Convention on Long-Range Transboundary Air Pollution

Assessment Report 2016

Draft 3 September 2015

Contents

Document status

Comments received up to 2 September have been included

To do:

- Text has to be shortened:
  - Focus on scientific findings; less description of methodology and internal CLRTAP organisational issues
  - Assessment Report, WGE-trend report and Batumi report of CEP-chair & secretariat should be made consistent, complementary with minimum overlap
- Text has to be completed:
  - Edit and streamline text
  - Include short introduction to the report, reasons why, etc (RM/PG)
  - Include analysis of avoided scenario of continued pollution growth 1980-2015 (CIAM/MSC-W)
  - Improve text on long term perspective & sustainable development
  - Include more info on challenges and options for North America
  - Include annex with country emission data 1980-2030 (CEIP/CIAM)
  - Prioritize figures to be professionally produced
  - Include missing references and figures

Main points

1. More than 98% of the urban population in Europe is exposed to concentrations of fine particles (PM2.5) and ozone above the WHO guideline level. The current number of premature deaths associated with air pollution (nearly 600 000 within the UNECE region) is 10 times higher than the number of lethal traffic accidents. The costs for industry of absence from work due to air pollution, is higher than the cost of abatement measures.

2. International coordination of air pollution policy remains indispensable, as a substantial part of health and ecosystem impacts is caused by transboundary transport of pollutants. Effective reduction of the PM2.5 exposure of the urban population requires emission reductions of precursor emissions in a wider area: especially further reduction of ammonia is cost-effective.

3. Excess deposition of nitrogen is a major cause of the loss of red list species. It stimulates dominant species such as grasses, bushes, algae and nettle. Reducing emissions of ammonia and nitrogen oxides is more cost effective than additional nature management to protect threatened species. Cost-effective ammonia measures would only affect the 3% largest livestock farms in Europe.

4. Current ozone concentrations reduce potential wood and crop production in Europe by 15%. Background concentrations of ozone, mercury and several persistent organic pollutants in Europe and North America are influenced significantly by emissions outside these continents. Reduction of background concentrations in Europe and North America therefore needs scientific and policy collaboration across the Northern Hemisphere, e.g. in order to identify cost-effective abatement options of precursor emissions of ozone (including methane).

5. Climate policy and air pollution policy cannot be seen separately. Energy savings and shifts in the energy mix have contributed to cleaner air and will continue to be important in the coming decades. However, promoting the use of biomass and biofuels could increase air pollution. Emission reduction of black carbon (e.g. from diesel and inefficient stoves) and methane can limit the speed of temperature increase in the next decades.

6. The net impact of abatement measures on national income and employment will be neutral as production of the technologies required, also create employment.

7. Ratification of CLRTAP protocols will enable an international level playing field for industries and prevent that countries will compete with each other at the expense of environment and health within free trade zones.

8. Air pollution control is linked to several sustainable development targets, promoting e.g. healthy lives and well-being, sustainable energy, safe and sustainable cities and protection of ecosystems.

A. Where are we?

A1. Health impacts of particulate matter

Marie-Eve Héroux; Contributors: Markus Amann, Bill Harnett and colleagues, HC Hanson, Till Spanger, Eli-Marie Asen, Ivan Angelov

Reduction of emissions and the exposure of the population to particulate matter has increased the average life expectancy in Europe by almost 3.5 months between 2000 and 2010. But still in 2012, almost 600 000 premature deaths related to ambient air pollution were estimated in the UNECE region. The majority of these are due to exposure to particulate matter (PM). PM concentrations in 2005 were estimated to lead to an average loss of life expectancy of 8.3 months. In many cities, however, the loss in life expectancy from air pollution remains significantly higher than this average. Furthermore, in some areas such as Eastern Europe, the Caucasus and Central Asia, more monitoring is required to quantify the impacts to health from air pollution.

Air pollution is the largest contributor to the burden of disease from the environment, and is one of the main avoidable causes of death and disease globally. Even at relatively low concentrations air pollution poses a risk to health and due to the large number of people exposed, it causes significant morbidity and mortality in all countries. A recent international study has ranked ambient particulate air pollution as the 9th cause of disease burden globally for year 2010 (Lim et al., 2012). This ranking varies by region, and in Europe and North America, sub-regional analyses show that ambient particulate air pollution is ranked between 11th and 14th cause of death and disease. Household (indoor) air pollution also poses an important burden of disease, especially in developing countries where solid fuel combustion for cooking, heating and lighting is common practice. Furthermore, household solid fuel combustion is a significant contributor to ambient air pollution.

In 2012, exposure to ambient (outdoor) air pollution contributed to 582 000 premature deaths in the WHO European Region and in high-income North America (WHO, 2014). According to current knowledge, health effects have been calculated for the exposure to small PM (PM10: ≤ 10µm in diameter or PM2.5: ≤ 2.5µm in diameter (i.e. fine PM)), which causes cardiovascular, cerebrovascular and respiratory disease, as well as cancer (Loomis et al., 2013; WHO Regional Office for Europe, 2014). Fine PM is a useful indicator that is widely measured and used to describe the exposure to air pollution that may be responsible for the observed health effects or act as a proxy for the mix of pollutants responsible for the health effects (WHO Regional Office for Europe, 2013a).

The WHO European Centre for Environment and Health is the Chair of the TFH. The WHO has recently reviewed the state of the science on health aspects of air pollution (WHO Regional Office for Europe, 2013a). The importance of air pollution as a risk factor for major non-communicable diseases (such as cardiovascular diseases) has been coming to the fore in recent years due to recent research findings strengthening the existing, strong evidence on health effects of ambient air pollutants such as PM, ozone and nitrogen dioxide even further,

particularly for the specific effects of nitrogen dioxide and the effects of long-term exposure to ozone.

Exposure to air pollutants such as PM and ozone continues to be a threat to public health. Increased monitoring coverage of population exposure to air pollution, especially for PM2.5, has led to improvements in estimating population exposure. More than 75.4% of the population of the cities for which PM data exist is exposed to annual PM10 concentrations exceeding the concentrations recommended in the WHO air quality guidelines (AQG) (WHO Regional Office for Europe, 2006; WHO Regional Office for Europe, 2015a). Although this proportion remains high, there have been some improvements compared to previous years, with average PM10 concentrations slowly decreasing in most countries during the last decade (EEA, 2014; WHO Regional Office for Europe, 2015b).

According to the latest assessment of the European Commission, in the European Union (EU) the health impacts of PM, the main cause of death from air pollution, have been reduced by approximately 20% between 2000 and 2010 (EC, 2013). Modelled trends in pollutant concentrations show when considering a "business as usual scenario" (baseline projection) that the impacts of air pollution will continue to decrease by 2020, when the absolute number of estimated premature deaths will amount to 340 000. Beyond 2020, and without further measures, further reductions in health impacts from air pollution are expected to progress at a considerable slower rate. On average across the EU, the baseline projection suggests a decline of the loss of statistical life expectancy attributable to the exposure to PM2.5 from 8.5 months in 2005 to 5.3 months in 2025. However, if the maximum technically feasible reduction measures would to be implemented in the EU, the loss of statistical life expectancy could be further decreased by 2030 to about 3.6 months on average.

Findings of the European Aphekom ("Improving Knowledge and Communication for Decision-making on Air Pollution and Health in Europe") project, that used health impact assessment methods, indicate that average life expectancy in the most polluted cities in Europe could even be further increased by approximately 20 months if the long-term PM2.5 concentrations would be reduced to the WHO AQG annual concentration (Figure 1).

Recently, the Executive Body of the Convention has adopted amendments to the Convention's 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level ozone. The revised Protocol includes, for the first time, commitments to reduce the emission of fine particulate matter (PM2.5). Furthermore, black carbon is now included in the revision as an important component of PM2.5 (UNECE, 2015).

Monitoring and modelling of air pollution concentrations are continuously reviewed. However, ground-level monitoring is very limited in countries in Eastern Europe, the Caucasus and central Asia, with only a small number of monitoring stations. There is a need to improve (i) the identification of emission sources and subsequently (ii) the monitoring network in many countries to assess population exposure and assist local authorities in establishing plans for improving air quality.

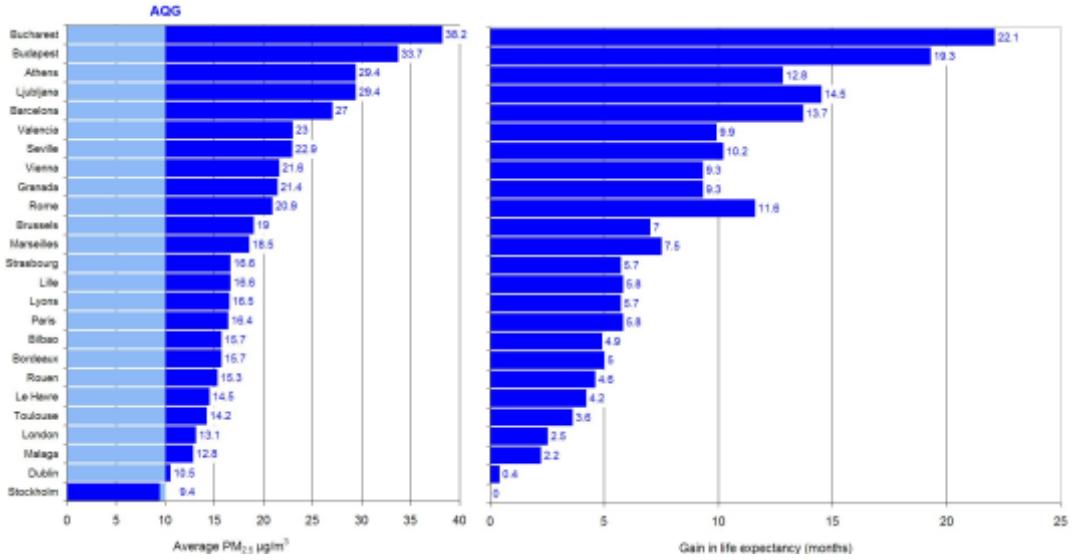

Figure A1: Predicted average gain in life expectancy [months] for people aged 30 years for a reduction in average annual concentrations of PM2.5 down to the WHO AQG annual mean concentration of 10µg/m3 in 25 European cities participating in the Aphekom project Source: Based on Aphekom Summary Report (2011)

Environmental health policy (comment MEH: move section to part B)

Air pollution is amongst the top ten causes of death and disease globally. Therefore the WHO, the Organization for Economic Co-operation and Development (OECD) and the United Nations Environment Programme (UNEP) have put air pollution high on their political agenda. Moreover, cost-effective interventions exist that reduce air pollution and lead to health benefits. Broadening the cooperation of CLRTAP with other international bodies and health ministries could further stimulate air pollution policy.

In addition to the human health impacts incurred, the morbidity and premature mortality due to air pollution are associated with significant economic costs. These include, but are not limited to, the cost to society resulting from premature deaths, the costs of healthcare for the sick due to poor air quality, and the loss of productivity associated to that sickness and/or caregiving for oneself or others (Holland, 2013). Therefore, in addition to health benefits significant cost savings can be achieved through air pollution abatement. According to a recent joint report from WHO Regional Office for Europe and the OECD, the cost of the premature deaths and diseases caused by air pollution in the 53 Member States in the WHO European Region was about USD 1.6 trillion in 2010. This economic value corresponds to the amount societies are willing to pay to avoid these deaths and diseases with necessary interventions (WHO Regional Office for Europe, 2015c). In the EU, the health-related external costs from air pollution ranged between €330 billion and €940 billion in 2010, and are expected to be reduced under a business-as-usual scenario (baseline projection) to €210-730 billion in 2030 (considering € prices in 2005) (EC, 2013). The corresponding economic benefits of the proposed EU air policy package can be monetized, resulting in about €40-140 billion, while the costs of pollution abatement to implement the package are estimated to reach € 3.4 billion (per year in 2030). The impact assessment states that the monetized benefits therefore will be about 12-40 times higher than the costs (EC, 2013).

Ambient air pollution is therefore considered as the most important environmental risk factor for health and deserves particular attention. In addition to efforts under the UNECE LRTAP Convention, other United Nations organizations have put air pollution high on their political agenda, including:

- World Health Organization: In the Parma Declaration in 2010, Ministers of Health and Environment of the WHO European Region have committed to reduce exposure to air pollution, decrease diseases, and take advantage of the approach and provisions of the LRTAP protocols and support their revision, where necessary (WHO Regional Office for Europe, 2010). More recently, the World Health Assembly adopted a Resolution on "Health and the environment: addressing the health impact of air pollution" at its 68th session in May 2015 (WHO, 2015). The key aim of the Resolution is strengthening the support to Member States to amplify the health sector's ability to act in order to protect and improve public health.
- United Nations Environment Programme: The UN Environment Assembly has called for strengthening actions on air quality in 2014. The delegates unanimously agreed to encourage governments to set standards and implement policies across multiple sectors to reduce emissions and manage the negative impacts of air pollution on (i) health, (ii) the economy, and (iii) an overall sustainable development (UNEP, 2014). In addition, the UNEP hosts the Secretariat of the Climate and Clean Air Coalition (CCAC), which focuses on methane, black carbon and hydrofluorocarbons. It was created in order to raise awareness, enhance and develop actions, promote best practices, and improve scientific understanding.

Cost-effective interventions that reduce air pollution and lead to health benefits exist (WHO Regional Office for Europe, 2013b). There is consistent scientific evidence that shows that lowering air pollution concentrations results in health benefits for the population, and that these improvements occur soon (over a time period possibly as short as a year) after the reduction in pollution (Laden et al., 2006; Lepeule et al., 2012). To date, regulatory efforts have led to reduced emissions of some air pollutants in Europe and North America (EEA, 2014), which may in turn lead to a reduced population exposure and a reduced burden of disease.

The reductions in primary PM, sulphur, NOx and VOC emissions achieved to date have contributed to a reduction in PM-exposure, [but the relative contribution of nitrogen related secondary particles has increased (source)]. [Further control measures on emissions of nitrogen compounds, especially those of ammonia would be cost effective for human health benefits and would reduce exceedances of nitrogen deposition effects on ecosystems (source)].

The health impacts of air pollution are linked to emissions from various sectors, such as industry, transport, power and heat generation, and agriculture. The health sector needs to engage with a range of other sectors in order to provide advice to the other sectors on policy options that will yield the greatest benefits to health. Furthermore, air pollution can travel thousands of kilometres and cross national borders. Therefore, strengthened inter-sectorial

cooperation, and actions at local, national, regional and international levels are essential to decrease the burden of disease from air pollution. The UNECE LRTAP Convention can play a crucial role in stimulating air pollution policy and fostering inter-sectorial cooperation at international level across Europe and North America, and even possibly beyond.

The overall compelling scientific evidence and significant burden of disease from air pollution provide convincing arguments for the need to take further action in all relevant sectors, to reduce emissions and as a result, improve air quality and public health.

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A2. Biodiversity and eutrophication

David Fowler & Dick Wright, Heleen de Wit, Kjetil Törseth, Katja Mareckova, Anne-Christine LeGall, Isaura Rabago, Jean-Paul Hettelingh

In large parts of Europe the loss of plant biodiversity due to excess nitrogen continues, despite the reduced deposition of nitrogen.

The emissions of nitrogen oxides and ammonia have over the 20th century caused significant changes in European ecosystems. Low fertility heathlands have been converted to grasslands and many rare plant species adapted to low nitrogen availability have disappeared. In large parts of Europe the loss of biodiversity due to excess nitrogen continues, especially in areas with high density of livestock and consequently high ammonia deposition. Monitoring of natural ecosystems and experimental studies show nutrient imbalances, a declining biodiversity and elevated nitrate leaching. (Sutton et al. 2011). Figure B1 shows the decline in species richness in acid grassland with increasing nitrogen deposition across Europe, indicating a 50% reduction in species richness as nitrogen deposition increases by 30 kg ha^{-1} annually (as N) (Stevens et al., 2010).

The deposition of nitrogen compounds exceeds the critical loads over large parts of Europe and measures taken so far have not been significantly changed the situation (ref.).

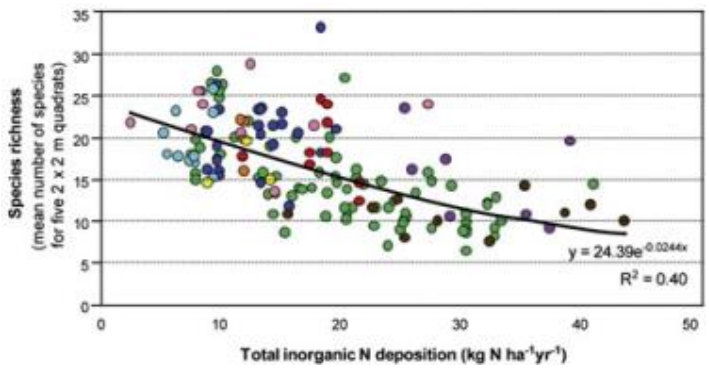


Figure A2: Relationship between species richness of acid grasslands in the Atlantic region and N deposition. (Stevens et al. 2010)

Emissions of nitrogen compounds from combustion processes in Europe have declined by about half since their peaks around 1990, while emissions of ammonia from agriculture have declined by a quarter (Figure A2). The downward trend in NOx emissions is also reflected in monitored concentrations of oxidized nitrogen compounds in the atmosphere and precipitation (Figure A3). Significant downward trends have also been observed for ammonium in air and precipitation in line with emission trends. (Figure A4)

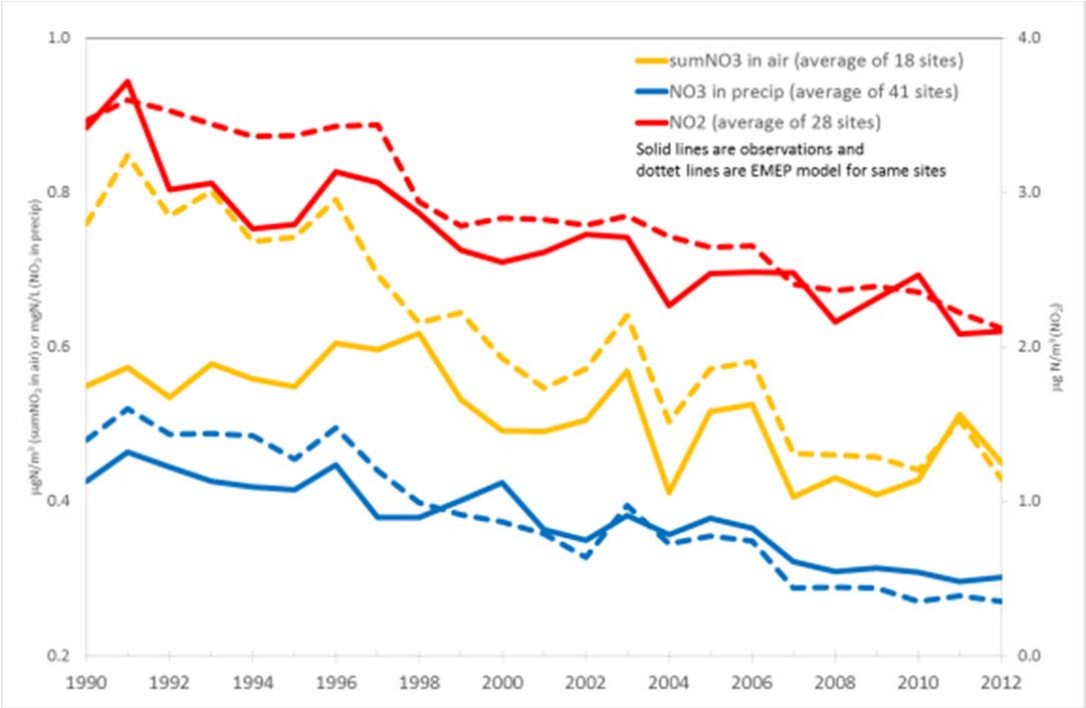


Figure A3**:** The observed and modelled annual average concentration in oxidized nitrogen components in precipitation and air at EMEP sites with measurements for at least 75% of the time period, 1990-2012.

