons (PAH);
- sulphur dioxide (SO₂).

Ground level ozone (O₃) is not emitted directly into air but is formed through the reaction of volatile organic compounds (VOCs including methane CH₄), nitrogen oxides (NO_x) and also CO in the presence of sunlight. Particulate matter (PM) can be emitted directly to the

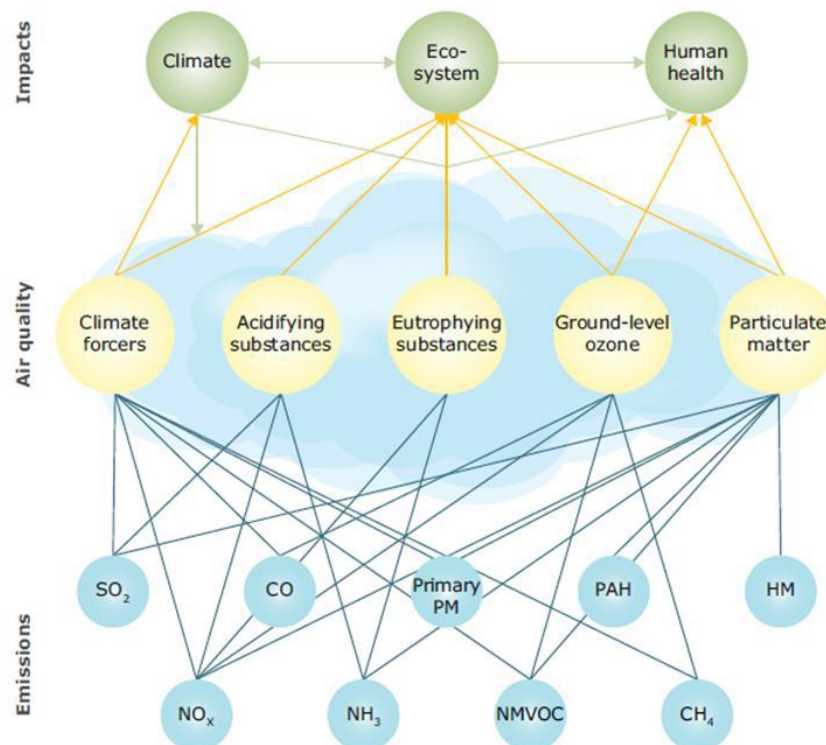
air (so-called primary particles) or it is formed in the atmosphere as “secondary particles”. These can be either inorganic secondary particles from gases such as SO₂, NO_x and NH₃ or organic secondary particles from various organic substances. Primary particles can result from anthropogenic sources (combustion and mechanical processes) or natural sources (windblown dust, plant debris, pollen, volcanoes etc.).

The pollutants of most concern in Europe from a human health perspective are currently PM, O₃ and NO₂. NH₃, SO₂ and NMVOC contribute to secondary pollutant formation and are thus of importance as well.

Ecosystems are damaged by the deposition of acidifying, eutrophying substances and ground level O₃. Acidifying substances include SO₂, NO_x and NH₃, whereas eutrophication is caused by excess nutrient nitrogen in the form of NO_x and NH₃.

The NECD and the Gothenburg Protocol on UNECE level address the impacts of these pollutants on ecosystem and human health simultaneously. The amended Gothenburg Protocol²⁶ and the proposal for a new NECD address the impact on climate as well (UNECE 2012; EC 2013b, 2013c). They also address the impact of O₃, CH₄ and black carbon (which is a constituent of PM) as these substances are important so-called short-lived climate forcers (UNEP 2011). The interactions between emissions ⇔ impacts ⇔ measures ⇔ costs of these pollutants are modelled in the GAINS²⁷ model, developed by IIASA (see Section 5).

Figure 9: Interlinkages between emissions of air pollutants, air quality and impacts of air pollutants



Note: From left to right the pollutants shown are as follows: sulphur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), ammonia (NH₃), particulate matter (PM), non-methane volatile organic compounds (NMVOC), polycyclic aromatic hydrocarbons (PAH), methane (CH₄), heavy metals (HM).

Source: EEA 2013a

²⁶ http://www.unece.org/env/lrtap/multi_h1.html.

²⁷ Greenhouse Gas - Air Pollution Interactions and Synergies: <http://gains.iiasa.ac.at/models/index.html>.

In order to address the impacts on the environment and human health as mentioned above the NECD currently covers the emissions of four pollutants, not to be exceeded by 2010 and thereafter:

- sulphur dioxide (SO₂);
- nitrogen oxides (NO_x);
- volatile organic compounds (VOC);
- ammonia (NH₃).

The proposal for a new NECD includes the emissions of PM_{2.5} and methane (CH₄) as well. It foresees substantial emission reductions between 2020 and 2030 (Table 5, Section 3.9).

The challenges of achieving these reductions are described for each pollutant below. This analysis takes into account the results of bilateral consultations which were held in spring 2014 between IIASA and the Member States (IIASA 2014b).

3.2. PM₁₀ and PM_{2.5}

In many cases a combination of factors is responsible for elevated PM levels in Europe (see e.g. Umweltbundesamt 2010 and Section 2.4.3). In general, these are anthropogenic and natural factors. The former include emissions from sources such as traffic, industry, domestic heating (primary PM emissions as well as emissions of precursor gases), the latter include the topographic and climatic situation as well as natural emissions. A further aspect is the administrative, legal, political and financial capacity for air quality management, i.e. to identify the main sources and to apply (cost) effective measures.

Thus, also the challenges of addressing these different factors vary throughout Europe. In addition, the impacts of air pollution have become less visible as a result of emission reduction efforts in the past and are thus more difficult to address by policy-making.

Future emission reductions for PM_{2.5} should result mainly from measures in the residential and commercial sector (biomass burning), and from banning agricultural waste burning (Annex 2, Figure 15; for agricultural waste burning see Section 3.6 below). Emission reduction strategies and challenges for implementation in the domestic heating sector are described in the table below. All mentioned measures can be based on funding, information and awareness initiatives, or on organisational, legislative or normative provisions such as stricter standards for buildings and heating systems.

Table 4: Measures and challenges to reduce PM_{2.5} emissions in the domestic heating sector

Measure	Challenge
Dust abatement technologies	Expensive; difficult to integrate in small combustion facilities; difficult to operate in an efficient way over a long period of time. Might require intensive service and a considerable amount of electric power.
Changing domestic heating systems	High investment costs, which might exclude low income households. Investments are often unfavourable for either tenants or landlords.
Switching to fuels with lower emission factors	High investment costs if heating systems needs to be changed.
Improving the incineration process	Appropriate funding for research on technological improvements; implementation of strict inspection standards.
Reduced use of final energy (insulation, heat management)	High investment costs. Difficult to apply to certain existing (listed) buildings.
Inspection and improvement of existing small combustion facilities	Currently not regulated on EU level.

An additional challenge arises from several counter-productive funding schemes and measures on both national and EU level for this sector.

3.3. Ozone

As described in more detail in Section 2.4.3, ozone is a secondary pollutant that is formed through complex and highly non-linear reactions of precursor gases (NO_x, NMVOC, CO, CH₄). The challenges in reducing the emissions of these precursor gases (except for CO) are described in the respective sections.

A further challenge arises from the transport of ozone and its precursors from both North America and Asia, which contributes substantially to observed mean ozone levels in Europe (UNECE 2010).

3.4. Nitrogen oxides

NO_x is the pollutant for which most exceedances of the emission ceilings occurred (EEA 2014a). The reasons are (Ecorys 2013):

- Real world driving emissions of diesel vehicles are much higher than those measured in the type approval tests (see Annex 3);
- Due to tax incentives the share of diesel passenger cars and light duty vehicles has increased in many Member States;
- Additional sources such as NO_x from agricultural soils and off-road vehicles were incorporated in the emission inventories after the ceilings had been set;
- Road transport has increased more substantially than previously expected;
- No additional measures have been taken to address levels that were higher than expected; measures proved to be less effective than expected.

The main uncertainty concerning the attainability of the NO_x ceiling foreseen for 2030 will be whether real world emission from Euro 6/VI will be aligned with the limit values of the type approval test from 2017 onwards²⁸. In the past, the real world NO_x emissions from road vehicles were much higher than the type approval limit values of EU-type approval legislation (see Annex 3).

There is a rising awareness among European legislators of the discrepancy between real world emissions and laboratory values, especially for NO_x but also for fuel consumption. Suitable steps have been taken to solve this issue. Nonetheless, the future will show whether these legislative measures are effective.

Hence there are considerable uncertainties when it comes to projections for future exhaust emissions, especially for NO_x.

International shipping on seas within Europe's Exclusive Economic Zones (200 nm) is an important source of NO_x. The baseline emission scenario (Section 5.2.1) suggests that NO_x emissions will decline by 13 % in the period up to 2020 (compared to 2005), but increase afterwards, reaching almost the same levels as in 2005 (VITO 2013). Therefore, NO_x emissions from shipping will equal those from land-based sources in 2050. Abatement measures and technologies are available, such as designating NO_x emission control areas under IMO MARPOL Annex VI within Europe's Exclusive Economic Zones.

3.5. Sulphur dioxide

Over the 2010 – 2012 period, SO₂ emissions were well below the ceilings in all Member States (on average around 50 % lower, EEA 2014a). One of the reasons for this stronger than anticipated decline lies in European emission control legislation (e.g. sulphur in fuels regulation; Large Combustion Plant Directive etc.), which overcompensates a higher than previously anticipated use of coal (IIASA 2012).

In addition, some Member States had rather unambitious ceilings for SO₂, which facilitated compliance with the ceilings.

The major part of the emission reduction of SO₂ has been achieved by reducing the sulphur content in fuels. For the remaining emissions the major challenge will be to find a balance between the retrofitting of existing installations and the phasing out of existing installations.

For industrial combustion and power plants the retrofitting of existing installations is rarely economically viable, as the plants using coal and oil are nearly at the end of their life-time. Therefore, switching from coal and oil to gas is a more viable option. In new facilities the best equipment should be used to cut emissions.

Technical descriptions of the reduction technologies applied for industrial processes are not available in the GAINS models. Therefore the assumptions leading to emission reductions cannot be reproduced.

In the domestic sector emissions could be reduced in a more cost-effective way by banning sulphur-containing fuel (as it was done in the transport sector), e.g. by widely banning the use of coal and oil.

²⁸ Euro 5 and 6 standards for cars and light duty vehicles: Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information.

Euro VI for heavy duty vehicles: Commission Regulation (EU) No 582/2011 of 25 May 2011 implementing and amending Regulation (EC) No 595/2009 of the European Parliament and of the Council with respect to emissions from heavy duty vehicles (Euro VI) and amending Annexes I and III to Directive 2007/46/EC of the European Parliament and of the Council.

According to the analysis from IIASA (see Annex 2, Figure 16), refineries may have a substantial SO₂ reduction potential in some Member States. However, an assessment of the reduction potential and the costs involved in identifying the challenges for this sector would require an analysis on plant level which is beyond the scope of this study.

3.6. Non-methane volatile organic compounds

NMVOCs contribute to the formation of PM and ground-level ozone (see Section 3.1). Emissions of NMVOCs in EU 27 were below the ceilings in all²⁹ Member States in recent years. On average, emissions were about 20 % lower than the ceilings for 2010 (EEA 2014a).

