Annex II Policy background (draft 22 Aug)

(please send written comments/additions to Rob.maas@rivm.nl before 8 September)

I. Brief introduction

1. The purpose of this document is to provide additional policy-relevant information to supplement the conclusions in the Gothenburg Protocol review report.

II. Scenarios

Current reduction plans

2. Current reduction plans in Europe show relatively small decreases for NH_3 compared to the projected emission reductions of SO_2, NO_x and primary PM. The regional deposition rates of S and N are projected to change similarly to regional emissions of SO_x, NO_x and NH_3. Reductions of primary PM emissions, together with precursors of the secondary inorganic aerosols, are projected to lead to reduced $PM_{2.5}$ concentrations by 2030. Even so, the 2005 WHO air quality guideline value for $PM_{2.5}$ (yearly and daily) is expected to still be exceeded in some areas (North Italy, areas in Western Balkan and EECCA). In the longer term, some processes may lead to increasing PM levels again, for example, higher temperatures may increase biogenic VOC emissions (and hence formation of secondary organic aerosols) and increasing NO and NH_3 emissions from soils might also increase secondary PM formation. GAINS calculations show that the 2021 annual WHO air quality guideline value for PM2.5 will be exceeded in large areas by 2030 on the basis of current legislation.

Additional reduction options

3. Further emission reductions are considered possible in international shipping, for example, via the International Maritime Organization (IMO) agreements on emission control areas or initiatives by port authorities to encourage clean ships. Within the United Nations Economic Commission for Europe (ECE) region, further technical reductions in NH_3 emissions from agriculture, fine particulate matter ($PM_{2.5}$) emissions from residential solid fuel burning and agricultural waste burning, and methane (CH_4) emissions from waste treatment, the fossil fuel sector and agriculture are also possible.

4. Additionally, in countries of Eastern Europe, the Caucasus and Central Asia, South-Eastern Europe, technical emission reductions are possible, inter alia, from coal burning, transport and waste treatment.

GAINS model improvements by CIAM

5. The GAINS modelling domain is extended and includes all EECCA countries, i.e. covers EECCA, including Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, Tajikistan. Soil NOx emissions are added consistent with the EMEP/EEA Guidebook and national reporting. NMVOC emissions from livestock manures and crop production are implemented in GAINS applying EMEP/EEA Guidebook methodology. Slurry acidification is added as NH_3 mitigation option. Waste management options (including methane emissions) are included. The critical load 2021 database is updated jointly with CCE. Health impacts assessment methods are discussed with TFH. New global scenarios will follow in summer-autumn 2022. New source receptor coefficients were developed jointly with MSC-W and include urban-rural interactions. Draft results of including the condensable fraction are available.

GAINS scenarios

6. The **Baseline** includes air pollutants (SO_2, NO_X, $PM_{2.5}$, BC, NH_3, VOC) and methane emissions up to 2050 and is based on current legislation. Historical data were updated and validated with nationally reported emissions in 2021; jointly with CEIP. For $PM_{2.5}$, the baseline scenarios still give a mixed picture of the uptake of condensable PM for residential heating. Recent policies and measures and national implementation progress and plans were included. For the EU, energy and agriculture policies follow the 55% greenhouse gas reduction target for 2030 and net-zero carbon in 2050. Note, that this assumption gives a more optimistic picture than the nationally reported emission projections for 2030 (see section VI-A of the main review report). For West Balkan, Rep of Moldova, Georgia, and Ukraine new energy and agricultural scenarios were developed. For EFTA, Türkiye, and remaining EECCA-countries activity projections were derived from the IEA World Energy Outlook and FAO. Recent shock events have not been considered; scenarios developed before the Ukraine war.

7. The baseline scenario shows strong reductions of air pollutants (SO_2: -80% between 2005 and 2030, NO_x: -50-80%, $PM_{2.5}$: -25-70%) in the EU, North America, and also in West Balkan countries, owing to the Energy Community agreements to reduce emissions strongly in the coming decades. EECCA countries will still have increasing fossil fuel use, but even here, due to ongoing technical progress, emissions of SO_2 and NO_x are expected to be reduced over time, with about 40% and 20% respectively between 2005 and 2030.