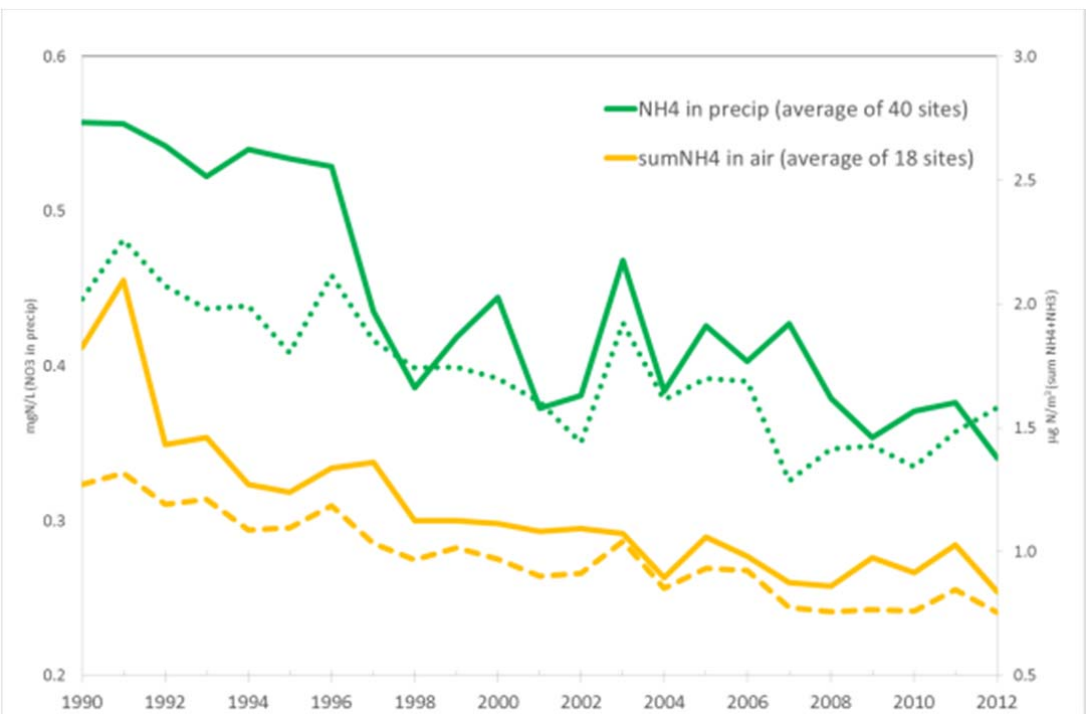


Figure A4: The observed and modelled annual average concentrations in reduced nitrogen components in precipitation and air at EMEP sites with measurements for at least 75% of the time period, 1990-2012.

The present controls agreed within the 1999 Gothenburg Protocol and its amendment will further reduce nitrogen deposition, but there is no evidence of ecosystem recovery from the reduced emissions to date and it is unclear how long it will take for ecosystems to respond to reduced N deposition. The current commitments are insufficient to prevent further accumulation of nitrogen in ecosystems, presenting a growing risk to ecosystem stability in the longer term. In particular the lack of success for emission reductions of ammonia should be highlighted. The trend of areas at risk of eutrophication between 1980 and 2030 (Fig. A5) shows that the risk of eutrophication is persistent. The area at risk of eutrophication decreases from 75 % in 1980 (80 % in the EU28) to about 55 % in 2020. In 2030 a further reduction to about 49 % under MFR2030 could be technically feasible (Hettelingh et al., 2015).

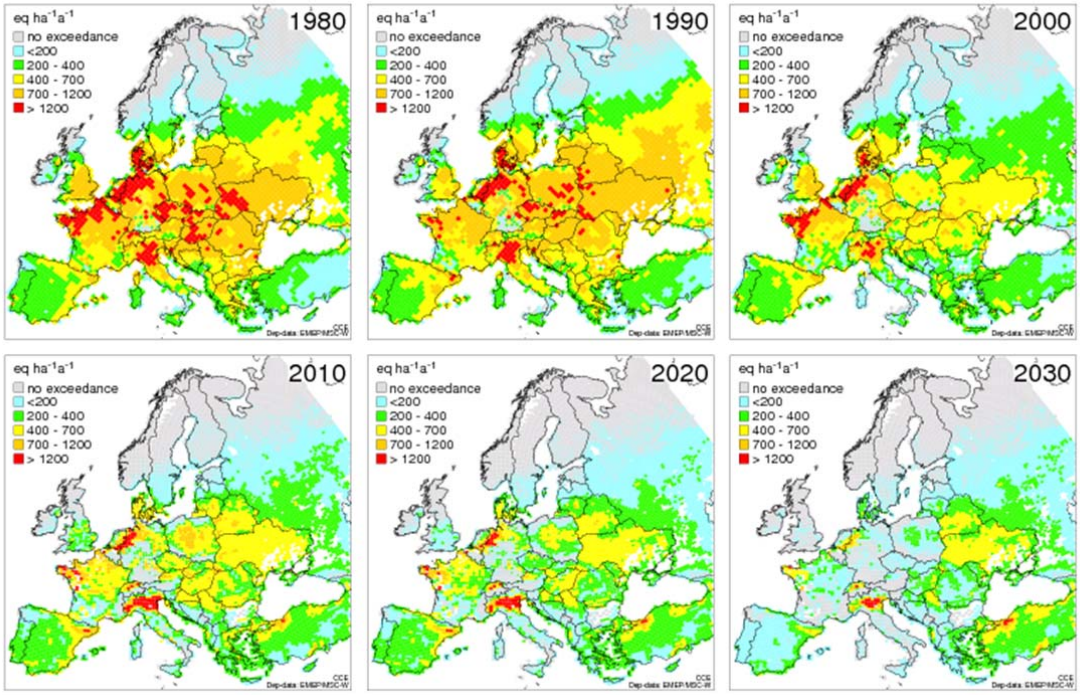


Figure A5: Average Accumulated Exceedance (*AAE*) of computed critical loads for eutrophication in 1980 (*top left*), 1990 (*top centre*), 2000 (*top right*), 2010 (*bottom left*), 2020 under the revised Gothenburg protocol (GP-CLE scenario) emission reduction agreements (*bottom centre*), and in 2030 when applying Maximum Feasible Reductions (*bottom right*) (Source: Hettelingh *et al.*, 2015)

Deposition of nitrogen is also a driver for acidification and its relative role has increased due to the successful control of sulphur emissions (See KM on Acidification). In addition nitrogen oxides and ammonia contribute to the formation of particles and may make up a significant part of the PM2.5 concentrations in Europe and North America. (See KM Health effects) NOx is also a key precursor for the formation of photochemical oxidants, in particular ozone. (See KM on Ozone)

The global nitrogen (N) cycle has been severely altered over the last decades. Of the total annual fixation of atmospheric nitrogen of 413 Tg-N, 51% results directly from human activity. Scenarios for the time up to 2100 indicate that the nitrogen problem will cause an increasing threat to human health, ecosystems and climate. The nitrogen cycle is very sensitive to changes in climate as shown in figure A6, with substantial increases in emissions as the climate warms in the next few decades. Coordinated policies to mitigate air quality and climate change through reductions in emissions of NO_x and NH_3 would avoid large increases in emissions of NH_3 emission during the later decades of this century. (Fowler et al 2015)

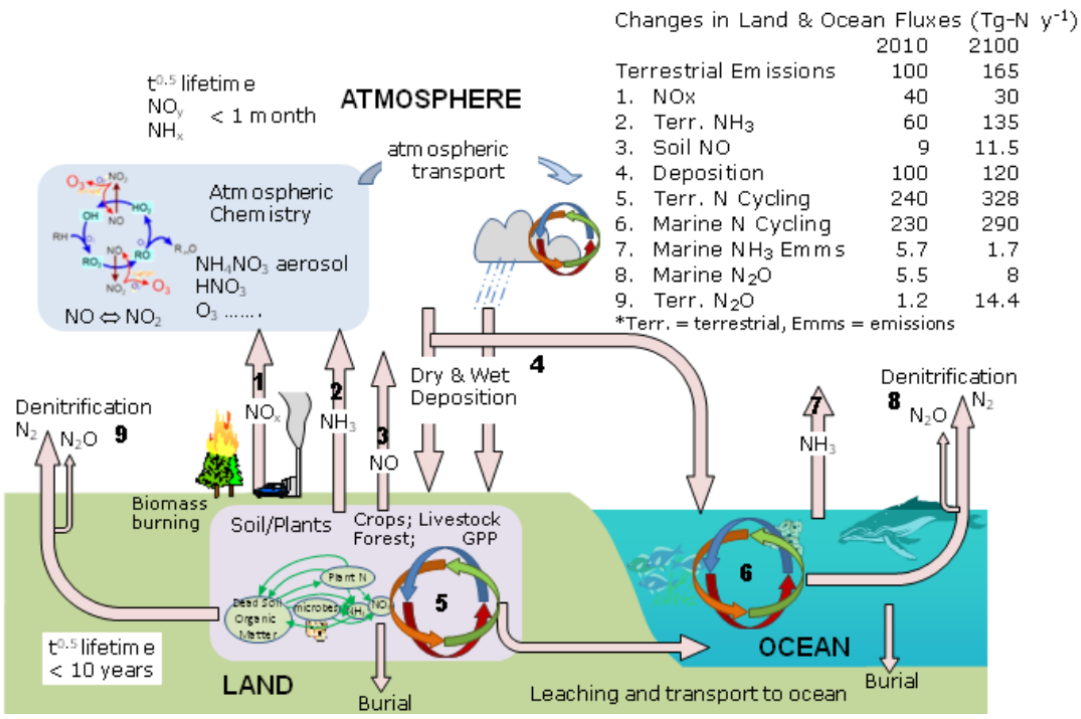


Figure A6: Changes in the major fluxes and in the terrestrial, marine and atmospheric processing of reactive nitrogen (N) between 2010 and 2100 (Fowler et al 2015)

Further control measures on emissions of nitrogen compounds, especially those of ammonia would be cost effective for human health benefits and would reduce exceedances of nitrogen deposition effects on ecosystems. The reductions in sulphur and VOC achieved to date have contributed to a reduction in PM, but this has also increased the relative contribution of nitrogen emissions to the human health effects of particulate matter (refer here to the human health section which quantifies the role of NH_4NO_3 in PM2.5 especially winter and spring episodes).

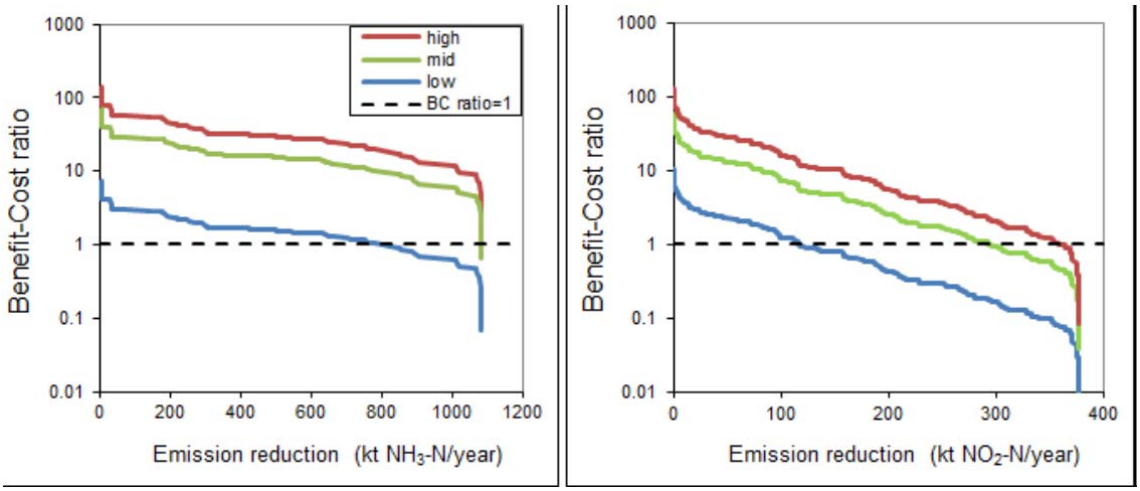


Figure A7: Van Grinsven et al. (Environmental Science and Technology, 2013) May go to part B?

Thus the overall message on nitrogen is that the useful steps taken to reduce emissions of nitrogen compounds to date have been insufficient to provide conditions in which ecosystems can begin to recover and that further reductions are necessary. Furthermore, the relative contribution of nitrogen compounds to particulate matter has grown as sulphur emissions have declined and with the emphasis on effects of PM on human health, further reductions in emissions NH_3 and NO_x have become a priority in Europe, both nationally and for the inter-country exchange of pollutants. Lastly the effects of climate on emissions of nitrogen compounds may substantially offset the reductions in emissions to date and new measures to reduce emissions would avoid much larger costs later.

A3. Acidification of lakes and forest soils

David Fowler & Dick Wright, Heleen de Wit, Kjetil Törseth, Katja Mareckova, Anne-Christine LeGall, Isaura Rabago, Jean-Paul Hettelingh, Johan Tidblad, Hilde Fagerli

Since the peak in 1980, European emissions of sulphur have been reduced by 80%. Although recovery is progressing the acidification problem is not solved.

In the 1960s and 1970s there was growing concern about the effects of air pollution on the environment. Thousands of lakes and streams in Norway, Sweden, Finland and other acid-sensitive parts of Northern Europe had lost or damaged fish populations (Tammi et al. 2003). Forests were threatened in large regions of central Europe. Substantial damage to materials, including historic buildings and cultural monuments, was also reported. Acid deposition was also a concern in eastern North America. Acid rain damage was observed in the Muskoka and Haliburton lakes areas of Ontario, in southern Quebec, in much of northern New York State and New England, and as far east as Nova Scotia.
In response to the public concern about the adverse effects of air pollution, countries of the UNECE region adopted in 1979 the Convention on Long-range Transboundary Air Pollution (CLRTAP). The first international agreement to reduce the emissions of acidifying compounds came with the 1985 Sulphur Protocol, which specified a 30% reduction in Sulphur emissions in 1993 relative to 1980 levels. Subsequent protocols specify further reductions in both Sulphur and Nitrogen emissions, and in 2010 the deposition of S had decreased by nearly 90% in Europe relative to 1980 (Figure A8).

Today we are facing a situation with recovering lakes and streams. The exceedance of Critical Loads for acidification has decreased substantially and significant exceedance is only observed in limited parts of Europe. Acidified soils have also started to recover. Water quality is improving as demonstrated by increased pH and buffering capacity (acid neutralizing capacity) (Garmo et al., 2014), and recovery of acid-sensitive sediment-dwelling insects and snails is taking place. The salmon which was almost extinct in many rivers in Norway is now returning, partly because of remediation measures such as liming and fish stocking. In many lakes, fish populations are recovering but as for the rivers, this development is strongly promoted by liming and fish stocking. Norway uses annually over 100 million NOK (€10 million) for liming of surface waters. However, soil and surface water acidification remains an issue in the most sensitive areas in Nordic countries, the UK and central Europe. Recovery from acidification of acidified soils and waters will take decades to centuries, because of depleted buffers of base cations in soils, which recover through the slow process of mineral weathering. Further reductions in N and S emissions will improve the situation and decrease time for recovery.

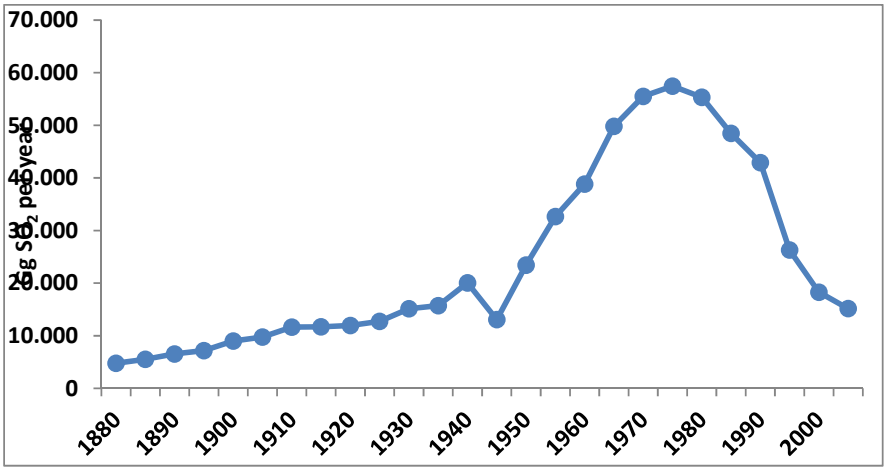


Figure A8: Emissions of Sulphur in Europe Sulphur dioxide (1000 tonnes)-showing the progressive decline in emission resulting from the succession of UNECE_LRTAP protocols 1983, 1987, 1991,1998, 1999. Reference, the Y axis needs to be adjusted. I suggest that we use million tonnes of SO2.

