Working Group on Strategies and Review

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Review of sufficiency and effectiveness of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone

Draft report on the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone

Cover note: This informal document is a compilation of inputs from subsidiary bodies received to date and incorporated into the annotated outline (ECE/EB.AIR/WG.5/2021/4). This constitutes the Gothenburg Protocol Review Group's (GPG) working draft of the Review. This draft is at the compilation and editing stage and will continue to be elaborated by the GPG through the EMEP/WGE meetings this September and will become an official document for the Executive Body meeting in December 2021. The input of the Task Force on Reactive Nitrogen is contained in a separate WGSR-59 informal document "Issues to consider for nitrogen in relation to review of the Gothenburg Protocol" and will be subsequently incorporated in the main review report. At this stage, we are learning how each subsidiary is going about their work and seeing different examples of providing updates and text into the draft. This document will be open for further improvements and additions until 15 July 2021. A detailed timeline is available as an informal document for WGSR59.

I. Introduction

1. Summary of the Review process

II. Report on the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone

A. Introduction

1. A short history and background to the review with references to some of the key milestones (the scientific assessment of the Convention[1], the long-term strategy for the Convention for 2020–2030 and beyond, the entry into force of the Gothenburg Protocol as amended, article 10 provisions and Executive Body decision 2019/4). A description of the purpose and scope of the review report, applied methodologies for the analysis and general approach for the review will also be included here.

B. Legal requirements for the review

2. Article 10 of the Gothenburg Protocol requires that Parties keep under review the obligations of the Protocol and broadly specifies the modalities of such reviews. Paragraphs 2 (a) and (b) of article 10 are important in determining some of the content and structure of the review report, while paragraph 2 (c) deals with procedural matters for the review. Although paragraphs 2 (a) and 2 (b) include information on a broader review of the Gothenburg Protocol, paragraphs 3 and 4 refer to specific elements that shall be included in the review, i.e., measures to address black carbon and ammonia, respectively.

3. Include explanation of the broader elements that legally need to be addressed under the review, including their content and related issues (the adequacy of the obligations, assessment of emission reduction commitments). Description of the specific elements to be addressed under the review (evaluation of ammonia and black carbon measures).

C. Emissions

Emissions trends will be elaborated and updated with data from the 2021 submission, which is still under process. Graphs and figures will be delivered by September.

4. Although the situation significantly improved over the past years there is still space for further improvement regarding quality of the emission reporting processes. In 2020, 48 Parties submitted emissions inventories under the Convention. The coverage of reporting Parties increased over the last years to 94%. However, for 17 Parties the completeness was not satisfactory in the submission 2020, either because they did not submit any data or they did not provide data for all priority pollutants or they did not provide a full time series or they did not provide activity data (Technical Report CEIP 4/2020). It should be noted that for countries in the ‘EMEP East’ domain, the reporting situation has considerably improved over the years, although a decline is observed between 2019 and 2020 submission round: for the year 2018 (reported in 2020), the share of ‘no submissions’ amounted to 40 % in this region, while it was only 20% of countries included in ‘EMEP East’ region in 2017 (reported in 2019). According to the emission reporting procedure, the key element to ensure good transparency of the inventories is a good Informative Inventory Report. Eleven Parties did not provide an Informative Inventory Report (IIR) in the year 2020 and three Parties provided an (IIR) but did not follow the recommended structure. For these Parties the transparency was not given.

[1] See Rob Maas and Peringe Grennfelt, eds., *Towards Cleaner Air: Scientific Assessment Report 2016* (Oslo, 2016); and United States Environmental Protection Agency and Environment and Climate Change Canada, *Towards Cleaner Air: Scientific Assessment Report 2016 – North America* (2016).