8. Methane declines in the baseline only in the EU (Green Deal scenario). In North America an increase is associated with the oil and gas sector. GAINS assumes higher (documented) emission factors for unconventional gas exploration, than the US-EPA.

9. The **MTFR** scenario uses the same activity data (energy scenario, agriculture scenario) as the current legislation scenario and explores the potential for further mitigation applying best available techniques (BAT) globally. These techniques are characterized with lowest emission factors attainable with reduction technologies for which experience exists. These include highly efficient end of pipe technologies in industry (filters, scrubbers, primary measures), transport sector (up to Euro 7), residential combustion (clean burning stoves, pellet stoves and boilers), measures in agriculture (including new low emission animal houses (such as cleaning ventilation air where applicable), covered storage of manures, immediate or efficient application of manures on land and urea use with inhibitors), solvent substitution, control of leaks on oil and gas production and distribution systems to name some of the key measures. Note that this scenario does not include any cost constraint or lack of necessary resources to fund investments. It focuses on the technical mitigation potential. The scenario includes constraints due to the applicability of technology in particular sectors and uses information about the age structure of capital goods. No early shutdown or scrapping of cars or boilers is assumed. Consequently, one can see that the mitigation potential increases towards 2050.

10. For SO_2 (apart from EECCA) most of the further mitigation potential is already committed in current legislation. Assuring enforcement is essential here. For NO_x some further mitigation measures are available. Note that remote sensing data (and N deposition measurements) indicate that emission inventories have overestimated the decline in emissions in the last decade. The effective reduction potential will depend on the decline in real-life emissions.

11. For NH_3 current abatement policies are very modest. Further reduction options exist across all regions (with the exception of single countries where policies are more advanced). However overall, the technical mitigation potential for NH_3 is much smaller than for other air pollutants.

12. For primary $PM_{2.5}$, with the exception of the EU+EFTA, a large abatement potential exists, especially in industry and residential heating in EECCA and West Balkan countries. Residential heating is dominating in many EECCA cities, while the power sector is an important regional source for local background concentrations.

13. The **LOW** scenario includes changes in activity data due to global climate mitigation policy, including a significant transformation in the agricultural sector leading to strong reduction of livestock numbers, especially cattle and pigs. This brings significant additional reductions of ammonia and methane. Compared to the MTFR an additional 20-40% reduction is estimated. The LOW scenario assumes for all regions climate policies with strong reduction of fossil fuel use and a simultaneous increase in biofuels and renewable energy (wind, solar, etc. The trajectories for fossil fuels use, as well as the structure of energy use in general differs across the regions. For the EU the baseline already includes a strong reduction of fossil fuel use and therefore this energy projection for the EU is also are used in the LOW scenario.

14. For SO_2 and NO_x most regions have significant reductions in the baseline (although less in EECCA countries) and therefore the further mitigation potential is limited. However, one needs to note that in relative terms emissions in the LOW scenario can be 50% lower than in the MTFR scenario. For NH_3 the picture is different, the baseline shows no significant reduction, but for all regions the structural and behavioral changes in the LOW scenario provide a significant additional abatement potential and will also bring CH4 co-benefits).

Results

15. Calculations with the GAINS model show that mean annual $PM_{2.5}$ concentrations in 2015 were above the 2005 WHO guidelines in several regions. Most of the population in the EMEP domain (the UNECE domain excl. North America) lives in areas where $PM_{2.5}$ is above the current WHO annual mean guideline value of 5 $\mu g/m^3$. The Baseline scenario brings declining concentrations and in the EU the EU limit values are met in 2030. Still elevated concentrations persist in Balkan and EECCA countries. Overall levels in large parts of the EMEP domain remain above the WHO guideline in 2030. The MTFR scenario for 2030 does not bring a lot of improvement, although locally the concentrations drop. Both MTFR and LOW are not yet fully effective in 2030 due to short time available for full introduction of abatement measures or transformations embedded in the LOW scenario.

16. The baseline for 2050 shows further improvements, but only for 1/3 of the population the WHO guideline level would be attained. MTFR brings large scale improvements, also across the Balkan, as there is enough time to introduce further technical measures. Finally, the LOW scenario gives even lower concentrations. More than 70% of the population in the EMEP domain would be exposed to $PM_{2.5}$ levels below the 2021 WHO guideline (80% in the EU+EFTA, 30% in EECCA + Türkiye).