The emission reductions in Europe over the last 25 years have also resulted in a corresponding decrease in atmospheric concentrations and deposition (Figure A9). The downward trend has been larger for sulphur dioxide than for particulate sulphate and for sulphate in wet precipitation. The figure also shows that there are good agreements between monitored and modelled concentrations of sulphur in air and precipitation.

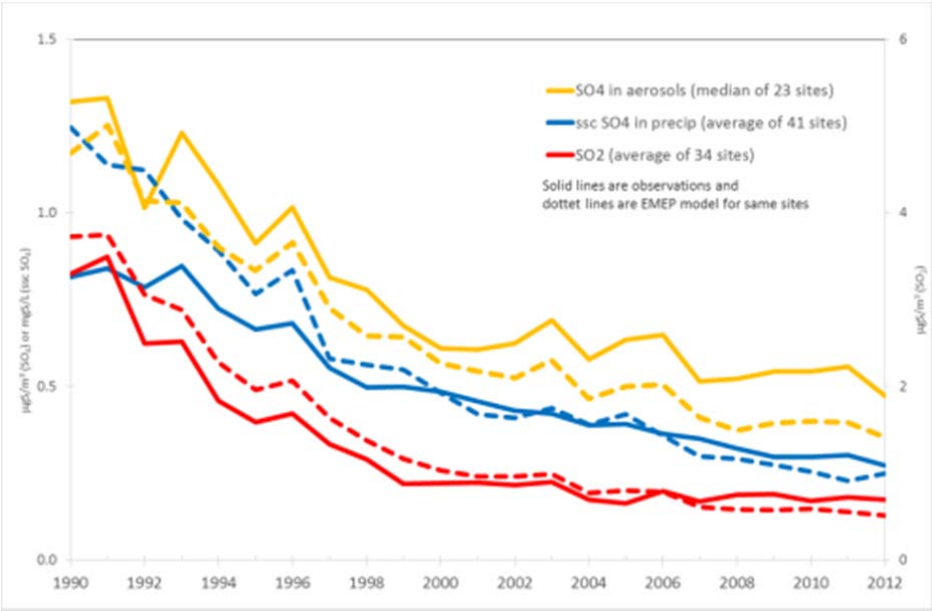
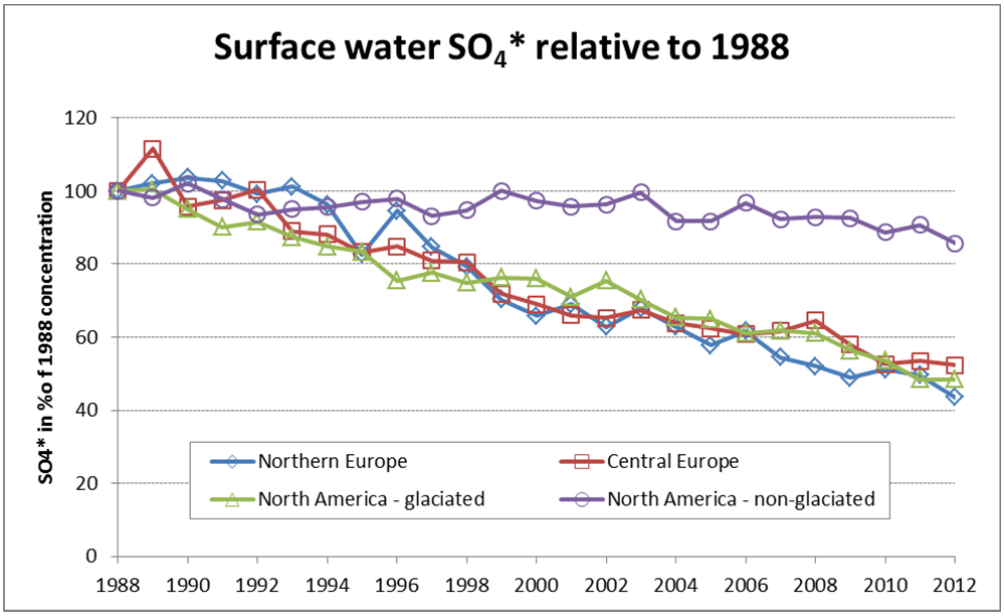


Figure A9: The observed and modelled annual average concentration in sulphur components in precipitation and air at EMEP sites with measurements for at least 75% of the time period, 1990-2012. (MSC-W, WGE Trends report). The figure includes both monitored and modelled data showing that there is quite good agreement between monitored data.

These reductions in emissions have also resulted in substantial improvements in freshwater and terrestrial ecosystems (Figure A10). The strongest evidence that emission control programmes are having their intended effect comes from long-term records from monitored

lakes and streams (ICP-Waters data). Concentrations of sulphate have decreased, the acidity has decreased and waters are more suitable for fish populations.



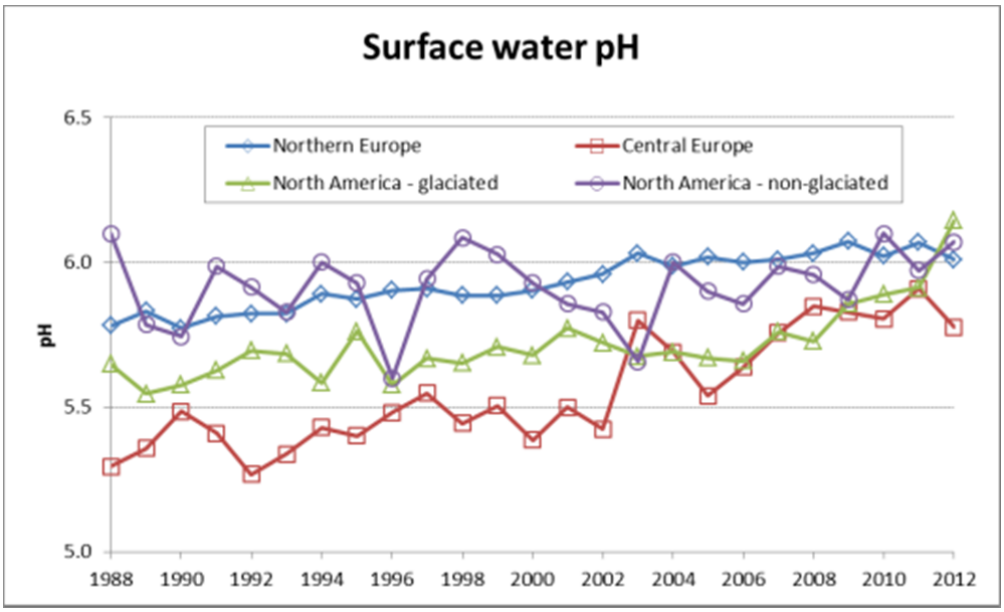
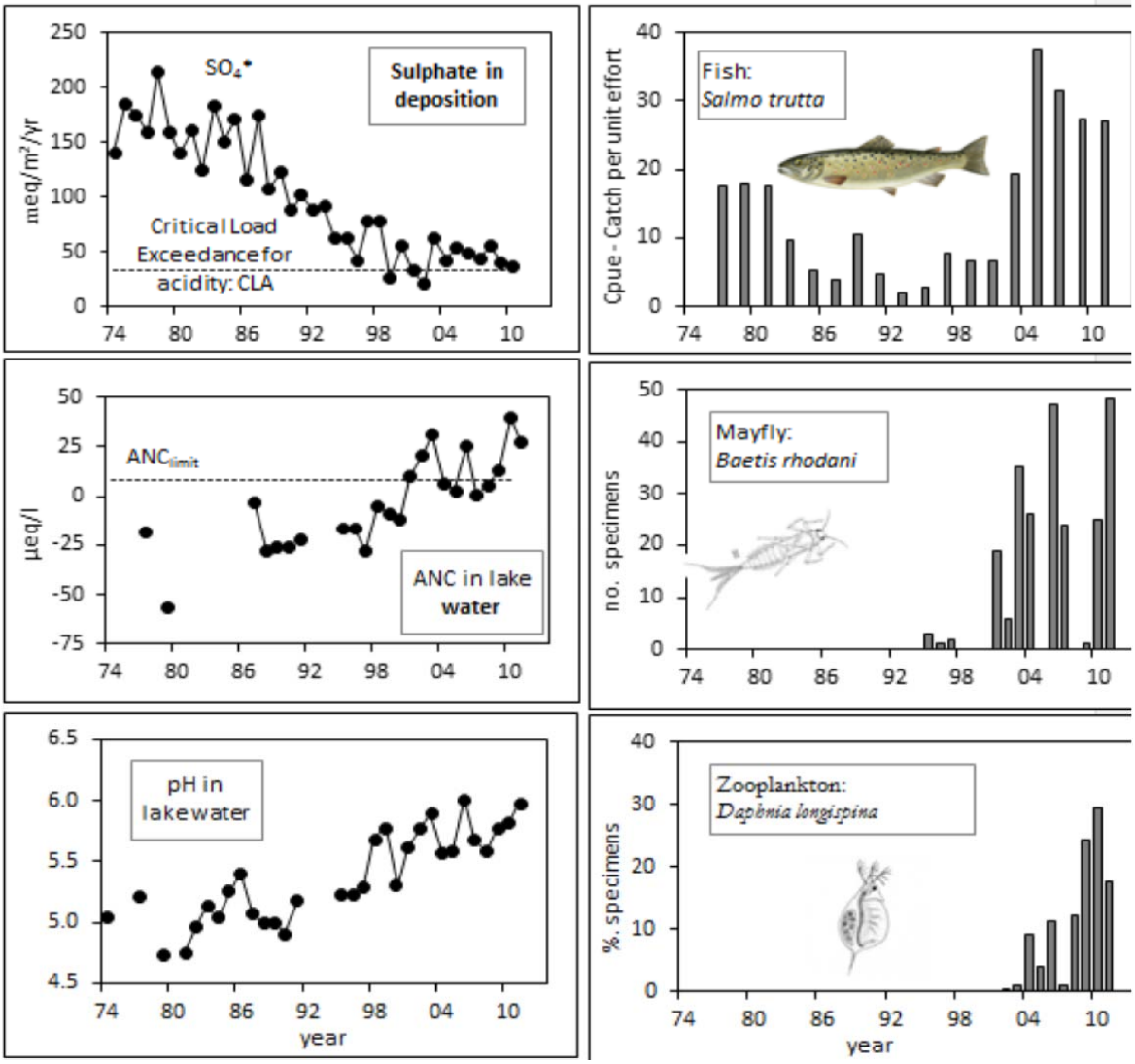


Figure A10: Trends in surface water chemistry at ICP Waters sites 1988-2012. Shown are the mean concentrations of non-marine sulphate (SO_4*) and pH at 22 sites in northern Europe, 21 sites in central Europe, 37 sites in glaciated areas of eastern North America, and 7 sites in non-glaciated areas of eastern North America. Source: Garmo et al., 2014 (WASP) and Garmo et al, 2015. Chemical and biological recovery in acid-sensitive waters: trends and prognosis (ICP Waters report 119/2015). Oslo: Norsk institutt for vannforskning 2015 (ISBN 978-82-577-6582-8) 97 s. NIVA-report (6847)

An example from Norway

Recovery from acidification at Lake Saudlandsvatn, Norway. As S deposition has decreased, the acid neutralising capacity (ANC and pH have increased) in the lake, and the populations of three sensitive species have begun to recover (modified from Hesthagen et al. 2011).



Data from T. Hesthagen, NINA (fish), NIVA (water chemistry), NILU (deposition), UiB (invertebrates)

Recent CTRTAP protocols have been formulated to maximise the environmental benefits of measures to reduce the emissions of S and N. The approach has been based on the use of Critical Loads (see text box) for acidification eutrophication and for the effects of ozone on ecosystems. .

Critical load and exceedance

Critical loads are derived to characterise the vulnerability of an ecosystem in terms of atmospheric deposition. The critical load for acidity is defined as ”the highest deposition of acidifying compounds that will not cause significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt 1988).

Exceedance occurs when the deposition is greater than the critical load. Maps of critical loads and exceedance have been made for various ecosystem types and for various years.

Over the years the methodologies as well as the geographical resolution have been improved due to new scientific findings as well as improved resolution in modelling and mapping.

Figure 1.1 Areas where critical loads for acidification (2008 database) are exceeded by acid depositions (EMEP50 model) caused by emissions between 1980 (top left) and 2020 (bottom right), the last projected under the Revised Gothenburg Protocol (RGP)

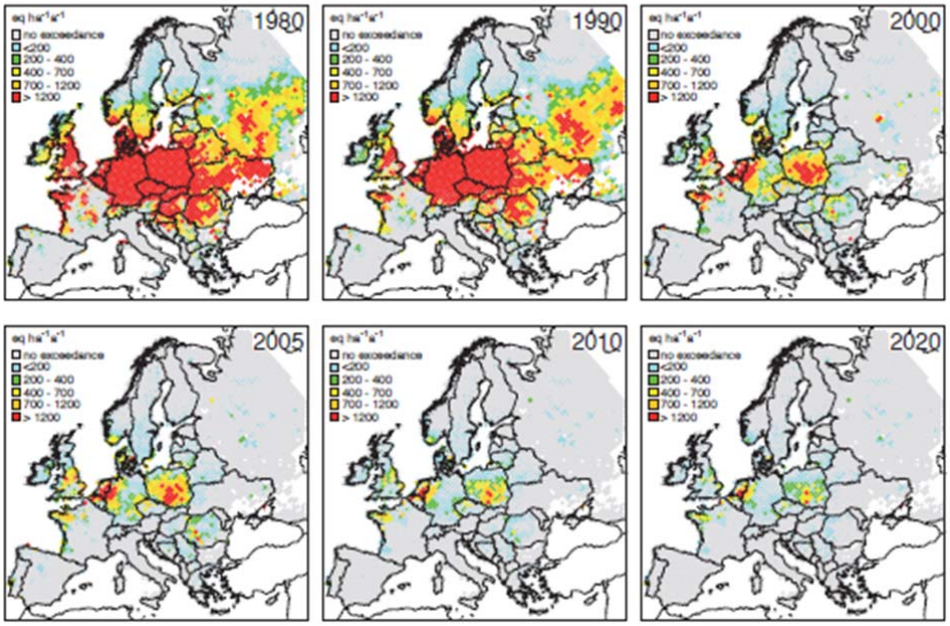


Figure A11:. Average Accumulated Exceedance (*AAE*) of computed critical loads for acidification in 1980 (*top left*), 1990 (*top centre*), 2000 (*top right*), 2010 (*bottom left*), 2020 under the revised Gothenburg protocol (GP-CLE scenario) emission reduction agreements (*bottom centre*), and in 2030 under Maximum Feasible Reductions (*bottom right*) (Source: Hettelingh *et al.*, 2015)

The trend between 1980 and 2030 of European ecosystem areas where critical loads for acidification are exceeded (Fig A11) illustrates the decrease of the area at risk. The area at risk diminished from about 30 % in 1980 to about 2 % in 2020 under the revised Gothenburg Protocol including the implementation of current legislation. A further decrease to 1% could be achieved in 2030 when Maximum Feasible Reductions are applied (Hettelingh, 2015)

Emissions of S and N compounds also cause damage to materials in particular corrosion. Long term monitoring show that the rate of corrosion has decreased in Europe in parallel with the decrease in emissions (Figure A12).

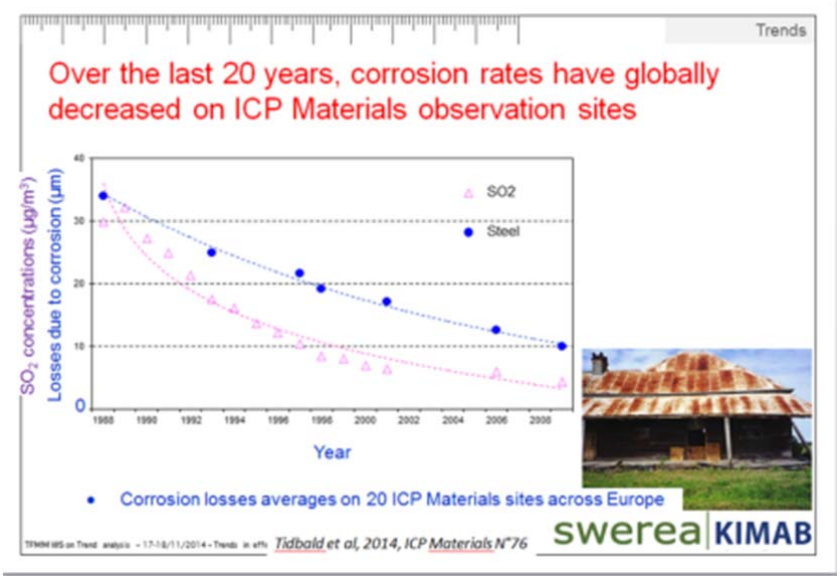


Figure A12: Trends in corrosion rates between 1998 and 2008 at 20 ICP monitoring sites in Europe. (Tidblad et al. 2014)

Emission reductions were not only driven by end of pipe control. The close connection to energy and energy policies has been important for the overall outcome of the emission reductions over the last decades. Historical energy balances, along with population and economic growth data, were used to quantify the impacts of major determinants of changing emission levels, including energy intensity, conversion efficiency, fuel mix, and pollution control (Figure A13). The study, covering the period from 1960 to 2010, shows that 75% of the decline in SO_2 emissions in Western Europe emanated from a combination of reduced energy intensity and improved fuel mix. The importance of direct air pollution abatement measures have been more important in Western Europe compared to Eastern Europe (Rafaj et al 2014).