Due to further Euro standard implementation, resulting in decreasing emissions from road transport, the by far most important source in the future will be solvent use in industry and households. Several measures under EC legislation³⁰ and on national level have achieved emission reductions in the past. However, this sector still has a high technical potential for further reductions, e.g. by further substitutions by low-solvent and water-based products and processes.

But, if the costs are considered, the most cost-efficient measures for NMVOC reductions are on the one hand the replacement of old stoves for residential heating (see Section 3.2), and on the other hand to reduce agricultural waste burning (which is specifically relevant in some new Member States, see Annex 2, Figure 17). Both measures also have a significant impact on PM levels.

The open burning of crop residues on fields has been banned in many countries, albeit with some minor exceptions in certain specified circumstances. The alternative to burning is ploughing the crop residues into the soil before establishing the next crop, which is good agricultural practice in most Member States. Technically, there are therefore no challenges in limiting or prohibiting open agricultural waste burning; however, compliance checking might be a problem in some Member States in remote areas³¹.

3.7. Ammonia

Ammonia (NH₃) is an essential constituent of secondary inorganic aerosol and thus contributes to PM_{2.5}. Depending on the specific aerosol chemistry the reduction of NH₃ will be the most efficient way to reduce PM_{2.5} levels, especially for background levels in some parts of Europe (Umweltbundesamt Dessau 2012, 2013; Aksoyoglu et al. 2011; Derwent et al. 2009). In addition, NH₃ causes eutrophication of ecosystems. The main source of NH₃ is agriculture and its emissions resulting from livestock manure and the application of fertilisers. Emissions above the NH₃ ceiling occurred in Denmark, Spain and Finland (EEA 2014a). The reasons for non-compliance with the ceilings are (Ecorys 2013):

- poor quality of data on both the activity and emission factors for the agricultural sector at the time when the ceilings were set;
- inadequate national emission reduction measures for agricultural NH₃, or measures that were taken too late.

²⁹ Except for Luxembourg in 2012 (based on preliminary data).

³⁰ Solvents Directive 1999/13/EC, the Paints Directive 2004/42/EC, the Petrol Vapour Recovery I (94/63/EC), the IPPC Directive, and measures such as EU and national labelling schemes to reduce the VOC content in household products.

³¹ Remote sensing can support detection of open burning, see: <http://www.globalfiredata.org/data.html> and a presentation given by M. Amann at the 4th Stakeholder Expert Group meeting: <https://circabc.europa.eu/d/a/workspace/SpacesStore/c1a6851f-ab06-49ba-b5cb-c41b8fd78fed/amann-SEG4-ag%20burning.pdf>.

Possible measures are described e.g. in an UNECE Guidance Document³². The applicability of these measures depends on some criteria, e.g. the size and structure of the farms as well as the costs, morphology, climate conditions and agricultural advancements. These factors vary considerably across Member States.

The existing EU source legislation on air pollution emissions from agriculture is very limited in scope while the NECD ceiling on ammonia has not been very challenging and, consequently, has been complied with in most Member States. In addition, work has been done to implement the IPPC and the Nitrates Directives, but these instruments have been too weak to achieve significant emission reductions from agriculture as a whole. So, until now it has been left to the Member States to regulate emissions in their countries and the main challenge would be to implement EU-wide regulations.

3.8. Methane

Methane plays an important role as a precursor of background ozone in the hemisphere. CH₄ emissions have been increasing significantly in the last decade, which has had a negative effect on NO_x and VOC emission reduction achievements. The main sources of CH₄ are the agriculture (enteric fermentation and manure management) and the waste sectors (solid waste, waste water treatment).

The GAINS model shows that already agreed legislation leads to substantial reductions of CH₄, but that there are more reduction measures which could be taken at low or even zero costs.

The main challenge in reducing methane emissions is to include methane ceilings in EU legislation as recently suggested by stakeholders in the new NECD consultation process (EC 2013a). Like all the other greenhouse gases, methane emissions are covered by the Effort Sharing Decision (ESD) and emission ceilings might limit the flexibility of the ESD mechanism.

Appropriate targets could be differentiated by Member States and could be an incentive for other countries to implement methane reduction targets. Nevertheless, the emission reduction potential is fraught with uncertainties, e.g. about the impacts of the abolishment of milk quotas.

3.9. Conclusions

Compliance with emission ceilings has proved to be challenging especially for NO_x and NH₃. The following conclusions can be drawn for the new NECD:

- The regulations that aim to achieve emission reductions for crucial source categories have to fulfil expectations (see NO_x real world driving emission of diesel vehicles);
- On the other hand, flexibility is needed with respect to the ceilings to account for unforeseeable failures of regulations and also for new sources of emissions. The amended Gothenburg Protocol and the Commission's proposal for a new NECD foresee a restricted flexibility mechanism, where the proposed changes in the relevant commitments have to be independently reviewed;
- Inadequate national programmes, or programmes that came too late, have contributed to non-compliance. Therefore, the new NECD should foresee a more effective monitoring and reporting regime.

³² ECONOMIC COMMISSION FOR EUROPE (2014): Guidance Document on preventing and abating ammonia emissions from agricultural sources. ECE/EB.AIR/120. February 2014:
http://www.unece.org/fileadmin/DAM/env/documents/2012/EB/ECE_EB.AIR_120_ENG.pdf.

The proposal for a new NECD foresees substantial emission reductions between 2020 and 2030 compared to 2005 (Table 5).

Table 5: Proposed emission reduction commitments for 2020 and 2030 compared to 2005 for EU 28 based on fuels sold, proposal for new NECD

Pollutant	Reduction until 2020	Reduction until 2030
SO ₂	59 %	81 %
NO _x	42 %	69 %
NM VOC	28 %	50 %
NH ₃	6 %	27 %
PM _{2.5}	22 %	51 %
CH ₄	-	33 %

Source: EC 2013b

There are no fundamental technological challenges to achieve these emission reductions by implementing adequate measures. The main challenges are of political, administrative and economic nature. Achieving these goals is facilitated by ambitious climate and energy policies, even though emissions from increased use of biomass have to be tackled. From a political perspective the major challenge will be how to implement sometimes unpopular and costly measures in times of economic difficulties. For administrations – especially on regional and local level – in some Member States the challenge will be to obtain data on sources, costs and impact of measures.

In addition to these challenges there are some overall uncertainties of the underlying model calculations for the new NECD (see also the analysis of the baseline scenario in Chapter 5); if some of the basic assumptions will prove to be false, there is no clear mechanism to adjust the ceilings accordingly:

- validity of the projections for the PRIMES 2013 energy scenario and underlying assumptions for the main drivers (economic growth, energy prices etc.);
- technological developments and synergies and interactions with climate and energy policies.

4. CASE STUDIES IN MEMBER STATES

KEY FINDINGS

- NO_x emissions from Germany in recent years were above the ceiling of the NEC Directive mainly due to the difference between type approval and real world emissions of diesel vehicles, higher than projected fuel consumption by heavy duty vehicles, inclusion of previously not estimated emissions from specific sources in agriculture, and an increase in the use of biomass combustion.
- Luxembourg has lower rates for diesel fuel excise duties and fuel prices. This has led to a much higher (than previously projected) consumption of diesel in cars, light and heavy duty vehicles. As the NO_x emissions from diesel vehicles are higher than from gasoline vehicles, the NO_x ceiling has been exceeded. Reducing CO₂ emissions from passenger cars has been stated as a reason for fuel price policies. The effect on CO₂ is, however, not directly visible given the average passenger car emissions in Luxembourg.

As described in Sections 3.4 the countries showing the largest relative discrepancy between NO_x ceilings and actual emissions are Luxembourg and Austria; the largest absolute discrepancy has been found in Germany (EEA 2013b).

4.1. Case study 1: NO_x emissions in Germany

NO_x emissions in recent years and ceilings according to the NECD for Germany are shown in Table 27. Emissions in 2010 were about 280 kt above the ceiling (26 %).

The reasons for non-compliance were analysed in detail on the basis of a questionnaire in a recent study (ECORYS 2013):

- real world driving emissions from diesel vehicles (see Annex 3 for more details);
- strong increase in share of diesel passenger cars;
- higher than projected traffic volumes of heavy duty vehicles;
- inclusion of previously not estimated emission sectors;
- increase in use of biomass;
- delay in emission regulations for off-road machinery;
- overestimation of emission reductions from planned measures.

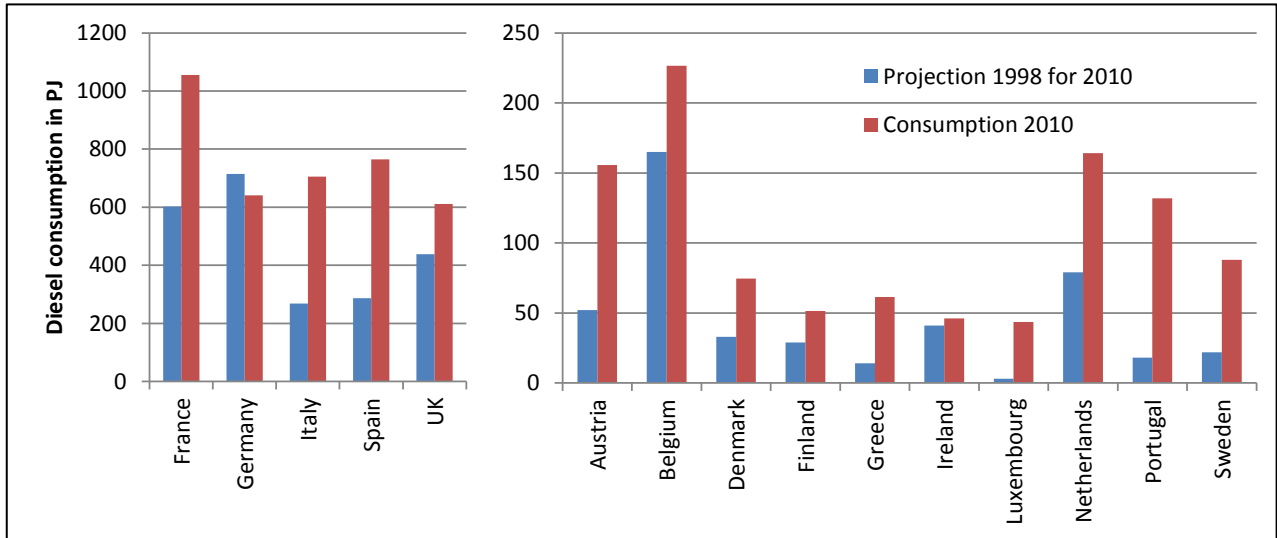
The main reasons for these discrepancies could be quantified; it is expected that Germany will comply with the ceilings in 2015.

4.2. Case study 2: Policies for diesel in Luxembourg

The consumption of diesel by cars and light duty vehicles in recent years was much higher than expected in the late 1990s when the NECD was negotiated (IIASA 1998). Figure 10 shows that for almost all EU 15 countries diesel consumption³³ was higher than projected; in some countries even several times higher (the only exception being Germany).

³³ Overall consumption in EU 15 of both gasoline and diesel was 14 % lower than projected for all vehicle categories.