Health impacts

17. Exposure to $PM_{2.5}$ levels above the 2021 WHO-guideline value is estimated to have caused about 128.500 cases of premature death in the EU27 in 2020. This is higher than the EEA estimate of 307.000 cases, that also include impacts of exposure below the WHO-guideline

value. Exposure to NO_2 caused about 21.200 cases (EEA: 40.000). The EEA estimates that the number of cases due to ozone-exposure above 70 microgram (SOMO 35 ppb) was 16.800 in 2019. Note that, $PM_{2.5}$, NO_2 and ozone numbers cannot be added because of double counting.

18. GAINS-estimates for the EU27 show that between 2020 and 2030 the baseline scenario will already give a decrease in premature mortality due to (excess) $PM_{2.5}$ exposure by about 55% Premature mortality due to (excess) NO_2-exposure is expected to decrease by more than 80%. The MTFR scenario for 2030 would lead to premature mortality reductions of 80% for $PM_{2.5}$ and 85% for NO_2. In 2050 MTFR would give 90% less cases of premature mortality due to $PM_{2.5}$ compared to 2020 and 97% less due to NO_2-exposure.

Black carbon

19. On average 10%? of the $PM_{2.5}$ emissions consists of elemental carbon and organic carbon (EC/OC). Abatement of $PM_{2.5}$ emissions would in general also reduce EC/OC emissions. The share of EC/OC varies among sectors: diesel engines, agricultural waste burning and wood burning are notorious for their high share of EC/OC. This offers opportunities to focus $PM_{2.5}$ emission reduction to these sectors in order to maximize the reduction of EC/OC emissions and obtain a better climate co-benefit. The OC-emission also contains a so-called condensable part: volatile organic compounds that condensate to particles when the flue gas cools down. For emissions from domestic wood burning the first estimates have been made. Inclusion of these condensables will increase total $PM_{2.5}$ emissions. In Austria, Germany and Switzerland this emission increase can be around 40%. And the estimated number of people exposed to more than 10 ug/m3 $PM_{2.5}$ in these countries will rise by 10-20%.

Ecosystem protection

20. The exceedance of the critical loads for acidification will for the EU in the baseline scenario be reduced from 8% of all ecosystems in 2015 to 3% in 2030 and 2% in 2050. In the LOW scenario 1% of the ecosystems in the EU will remain with an exceedance. For non-EU countries in the EMEP domain, the exceedance will decline from 4% of the ecosystems in 2015 to 1% in the 2050 baseline and less than 0.5% in the LOW scenario.

21. The exceedance of the critical loads for eutrophication will for the EU in the baseline scenario be reduced from 80% of all ecosystems in 2015 to 70% in 2030 and 65% in 2050. In the LOW scenario 30% of the ecosystems in the EU will remain with an exceedance. For non-EU countries in the EMEP domain, the exceedance will decline from 40% of the ecosystems in 2015 to 1around 35% in 2050 baseline and 15% in the LOW scenario.

Ozone

22. The GAINS-baseline (and MTFR) scenario assumes a further increase in global methane emissions between 2005 and 2050. Only in the EU (+EFTA) methane emissions are expected to decrease (by more than 40%) due to measures in the energy and waste sector. Methane emissions in EECCA region and West-Balkan are expected to remain constant. Methane emissions in US and Canada are expected to increase. They are associated with the unconventional gas exploration, Note, that there are documented differences in emission factors used in the GAINS model and by the US-EPA (GAINS assumes higher losses). The increase in global methane emissions is expected to offset the decreases in surface ozone due to NO_x and NMVOC controls within Europe and North America (see GPG document on Synergies and interactions with other policy areas).

23. The LOW-scenario assumes reductions of methane emissions in North America, EECCA and West-Balkan consistent with the 30% reduction target in 2030 of the Global Methane Pledge. Together with the regional policies in Europe and North America to reduce other ozone precursors (NO_x and NMVOC), and a reduction of NO_x-emissions from marine shipping, this could result in decreasing ozone concentrations (*with up to 5 ppb in 2030 – HTAP/MSC-W?*) and give benefits for health, crop production and ecosystem protection. This will also reduce temperature increase.