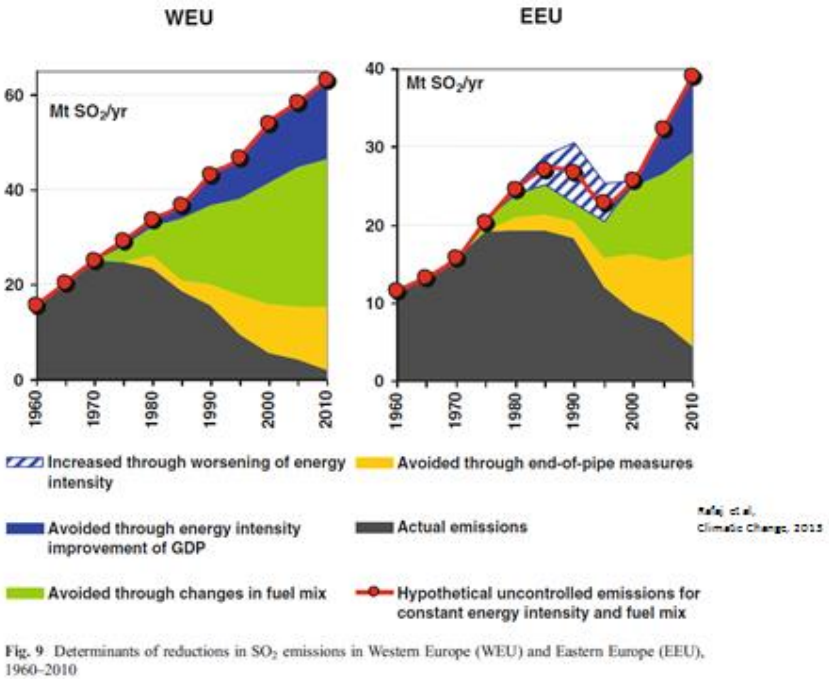


Figure A13: Determinants of reductions in SO2 emissions in Western Europe (WEU) and Eastern Europe (EEU) between 1960 and 2010. (Rafaj et al 2014)

The recovery of acidified ecosystems will take time. The delay is to a large extent dependent on the accumulated sulphur in soils and to what extent and at which rate it will be released. Experiments, observations and model calculations indicate that it will take decades for ecosystems to recover.

The control of emissions of sulphur has during the last decade not primarily be driven by acidification but rather by the role of sulphate particles as a main contributor the the PM2.5 in the atmosphere. It is realistic to assume that this will continue to be the situation in the future.

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A4. Ozone trends and impacts on health and ecosystems

Frank Dentener, David Simpson, Contributors: Oliver Wild, Zig Klimont, Augustin Colette, Oksana Tarasova, Sverre Solberg, Harry Harmens, Hilde Fagerli, Gina Mills, Marie-Eve Heroux

Peak concentrations of ground-level ozone have been reduced in the last decade, but reductions of the average concentration and other ozone metrics during the summer do not show a clear decline. In particular in Asia, ozone precursor emissions (including methane) have been increasing, contributing to background ozone. Less ozone is taken away by NOx-emissions close to the source regions. Ozone is therefore still a threat to public health, crops and forests.

Ozone (O_3) is formed by the photochemical transformation of emissions of nitrogen oxides (NOx), methane (CH4), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs). Differences in the magnitude and distribution of precursor emission, climatic and chemical conditions lead to significant regional differences in ozone concentrations.

Short-term (few hours) exposure to ozone is associated with mortality and respiratory morbidity (REVIHAAP, 2013). The EU Ambient Air Quality Directive target value for ozone specifically addresses short-term health risks using a maximum daily 8-hour mean ozone concentration of 120 µg m^{-3} (or 60 ppb) not to be exceeded more than 25 times a year. The WHO advisory guideline value is 100 µg m^{-3} (or 50 ppb) for a daily maximum 8-hour mean.

Monitoring of ozone at rural and urban sites throughout Europe shows that episodes of high concentrations of ground-level ozone occur over most parts of the continent every summer, during warm and stagnant weather conditions (Figure 14), and EU O3 target values were exceeded especially in Southern and Central European countries. Measured and modelled SOMO35, an indicator for long-term risk of ozone health impacts, also display higher values in Southern Europe (Figure A14).

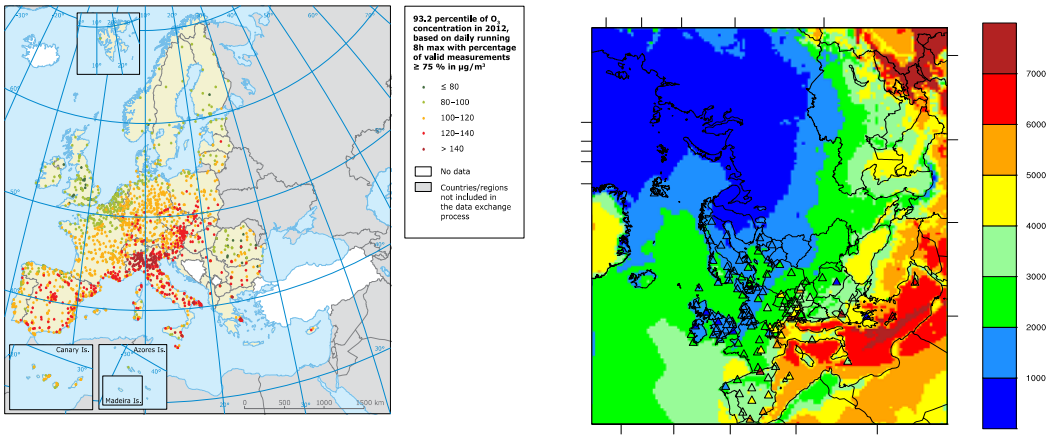

Figure A14 a) The 93.2 percentile O_3 concentrations (25 days with highest ozone levels) in Europe in 2012. Light and dark red colours indicate the exceedance of 120 ug m^3 (60 ppb) during more than 25 days per year. Source: EEA, 2014. b) EMEP model calculations (for the year xxx) of SOMO35 [ppb days] (the annual sum of the maximum of 8 hours running average ozone over 35 ppbv; http://www.emep.int/mscw/SR_data/definitions.pdf), together with observations (triangles). The color scheme need to be changed in this case. This figure should be addressing health, crops will follow below, can projection be adapted?

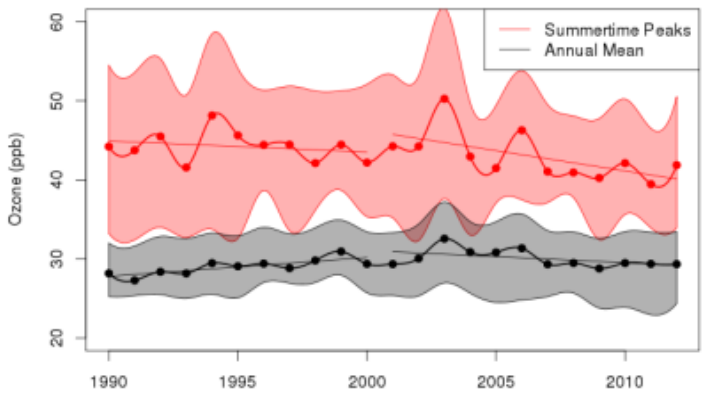

Figure A15: Evolution of ozone peak (summertime – JJA – average of daily maxima) and annual mean at EMEP monitoring stations. Shaded areas indicate the 1 **σ st**andard deviation. Trend lines are indicative for the periods 1990-2000 and 2001-2012. Source: preliminary analysis of EMEP TF MM, December 2015.

Epidemiological studies provide accumulating evidence of mortality related to long-term ozone exposure (Revihaap, 2013), although it is currently not possible to establish a lower threshold for absence of effects. An analysis at 6 coastal, rural and mountain-top sites in Europe showed that mean annual ozone concentrations have increased by 0.3-0.7 ppb yr^{-1} through much of the 1980-1990s, but has either levelled off or slightly decreased since 2000 (Cooper et al. 2014). Simpson et al. (2014), using a subset of 14 'screened' EMEP stations and comparing 1990-1999 and 2000-2009, found generally increasing ozone concentrations of 0.1-0.4 ppb yr^{-1} up to the 95th ozone percentile, and ozone reductions of 0.5 to 1.5 ppb yr^{-1}

above the 95th percentile. Analysis of an extended set of observations from the EMEP regional network conducted by the Task Force on Measurement and Modelling (Figure 2) show that in the period 2002-2012 summer peak ozone concentrations significantly declined, while in the preceding decade (1990-2001) the declines were smaller and mostly not significant. Ozone annual mean concentrations somewhat increased in the 1990s and levelled off in the 2000s. Other studies (e.g. EEA, 2014) confirm a declining trend in the 2000s in peak ozone in parts of Europe. Thus, while summer peak ozone values have come down, these studies indicated that a similar decline in mean ozone levels was not observed. Likewise, country-averaged SOMO35 did not change between 2000-2002 and 2010-2012; WGE trend report, 2015).

Under environmental conditions conducive to high ozone uptake, ozone damage to vegetation occurs during the growing season at concentrations 30 ppb or lower. Effects include visible leaf-injury (Figure 3), increased or pre-mature die-back and reduction in seed production and growth of sensitive species, including trees, (semi-)natural vegetation, and several important crops, including wheat, soybean and rice (Ainsworth et al., 2012, Mills and Harmens, 2011).

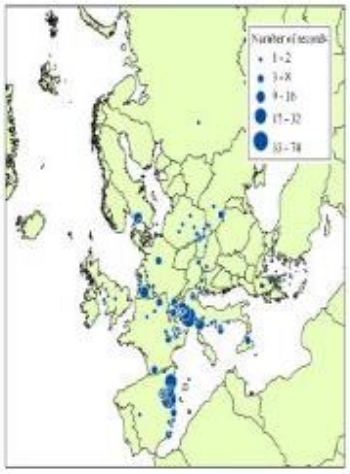

Figure A16: (a) Visible ozone injury symptoms on wheat (*Triticum aestivum*) and (b) Locations of records of visible injury attributed to ozone on crops, (semi-)natural vegetation and shrub species (1990 – 2006, Mills et al., 2011).

A variety of methodologies are used to estimate ozone damage to crops. Most widely used in Europe is the empirical indicator AOT40 (growing season ozone above a threshold of 40 ppb). Globally (based on AOT40), ozone is estimated to account for yield losses of between 3% and 12% for the major staple crops (Van Dingenen et al., 2009). More recent ozone flux-based estimates, taking into account impact of environmental conditions on ozone uptake, show wheat yield losses to be 4.6 billion Euro in the EMEP region, equating to a yield loss of 13%, with the highest economic losses found in important wheat growing areas in western and central Europe, and ca. 40% in EECCA and SEE countries alone (Figure A17; Table A1).

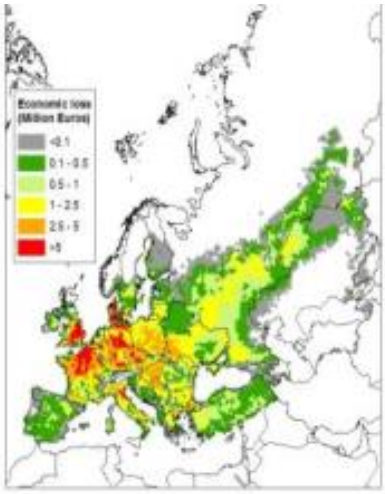

Figure A17: Wheat yield losses (in million Euro per 50 x 50 km grid square), using rain-fed wheat production values for 2000 (GAEZ; http://www.fao.org/nr/gaez/en/), calculated average ozone flux for crops (EMEP; http://emep.int/mscw/index_mscw.html) and average wheat prices for the period 2007 to 2011.

Table A1: Wheat yield losses (in million Euro per 50 x 50 km grid square), using rain-fed wheat production values for 2000 (GAEZ; http://www.fao.org/nr/gaez/en/), calculated average ozone flux for crops (EMEP; http://emep.int/mscw/index_mscw.html) and average wheat prices for the period 2007 to 2011.

	EMEP region	EU28+CH+NO	SEE[1]	EECCA[2]
Total production loss (million t)	23.7	15.4	2.8	6.7
Economic loss (billion Euros)	4.6	3.0	0.5	1.3
Percentage yield loss	13.2	14.6	10.7	12.0

[1] Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Macedonia, Montenegro, Romania, Serbia, Slovenia and Turkey

[2] Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan

Do we understand why peak ozone has come down and average ozone not, despite a 40% reduction in European emissions of ozone precursors from 1990-2013 [EMEP, 2015]? There are several factors that need to be considered. Firstly, there are substantial natural variations of ozone between years and even decades. Long, and high-quality observational time series are needed to detect changes, and unfortunately such measurement data are less abundant before the year 2000. Secondly, decreasing NOx emissions can lead to increases in ozone concentrations (especially affecting the lower/middle O_3 concentration range) close to the emission source, while the benefit in improving air quality will only be felt at some distance away from the source. Models qualitatively can reproduce this phenomenon, but quantitative understanding requires high-resolution modelling and reliable information on historical emission inventories and intercontinental ozone inflow (Colette et al., 2012). Thirdly, ozone changes are variable across the world (Figure A18), and inflow conditions of ozone into Europe and North America may have changed [Wild et al., 2012; Verstraete et al., 2015;

Doherty et al., 2015]. Strong and continued increases of ozone were observed in Asia and at the west coast of North America since 1990, while trends were mixed at other locations. Since tropospheric ozone has a lifetime of about 20 days, it can be transported across the Northern Hemisphere, and ozone produced from emissions in other regions can contribute to ozone concentrations in Europe. Natural large-scale ozone variability, but also changing emissions in the Northern Hemisphere are likely contributing to the changing inflow conditions. Analysis performed by the Task Force Hemispheric Transport indicates that declining ozone contributions from air pollutant controls in North America have been compensated by increases from Asia and other part of the world, and by increases of methane emissions (Figure A19). In the next decades, methane emission controls will increasingly determine whether ozone will further decline or not (see section B3).

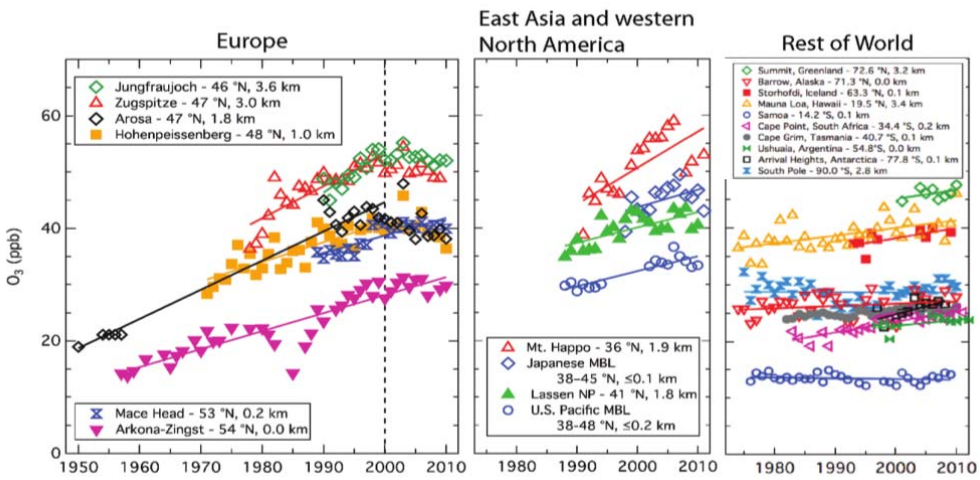

Figure A18: Surface ozone time series at several rural sites around the world. Trend lines are fit through the yearly average ozone values using the linear least-square regression method. Trend lines in Europe only extend through 2000 when the positive trend appears to have ended. From Cooper et al. (2014).

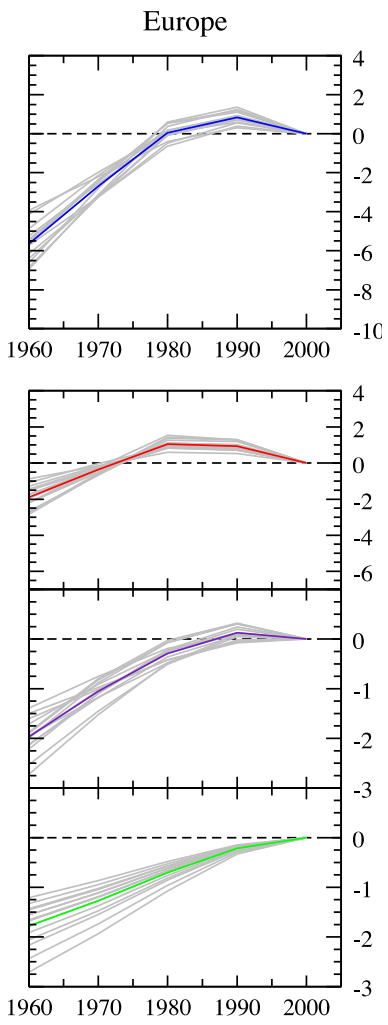

Figure A19**:** Calculated Ozone trends in Europe (a) and the contributions from an ensemble of models from European sources –red (b), non-European sources -blue (c) and methane –green (d). Taken from Wild et al. (2012).

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A5. Persistent pollutants

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After significant emission reductions of HM and POP before 2005, Little improvements have been noted since then. Pollution levels are still a concern.

Heavy Metals (HMs) and Persistent Organic Pollutants (POPs) differ in several respects to the classical air pollutants in terms of sources, long-range atmospheric transport behavior and regulatory context. HMs and POPs are known for their toxicity and have adverse effects on human health and the environment (carcinogenicity, mutagenicity, reproduction toxicity, endocrine disruption, etc.[1]). HMs are elements which are naturally present in the environment. Their levels in ecosystems have been significantly enriched compared to pre-industrial time because of anthropogenic activity. POPs are either intentionally produced chemicals (e.g. pesticides, industrial chemicals) or/and unintentional by-products, often from combustion (e.g. polyaromatic hydrocarbons - PAHs, dioxins and furans – PCDD/Fs). POPs accumulate along food chains and in individuals: low environmental concentrations can lead to significant exposures over time. Many POPs furthermore undergo reversible atmospheric deposition, and uncertainties therefore remain whether contemporary atmospheric burdens reflect "fresh" primary emissions amenable to further control strategies - or secondary emissions from contaminated reservoirs as polluted in the past.