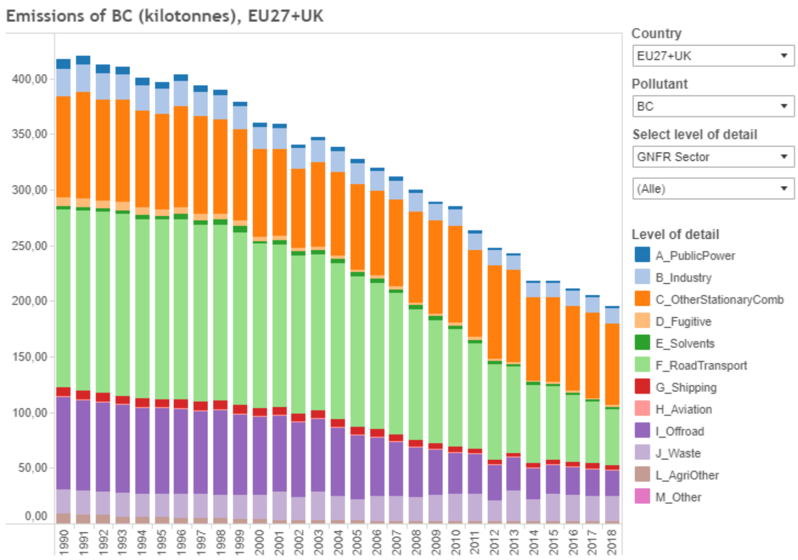
5. All emissions inventories bear uncertainties. Uncertainty information should be part of every emission inventory as stated in the Guidelines for Reporting Emissions and Projections Data under the Convention (ECE/EB.AIR/125). However, less than half of the Parties reported uncertainty estimates in their inventory submission in 2021. Usually Parties report the uncertainty for total emissions and emission trends. The availability of uncertainty estimates has increased in recent years although progress has been rather slow. It can be concluded that uncertainty estimation is still a topic that receives too little attention in the Informative Inventory Reports of many Parties and that it is currently not possible to estimate the uncertainty of pollutant emissions in the whole EMEP area with the information provided by Parties.

Pollutant	Uncertainty range reported by Parties for National Total (%)	Number of Parties providing an uncertainty estimate for National Total	Uncertainty range reported by Parties for the emission trend (%)	Number of Parties providing an uncertainty estimate for the emission trend
NO_x	8.5 to 59	19	1 to 31	19
NMVOC	15 to 112	19	1.8 to 32.2	19
SO_x	5 to 47	19	0.2 to 103	19
NH_3	9.5 to 143	19	3.1 to 364.8	19
$PM_{2.5}$	9.96 to 96.6	17	3 to 140	18
BC	27.1 to 302	7	3.1 to 67	7

Note: The values in this table are from the 2021 submission and will be updated with resubmissions later in the year

6. The specific question of black carbon and inclusion of condensable in PM will be developed in the future versions of the document once the latest reports will be analysed. What can be said today about BC:

7. Black carbon emissions are reported on a voluntary basis. The number of countries which provide emission estimates for black carbon increased over the past year. In 2021, 40 countries reported BC emissions. Quality of the data reported still needs to be improved, since inconsistency between country and sector sharing are noted.



1.2(a), 1.2(b), 1.2(c), 1.2(d), 1.2(e) (CEIP[2], TFEIP[3])

➔ see above and in the joint CEIP's note. This section will be elaborated and updated with data from the 2021 submission. Used sources of information are the Inventory Review 2020: Review of emission data reported under the LRTAP Convention Stage 1 and 2 review Status of gridded and LPS data (https://www.ceip.at/status-

[2] The Centre on Emission Inventories and Projections.
[3] The Task Force on Emission Inventories and Projections.

of-reporting-and-review-results/2021-submission and https://www.ceip.at/review-of-emission-inventories/technical-review-reports and https://www.ceip.at/ceip-reports/inventory-review-2020-dataviewer) and the stage 3 review reports (https://www.ceip.at/review-of-emission-inventories/in-depth-review-of-ae-inventories)

➔ Regarding uncertainties, a report is in preparation: "Uncertainties and recalculations of emission inventories submitted under CLRTAP", CEIP Technical Report XX/20201. Further inputs available in *the Informative Inventory Reports (https://www.ceip.at/status-of-reporting-and-review-results/2021-submission)*

1.3 (CEIP, TFEIP)

➔ Answers will be provided in Spring 2022

1.4(a), 1.4(b), 1.4(c), 1.4(d) (TFEIP, TFIAM[4])

➔ Answers will be provided in September 2021 (trends) and on projections in Spring 2022[5]

4.1 (CEIP, TFEIP)

➔ See above for BC. Answer will be updated in September 2021 once 2021 reports have been reviewed and analysed