24. The ICP Vegetation expects that the average wheat yield loss in Europe due to ozone (using the POD3IAM metric) will decrease from 9.3% in 2015 to 7.8% in 2050 in the baseline scenario. In the LOW-scenario (with maximum technical abatement measures, climate and energy policies and dietary change) the average yield loss will be further reduced to 6.7% in 2050. For deciduous forests, the average % biomass loss in the 25 European countries with the greatest deciduous forest cover is expected to decrease from 18.6% in 2015 to 16.5% in 2050 in the baseline scenario and to 14.7% in the LOW-scenario.

25. In 2015, estimated total wheat production losses for Europe due to ozone were 23.8M ton, greater than the annual production for Ukraine (21.8 M tons). By 2050, total losses for Europe are predicted to have reduced by 7M ton for the LOW-scenario, equivalent to the current wheat production for Poland. However, overall, results show that significant production losses of wheat will still occur even under the most stringent of the scenarios, with an estimated 16.8M ton loss for Europe under the 2050 LOW-scenario.

Damage to materials

26. All scenarios show that by 2030 air quality targets will be reached that prevent carbon steel corrosion and limestone recession. For soiling of modern glass, the target is reached for almost all sites to protect modern technical constructions but the target for cultural heritage is not reached for about 30% of the 23 investigated sites. The largest contribution to soiling is from particulate matter. Even if the modelled data shows that most of the targets are reached it is also noted that decreasing trends are not always confirmed by measured data. Therefore, it is important to improve dose-response functions that show the largest discrepancy to increase the confidence that the protection targets will be reached.

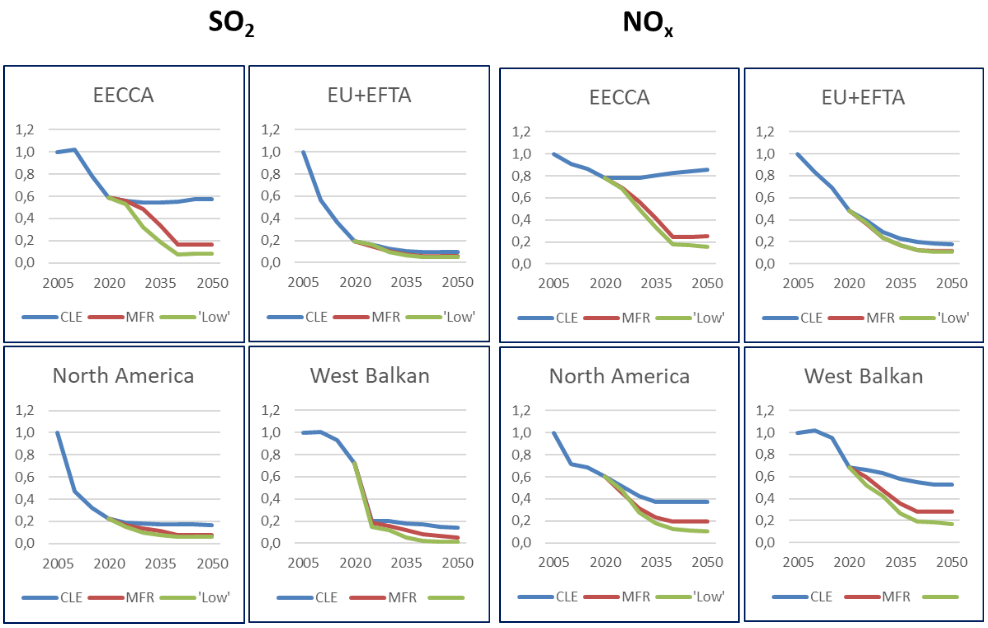
To be added (or online): Tables with national emissions, share of the population above WHO-AQG, (or life years lost) per country and share of the ecosystems with exceedance of Nitrogen critical loads for 2015, 2030 and 2050 baseline, 2050 MTFR and 2050 LOW.