Relevant efforts under CLRTAP have resulted in valuable infrastructures and an important knowledge base for both HMs and POPs (emission inventories, models, observations and assessments). These results are unique and would not have been accomplished otherwise. The infrastructure not only ensures compliance under LRTAP, but also provide a valuable knowledge base available to support relevant efforts under global agreements, such as the Stockholm Convention on POPs and the Minamata Convention on mercury. Additionally, data and assessments developed under CLRTAP furthermore provide valuable data and assessments for many other regional programs and Conventions (HELCOM, OSPAR, AMAP). Another positive development in recent years are the increasing involvement by the EECCA countries under CLRTAP. This paragraph may be more appropriate for general characteristic of CLRTAP results

Anthropogenic emissions of heavy metals and some POPs were significantly reduced in the EMEP countries over the last two decades. Emissions of heavy metals declined from 60% (mercury) to 90% (lead). POPs emissions decreased from 40% (PAHs) to 85% (PCB and HCB). /**CEIP**/ Many POPs and POP-like substances not included in the convention are however not monitored regularly and the overall emissions of persistent chemicals are likely increasing or unchanged.

[1] REACH data, http://scorecard.goodguide.com, www.echemportal.org, and others

Source categories

Decrease of emissions and consequent decline of pollution levels of HMs and B[a]P is achieved due to reduction of emissions from particular emission source categories. Prevailing contribution of road transport for lead and metal production for cadmium in 1990 was replaced by industrial and non-industrial combustion in 2010. Changes in sectoral composition of mercury and B[a]P emissions were less significant. Nowadays, the prevailing sectors in deposition of all three metals include industrial combustion, non-industrial combustion, metal production and energy production (Figure A20). For B[a]P major contribution originates from residential heating and industry-related sources.

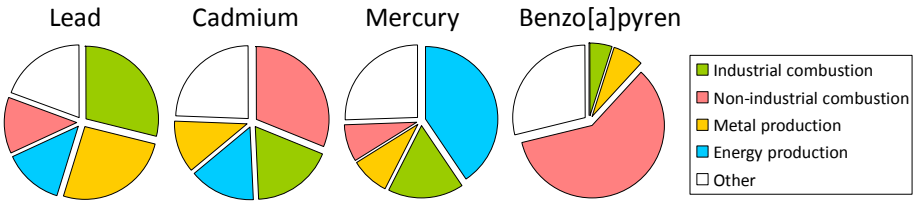

Figure 20: Relative contribution of the key source categories to pollution levels of lead (a), cadmium (b), mercury (c) and B[a]P (d) in the EMEP countries in 2010.

Pollution reduction

The reduction of emissions (primary and secondary) has led to decline of pollution levels in the EMEP countries. HM levels declined from 75% (lead) to about 35% (mercury) (Figure A21). (Legacy) POP level (as far as monitored under CLRTAP) decline ranged from 90% (HCB) to 40% (B[a]P). The rate of the decline was not uniform and differed among the considered pollutants. Lead and HCB levels had been rapidly decreasing in the beginning of 1990-s, and since 2000 the rate of the decrease slowed. Mercury and cadmium levels have been declining almost uniformly from 1990 to nowadays. B[a]P and PCDD/Fs levels are characterized by fast reduction in 1990-2000, replaced by some growth in present time.

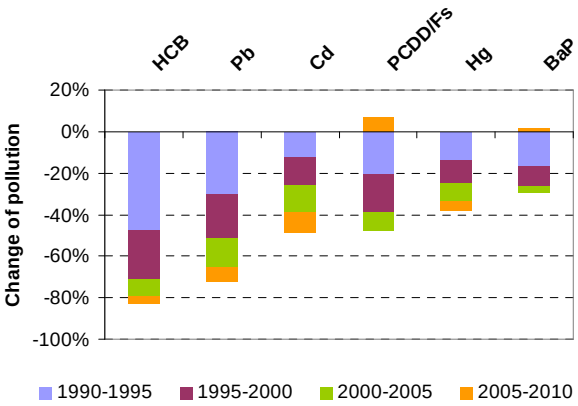

Figure A21: Relative reduction of HM and POP pollution levels over the period 1990-2010 in the EMEP region

Long-term changes of the levels assessed by modeling are generally confirmed by available data from EMEP monitoring network. Besides, similar reduction rates of HM levels are demonstrated by results of Biomonitoring of HM concentrations in mosses.

Because of relevant long-term monitoring efforts under CLRTAP, we now have a far better understanding of the temporal and spatial distribution of both HMs and many POPs than in the past. However, long-term temporal trends often varies across sites and pollutants as illustrated for POPs (Figure A22). Some organochlorine pesticides now banned for an extended time period show a sharp decline (Fig A22a), whilst for other POPs no trend could be observed for many sites (Fig A22b). Even within groups of similar POPs like the PCBs, differences in time trends could be notable (Fig A22c,d).

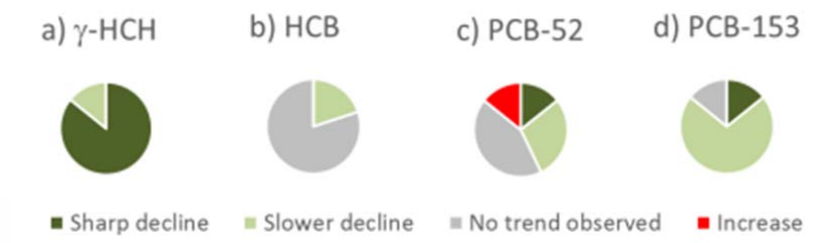

Figure A22:. Lumped long-term time trends in concentrations of selected POPs in air from selected EMEP sites. Data represent up to 7 sites and up to two decades of monitoring (for details, see WEOG 2015).

The reductions in heavy metal emissions within Europe have been extensive, and the observation data clearly reflect these changes. All the EMEP sites with long term measurements since 1990 shows significant reductions in concentrations for lead (up to 90%) and cadmium (up to 70%). For mercury the observed levels decreased significantly up to end of the nineties and leveled off the last decades (Tørseth et al, 2012). **especially for POPs**…

EECCA vs EU

Reduction of pollution levels strongly varies among the EMEP countries. While in the EU-28 countries the reduction is much stronger than EMEP-average value, in the EECCA countries it is relatively low. The highest total reduction of pollution levels was noted for EU28 countries. On average, it occurred to be more than 80% for lead, 60% for cadmium, 35% for mercury and 41% for B[a]P. (Figure A23). In the EECCA countries the decline of the pollution levels is smaller: total reduction for 1990-2012 amounted to 76% (lead), 49% (cadmium), 19% (mercury) and 3.6% (B[a]P). Both within EECCA and EU28 groups the range of total reduction among countries is large. In some countries the total reduction of cadmium and mercury is even negative, which means that pollution levels tend to increase in long-term perspective. In case of B[a]P, the long-term increase of pollution levels takes place for almost 60% of the EECCA countries and for about 20% of the EU28 countries.

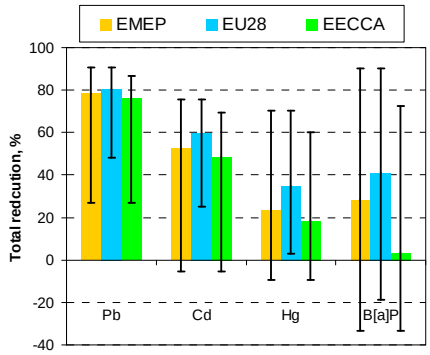

Figure A23: Total reduction of lead, cadmium and mercury deposition and B[a]P air concentrations in the EMEP region as a whole, in EU28 and in EECCA countries. Whiskers indicate range of the reductions among the countries. Negative values of the reductions mean increase.

Transboundary transport and secondary sources

In spite of HM and POPs pollution reduction in the EMEP region transboundary transport continues to play an important role. Change in the emission pattern led to redistribution of transboundary fluxes between the EMEP countries. Contribution of foreign sources to anthropogenic deposition has changed substantially in some countries but still remains significant in most of them.

HM and POP pollution levels are caused by anthropogenic emissions, secondary sources in the EMEP region and intercontinental transport. For lead and cadmium the decline of pollution levels is smaller than the reduction of anthropogenic emissions because of effect of secondary emissions which long-term changes are relatively small. Mercury levels are strongly affected by emission sources located outside the EMEP region. Decline of HCB, PCB and PCDD/Fs levels considerably depends on long-term changes of secondary emissions. The decline of these POPs is mainly linked with strong regulation in ECE on major stationary sources. If these regulations would not continue things could get much worse.

In recent years, significant progress has been made to develop and apply models for hemispheric or global cycling of mercury and POPs where transfer between environmental compartments is included. Many of these activities have been carried out within the framework of the Task Force on Hemispheric Transport of Air Pollutants (HTAP) (reference to HTAP/MSC-East reports and/or web site).

Available model estimates indicate that intercontinental transport of Hg as well as PCDD/Fs, HCB, and PCBs can substantially contribute to pollution of the EMEP countries (from 20 to 70%, Figure A24). In particular, Hg deposition on average consists of almost equal contributions of contemporary anthropogenic emissions and emissions from secondary sources (Figure A25). A half of the anthropogenic part is contributed by domestic emission sources and the other half is by transport from sources located in other regions. The largest external contributors include East Asia (11%), Africa (4%), Southeast Asia (2%) and South America (2%). Similar or even larger contribution of secondary sources (re-emission) is characteristics of HCB and PCBs, which are cycling between the atmosphere and other environmental compartments for decades.

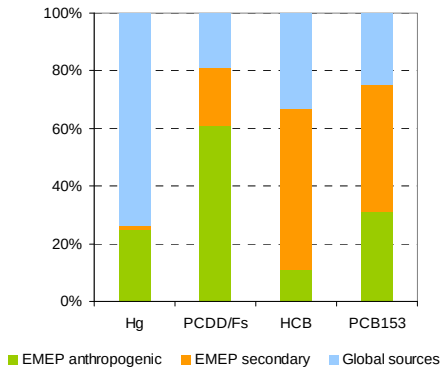

Figure A24: Relative contribution of different source types to contamination of the EMEP countries with Hg and some POPs. Global sources include both anthropogenic and secondary emissions

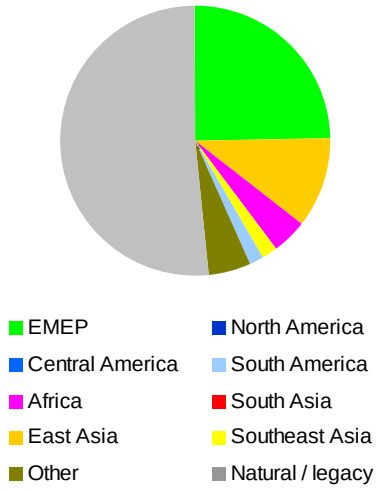

Figure A25: Source attribution of average mercury deposition to the EMEP countries

Effects

For both heavy metals and POPs, human and ecosystem exposures occur via a number of pathways and atmospheric emissions and long range transport contribute in varying degrees to the exposure either directly or indirectly (e.g. via uptake in food chains in remote areas). Science-based policies aimed at reducing exposure need to consider all relevant exposure pathways. Given the increasing epidemiological evidence of low-dose effects, the present concepts of thresholds or safe exposure levels are not sufficient. The focus for future policies should be to reduce exposures to a minimum.

Decline of pollution levels for 1990-2010 period resulted to improvement of the environmental conditions from viewpoint of negative effects on human health and biota. However, human health and the environment continue to be at risk in many EMEP countries despite important reductions of HMs and POPs. In a number of countries critical loads of lead and mercury are still exceeded (Figure A26). High deposition levels of cadmium still remain in a number of 'hot spots' close to industrial regions.

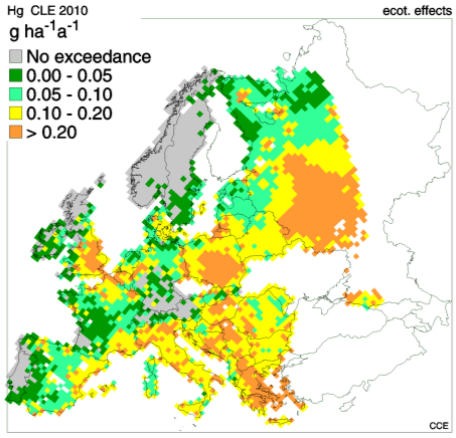

Figure A26: Critical load exceedance of Hg in 2010

Although number of people exposed to B[a]P concentrations above EU target value of 1 ng/m^3 (Directive 2008/50 EC) substantially (around 6 times) decreased from 1990 to nowadays, it is still significant (about 16 mln). The number of people living in these areas in particular EMEP countries is shown in Figure A27.

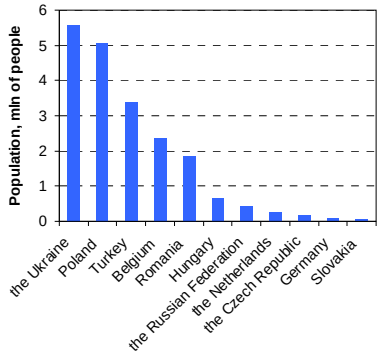

Figure A27: Number of people living in regions where B[a]P air concentrations exceed EU target value of 1 ng/m^3 in EMEP countries in 2012.

Hemispheric and global cycling of mercury and some POPs is an important aspect when discussing policy actions to reduce environmental concentrations and human exposure of these contaminants. The UN – ECE region is thus affected by emissions from other parts of the globe and emissions occurring within the region consequently contributes to deposition in other areas. The capability to quantify the inter-continental transport is thus an important part of the development of international agreements. This global aspect has also been the foundation for the Stockholm Convention on POPs and the Minamata Convention on Hg.

The geo-atmospheric cycling of mercury and POPs includes not only atmospheric transport and transformations but also interactions with the earth´s surface with deposition processes as well as re-emissions are important factors in determining the fate of these contaminants. Marine transport, biological transport as well as international transport in goods and (e-) waste is part of the global cycle.

Re-emissions from environmental media such as land, vegetation and water surfaces is partly driven by concentrations in the surface media and processes occurring in these media that can lead to transformations or retention. This places large challenges on model development where a multi-compartment approach is often required to represent the environmental behaviour and fate. The multi-compartment aspects are especially important when modelling inter-continental transport where interactions with land and oceans are of importance.

Though the evidence for intercontinental transport of Hg and POPs is provided from observations in remote locations far from emission sources, to understand its significance and contribution to health and environmental impacts, the observational evidence must be combined with application of quantitative models that describe the processes of emission, transport, transformation, and removal in different environmental media.

Remaining issues

The concern for health effects caused by HM and POP warrants further policy action to reduce atmospheric emissions and long-range transport. Since a significant proportion of the deposition in many regions have hemispheric or global origin, the actions need to take these geographical scales into account.

Along with progress achieved in understanding the fate and transport of Hg and POPs on a global scale, there are significant uncertainties associated with incomplete information on anthropogenic emission sources, limited knowledge of physical and chemical transformations of these substances in the environmental media, and processes driving accumulation and re-emission to the atmosphere.

Therefore, there is a need for an improved understanding of emissions, long range transport and exposure of HM and POP to allow for a systematic identification of risks and for evaluation of options for emission control. An integrated approach is necessary to exploit synergies in research i.e. including emissions, modelling and monitoring as well as impact assessment. The results of extensive monitoring and modelling activities performed under the framework of CLRTAP can make a valuable contribution to this challenge. A vast number of new substances that are to be assessed are already listed and the number of new POPs will be growing in the future. How can we design effective ways to monitor and model a subset of "indicator" substances and how can monitoring and modeling help in screening for new pops? How can we go from indicator substances to "real" mixtures in models and assessments?

- **Emission inventories**. Alternative methods for emission inventories for POPs and Hg based on either a combination of monitoring and modelling at regional and local scales, or on substance flow analyses (in the case of intentionally produced POPs), should continue to be developed, and incorporated into emission inventories. Most POPs are deliberately produced chemicals and a fundamental challenge for the development of reliable emission inventories of many such chemicals is the lack of accessible and accurate data on production rates and use (as this is often confidential business information). In addition, historical emission data and models are needed to be able to take into account re-emissions of POPs and Hg.
- **Occurrence in ecosystems and process understanding**. As a basis for model testing and development, there is a need for better knowledge on occurrence of HM (particularly Hg) and POPs in relevant compartments of the environment and with global geographical coverage. Especially important for capability to model transfers between different ecosystem compartments such as air-water, air-soil and air-vegetation exchange. Also to link global transport to human exposure there is a need to better understand bioaccumulation/biomagnification in terrestrial and marine food chains.
- **Abatement strategies**. Knowledge on abatement options for HMs and POPs needs to be improved and the knowledge applied to assess benefits of action. Since Hg and POPs have more complex emission sources and pathways than traditional pollutants (point sources, diffuse emissions from industry and households etc.) current tools for assessing abatement strategies (e.g. GAINS) are not yet applicable, but the

information available in the BAT/BEP information of the Risk management profiles for each substance provides a base to improve modelling of abatement options. Systematic methods for assessing and evaluating abatement options are needed.

- Initiate a process to enhance the **synergies and cooperation** between the CLRTAP and other international conventions, programs and policies (UNEP Stockholm Convention on POPs the Minamata Convention and others, Arctic Monitoring and Assessment Programme under the Arctic Council, and regional sea conventions such as HELCOM and OSPAR).

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B. What are key challenges and opportunities?

B1. Air pollution measures could improve the economy

With current policies emissions in the Europe are projected to decrease by ..% between 2005 and 2030, Technically a further ..% reduction is possible. The costs of such an effort will be €..bn (or ..% of the total costs of current policies). The damage to health would be reduced by ..%. Almost 70% of this reduction (..%-points) can be obtained at 10% of the costs. Such a policy strategy would be optimal as the marginal costs would equal the marginal benefits (when taking the lower range of the uncertainty margin of health benefit estimates). (See COM 2013 (Impact Assessment), IIASA 2013 (EC4MACS final report)).