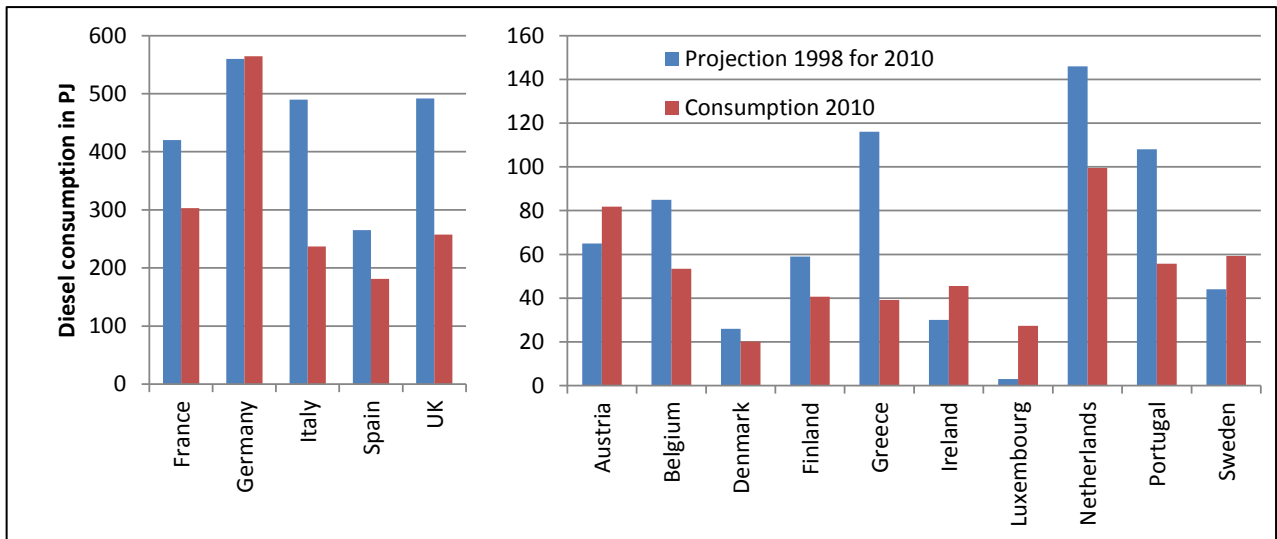
Figure 10: Diesel consumption by cars and light duty vehicles as projected in 1998 for 2010 and actual consumption in 2010



Source: IIASA 1998, GAINS Europe online, Scenario: PRIMES 2013 REF-CLE (ID: TSAP_Sept2013_P13_REFv3)

Consumption by heavy duty vehicles saw a different development; in most countries consumption was lower than projected (Figure 11). However, Germany (see also Section 4.1), Austria, Ireland, Luxembourg and Sweden showed higher consumption levels.

Figure 11: Diesel consumption by heavy duty vehicles as projected in 1998 for 2010 and actual consumption in 2010



Source: IIASA 1998, GAINS Europe online, Scenario: PRIMES 2013 REF-CLE (ID: TSAP_Sept2013_P13_REFv3)

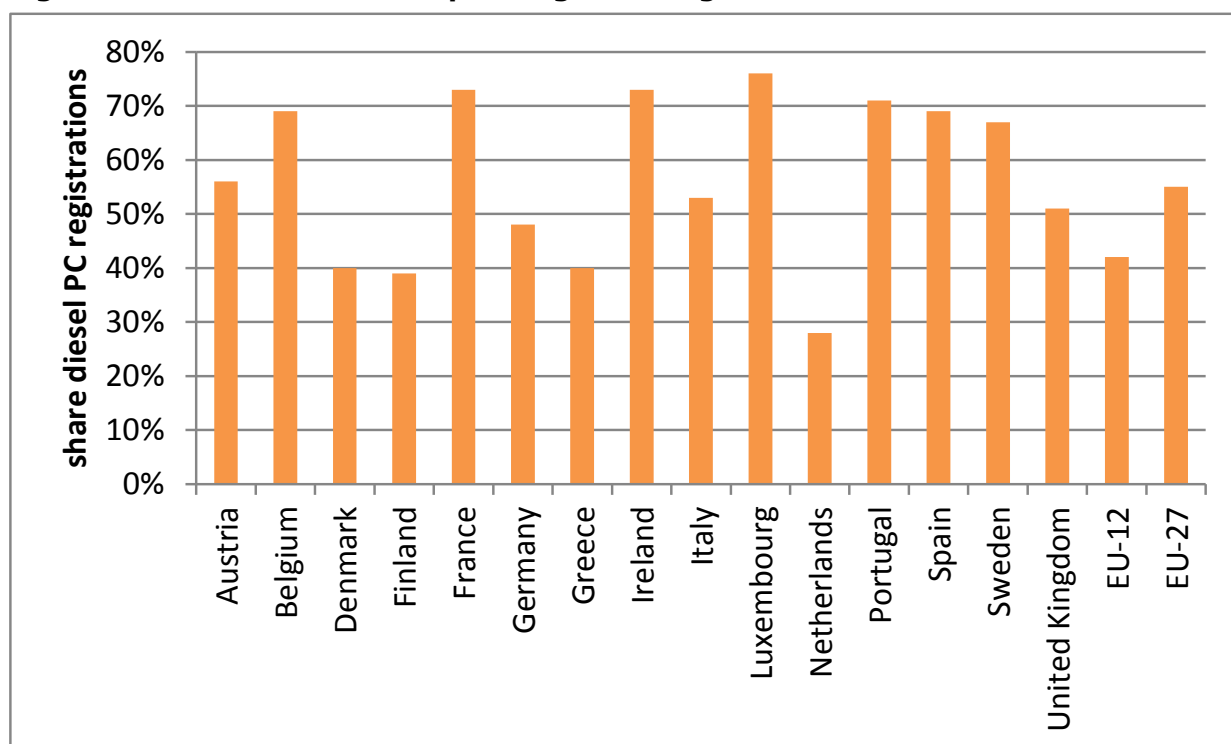
This increase in diesel consumption in Luxembourg and Austria is directly related to tax policies for fuels and vehicles. It has been one of the main reason for non-compliance with NO_x emission ceilings³⁴ (ECORYS 2013).

³⁴ Both countries report NO_x emissions based on fuel used in contrast to most other countries where calculations are based on fuel sold.

The high level of diesel consumption results from low rates for fuel excise duties overall and for diesel fuel especially, as well as from low fuel prices (see Annex 4) in Luxembourg. As Luxembourg (like Austria) is a small country surrounded by countries where diesel prices are higher, this leads to fuel exports, also referred to as “tank tourism”. In addition low fuel prices can lead to increased vehicle traffic within the country (Delsaut 2014).

Even when emission calculations are based on fuel used (thus disregarding emissions based on fuel sold in Luxembourg but mainly used outside the country), the NO_x emissions are found to have increased as diesel vehicles are favoured under this taxation scheme. This leads to the fact that Luxembourg has the highest share of diesel passenger cars in Europe (Figure 12).

Figure 12: Share of diesel in passenger car registrations in 2012



Source: ICCT 2013

Luxembourg has stated that policies to reduce CO₂ emissions have been the reason for introducing lower taxes on diesel than on gasoline (ECORYS 2013). Whether these policies can be regarded as successful would require a more extensive analysis which is beyond the scope of this study. When using the average CO₂ emission from passenger cars as an indicator, the success of these policies seems uncertain.

5. ANALYSIS OF THE BASIC SCENARIOS

KEY FINDINGS

- A comparison of the Current Legislation scenario and the Maximum Technically Feasible Reduction scenario demonstrates that the emissions could be reduced substantially for all air pollutants in 2025/2030.
- However, compliance with WHO air quality guidelines for PM_{2.5} would additionally require substantial structural changes. Still compliance would only be achieved until 2050.
- Further improvements of health and environmental impacts can be achieved through additional measures.
- The most cost-effective scenario with a view to a 70 % gap-closure (i.e. achieving 70 % of the effects on health of the Maximum Technically Feasible Reduction scenario), as agreed by the Commission for 2025, achieves a 67 % gap closure between the Current Legislation Scenario and the Maximum Technically Feasible Reduction scenario in 2030.
- The pollution control costs of EUR 3.3 billion per year in 2030 would be completely compensated by health benefits, which are estimated at EUR 40 billion per year.

The Commission proposal³⁵ on the reduction of national emissions of certain atmospheric pollutants has been developed within the framework of the new Thematic Strategy on Air Pollution 2013³⁶ (TSAP 2013). The whole strategy has been developed on the basis of and accompanied by the GAINS model³⁷ of the International Institute for Applied Systems Analysis (IIASA). The main model outputs are baseline emissions and impacts as well as information on the effects of different reduction scenarios.

The Commission proposal now focuses more strongly on health impacts and sets binding targets for 2020 and 2030 for sulphur dioxide (SO₂), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), PM_{2.5}, methane (CH₄) and ammonia (NH₃). The targets for 2020 comply with the revised Gothenburg Protocol³⁸ for SO₂, NO_x, NMVOC, PM_{2.5} and NH₃.

³⁵ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0920&from=EN>.

³⁶ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0918&from=EN>.

³⁷ http://www.ec4macs.eu/content/report/EC4MACS_Publications/MR_Final%20in%20pdf/GAINS_Methodologies_Final.pdf.

³⁸ http://www.unece.org/env/lrtap/multi_h1.html.

The following main scenarios were analysed within the review process:

Table 6: Overview of the main scenarios

Name of scenario	Synonyms, abbreviations	Description
TSAP 2013 baseline scenario	baseline scenario, baseline	Timescale: 2005-2020
Current Legislation Scenario	CLE, Option 1	Timescale: 2020-2030, extended baseline scenario
Gap closure options	6A-6C	25 %, 50 % and 75 % gap closure, respectively, for PM _{2.5} health impacts between CLE and MTR
Maximum technically feasible reduction scenario	MTR, 6D	Timescale: 2020-2030, considers all technically feasible measures that are available on the market
Compliance with WHO guidelines	6E	Compliance with WHO air quality guidelines until 2030

Source: EC 2013a

5.1. Policy option compliance with WHO guidelines

The 7th Environmental Action Programme requires the EU to “move closer to WHO recommended levels” by 2020. Therefore one of the review’s policy options looked at achieving the WHO guidelines for PM_{2.5} until 2030 (see also Section 2.4.4 for details). IIASA’s analysis shows that technical measures alone are not sufficient. Additional substantial structural changes would be necessary, by which compliance is possible until 2050.

5.2. Baseline, current legislation and MTR scenarios

The TSAP 2013 baseline scenario includes the most recent data and projections available on EU level and covers the time period 2005-2020 (Section 5.2.1).

On the basis of the baseline scenario two further sub-scenarios covering the period from 2020 to 2030 have been developed to analyse potential ranges of future emissions, related emission control costs and the impacts on air quality (Section 5.2.2 and 5.2.3).

Table 7 lists impacts on health and environment as projected for 2025 and 2030 and indicates if the TSAP 2005 target for 2020 will be achieved according to the baseline scenario³⁹.