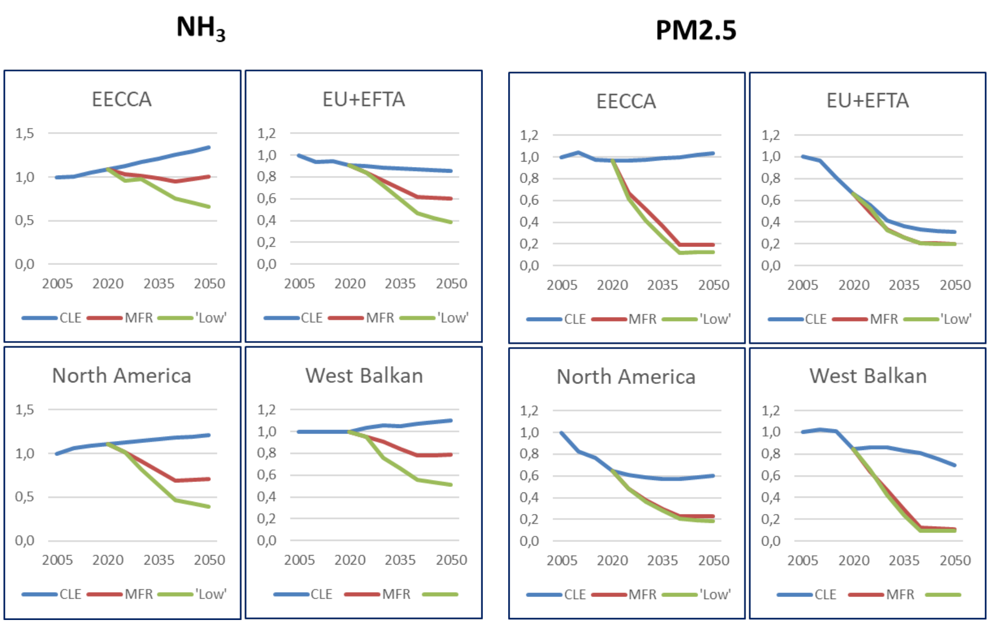
Conclusion

27. Current reduction plans will in the coming decades improve air quality and lead to less acidification and eutrophication than with the current emission reduction obligations for 2020 (and beyond) in the Gothenburg Protocol. At the same time the scenario analysis shows that there are technical and non-technical options for further improvement. However, the long-term targets of the Air Convention to protect health and ecosystems will remain a challenge. Even the most optimistic scenario for 2050 still shows that 30% of the people in the EMEP domain would be exposed to $PM_{2.5}$ concentrations above the 2021 WHO guideline level and that in 30% of ecosystem area the nitrogen critical load will be exceeded.

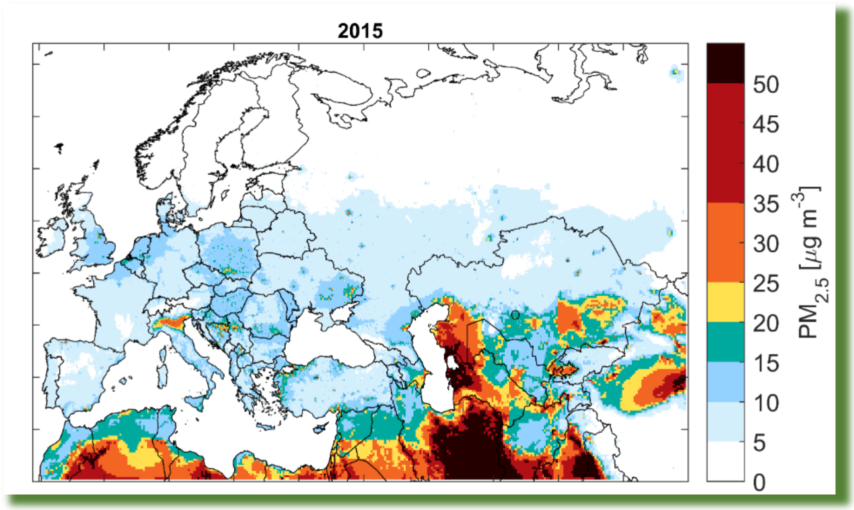
Figures (suggested)

Emission trends in baseline, MTFR and LOW scenario (EECCA includes Türkiye)