The costs of air pollution abatement can be reduced substantially (..%) with implementation of a successful climate and energy policy, e.g. energy saving and replacing fossil fuels with renewable energy (IIASA 2014 (EP-report). Moreover air pollution abatement costs are estimated conservatively: technological changes (e.g. fast implementation of electric vehicles) have not been taken into account. The costs of an optimal air pollution strategy would be ..-..% of the European GDP, although these percentages would differ between countries. Financial and technological assistance could help to reduce the cost burden for EECCA countries, including assistance in increasing the energy efficiency of EECCA-economies (e.g. less leakage of gas) and a gradual switch towards a low carbon economy.

The GEM-E3 model (JRC) shows that the macro economic impacts of additional air pollution measures are close to zero (COM 2013 (Impact Assessment)). Comparable results were found for additional climate and energy measures. One of the reasons is that such measures would increase costs in some sectors (e.g. the energy sector or agriculture), but at the same time create jobs in other sectors (e.g. the construction sector or metal industry). Air pollution measures could increase the production cost in exporting sectors and lead to a loss of competitiveness and jobs. These effects will be considerably less when the geographical coverage of the international agreement to reduce air pollution is larger. Investments in abatement measures could decrease investments in production capacity, but would also lead to less waste of energy or materials and a higher efficiency of production processes. Cleaner air would mean a healthier work force and less absence from work. This could lead to lower labour costs increase the competiveness of the economy.

Air pollution policy has winners and losers. It is understandable that the fossil fuel energy sector and (industrial) farmers are critical about air pollution policy plans, but from a welfare economic point of view the societal benefits are almost always substantially higher than the costs some sectors have to make.

B2. Transboundary and multisectoral approach needed

The atmospheric emissions of most of pollutants have decreased significantly in the UNECE region over the two last decades. Ambient air concentrations have decreased as well, but not with the same slope, and it can even be disappointing for stakeholders that their efforts for reducing emissions are not so visible considering population or ecosystem exposure. The key point is that air pollution concentrations and deposition are results of multiple factors. Among them, transport and chemistry influence the impact of air pollution sources over large domains and this is the reason why the relevant scale for air pollution control often needs to go far beyond the exposed and affected areas. A transboundary approach must be promoted in and beyond the UNECE region to tackle many of the most important air pollution issues in order to achieve significant improvements and meet long term objectives. This experience was also the driving force for the establishment of the LRTAP Convention.

The use of fossil fuels and biomass for electricity production, heating and transport, as well as the nitrogen losses from agriculture continue to be the main causes of air pollution and the associated risks for human health and ecosystems.

Emissions of several air pollutants, especially SO2, NOx, NMVOC and particulate matter could benefit from international climate and energy policies aiming to reduce the use of fossil fuels.

Ammonia emissions from agriculture however would not profit from such climate policies and remain to require attention from air quality managers. The transboundary component of air pollution will remain to be important: secondary inorganic particles (ammonium sulfate and ammonium nitrate) form an important part of the transboundary fluxes of particulate matter and contribute significantly to the exposure of the population in several European cities (see figure B1 left panel). Moreover the use of biomass and coal for residential heating forms an important source in several cities (see figure B1, right panel).

Effective reductions of PM2.5 levels to meet the WHO annual guideline value of 10 ug/m3 cannot be achieved by isolated local measures, but need to involve multiple economic sectors, and must be internationally coordinated. Remaining hot spots areas, especially in large cities or cities where local meteorology and site characteristics contribute to high PM levels can to a large extend be managed with additional local control measures, but betting on local policies alone to deal with PM exposure in the cities can lead to inefficient and disappointing results.

Source apportionment studies demonstrated the large influence of long range transboundary transport to PM patterns in Europe. Figure XX illustrates clearly the influence of transboundary and national contributions in PM2.5 concentrations in Dutch cities, and the little improvement that can be expected from local control policies. Of course, international/local ratios differ across Europe (e.g see the Polish case) depending on the location of the city, the industrial profile and the technologies implemented by the country, but a significant part of the measures to reduce PM exposure in cities must in most cases be the result of international or national strategies.

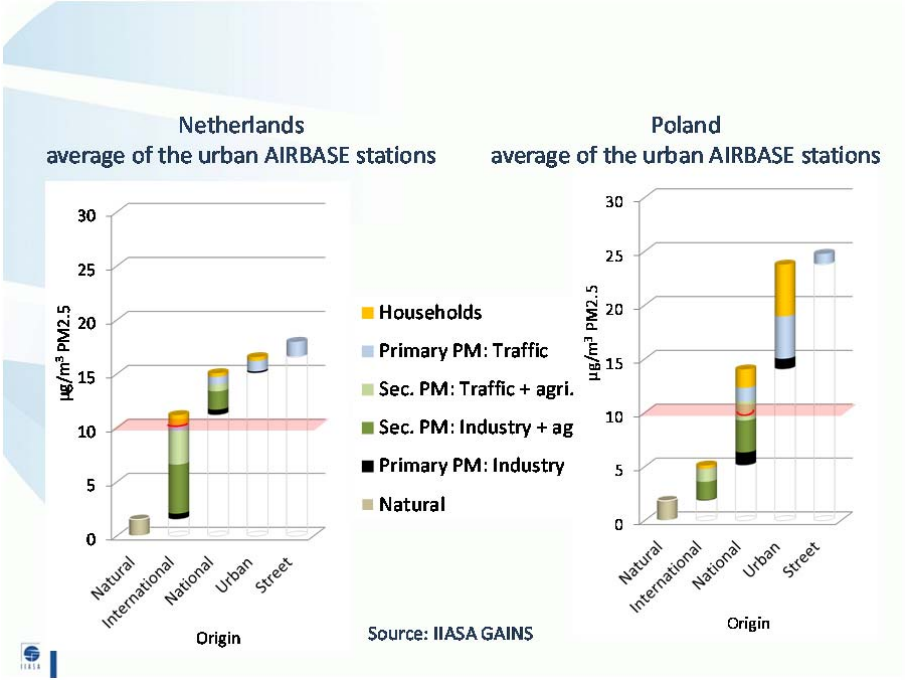

Figure B1: Sectoral contributions to PM2.5 exposure in cities in the Netherlands and Poland, 2009. Source: Kiesewetter et al., ACP, 2015

The Protocols of the LRTAP Convention provide a prime example for effective strategies that involve emissions of multiple substances emitted from a wide range of economic sectors. This experience also points the way forward towards achieving the WHO guideline values throughout Europe in the most cost-effective way.

However, while in the past, controls involved mainly emissions from the power sector, industry and transport sources, for further air quality improvements the focus must necessarily shift towards small stationary combustion sources, especially in the residential and commercial sector, and to agriculture.

Although additional emission controls will involve additional costs, the tools developed under LRTAP can identify cost-effective portfolios of measures in different sectors that achieve the envisaged health improvements at least cost. Such analyses takes into account that in many sectors significant emission reductions have already been implemented, and that further cuts will be costly. They also consider that in other sectors additional measures, although cost-effective from a social planner's perspective, might put unproportioned burdens to certain groups of the society or economic sectors.

As mentioned above, NH3 emissions from agriculture emerge as a key focus for further measures. All analyses indicate a strong need for substantial reductions of NH3 emissions in Europe, both for approaching the WHO guideline values for PM2.5, to which secondary inorganic aerosols (i.e., NH4SO2 and NH4NH3) whose formation is strongly steered by the availability of NH3 in the atmosphere) and for preserving biodiversity of ecosystems, which is threatened by excess nitrogen deposition.

The WHO review of the health effects of air pollution (REVIHAAP) has clearly established total PM2.5 mass concentrations (including secondary inorganic aerosols) as the most health-relevant particle metric (check for exact wording), and the WHO guideline value for fine particulate matter is defined in terms of PM2.5 mass concentrations. As the formation of secondary inorganic aerosols is steered by the abundance of NH3 in large areas of Europe (REF EEA report), controls of NH3 emissions emerge as the logical requirement for an effective reduction of health effects. However, as also pointed out by the WHO- report, it cannot be ruled out that the potency of health effects is different for different components of PM. (check for wording).

This uncertainty might have important consequences for the relative importance of NH3 emission reductions compared to other PM precursor emissions, if a policy is solely targeted at reducing health impacts. However, as practiced for the multi-pollutant/multi-effect Protocols of the Convention, a multi-effect perspective that addresses health impacts in conjunction with, e.g., biodiversity concerns, offers a robust risk management approach that hedges against the uncertainty of the health impacts of secondary inorganic aerosols. If these aerosols would not be linked to negative health effects, NH3 reductions will be still warranted for the protection of biodiversity.

Secondary particles

PM concentrations result from both primary PM emissions and the formation in the atmosphere from complex chemical processes involving many organic and inorganic precursors. New and better methods for measurements of PM composition that have been developed over the last 10 years now (ref EMEP IOP) allow better qualification of the relative contributions from primary emissions which may be controlled locally, and secondary aerosols. The secondary aerosols result from complex chemical processes that involve organic and inorganic species and develop over large geographical areas (see map below). More or less all significant air pollution sources are of importance for the secondary aerosol formation: biomass burning and residential heating, road and off-road traffic, industry, agriculture. Inorganic aerosol formation processes (that lead for instance to ammonium nitrate or ammonium sulfate) are generally better known than organic aerosols that involve a large number of partly unknown chemical species (ref).

PM10 *simulated by CHIMERE over winter 2009 : main contributing compound: sea salts and biogenic (**blue**) / **secondary anthropogenic PM** (**green**) / primary PM (**pink**) / Dusts (**Brown**) (Source : INERIS)*

Huge PM spring episodes that still occur in Western Europe are acknowledged to be mainly influenced by agricultural practices (manure and fertilizers spreading) which are responsible for large ammonia emissions in favorable meteorological conditions. Several results (ref Bessagnet et al + EEA report) show that a significant decrease in the PM peaks can only be achieved through concerted actions in several countries.

Map of ammonia emission reduction scenario

The influence of residential heating and wood burning to transboundary and national PM is also high but more difficult to assess because of uncertainties in emission inventories (including practices in various countries). In the UNECE region, a large panel of practices and technologies makes concerted management more challenging than controlling LCP or road transport, but it should be promoted because it should lead to significant results (do we have some simulation results here ?)

Map illustrating impact of control measures in residential and wood burning sectors?

B3. Air pollution at a wider scale

Frank Dentener, Zbigniew Klimont, Oliver Wild (+ comments from Augustin Colette, Harry Harmens, Gina Mills, Hilde Fagerli)

Air pollution related to ozone and some of its precursors, or to mercury and persistent organic pollutants such as PCDD/Fs, PCBs and HCB, is significantly influenced by sources around the world. The first steps to share knowledge at a wider geographical scale and define potential cost-effective measures have been taken both by the Task Force on Hemispheric Transport of Air Pollutants of the Convention of Long-Range Transboundary Air Pollution (TF HTAP), and UNEP's Climate and Clean Air Coalition (CCAC). Knowledge and experience from the CLTRAP is being shared with global Conventions on Mercury and Persistent Organic Pollutants.

[place holder: section on Hg and POPs here or after the next paragraph]

Tackling the damage of long-term ozone exposure to public health, crops and forest growth in Europe effectively would require a Northern Hemisphere abatement strategy. Although peak concentrations of ozone have declined in parts of Europe, the background concentrations in some major regions of the Northern Hemispheric, such as Asia and the west coast of North America, show an increasing trend (see section A3). While peak ozone concentrations are largely determined by local emissions of NOx and VOCs, on hemispheric to global scales ozone concentrations are also determined by emissions of the long-lived greenhouse gas methane (CH_4) and carbon monoxide (CO), as well as by natural variability of biogenic emissions and transport of stratospheric ozone into the troposphere. Together, NOx, VOCs, CO and CH_4 interact to form ozone, changing the oxidation capacity of the troposphere (governed by the reactive OH radical) and forming long-lived reservoir species such as peroxyacetyl nitrate (PAN).

Global emission changes between 1990-2010

While the emissions of ozone precursor gases NOx, VOC, and CO have declined by about 40 % from 1990-2013 in Europe (EMEP, 2015), and similar reductions have been achieved in North America, emissions have increased by 20-30 % in the rest of the world, and by as much as 50 % in emerging economies like China and India (Figure 1). Global anthropogenic emissions of CH_4 were stable in the 1990s, but increased in the 2000s (Figure 1 and 2). Due to its 10-year lifetime and uniform global distribution, the global abundance of methane can be determined accurately. Methane observations from the global NOAA network show strong increases until 1998, followed by a decade of near-stagnation, and have been growing again since 2008. This points to a strong inter-annual variability of natural sources and sinks, but an underlying long-term trend that is driven by anthropogenic emissions.

HTAP scenarios between 2010-2050

How will future ozone respond to changes in anthropogenic emissions in Europe, North America, and the rest of the world? And what is the role of CH_4 relative to CO, VOC and

NOx emissions? To assess this, the GAINS model (Amann et al., 2011) was used to generate a set of emissions under a range of assumptions about air pollution and climate policies.

The HTAP (ECLIPSE V5a) Current Legislation (CLE) and Maximum Technically Feasible Reduction (MTFR) scenarios both use business-as-usual projections from the Energy Technology Projections study by the International Energy Agency (IEA, 2012) and Food and Agricultural Organization (FAO) projections of livestock (Alexandratos and Bruinsma, 2012). The IEA projections are similar to the RCP6 scenario (until 2050) used by IPCC AR5 (van Vuuren et al., 2011) with regard to global fossil fuel CO_2 emissions. The Ref-MTFR scenario, developed for the time slices 2030 and 2050, shows the implications for emissions of implementing all currently existing technology options to mitigate air pollution and methane emissions, irrespective of their costs. This hypothetical scenario illustrates the full scope of emission reductions when known and proven measures are unconditionally implemented and enforced.

An additional energy-climate scenario (Clim-CLE) provides a perspective on the potential of changes in the energy system to reduce air pollutants and methane emissions. Clim-CLE draws on the IEA "2 degrees" energy projections, which target 450 ppm CO_2 concentrations (IEA, 2012) through energy efficiency improvements, lower coal use, etc. Assumptions on air pollution legislation were adopted from Ref-CLE. The CO_2 emission trajectory is comparable to the RCP2.6 pathway used in the IPCC AR5 report. In contrast to the scenarios developed by a number of global integrated assessment models, the GAINS reference (Ref-CLE) and climate (Clim-CLE) scenarios do not assume 'automatic' reduction of air pollution emissions with progressive economic development (Amann et al., 2013). Therefore, for NOx, NMVOC and CO some rebound effects are evident after 2030 (Figure B2), while CH_4 emissions are nearly constant in Clim-CLE (Figure B3).

Compared to earlier estimates (Amann et al. 2013), the global emissions in Figure B2 show a stabilization or slight decline after 2010 owing to recent control efforts in China (12th Year Plan and Action Plan, e.g., Zhao et al., 2013; Wang et al., 2014; Klimont et al., in preparation, 2015), and assume effective enforcement of existing legislation. At the same time further strong growth of ozone precursor emissions is expected in several other regions (Figure B2).

The contribution of Europe and North America to global air pollutant and methane emissions is declining over time. While Europe contributed 30 %, 23 %, 16%, and 19 % of global NOx, VOC, CO, and CH_4 emissions in 1990, these fractions decline to 9 %, 10 %, 7 %, and 9 % for Ref-CLE in 2050, with similar fractions for the other scenarios. Similar declining contributions are seen for North America, except for methane. In contrast, the contributions of East Asia, South Asia, and the rest-of-the world are increasing, reaching about 80 % of global emissions for all scenarios by 2050. There is a huge potential for methane emission reductions in the waste and fossil fuel production sectors (Ref-MFTR and Clim-CLE, Figure B3), while emissions from the agricultural sector are more difficult to reduce. The growth of CH_4 emissions takes places mainly outside of the UNECE domain.

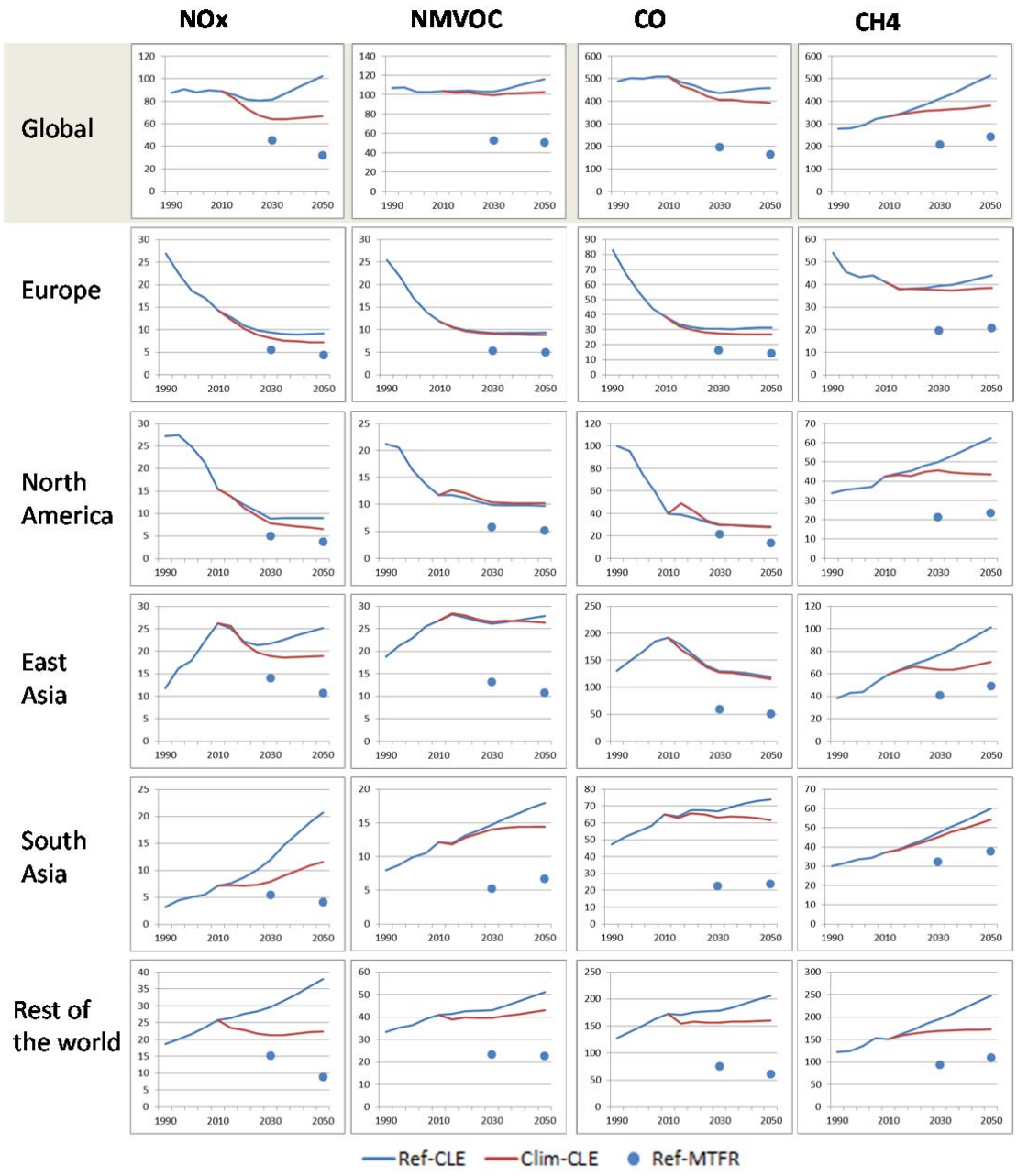

Figure B2: Trends in the anthropogenic emissions [Tg] of NO_x (as NO_2), NMVOC, CO and CH_4 for the world and five major regions, and the Ref-CLE, Clim-CLE and Ref-MTFR scenarios. The first scenario year is 2015.