³⁹ The model calculations provide estimates of the expected health and environmental impacts under the scenarios described for the EU 28 as well (IIASA 2014a). The targets for PM_{2.5}, nitrogen deposition, and partly for NO₂ and PM₁₀, will not be achieved in 2020 in the baseline scenario. Possible reasons are e.g. a lack of transboundary pollution control, absence of legislative regulations, and insufficient implementation of measures by the responsible authorities. On the other hand, ground-level ozone and the acidification of forests will have decreased sufficiently to meet the targets.

Table 7: Impacts on health and environment projected under the CLE and MTR scenarios for 2025 and 2030; achievability of the TSAP 2005 target for 2020 in the baseline scenario

Impacts	Scenario	Development of indicators until 2025/2030	TSAP target for 2020
Health impacts from PM _{2.5}	CLE	Loss of statistical life expectancy: 5.2 months in 2030 (200-220 million life years lost)	Not achieved
	MTR	Loss of statistical life expectancy: 3.6 months in 2030 (60 million life years saved)	
PM ₁₀ limits values	CLE	In 2010, 60 out of 503 zones exceeded the limit values. For 2025 it is expected that less than 20 zones will exceed the limit values.	Partly achieved
	MTR	Measures at urban scale could achieve further improvements.	
Health impacts from ground-level-ozone	CLE	18 000 premature deaths due to ground-level ozone in 2025	Achieved
	MTR	Additional measures could lead to further 2 800 avoided premature deaths.	
NO ₂ limit values	CLE	Zones which exceed the limit value for annual concentrations will decrease from 100 in 2010 to less than 10 in 2025.	Partly achieved
	MTR	Only small improvements compared to CLE	
Nitrogen deposition in protected areas	CLE	In 2005, 77 % (423 000 km ²) of the protected zones are strongly exposed to nitrogen deposition. NO _x emissions are expected to decline in the CLE scenario and leave only 62 % of the protected area excessively exposed to nitrogen deposition in 2025.	No targets
	MTR	Additional measures especially for ammonia reduction could save another 100 000 km ² of protected areas.	
Nitrogen deposition in other ecosystems	CLE	In 2005, 66 % (1.1 million km ²) of the EU ecosystems were subject to nitrogen deposition and eutrophication. In the CLE scenario the area affected would be reduced to 880 000 km ² in 2030.	Not achieved
	MTR	Additional measures could further protect another 220 000 km ² in 2030.	
Acidification	CLE	In 2005, 12 % (160 000 km ²) of the forests in the EU were subject to critical loads for acidification. SO ₂ reduction is expected to result in a reduction of this area by another 110 000 km ² in 2025.	Achieved
	MTR	Additional measures could save another 30 000 km ² of forest from acidification; only 1.4 % of the EU forest would remain threatened.	

Source: IIASA, 2014a

5.2.1. TSAP 2013 baseline scenario 2005 - 2020

The baseline scenario has been developed by incorporating the most recent data and projections available on EU level. It gives projections by assuming a future business-as-usual situation⁴⁰ in the EU 28. The baseline scenario has been designed in line with the PRIMES Reference energy scenario 2013⁴¹ and is based on the CAPRI⁴² model for the agricultural sector. The analytical background and the assumptions used in this scenario are consistent with the underlying scenarios for the 2030 Energy and Climate Package⁴³, taking into account national and EU policies adopted before spring 2012. The PRIMES Reference scenario 2013 follows the assumptions of the Roadmap for moving to a low-carbon economy in 2050⁴⁴.

The GAINS model considers emissions, mitigation potentials and costs for air pollutants (SO₂, NO_x, PM, NH₃ and VOC) and greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆) to allow for an analysis of their impact on human health and the environment and for an identification of cost-optimal reduction strategies for given environmental targets.

For the underlying main assumptions see Annex 2.

5.2.2. Current legislation scenario

The Current Legislation scenario (CLE) is the extension of the TSAP baseline scenario for the time horizon 2020-2030. It assumes that EU-wide national emission control legislation will be fully adopted by all Member States according to the foreseen schedule (list of legislation considered: see Annex 2). Other legislation whose effects on future air quality impacts cannot be quantified as yet due to uncertainties about the measures that will be implemented is not considered in the projection scenario (e.g. compliance with air quality standards for PM, NO₂ and ozone in the AAQD).

The CLE scenario does not take new policies into account; this implies that all existing limit values, reduction commitments etc. will not change: the AAQD will remain in place; the NECD will only include the new requirements agreed in the Gothenburg Protocol 2012.

Under the CLE scenario 8.9 million people are expected to live within air quality zones where NO₂ standards (both WHO and AAQD) will be exceeded in 2030. About 65 % of the monitoring stations would exceed the WHO guideline for PM_{2.5} (EC 2013a).

5.2.3. Maximum technically feasible reduction scenario

The Maximum Technically Feasible Reduction scenario (MTFR) considers, in addition to the CLE scenario, all technically feasible measures that are available on the market. The scenario focuses only on (technical) measures and does not assume changes in energy structures or behavioural changes of the consumers. Premature scrapping is not assumed under this scenario, old technical equipment will be substituted only when the operational life time is over. With a view to complex interactions, the policy assumptions underlying the CLE assumptions have not been changed either, despite the fact that changes in policies could lead to additional emission reductions. Therefore, this is a conservative scenario, limited to technical measures.

Under the MTFR scenario 8.1 million people are expected to live within air quality zones where NO₂ standards (both WHO and AAQD) will be exceeded in 2030. About 40 % of the monitoring stations would exceed the WHO guideline for PM_{2.5} (EC 2013a).

⁴⁰ It is synonymous for Option 1 "No further EU action" of the Impact assessment (EC 2013a).

⁴¹ http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2050_update_2013.pdf.

⁴² Common Agricultural Policy Regionalised Impact.

⁴³ http://ec.europa.eu/clima/policies/2030/index_en.htm.

⁴⁴ http://ec.europa.eu/clima/policies/roadmap/index_en.htm.

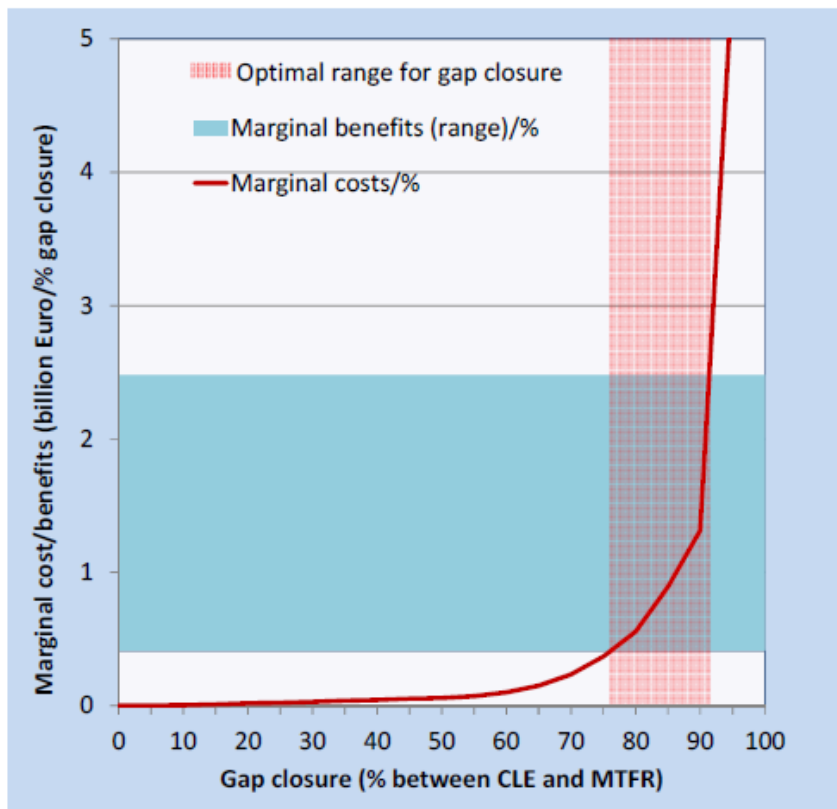
5.3. 'Gap-closure' and cost-benefit analysis of intermediate measures

This section shows which considerations have led to the final scenario chosen by the European Commission. The approach described in the TSAP 2013 (to set new targets) is a gap-closure approach⁴⁵ which aims to reduce the gap between the CLE scenario and the MTRF scenario. This gap-closure approach incorporates a cost-benefit analysis in order to approximate the point where marginal health benefits are equal to marginal pollution control costs (Figure 13). As there are many different parameters for health impacts it is difficult to identify a single reduction objective that covers all impacts EU-wide. Therefore, the EU-wide long-term health effects of PM_{2.5}, namely mortality due to PM_{2.5} exposure (expressed as Years of Life Lost, YOLL), have been used to create sub-scenarios for analysing the costs and benefits. Non-health benefits could not be expressed in monetary terms.

Figure 13 demonstrates that the point where marginal costs and benefits intersect, which is the theoretical economic optimum, lies between 76 % and 92 %, depending on the methodology used for assessment. The most conservative point in the optimal range can be found at a 76 % gap closure between CLE and MTRF, which matches with scenario 6C (75 % gap closure). This implies that scenario 6C is the least expensive option in the optimal range, but also with the fewest benefits compared to other options in the optimal range. The emission reduction cost of 6C (on top of current legislation) would amount to EUR 4.5 billion per year, and the health benefits are estimated to be about EUR 44 billion per year. (Under the CLE about 88 billion EUR/year will be spent.)

The marginal benefit amounts to EUR 424 million per additional percent of gap closed.

Figure 13: Optimal range for gap closure of EU-wide YOLL indicator in 2025



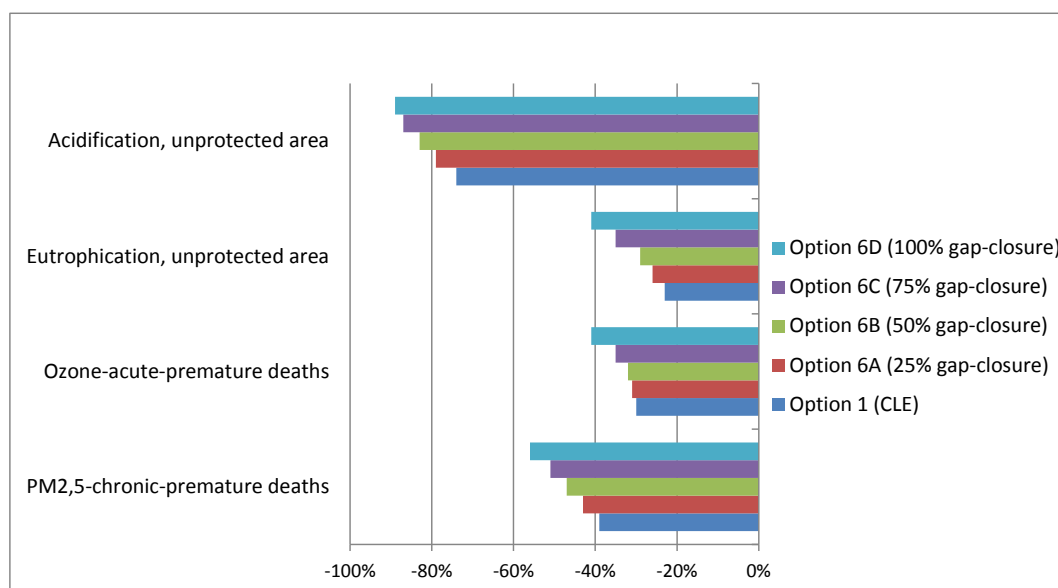
Source: IIASA, 2014a

⁴⁵ A '75 %-gap-closure scenario' implicates that the scenario would achieve 75 % of the benefits presented in the MTRF scenario.