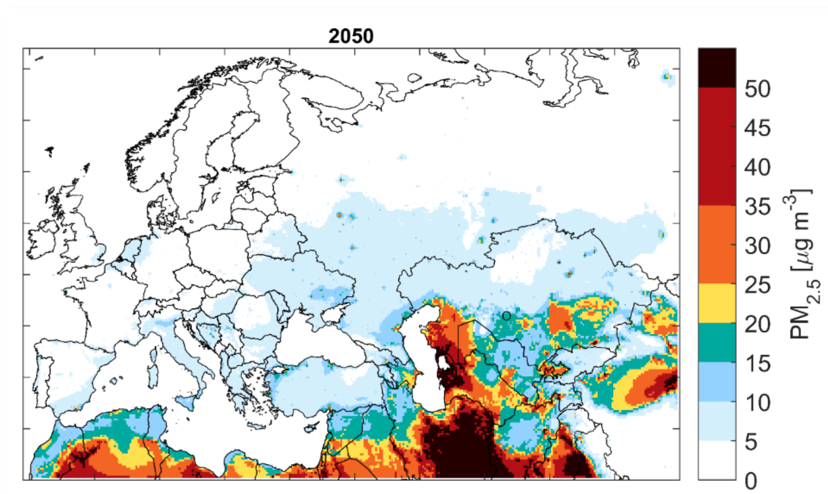




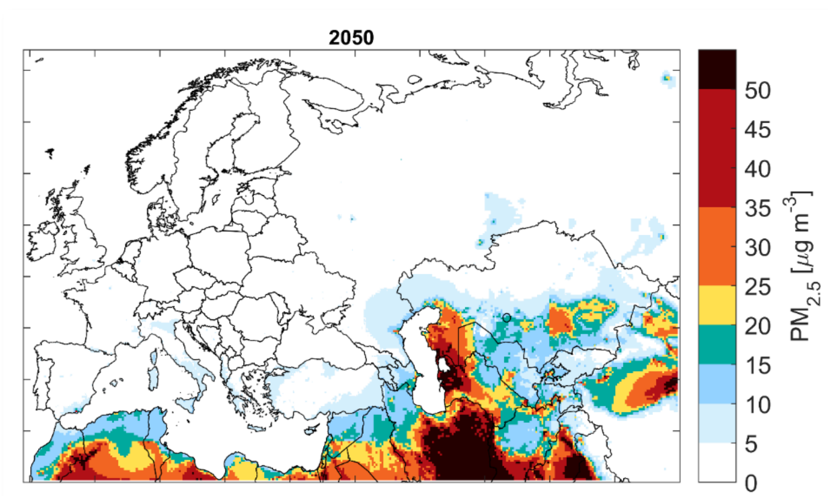
PM2.5 concentrations in 2015, 2050 baseline and 2050 LOW-scenario



PM2.5 concentrations



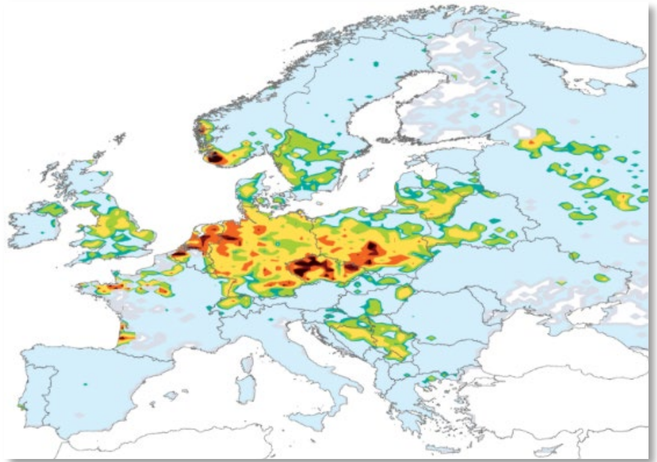
Baseline 2050



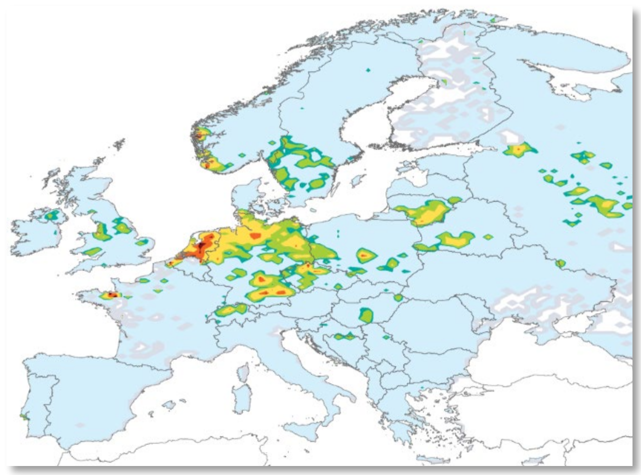
2050 LOW scenario

Acidification: exceedance of critical loads (preliminary)