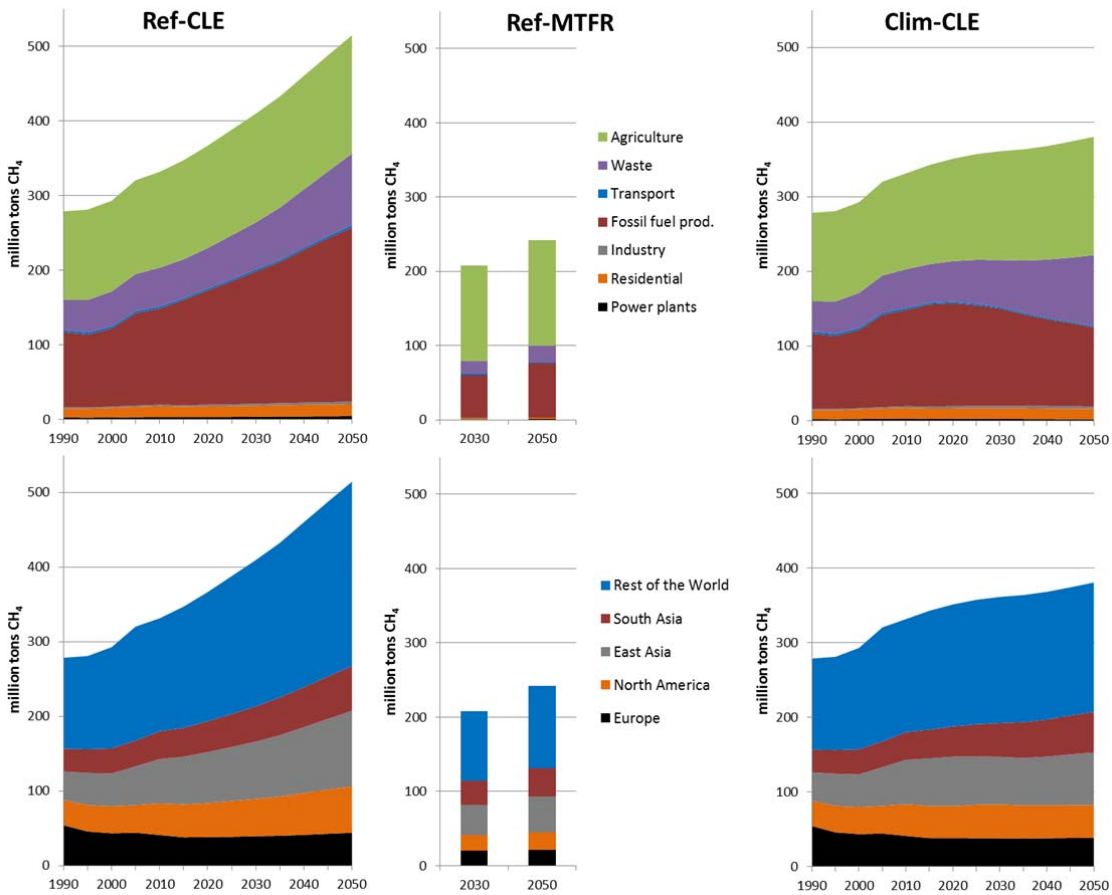

Figure B3: HTAP (ECLIPSE V5a) CH_4 emission scenarios; Baseline (Ref-CLE and Ref-MTFR) and climate scenario (Clim-CLE). 1 million ton is 1 Tg.

The HTAP simulations indicate that, after an initial decrease in region-wide annual average ozone in North America and Europe, ozone may start increasing again after 2020-2030, progressively driven by methane. Further ambitious pollution controls (MTFR) could drive down annual ozone in Europe by up to 6 ppb by 2030 and 8 ppb in 2050, with approximately equal contributions from European, external and methane emission controls. Although there is a significant model spread underlying these calculations, the difference between scenarios is generally larger than the spread. Ozone in summer, relevant for the growing season, declines more strongly than in winter, and stabilizes at a decline of 2 ppb for the Clim-CLE scenario, but then increases above 2010 levels by 2040. The Ref-MFR scenario, which also includes a number of progressive CH_4 emission reductions, reduces summer ozone by 10 ppb. (Figure B4).

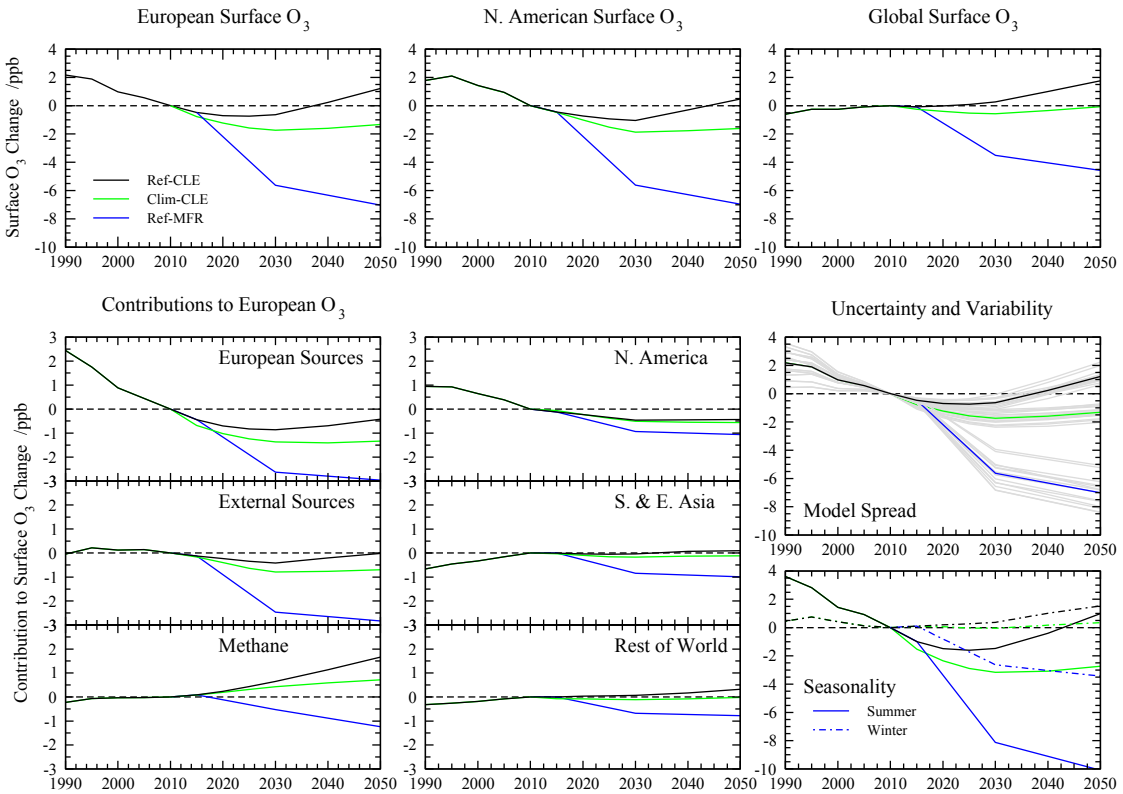

Figure B4: HTAP analysis of future annual surface ozone changes in Europe, North America and the world, and the contributions to ozone in Europe from European, North American, Asian, and Rest-of-the-world sources of NOx, CO and VOCs, and from global CH_4 emissions. Right-hand panels show model uncertainty and seasonal responses in summer (JJA) and winter (DJF). Emissions from ECLIPSEv5a database (Klimont et al., manuscript in preparation, 2015), and HTAP simulations described in Wild et al. (2012).

The TF HTAP analysis shows that in future, ozone in Europe will become increasingly dependent on the development of emissions in other parts of the world, with about two thirds of the ozone change driven by emissions outside of Europe and by methane. Effective implementation of air pollution policies in emerging economies will lower the hemispheric ozone concentrations arriving in North America and Europe. Methane, an important greenhouse gas, is included in the basket of emissions included in the Kyoto protocol. Methane is not only important for climate, but also increasingly for reducing impacts on health and vegetation, and needs consideration in its own right. The LRTAP Convention should therefore consider ways to include methane emission reductions in future negotiations and agreements.

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B4. Air quality and climate change: two sides of the same coin

Additional measures, if seen in isolation, are more costly, although benefits outweigh costs. In addition, they offer significant synergies (and potential trade-offs) with other policy priorities.

The necessity of further emission reductions across many economic sectors, including those that have not contributed substantially in the past, offers new opportunities for synergies with other policy priorities that could provide additional arguments for taking measures.

In particular, a wide body of scientific literature has highlighted numerous facets of physical and strategic interactions between air quality and climate change policies. Interactions occur along multiple pathways, and act in both directions.

Many of the air pollution controls have clear co-benefits on greenhouse gas emissions and climate change. To the extent air pollution controls increase energy efficiency and/or reduce consumption of fossil fuels, they will lead to concomitant cuts in CO2 emissions. Although the traditional focus on end-of-pipe air pollutant controls has paid only little attention to this aspect in the past, there is a significant potential for such win-win measures in the future, and they become more economically competitive with increasing costs of emission controls (e.g., co-generation). Vice versa, some of the technical air pollution emission controls that have been employed in the past lead to (slightly) higher CO2 emissions (e.g., flue gas desulfurization, denox), although in many case this increase is compensated by concomitant improvements of energy efficiency that emerges from better controlled process conditions.

Most of the air pollutants also affect climate during their (comparably short) residence time in the atmosphere, either enhancing or masking temperature increase. At present time, the climate forcing from the air pollutants is substantial (with a net cooling effect), and air pollution controls will alter the net balance. To limit the rate of temperature increase in the coming decades air pollution policies could focus more on the abatement of air pollutants that have a both a warming effect and impose risks to human health and ecosystems: black carbon and ozone precursors, including methane (Figure B5). [add recent findings on BC, or mention uncertainties?]

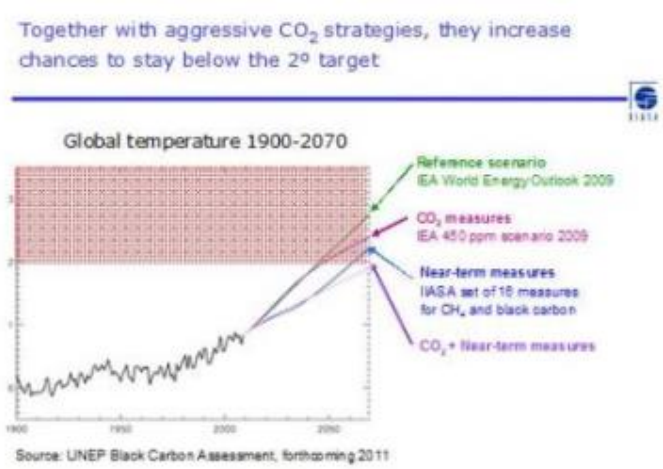

Figure B5: Role of Short lived climate pollutants in climate policy

Ozone formation is a good illustration of the positive feedbacks between climate change and air quality. Ozone itself would enhance warming. It would also reduce the uptake of CO2 from the atmosphere by vegetation and forests and thus influence the development of CO2-concentrations in the atmosphere. In turn a warmer climate could increase direct ozone formation and release more biogenic ozone precursors. Tackling ozone precursors would have positive effects for health, ecosystems and climate change mitigation.

On the other hand, climate policy will 'automatically' influence the emissions of air pollutants related to the use of fossil fuel. Reductions in fossil fuel use will not only reduce CO2-emissions, but also reduce emissions of SO2, NOx, NMVOC, particulate matter and several heavy metals (such as mercury) and persistent organic pollutants (such as PAH, PCDD and HCB). This could either lead to an additional reduction of risks for human health and ecosystems, or to a reduction of costs to meet air quality standards. Such co-benefits for air pollution are dominating the benefit/cost ratio of climate measures.

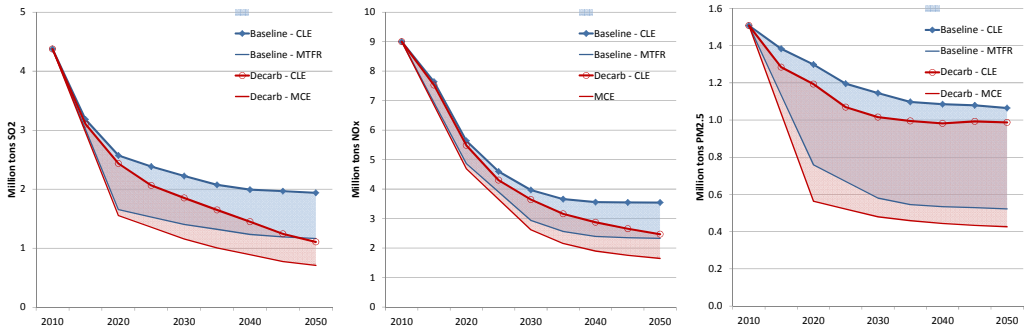

Figure B6: Scope for emission reductions for SO2, NOx and PM2.5 in the EU, with and without climate measures

However neither an ambitious climate change or air quality abatement policy will automatically yield benefits for each other without integrated policies aiming at co-beneficial solutions especially in the energy production and transport sector. The combination of an ambitious climate policy and maximum feasible air pollution emission reductions in these sectors is absolutely necessary to meet the WHO air quality guideline values in Europe as well as meeting a need for reduction of climate warming components.

Although for most climate measures would help to improve air quality, there is an exception for the use of biomass as a substitute for fossil fuels. Especially residential wood burning contributes to indoor and outdoor exposure to particulate matter and would reverse the positive health effects of air pollution policies. Increased use of diesel engines will potentially lower fuel consumption compared to gasoline engines. However their emissions of air pollutants require exhaust cleaning techniques that require energy and hence can increase fuel consumption and reduce the power produced. Even with these techniques their emissions of air pollutants, particularly NOx, even at Euro 6 level are still higher than those of gasoline engines in real-world use. The air pollution consequences of different power production techniques and mixing with biofuels have to be carefully assessed.

Reducing emissions of CO2 by exchange of fossil fuel with biomass in energy production might increase emissions of air pollutants as increased biomass production indirectly will affect land use and emissions of biogenic VOC.

B5. Air quality and agriculture

Although climate policy includes limiting emissions of N2O and methane from agriculture, NH3- emissions will remain unaffected by climate policy. With the expected climate change NH3-emissions from agriculture and natural sources even tend to increase (ref). This would pose additional risks for human health (via the formation of secondary inorganic aerosols) and for ecosystems (via excess deposition of nitrogen).

Besides the NH3 and N2O emissions to air, nitrogen losses during food production take place in the form of nitrate leaching to groundwater and runoff to surface waters. Environmental policy limitations on losses of NH3, N2O and NO3 form a coherent framework to encourage a more efficient use of nitrogen in agriculture. Guidelines for good agricultural practices have been formulated within CLRTAP and could – if complied fully – reduce emissions of NH3 by..%. Note that 80% of the NH3-emissions in EU-countries are generated by less than 10% of the farms. The majority of the livestock is kept by a small number of industrial size farms. Ammonia abatement measures at such large farms would be much more cost-effective than measures at smaller farms.

Further steps could be considered to increase the nitrogen use efficiency including food consumption. This would require behavioural changes. Reduction of food waste, increased attention to food quality aspects and a shift towards low meat diets could offer significant additional NH3-reductions and go hand in hand with encouraging healthy life styles.

Such changes would increase global food security and reduce the area needed to food production. This would offer opportunities for the protection of nature areas. There is however a potential conflict with increasing the use of biomass to substitute fossil fuels as a means to reduce CO2-emissions. More biomass production could put additional pressure on agricultural land and nature areas.

B6. Air pollution policy contributes to sustainable development targets

Air pollution policy contributes in several ways to the recently established Sustainable Development Goals of the UN:

- Improved air quality is the most effective environmental measure that can be taken to ensure healthy lives and wellbeing for all (SDG3). It is one of the elements to make cities and human settlements inclusive, safe, resilient and sustainable (SGD11).
- Nitrogen and ozone measures could help to promote sustainable agriculture, improve nitrogen use efficiency, increase food security and contribute to end hunger (SDG2). Such measures are also needed to protect, restore and promote sustainable use of terrestrial ecosystems, sustainable forest management, and halt biodiversity loss (SDG15).
- Substitution of polluting old power plants and residential heating by clean efficient technologies contributes to the target to ensure access to affordable, reliable, sustainable and modern energy for all (SDG 7).
- Air pollution measures contribute to a cleaner and more efficient agriculture, industry, power sector and transport system as part of the sustainable development targets to ensure sustainable consumption and production patterns (SDG 12) and to promote sustainable economic growth (SDG 8), industrialization and innovation (SDG 9).