In comparison, the cost of implementing the measures indicated in the MTFR scenario would amount to an additional EUR 47 billion per year in 2025. It can be concluded from the cost benefit analysis that at only 10 % of these costs, 75 % of the health improvements shown in the MTFR can be achieved and that the health benefits achieved with most of the measures are, in general, higher than the costs. It is noticeable that even in the MTFR the costs only exceed the lowest estimate of the expected range of health benefits.

With regard to the impacts of air pollution (Figure 14), the largest reductions achieved in 2030 are the reduction of acidification in unprotected areas (-74 % to -80 %) followed by the reduction in premature deaths from chronic disease due to PM_{2.5} (-39 % to -56 %).

Figure 14: Change of the impact indicators of air pollution in 2030 compared to 2005 levels



Source: EC 2013a

5.4. Sensitivity analyses and selection of a final option

To investigate different ambition levels around the optimal range, a series of further optimisations have been carried out to analyse sector-specific emission control costs. The largest share of costs falls under the domestic sector, followed by agriculture.

A 70 %-gap closure sub-scenario has been agreed by the college of the European Commission although it is not within the optimal range. It shows advantages compared to the optimal scenario (6C)⁴⁶ for mainly two reasons: The 70 % scenario decreases the overall costs for air pollution control by 25 % and reduces the financial burden for the domestic sector (which would have faced the strongest cost increases compared to other sectors). The health benefits are estimated at EUR 40 billion per year in 2030, while at the same time costs amounting to EUR 3.3 billion per year would arise, corresponding to an increase of +4 % compared to the CLE scenario.

⁴⁶ It should be noted that the final scenario B6 represents the most cost-effective solution for a 70 % scenario when looking at the EU-wide YOLL indicator. The 70 % scenario relates to 2025. However, the ceilings for the new NECD are aimed at 2030. Therefore, the marginal costs of the 70 % scenario for 2025 were used to determine the overall ambition level for 2030, resulting in a 67 % gap closure for 2030.

Based on this scenario for 2030, the European Commission set emission ceilings for 2030. A linear reduction trajectory between the emission levels for 2020 and those defined for 2030 has been established in the proposed new NECD.

The key results of the scenario for 2030 are summarised below:

Table 8: Key results for 2030 of the proposed scenario

Reduction of impacts		Reduction of emissions	
PM _{2.5} health impacts	-50 %	PM _{2.5}	-51 %
O ₃ health impacts	-33 %	SO ₂	-81 %
Acidification (unprotected area)	-85 %	NO _x	-69 %
Eutrophication (unprotected area)	-35 %	NH ₃	-27 %
		VOC	-50 %

Source: EC 2013a

The costs would amount to 0.02 % of GDP annually.

The scenarios of the Commission's impact assessment that provide the basis of the proposed new NECD do not consider the additional health benefits resulting from the EU climate policy target 2030 which would have positive side-effects on air pollution. Synergies with climate policy targets are also expected to reduce the costs for achieving the air pollution ceilings (e.g. structural changes in the energy system such as the reduction of coal use). In addition, it should be noted that abatement measures and health benefits also have positive side-effects on the economy (e.g. creation of new jobs or healthy employees) and could further reduce health expenditure (in relation to GDP).

5.5. Conclusions

The proposal for a new NECD achieves considerable positive impacts on human health and the environment by substantially reducing emissions of air pollutants. The benefits of these improvements of health by far exceed the costs of additional abatement measures. Therefore, the proposal is well justified. However, compliance with WHO guidelines for PM_{2.5} and ozone will be still out of reach.

For PM_{2.5}, various sources – some of them difficult to abate – will still contribute to elevated levels. Not only primary PM emissions have to be abated, but also various sources contributing to precursors of secondary organic (precursor: NMVOCs) and inorganic aerosols (precursors: SO₂, NO_x and NH₃). Also the relative importance of different sources will vary: The share of combustion emissions from traffic will decline, while the relative importance of agriculture and biomass burning in the domestic sector will rise. In addition, emission densities are high in many parts of Europe due to industrial, economic and agricultural activities and high population and traffic densities. The atmospheric lifetime is large enough that PM remains in the atmosphere for several days and can accumulate during winter episodes.

For ozone, the importance of hemispheric background levels is increasing and therefore, in order to further decrease the levels of this pollutant in Europe⁴⁷, measures within the EU and internationally will need to go hand in hand.

Current modelling results – while highly uncertain for the timespan after 2030 – suggest that additional structural changes are required to achieve substantial further emission reductions. Compliance with WHO guidelines might thereby be achieved until 2050. However, before 2030, health impacts and interferences with other policies (in particular climate change, agriculture and energy) should be reassessed. In addition, breakthrough technologies which allow for faster reductions could become available. The currently applied models also have shortcomings in analysing the effects of lifestyle and behavioural changes such as a shift to vegetarian diets, which might open further options for emission reductions.

⁴⁷ NO_x emissions reductions within cities might even increase urbane ozone levels due to reduced titration of ozone by primarily emitted NO.

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ANNEX 1: WHO AIR QUALITY GUIDELINES AND CURRENT EU AQ STANDARDS

WHO air quality guidelines

The table below shows the interim targets and the WHO air quality guideline for the annual mean PM_{2.5} levels.

Table 9: Air quality guideline (AQG) and interim targets for PM_{2.5}: annual mean

WHO PM _{2.5} AQG	Annual mean level [µg/m ³]	Basis for selected level
WHO interim target 1 (IT-1)	35	15 % higher long-term mortality risk than at AQG level
WHO interim target 2 (IT-2)	25	Appr. 6 % (2 %-11 %) lower risk of premature mortality than IT-1
WHO interim target 3 (IT-3)	15	Appr. another 6 % (2 %-11 %) lower risk of premature mortality than IT-2
WHO air quality guidelines (AQG)	10	Lowest level at which cardiopulmonary and lung cancer mortality have been shown to increase

Source: WHO 2006

The table below shows the interim targets and the WHO air quality guideline for the 24-hour mean PM_{2.5} levels.

Table 10: Air quality guideline and interim targets for PM_{2.5}: 24-hour mean

WHO PM _{2.5} AQG	24-hour mean level* [µg/m ³]	Basis for selected level
WHO interim target 1 (IT-1)	75	Based on published risk coefficients (about 5 % increase in short-term mortality)
WHO interim target 2 (IT-2)	50	Based on published risk coefficients (about 2.5 % increase in short-term mortality)
WHO interim target 3 (IT-3)	37.5	About 1.2 % increase in short-term mortality
WHO air quality guidelines (AQG)	25	Based on relationship between 24-hour and annual PM levels

* 99th percentile (3 days/year)

Source: WHO 2006

Table 11: Air quality guideline and interim targets for PM₁₀: annual mean

WHO PM ₁₀ AQG	Annual mean level [µg/m ³]	Basis for selected level
WHO interim target 1 (IT-1)	70	15 % higher long-term mortality risk than at AQG level
WHO interim target 2 (IT-2)	50	Appr. 6 % (2 %-11 %) lower risk of premature mortality than IT-1
WHO interim target 3 (IT-3)	30	Appr. another 6 % (2 %-11 %) lower risk of premature mortality than IT-2
WHO air quality guidelines (AQG)	20	Lowest level at which cardiopulmonary and lung cancer mortality have been shown to increase

Source: WHO 2006

Table 12: Air quality guideline and interim targets for PM₁₀: 24-hour mean

WHO PM ₁₀ AQG	24-hour mean level* [µg/m ³]	Basis for selected level
WHO interim target 1 (IT-1)	150	Based on published risk coefficients (about 5 % increase in short-term mortality)
WHO interim target 2 (IT-2)	100	Based on published risk coefficients (about 2.5 % increase in short-term mortality)
WHO interim target 3 (IT-3)	75	About 1.2 % increase in short-term mortality
WHO air quality guidelines (AQG)	50	Based on relationship between 24-hour and annual PM levels

* 99th percentile (3 days/year)

Source: WHO 2006

Table 13: Air quality guideline and interim targets for ozone: Daily maximum 8-hour mean

WHO O ₃ AQG	Daily max. 8-h mean [µg/m ³]	Effects at the selected level
High level	240	Significant health effects for substantial proportion of vulnerable populations
WHO interim target 1 (IT-1)	160	Important health effects; no adequate protection (3-5 % increase in daily mortality)
WHO air quality guideline	100	Adequate protection but some health effects may occur (1-2 % increase in daily mortality)

Source: WHO 2006

Table 14: Air quality guidelines for NO₂

Averaging period	WHO AQG for NO ₂
1 hour mean	200 µg/m ³
Annual mean	40 µg/m ³

Source: WHO 2006

Current EU air quality regulatory standards

The following tables show the current regulatory standards in the EU for PM, NO₂ and O₃.

Table 15: Limit values for PM₁₀ for the protection of human health

Averaging period	Limit value
One day	50 µg/m ³ not be exceeded more than 35 times a calendar year
Calendar year	40 µg/m ³

Source: Ambient Air Quality Directive 2008/50/EC

Table 16: National exposure reduction target for PM_{2.5} (to be met in 2020)

Initial concentration in µg/m ³	Reduction target in percent
< 8,5 = 8,5	0 %
> 8,5 — < 13	10 %
= 13 — < 18	15 %
= 18 — < 22	20 %
≥ 22	All appropriate measures to achieve 18 µg/m ³

Source: Ambient Air Quality Directive 2008/50/EC

Table 17: PM_{2.5} Exposure concentration obligation (to be met in 2015)

20 µg/m³

Source: Ambient Air Quality Directive 2008/50/EC

Table 18: Target value for the annual mean of PM_{2.5} (to be met in 2010)

25 µg/m³

Source: Ambient Air Quality Directive 2008/50/EC

Table 19: Limit value for the annual mean of PM_{2.5}

Limit value	Margin of tolerance	Date by which limit value has to be met
Stage 1		
25 µg/m ³	20 % on 11 June 2008, decreasing on the next 1 January and every 12 months thereafter by equal annual percentages to reach 0 % by 1 January 2015	1 January 2015
Stage 2 ⁽¹⁾		
20 µg/m ³		1 January 2020

⁽¹⁾ Stage 2 — indicative limit value to be reviewed by the Commission in 2013 in the light of further information on health and environmental effects, technical feasibility and experience of the target value in Member States.