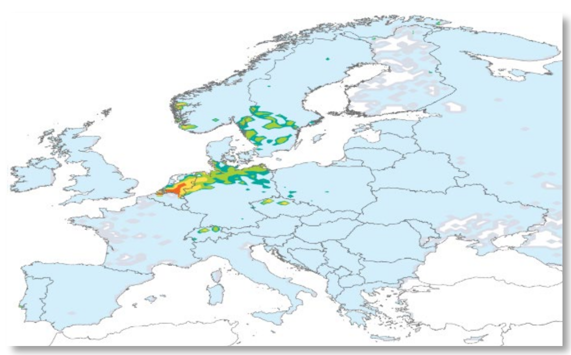
2015



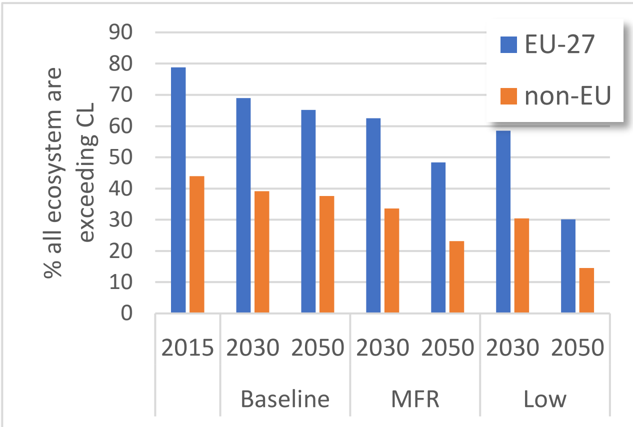
2050 Baseline



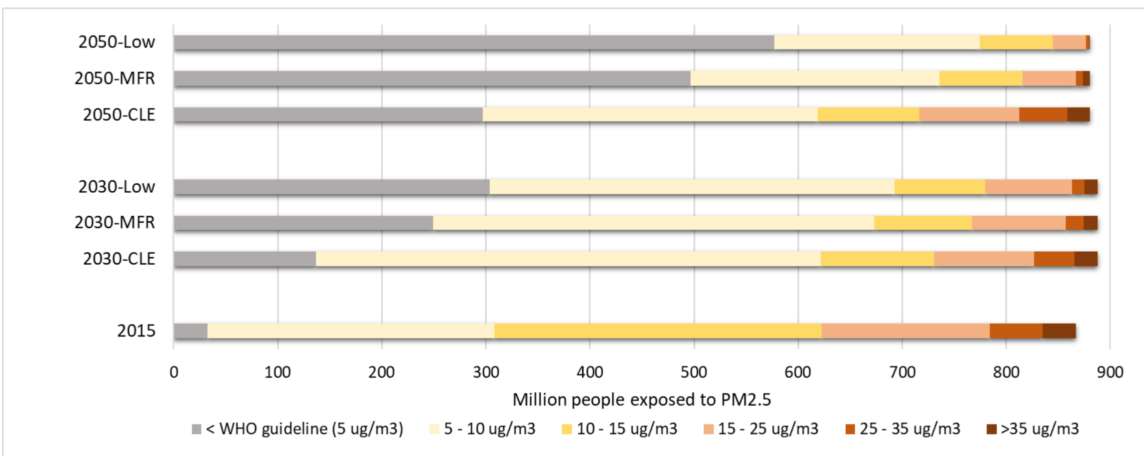
2050-LOW



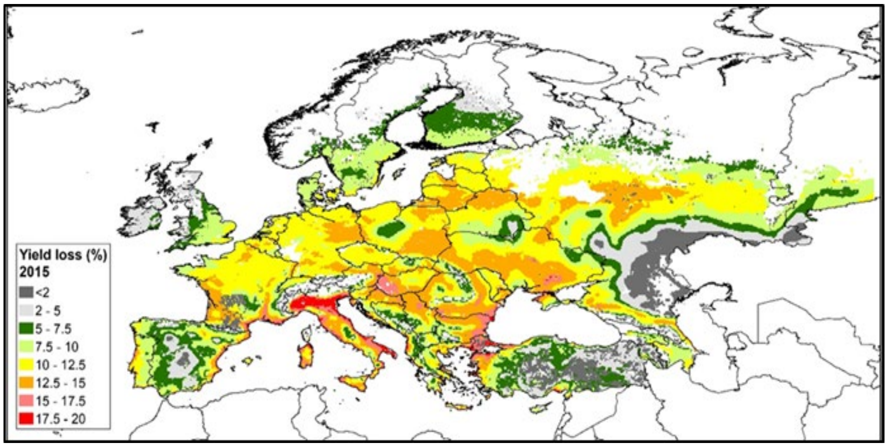
Exceedance of critical loads of nitrogen in Europe

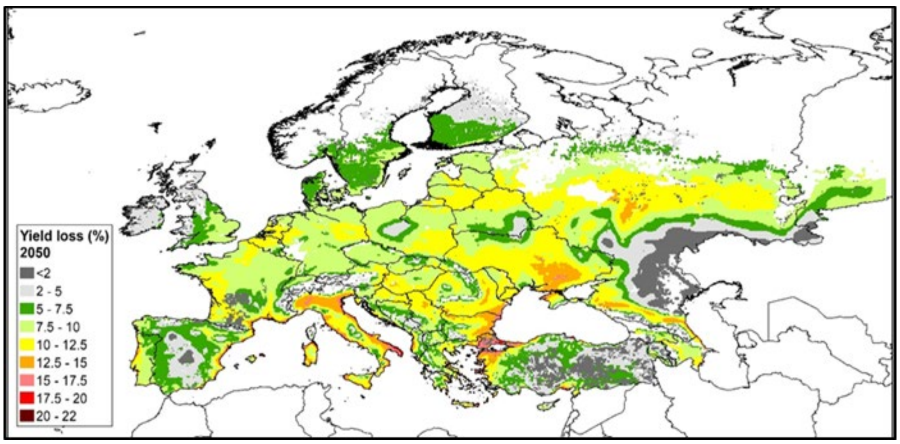


Population exposure in the UNECE domain, excl North America