Moreover as was shown before air pollution policies can strengthen actions to combat climate change and its impacts (SDG13)

B7. Institutional arrangements

Public health concerns currently dominate the air pollution policy agenda. Episodes with high levels of pollution raise public concern, cause health complaints and make air pollution literally visible. While such episodes raise public concern, the main burden of disease from air pollution is actually related to long-term, chronic exposure to air pollution, and not from occasional air pollution peaks. Several local initiatives have been taken to develop 'healthy' cities. Cities could learn from each other to choose the most effective options to reduce health risks. The Convention on Long Range Transboundary Air Pollution could choose to play a role in the exchange of knowledge and experiences between cities.
But cities cannot reduce the air pollution levels down to the WHO guideline levels on their own. Even during high pollution episodes the contribution of sources outside the city is often dominant. Local air pollution risks are still predominantly a transboundary phenomenon in many cities of Europe. Reduction of exposure to fine particles (PM2.5) would not only require reduction of emissions of particulate matter in cities (such as black carbon), but also of precursor emissions of secondary particles in a much wider area: sulphur dioxide, nitrogen oxides (NOx), ammonia (NH3) and volatile organic compounds. Collaboration and policy co-ordination within the EU and the Convention on Long-Range Transboundary Air Pollution remains important in defining the most cost-effective ways to reduce health risks due to air pollution.

European wide emission reductions of these precursor emissions will be indispensable to meet the WHO annual guideline level for fine particles of 10ug/m3. This would reduce the average loss of life expectancy in Europe with almost [6] months compared to the 2005 situation. Besides these health benefits, better nature protection due to reduced deposition of nitrogen would be a co-benefit.

Actions at different levels to reduce health risks

At the continental level:
- Make sure that vehicle emission standards work in reality
- Implement climate & energy targets
- Set emission standards for domestic stoves, NRMM, MCPs
- Set ammonia emission standards for large cattle farms

At the national level:
- Implement control on maintenance schemes for vehicles
- Stimulate scrapping of old vehicles and motorcycles
- Implement climate and energy policies
- Ratify CLRTAP protocols
- Enforce emission standards for farms and domestic stoves

At the local level:
- Implement low emission zones to encourage early scrapping of old vehicles
- Introduce speed limits on highways near urban areas
- Stimulate electric vehicles
- Improve infrastructure for public transport, cycling and walking (embed air pollution policy in healthy city designs)

In the Convention on Long-Range Transboundary Air Pollution long-term monitoring activities and developing the modelling capability have supported the issue framing and delivered robust data to derive salient policy information, in particular using risk quantification concepts and integrated assessment modeling to highlight the cause for action and the costs of inaction. The institutional setting provided by the Convention has been essential – also in building trust between different scientific fields as well as between science and policy. The flow of information is not unidirectional from science to policy: the explicit and implicit values expressed by national and international political processes find their way into the priority setting process for modelling and research, and the valuation of different, at times conflicting, policy targets (Voinov et al., 2014).

The success of the effect-based approach of the Convention is crucially dependent of the support from subsidiary scientific and technical bodies and it is important that these bodies continue to improve their efficiencies without losing focus on quality. The balance between a long term research agenda and a 'quick response' facility in the form of an integrated assessment model has proved to be an important element of the success of the Convention (Raes & Swart, Reis et al.2007).

The exchange of knowledge and experiences between scientific and technical bodies under the Convention and national experts is generally well organised. Dissemination of knowledge to national experts in EECCA-countries is currently being strengthened, with a focus on improving the quality of emission data and the assessment of health impacts of air pollution.

For some air pollution problems policy co-ordination at the European scale will not be sufficient: ozone, mercury and some POPs were mentioned above as pollutants that are transported at a hemispheric scale. This would require a co-ordinated policy that goes beyond the current domain of the LRTAP-Convention and would also include major polluters in Asia. Knowledge and experiences gained in the CLTRAP could be further shared with institutions working at a wider geographical scale, such as the IPCC, the CCAC, WHO, UNEP, WMO, the Arctic Council,, the Minamata Convention or the Stockholm Convention.

[A viable future of the Convention and its protocols depends on the positive and vigorous participation by the Parties in all parts of the region, and on ensuring its extensive geographical coverage. The capacity-building activities implemented by UNECE with support of several Parties to the Convention are aimed at improved ratification, implementation of and subsequent compliance with the key protocols to the Convention. The support to countries in Eastern Europe, the Caucasus and Central Asia is provided both at the technical and policy levels. It includes the organization of technical trainings and workshops related to the establishment of the national inventory system, development of national emission inventory for priority sectors, compilation of Informative Inventory Report, calculating gridded data, and other issues. The policy-level support is provided through the advice on identifying steps towards ratification and implementation, the analysis of the national air quality assessment and management policies and legislation with identification of gaps in relation to the

Convention's requirements, as well as through the information exchange at the meetings of the subsidiary bodies and task forces under the Convention.

Thus, there were trainings and workshops organized in Armenia, Azerbaijan, Georgia, Kazakhstan, Republic of Moldova and Uzbekistan, which resulted in an improved emissions reporting. A roundtable to present the results of the analysis of the national legislation with participation of the Parliament and stakeholder ministries took place in Uzbekistan to support the ratification. Dedicated sessions were organized within the regular meetings of the Working Group on Strategies and Review to support the exchange of information on policies and practices, as well as the challenges and progress in EECCA countries.

UNECE with support of several Parties will continue organizing technical trainings and consultations in other countries of the EECCA region covering the issues of emission inventory, calculating base year emission levels, emission reduction targets, as provided for by the amended Gothenburg Protocol, and making respective projections. It will also continue providing policy-level support based on the needs expressed and raising awareness of the effects of air pollution and the benefits of implementing the protocols to the Convention among decision-makers in the target countries.]

Requirements for ratification in EECCA countries

Current challenges

- Application of outdated highly-polluting technologies in EECCA countries, ineffective maintenance, no concern with resource efficiency
- Structure and scale of the transport sector, especially in major cities – elevated levels of pollution are generated either by high quantity of modern vehicles, and/or by EUR ZERO outdated fleet (assessment, monitoring and action required)
- Short summary of challenges in other sectors not yet mentioned above
- Insufficient understanding of links between air pollution and health-related issues as well as links to economic development at national level in the region – general awareness needs to be raised and on-going work to address this need
- Underline importance of submission of emission data

Capacity building activities

(a) Scientific level support

- Emissions inventory development/advancement in order to target key sources – still a major challenge in countries (actions already being undertaken and further actions required)
- Secretariat's plans to provide support in estimating base year emission levels and emission reduction targets for 2020 and beyond, as provided for by the amended Gothenburg Protocol, and making respective emission projections;

(b) Policy level support

- Policy level support provided: national legislation analysis, advice on necessary steps for ratification; information exchange on policies and measures at WGSR sessions (possibly provision of examples)

Ratification of CLRTAP Protocols and links with other international agreements

- Reiterate 'flexibility mechanisms' introduced to the revised protocols and benefits that countries can enjoy if they ratify before the end of 2019 Streamlined, simplified communication of benefits from ratification and implementation of the CLRTAP Protocols is essential (all messages should be 'translated' into language clear and understandable in order to be simple and direct)
- EECCA countries are parties to Stockholm Convention (all), Basel Convention (almost all), need to harmonize with GHG reporting under the UNFCCC, some countries are considering ratification of the Minamata Convention – link the work under these MEAs and CLRTAP would help (motivate) accession to the CLRTAP protocols, avoid duplication

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Annex 1: Emission trends 1980-1990-2000-2010-2020-2030

Emission data and CLE-projections per country or groups of countries to be added

Emission data and CLR-projections per sector to be added

Annex 2: Text on synergies between air pollution and climate change

Hans-Christen Hansson, Stefan Reis, Martin Schulz, Contributions: Marie-Eve Heroux, Stefan Astrom, Frank Dentener [elements still have to be included in main text]

Potential synergies between air pollution and climate change policies have scientifically been identified and have led to different recommendations on how drivers and pressures could be addressed in a cost-effective way.

Synergies between air pollution and climate change may occur at different levels:

- Emissions and emission control
- Atmospheric processes, where feedbacks may lead to synergies and / or unintended consequences
- Ecosystem feedbacks (e.g. N2O emissions due to N deposition, ozone effects reducing C sequestration)
- Environmental, human health and climate effects

Atmospheric processes, where feedbacks may in both ways

- Environmental and health effects
- Ecosystem feedbacks (e.g N2O emissions due to N deposition, ozone effects may reduce C sequestration)
-

Future air pollution abatement cannot be seen separately from climate and energy policy, and vice-versa. An ambitious integrated air quality and climate policy could generate substantial co-benefits in the form of further reduction of SO2, NOX and PM2.5 emissions giving leading to considerable ecosystem protection, and health benefits and climate mitigation. Several heavy metals (such as mercury, cadmium, lead and copper) and persistent organic pollutants (such as PAH, HCB and PCDD) come from the same sources as emissions of primary PM and are reduced with the same measures. Decreased methane emission will result in decreasing give lowerground level ozone concentrations further decreasing the climate warming but also giving less damage to health and and ecosystems and thus losses of food and timber production.

However neither an ambitious climate change or air quality abatement policy will automatically give yield benefits for each other without seeking integrated policies aiming at co-beneficial solutions especially in the energy production and transport sector. The combination of an ambitious climate policy and maximum feasible air pollution emission reductions in these sectors is absolutely necessary to meet the WHO air quality guideline values almost everywhere in Europe as well as meeting a need for reduction of climate warming components.

Background

There are several feedback processes affecting both climate and air quality, for example, climate warming might increase methane emissions which in turn increase ozone concentrations (ref ??IPCC2014). Ozone affects atmospheric chemistry, and decreases crop and forest growth, thus affecting the CO2 uptake and possibly biogenic VOC emission, in turn possibly affecting ozone production (Ref ??). There is a strong need for a holistic

approach, i.e. an earth system approach in assessing different air pollution or climate change abatement programmes.

The major common source for CO2, particles, SO2, particulate carbon, i.e. elemental and organic carbon, and ozone precursors such as NOX and VOC is combustion of fossil fuel to produce electricity, heat and transport. Air quality measures focusing on decreasing emissions of primary particulate matter/carbon and NOX, which to some extentmay increase the energy consumption increasing the CO2 emissions through the application of 'end-of-pipe' technologies. Reducing emissions of fossil CO2 by exchange of fossil fuel with biomass in energy production might increase emissions of air pollutants at the same time as increased biomass production indirectly will affecting the land use and emissions of biogenic VOC, e.g. methane affecting atmospheric chemistry and climate.

While recent model studies have shown that abatement measures focused on particulate black carbon have considerably lower climate effects than earlier studies have shown, reduction of methane emissions have a direct climate effect enhanced indirectly through a decreased production of ozone and its direct and indirect effects on climate (ref ECLIPSE, Varma / Acosta). Abatement of methane emissions will thereby also have beneficial health and ecosystem effects thus being co-beneficial for climate and air quality.

Effects of air pollution

Health

Air quality is the largest contributor to the burden of disease from the environment. Health effects are mainly due to exposure to small particulate matter (≤10µm in diameter – PM10 or ≤2.5µm in diameter – PM2.5), which causes cardiovascular and respiratory disease, as well as cancer. The black carbon part of PM2.5, which results from incomplete combustion, has attracted the attention of the air quality community owing to the evidence for its contribution to detrimental effects on health as well as on climate. Improving access and use of clean, sustainable sources of fuel and energy can have immediate benefits for health, and reduce some of the pollutants that cause climate change.

Ecosystems

The AQ effects on ecosystems have been a main issue addressed during the 35 years of CLRTAP resulting in a strong reduction of especially acidification, and to a lesser but substantial extent eutrophication (Ref EMEP??). The contamination from many heavy metals has also been strongly reduced (Ref EMEP??). However while acidification has been reduced over large areas of the UNECE region, excess nitrogen and eutrophication still affects large parts of the area. The contamination of heavy metals and organic pollutants is still a considerable threat to human health and ecosystems

Crops

Ozone affects the growth of crops causing a considerable threat to food production. The BC and methane emission reduction measures suggested in the UNEP/WMO study 2011 on the integrated assessment of black carbon and tropospheric ozone gives an increased crop yield of about 50 million ton of maize, rice, soybean and wheat.

Climate

The effect of particulate air pollution on climate has become better defined in recent years through more advanced modelling studies especially using earth system models. Varma/Acosta et al., 2015, show using the Norwegian Earth System Model NorESM that past European SO2 emission reductions have had the strongest effect on the Arctic climate rather than the European climate. However the effect of increasing CO2 is dominating. Projections of global emission reductions according to a technical maximum feasible scenario indicate similarly that the major effect will be in the Arctic but even here it is a minor fraction (about 25%) compared to the effect of an anticipated double to natural CO2 concentration (refs). Similar studies on BC do not show any significant climate effect. It is most likely that air pollution abatement measures focused on methods with lowest possible CO2 emissions will give considerable and needed reductions in both air pollution and climate warming.

The feedback from climate change on air quality has and will vary across Europe. It will also vary by season and the type of pollution.

- Increases in ozone are probable, partly driven by increasing biogenic emissions, but also increases/decreases of particle formation. Due to a warmer and dryer climate especially in the Mediterranean region there is significant risk for increased number and size of wild fires periodically giving very high air pollution levels.PM
- Potentially significant increase of wildfire emissions
- Ambitious emission controls (e.g. MFR-vs-CLE) will have larger impacts on air pollutant concentrations than will climate change.

Global – regional – local

Air pollution is the major environmental health threat to humanity (ref WHO). Local air pollution sources often have a major impact on the local air quality. However over most parts of Europe the long distance transported particles dominate the PM concentrations due to secondary particle formation. Intercontinental transport of aerosol occurs but has only a very small influence on the PM levels. While local ozone formation due to its longer atmospheric lifetime influence the ozone concentrations over the whole hemisphere.

The climate impact of particulate pollution, primary as secondary has a global effect. It is not confined to the region of emissions but have a spatially uneven effect on the global climate change such that the climate effects could be manifested in other regions quite far from the emission areas. Ozone has a more uniform effect probably have a more uniform climate effect as it has less spatial variability.

Regionally developed integrated air pollution and greenhouse gas abatement strategies will probably be the most effective and useful strategies, due to the mainly regional character of air pollution and its sources including climate gases.

Energy use in transport and energy production

Transport and energy production rely to a large part on combustion techniques. F When using fossil fuel combustion is a common source of anthropogenic CO2, particles and ozone precursors. Abatement focusing on either CC or AQ risks being counter-productive, e.g.

switching to biomass, particularly in smalls scale appliances, will give larger emissions of air pollutants. PM including Black Carbon and VOC's and thus cause larger societal costs through adverse effects on public health. On the other hand some abatement techniques to reduce emissions of air pollutants can cause small increases in energy use giving higher CO2 emissions. The planning of future transport and energy systems have to include an assessment of the impact on both AQ and CC in order to reach an optimal solution with acceptable AQ and climate change mitigation

Energy efficiency

Increasing energy efficiency implies decreased fuel consumption, which is an effective measure to reduce emissions of both GHG and air pollutants. The impact of energy efficiency depends on which fuels that are used when producing electricity and on whether the policy instruments used minimize potential rebound effects from efficiency improvements. For the transport sector there are many different types of efficiency improvements, some (such as smaller engines in personal cars) might have limited impact on air pollutant emissions, while others (such as improved urban planning) might have larger co-benefits.

Reduction of fossil fuel combustion

Reduction of fossil fuel combustion is absolutely necessary to prevent an exceedance of the 2 degree Celsius target. The EU have agreed on target of a 40% reduction in domestic CO2 emissions in 2030 compared with 1990. Not only a change to biofuels including stringent emission limits for air pollutants but also probably a larger scale infrastructure change is needed to reach this target. Future energy and transport system will most likely be more diverse, more adapted to local circumstances. The environmental impacts of many of the new techniques are not well known, including emissions of air pollutants. This information and aspects have to be brought into the planning process such that both CC and AQ effects can be taken into account simultaneously.

Switch to non-combustion energy production

Introduction and use of non-combustion techniques as wind, wave power and solar panels will reduce emissions not only of greenhouse gases but also of air pollutants. It is important that the potential and need for these techniques are fully investigated and assessed to be included in future scenarios. However the production of these power production techniques will have environmental effects, as greenhouse gases and air pollutants that have to be assessed and included in the emission scenarios. While nuclear power is not without its associated problems of waste disposal and public acceptability, it offers a solution to energy generation at least during a transition period that which involves no direct emission of air pollutants or greenhouse gases.

Trade-offs, biofuel, increase use of diesel, ammonia, regional –local planning

Especially in the transition to new sustainable production techniques trade-offs have to be accepted. However they have to be accompanied by a critical assessment including a time plan how to reach a sustainable solution. One example is the increased use of diesel engines with a potentially lower fuel consumption compared to gasoline engines. However their emissions of air pollutants require exhaust cleaning techniques that require energy and hence

can increase fuel consumption and reduce the power produced. Even with these techniques their emissions of air pollutants, particularly NOx, even at Euro 6 level are still higher than those of gasoline engines in real-world use. Different power production techniques and mixes have to be carefully assessed accompanied with considerable development efforts.

Increased exploitation of forest biomass as a biofuel can offset achievements in reducing soil and water acidification by decreasing sulphur and nitrogen deposition to forest ecosystems. Just as acid deposition acts to deplete soils of essential nutrients such as base cations calcium, magnesium and potassium, removal of biomass from forests also entails depletion of these cations. Thus increased use of forests as biofuels as a means to reduce use of fossil fuels poses an additional threat on these ecosystems.