Source: Ambient Air Quality Directive 2008/50/EC

Table 20: Limit values for NO₂ for the protection of human health (to be met in 2010)

Averaging period	Limit value
One hour	200 µg/m ³ not be exceeded more than 18 times a calendar year
Calendar year	40 µg/m ³

Source: Ambient Air Quality Directive 2008/50/EC

Table 21: Target values for O₃ for the protection of human health (to be met in 2010)

Averaging period	Target value
Maximum daily eight-hour mean	120 µg/m ³ not to be exceeded on more than 25 days per calendar year averaged over three years

Source: Ambient Air Quality Directive 2008/50/EC

Table 22: Long-term objective for O₃ for the protection of human health (achievement date not defined)

Averaging period	Target value
Maximum daily eight-hour mean	120 µg/m ³

Source: Ambient Air Quality Directive 2008/50/EC

ANNEX 2: DETAILS ON SCENARIOS

Main assumptions on key parameters for the baselines scenario

Table 23: Main assumptions on key parameters for the baseline scenario

Key parameters	Assumptions
Population	<ul style="list-style-type: none"> Slightly rising fertility rates Further life expectancy gains Decelerating inward net migration to the EU Average population growth rate: 6 % over the period to 2030 (compared to 2005) <p>Source: Eurostat population projections</p>
GDP	<ul style="list-style-type: none"> Recovery from economic crisis Steady GDP growth rates: 1.6 % per year from 2015-2030 Recovery of industrial sector: shift from mass production to higher value added products Recovery and slow growth of energy-intensive industries <p>Source: DG ECFIN</p>
Energy prices	<ul style="list-style-type: none"> Steady increase in oil and coal prices Gas prices decoupling from oil prices and rising to a lower extent Increasing reserves of oil and gas <p>Source: Eurostat</p>
Policies and measures	<ul style="list-style-type: none"> Consideration of all policies and measures adopted by MS in or before 2012 At EU level consideration of all policies and measures adopted or agreed in or before the first half of 2012

Source: IIASA, 2014a

The overall uncertainties in these scenarios and underlying the Commission's proposal are as follows:

- Validity of the projections for the energy scenario and the underlying assumptions for the main drivers;
- Technological developments;
- Synergies and interactions with climate and energy policies;
- Development and implementation of policies in the sectors energy transport, agriculture and international shipping.

List of legislation considered in the CLE Scenario

Legislations considered for CH₄ emissions:

- EU Landfill Directive (EC/31/1999);
- EU Waste Management Framework Directive (EC/98/2008);
- Ban on landfill of biodegradable waste in Austria, Belgium, Denmark, Germany, Netherlands, Sweden;
- EU urban wastewater treatment directive (EEC/271/1991);
- National legislation and national practices (e.g., the subsidy scheme for renewable energy in the Netherlands).

Legislation considered for SO₂ 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).

Legislation considered for NO_x emissions⁴⁸:

- 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;

⁴⁸ NO_x from transport: all emissions are assumed to be 1.5 times higher than the Euro 6 limit value from 2017 onwards. Therefore the real world driving emissions amount 120 mg instead of 80 mg/km.

- MARPOL Annex VI revisions from MEPC57 regarding emission NO_x limit values for ships;
- National legislation and national practices (if stricter).

Legislation considered for PM₁₀/PM_{2.5} 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).

Legislation considered for NH₃ 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).

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).

Population affected of PM₁₀ limit values exceedances under the CLE and MTR scenario

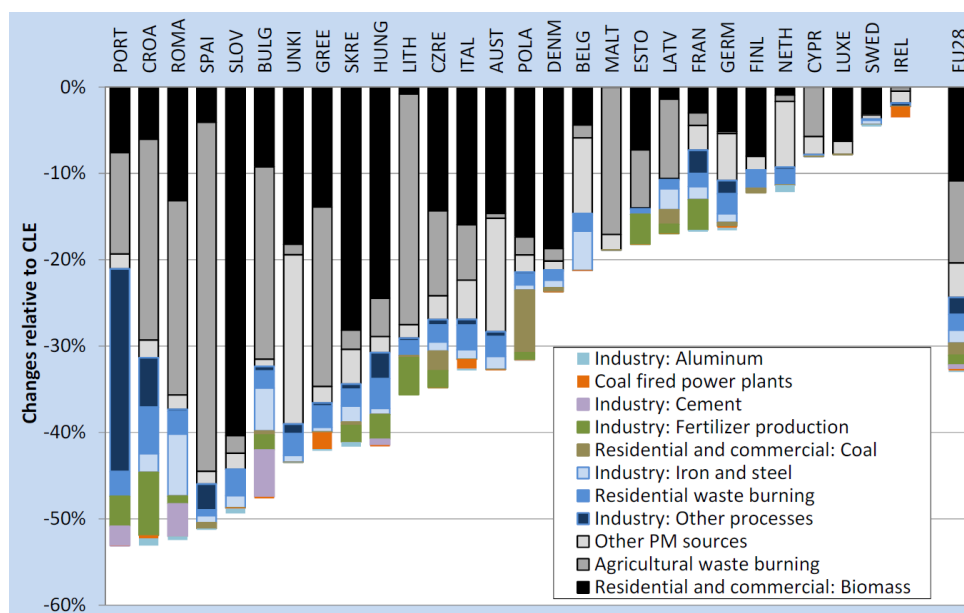
Table 24: Population living in air quality management zones with different compliance categories for PM₁₀ limit values (million people, % of European population)

	Compliance category					
	Unlikely	Uncertain	Likely	Unlikely	Uncertain	Likely
	Million people			% of European population		
2010	80.8	128.6	211.4	19 %	31 %	50 %
2020	47.8	75.9	297.1	11 %	18 %	71 %
2025	31.3	77.2	312.2	7 %	18 %	74 %
2030	12.9	52.4	355.5	3 %	12 %	84 %
MTR	2.5	30	388.2	1 %	7 %	92 %

Source: IIASA 2014a

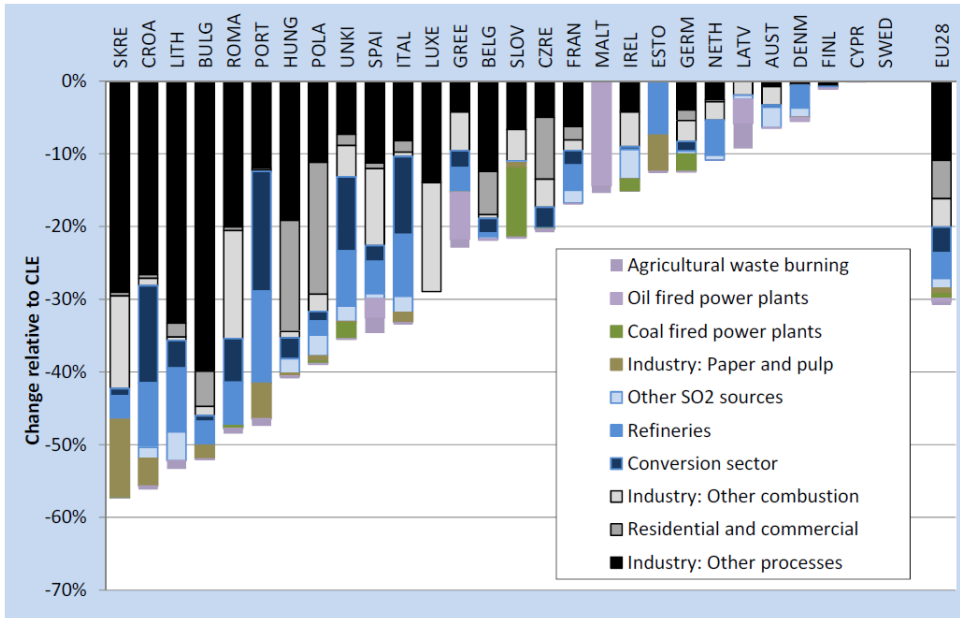
Emission reductions per sector and Member State

Figure 15: Further reductions of PM_{2.5} emissions (beyond the baseline) of the B7 scenario, relative to baseline



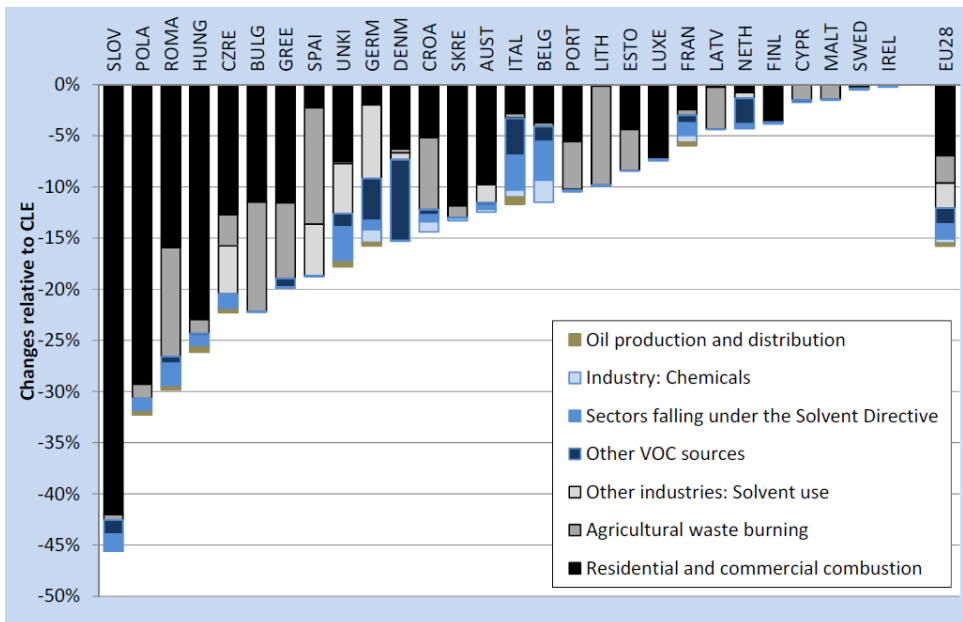
Source: IIASA 2014a

Figure 16: Further reductions of SO₂ emissions (beyond the baseline) of the B7 scenario, relative to baseline emissions



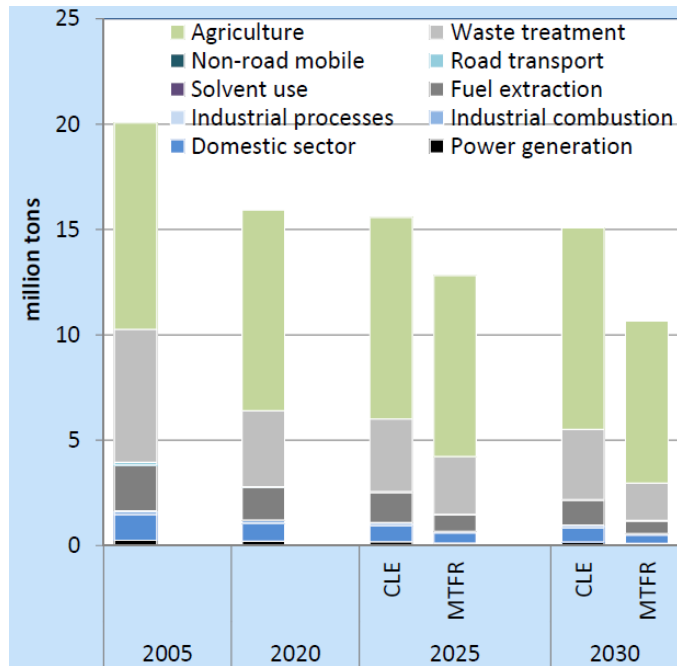
Source: IIASA 2014a

Figure 17: Further reductions of VOC emissions (beyond the baseline) of the B7 scenario, relative to baseline emissions



Source: IIASA 2014a

Figure 18 CH₄ emissions of the TSAP 2013 Baseline; Current legislation (CLE) and Maximum Technically Feasible Reductions (MTFR), EU 28



Source: IIASA 2014a

Emission reductions and drivers of the CLE and MTFR scenario

The following table summarises the emission reductions expected in 2025 and 2030 under the two scenarios (CLE and MTFR) for each air pollutant. The table further provides a short summary of the underlying drivers, or additional explanations.