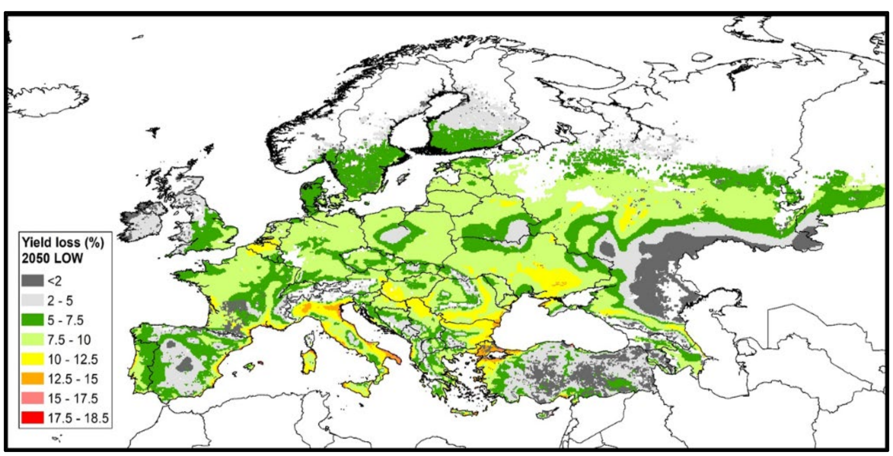


Wheat yield loss due to ozone (% loss based on the ozone flux metric POD_3IAM)





Baseline



LOW-scenario

III. Canada and the United States of America

IV. TFTEI inputs

V. Barriers to implementatio*n*

VI. Synergies with other policy areas

VII. TFRN input

VIII. Key Articles

IX. Methane

X. International Forum on Air Pollution