Table 25: Emission reductions by 2025 and 2030 in the CLE and MTR scenarios

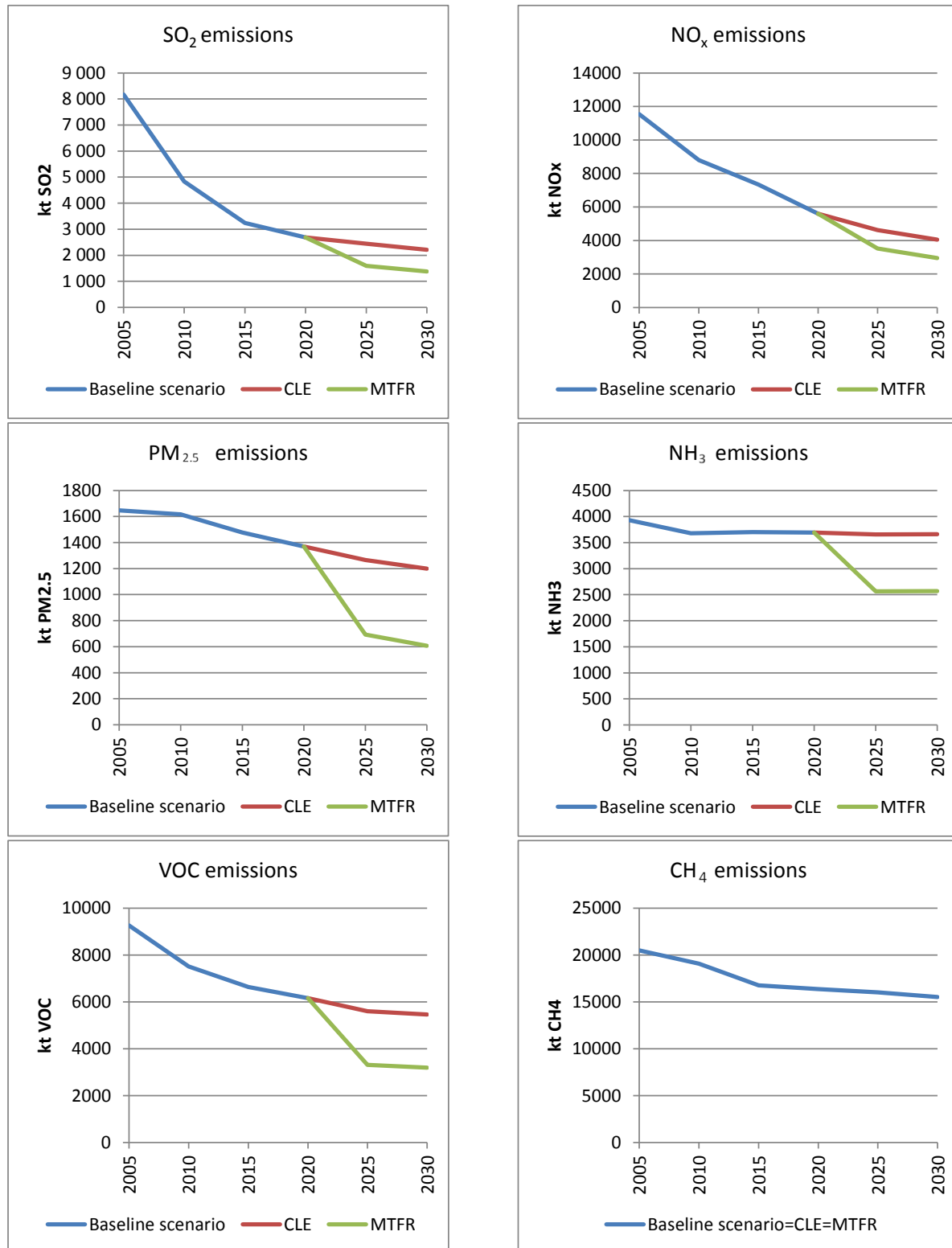
Pollutant	Trend expected by 2025/2030 compared to 2005 levels		
	Emission reduction		Explanation/Drivers
SO ₂	CLE	2025: -70 % 2030: -73 %	<ul style="list-style-type: none"> Main reductions in the power sector through structural changes in the energy system Progressive implementation of air quality legislation
	MTR	2025: -81 % 2030: -83 %	
NO _x	CLE	2025: -60 % 2030: -65 %	<ul style="list-style-type: none"> Main reductions in the power sector Implementation of Euro 6 standards for road vehicles
	MTR	2025: -69 % 2030: -74 %	
PM _{2.5}	CLE	2025: -23 % (whereas -65 % from mobile sources through diesel filters, -17 % in the domestic sector) 2030: -27 %	<ul style="list-style-type: none"> Progressive introduction of diesel particle filters from mobile sources Stationary sources in the domestic sector are the critical emissions, depending on the use of solid fuels (fossil and biomass) and on the introduction of new stoves, stricter product standards could lead to -65 % emission reductions in the domestic sector
	MTR	2025: -58 % 2030: -63 %	
NH ₃	CLE	2025: -7 % 2030: -7 %	<ul style="list-style-type: none"> NH₃ emissions fall mainly under the scope of agricultural emission control where the limits are too weak, only a small amount can be regulated by legislation for road transport Absence of emission control legislation in the agricultural sector, MTR includes EU-wide emission control measures
	MTR	2025: -35 % 2030: -35 %	
VOC	CLE	2025: -39 % 2030: -41 %	<ul style="list-style-type: none"> VOC emissions are strongly dominated by mobile sources Implementation of Euro standards expected to significantly reduce emissions
	MTR	2025: -64 % 2030: -66 %	
CH ₄		2025: -22 % 2030: -25 %	<ul style="list-style-type: none"> Emissions half from agriculture, half from other sectors such as waste Emissions expected to decline as a result of measures in the waste sector Only modest decrease in the agriculture sector

Source: IIASA, 2014a

Emission trends under the CLE and MTR scenario

From these graphs it can be seen that in the case of the PM_{2.5}, NH₃ and VOC emissions, the MTR scenario shows substantially lower emissions than the CLE scenario. For SO₂ and NO_x the reduction potential is relatively smaller.

Figure 19: Emission trends of air pollutants for the CLE and MTR scenario



Source: IIASA, 2014a

Costs and benefits of different scenarios

The costs of all scenarios reflected in this report are summarised in Table 26 below.

Table 26: Summary of the costs and benefits for all options and the sensitivity analysis for 2025

Options	Cost (billion EUR per year)	% of GDP	Net health benefits (billion EUR per year) ⁴⁹
Option 1 (CLE)	88		
6A	+0.2 (in addition to option 1)	0.002 %	14.4 – 49.2
6B	+1.2	0.008 %	28.7 – 99.3
6C	+4.6	0.032 %	43.2 – 148.8
6D (MTFR)	+47	0.324 %	58.0 – 198.4
Sensitivity analysis scenarios			
65 %	+2.5	0.017 %	
70 %	+3.3	0.023 %	
75 %	+4.6	0.032 %	
80 %	+6.6	0.046 %	
85 %	+9.7	0.067 %	

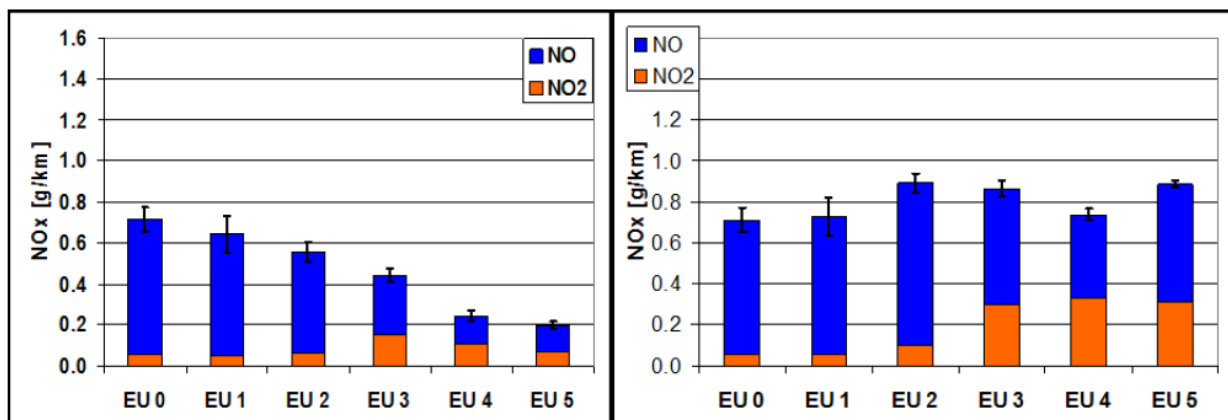
Source: IIASA 2014a; EMRC 2014

⁴⁹ Net health benefits were evaluated using two different approaches: VSL (Value of Statistical Life) and VOLY (Value of a Life Year). The estimates given in this table include ranges from the total core median VOLY (lowest), core mean VOLY, core medium VSL and core mean VSL (highest).

ANNEX 3: NO_x EMISSIONS IN TYPE APPROVAL TESTS VS. REAL WORLD EMISSIONS

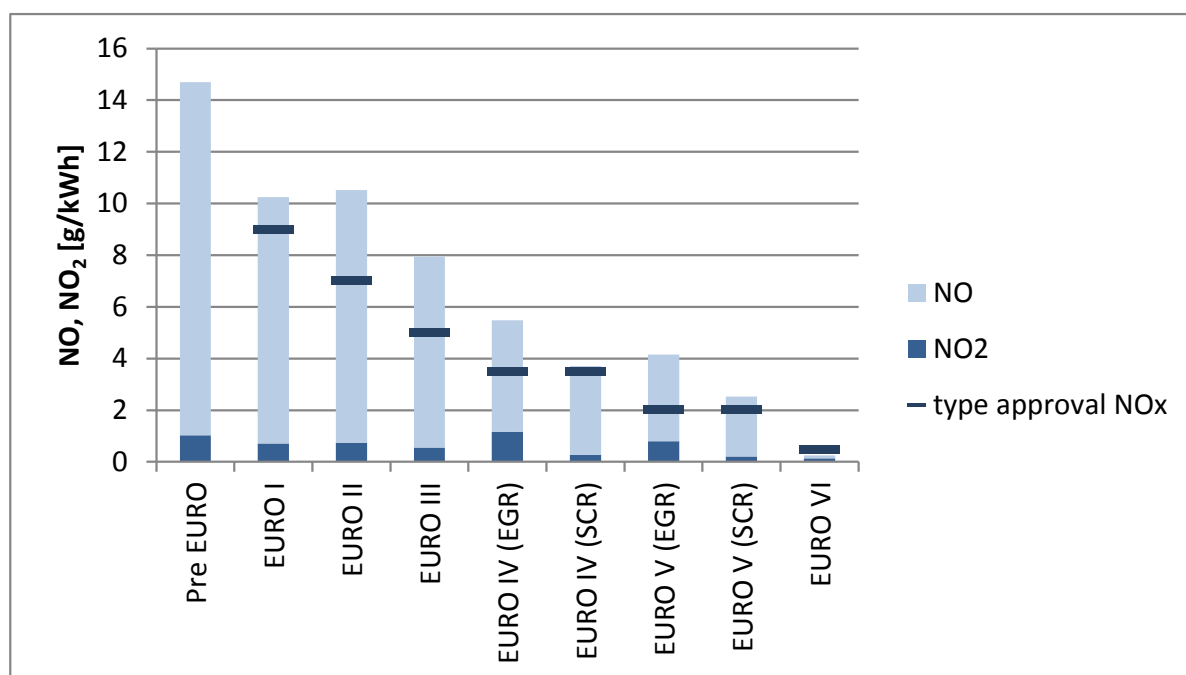
As described in a recent study, which analysed the reasons for non-compliance with the NECD, the discrepancy between type approval tests and real world emissions of diesel vehicles are one of the major reasons (ECORYS 2014). This relates to passenger cars (PC), light duty vehicles (LDV) and partly also to heavy duty vehicles (HDV). Figure 20 shows this comparison for PC and LDV, Figure 21 for a trailer truck as an example.

Figure 20: Type approval (left) and real-world emissions (right) from diesel light duty vehicles across Euro standards



Source: EC 2013a, COPERT

Figure 21: Type approval and real-world NO_x emissions from a trailer truck as an example across Euro standards



Example for a trailer truck, 50 % load, weighted mix of urban, rural and motorway driving situations

Source: HBEFA 3.2, TU-Graz

The reasons for the discrepancies were analysed in more detail for CO₂; however, the results are partly valid for NO_x emissions as well. From a technical point of view the main reasons for PC and LDV are (ICCT 2013; TU-Graz 2013; Umweltbundesamt 2008):

- The characteristics of the NEDC test cycle are not representative for real-life driving behaviour (low accelerations, low maximum speed, etc.);
- The test cycle is limited to 120 km/h. Above that speed especially large diesel PC such as Sport Utility Vehicles (SUVs) are controlled to reduce fuel consumption, leading to higher NO_x emissions;
- Cold start testing is performed at ambient temperatures close to 30 °C;
- At the type approval test the battery is charged to 100 % capacity;
- The weight of the test vehicle is lower than the real-life average;
- Air conditioning is turned off during the test.

The underlying non-technical reasons are more difficult to grasp and are partly anecdotal as no comprehensive analysis is available:

- The NEDC is based on regulations dating back to 1970 and 1990 (UNECE 2013). At this time vehicles were lighter, less powerful and mainly gasoline driven;
- Test cycles are developed on an international level by UNECE World Forum for Harmonization of Vehicle Regulations (WP 29)⁵⁰; negotiations therefore take several years in general;
- The regulations are complex to account for different circumstances. It thus requires a certain technical expertise that is often available only within car manufacturers.

This issue has been raised by high level group (CARS2020)⁵¹ and is reflected in the EU Commission work programme. It has also been addressed in an impact assessment which was carried out for the Clean Air Policy Package⁵.

Measures to align real world performance and type approval limit values are summarised by the European Commission under the heading "In-Service Conformity".

For commercial vehicles/heavy duty vehicles, the use of portable emission measurement systems (PEMS⁵²) is already required by the Euro VI standards (Regulation (EU) 582/2011).

Testing is conducted under a mix of urban (0-50 km/h), rural (50-75 km/h) and motorway (> 75 km/h) conditions, with the exact percentages of these conditions depending on the vehicle category showing compliance with type approval values, while allowing for a certain conformity factor.

PEMS measurements for cars and light duty vehicles will also be implemented in Euro 6 legislation under the term "RDE" ("Real Driving Emissions"). The form and scope of these measurements, as well as their evaluation are currently being discussed at European level, and they will serve the same purpose as for heavy duty vehicles. Additionally, the Commission is planning to implement a new type approval cycle called "World light vehicles test protocol (WLTP^{53, 54}) for these vehicle types to replace the current New European Driving Cycle (NEDC).

⁵⁰ http://www.unece.org/trans/main/wp29/meeting_docs_wp29.html.

⁵¹ <http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52012DC0636&from=EN>.

⁵² <http://iet.jrc.ec.europa.eu/pems/portable-emissions-measurement-systems-pems>.

⁵³ <https://www.dieselnet.com/standards/cycles/wltp.php>.

⁵⁴ http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/wltp_dhc11.html.

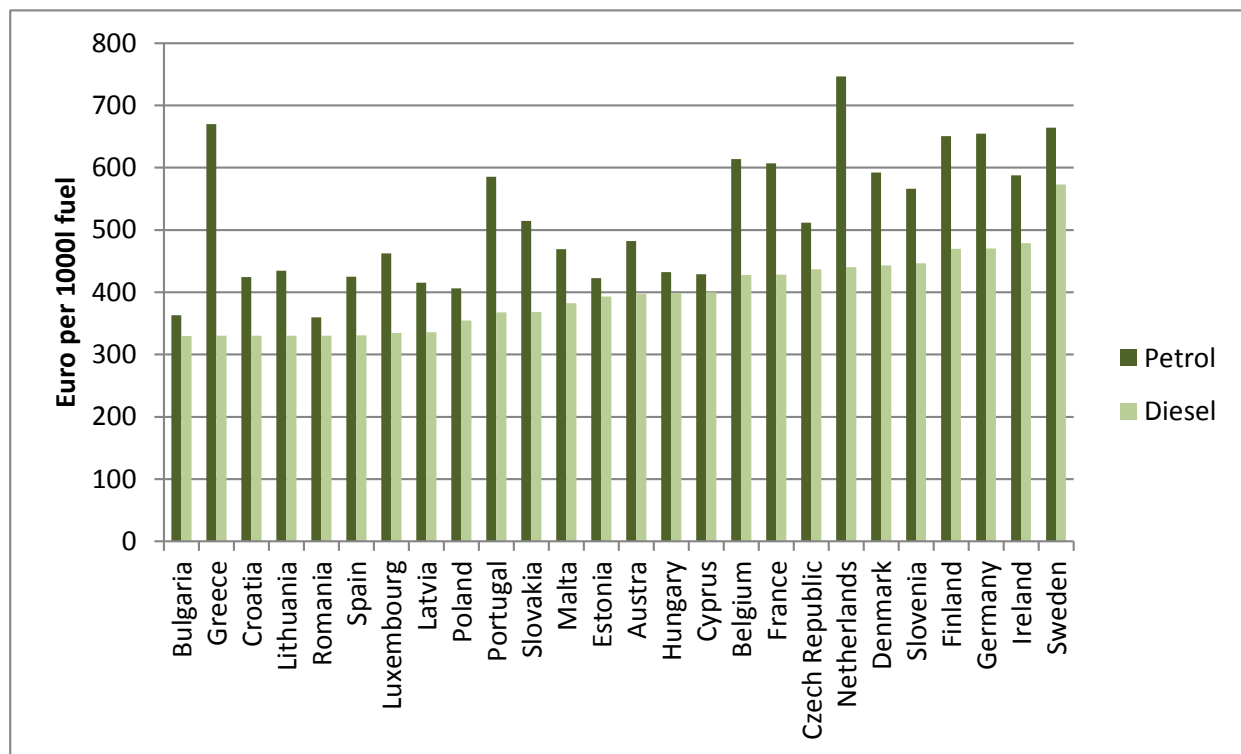
ANNEX 4: ADDITIONAL INFORMATION ON CASE STUDIES

Table 27: NO_x emission ceilings and actual emissions in Germany and Luxembourg (in kt)

	Germany	Luxembourg
2010 ceiling	1051	11
2010 emissions	1328	17.9
2011 emissions	1294	17.7
2012 emissions	1273	17.1

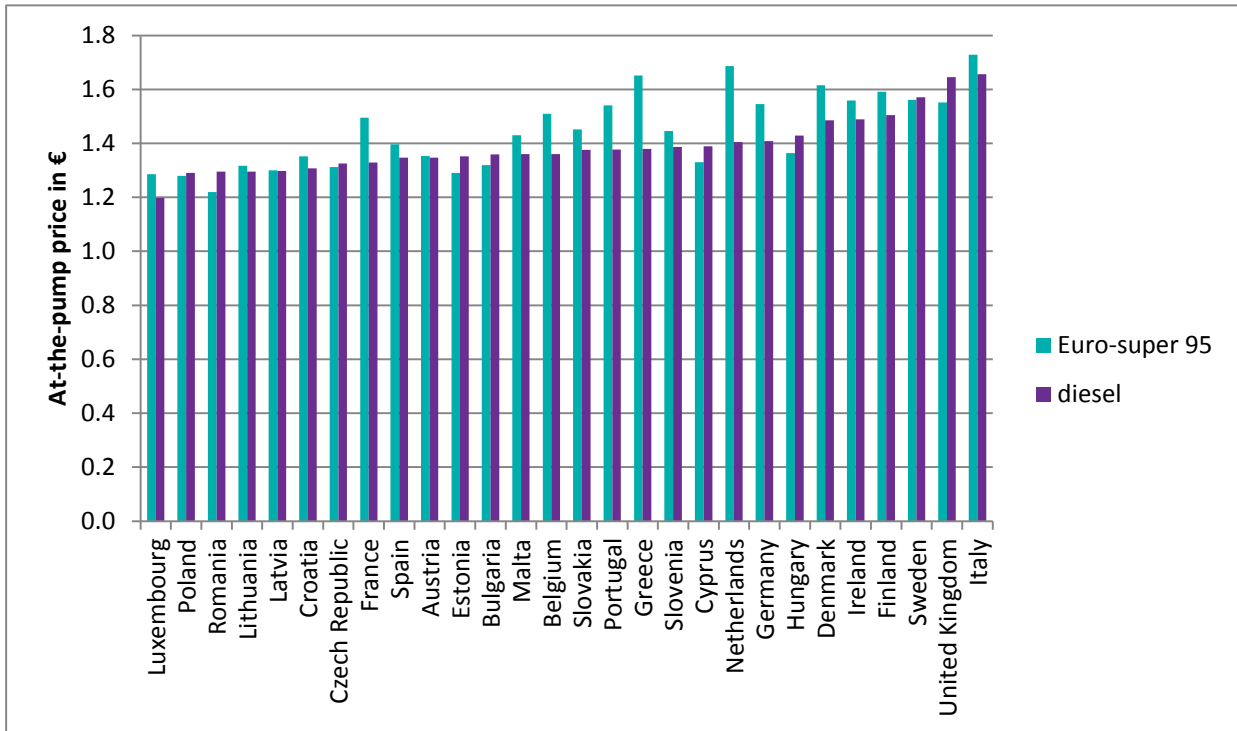
Source: EEA 2014a

Figure 22: Road fuel excise duties



Source: EEA, <http://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-3>

Figure 23: Consumer prices of petroleum products in EU 28 (end of second half of 2013)



Source: Eurostat, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Energy_price_statistics

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