4.4 (CEIP, TFEIP, TFIAM)

➔ Answers elaborated for spring 2022 accounting for the work of the ad hoc expert group on condensables

Fall 2021 – spring 2022, CEIP, CIAM/TFIAM:

1. Main causes of emission reductions and relative contributions to these reductions of climate, energy, transport and agricultural policies and measures

8. CIAM will analyze emission trends delivered by CEIP to guarantee consistency with trends in energy use, agriculture and traffic. CIAM could explain the contribution of abatement policy and energy policy to emission reduction. Both seem to be equally important, see Scientific Assessment Report 2016, p 11 figure 17 (Rafaj et al 2014). Several national ex-post assessments of air quality policies, showed that internationally agreed environmental legislation has had a significant influence on the improvement of air quality in their country, showing the success and benefits of international co-operation (e.g. UK, NL – see TFIAM48-report, Task Force on Integrated Assessment Modelling - TFIAM - IIASA).

9. Also see the JRC analysis of the role of European standard setting to emission reductions around the globe (M Crippa et al. Forty years of improvements in European air quality, acp-16-3825-2016.pdf (copernicus.org). The Clean Air Outlook 1 and 2 for the EU provided an assessment of the trends in the emissions and impact of various legislation in recent years. Review of the EU Air policy - Environment - European Commission (europa.eu). Additionally, for primary PM and black carbon the analysis[6] provided analysis and estimate of drivers of emission changes in the period 1990-2010.

[4] The Task Force on Integrated Assessment Modelling.

[5] Report on air quality and GHG emissions in the Western Balkans https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/status-air-pollutants-and-greenhouse-gases-western-balkans

[6] Klimont, Z., Kupiainen, K., Heyes, C., Purohit, P., Cofala, J., Rafaj, P., Borken-Kleefeld, J., and Schöpp, W.: Global anthropogenic emissions of particulate matter including black carbon, Atmos. Chem. Phys., 17, 8681–8723, https://doi.org/10.5194/acp-17-8681-2017 , 2017

2. Key sectors with large reduction potentials, specifically in Eastern, South-Eastern Europe and Turkey, the Caucasus and Central Asia

10. CIAM is currently updating (best available) emission projections for several EECCA- and west-Balkan countries. Large emission reductions seen possible in marine shipping[7] and within UNECE countries: ammonia from agriculture, PM2.5 emissions from residential solid fuel burning and agricultural waste burning and methane emissions from waste treatment. Additionally, in EECCA/SEE countries emission reductions are possible from coal burning, transport and waste treatment.

D. Measured and modelled atmospheric concentrations and deposition levels

11. Ozone is a secondary pollutant, and observed trends reflect meteorological variability to a much greater extent than trends in precursor compounds. Trends are also affected by titration effects, in which decreasing NOx emissions can increase ozone, especially in wintertime. Trends in summertime O3, and metrics of higher ozone (MDA8, SOMO35), are stronger and clearer than those in annual data, though site to site variability is large (Chang et al., 2017). Using stringent data-capture criteria, median trends in daily maximum ozone during June-August were -0.6 ppb/yr at EMEP sites (EMEP model -0.4 ppb/yr). Observed trends showed much more variability than modelled trends, and observed trends being more affected by the high ozone summers of 2003 and 2006 in some regions.

12. Annual average concentrations of sulphur dioxide and particulate sulphate, and wet deposition of oxidized sulphur, has been declining since the 1980s. At EMEP background sites, the changes from 2000-2018 is on average -4 %/y, -2.9 %/y and -3.3 %/y for sulphur dioxide, particulate sulphate and wet deposition of oxidized sulphur, respectively (EMEP model results: -5.3%/y, -4.0%, -4.5%/y.

13. From around 1990 onwards, the total emissions of NOx declined significantly in Europe, followed by declining nitrogen dioxide concentrations and total nitrate (nitric acid plus particulate nitrate) in air and reduced oxidized nitrogen deposition at EMEP background sites. From 2000-2018, the average reductions at long term EMEP background sites have been -1.5 %/y, -1.9 %/y and -1.7 %/y for nitrogen dioxide concentrations, particulate nitrate and wet deposition of oxidized nitrogen, respectively (EMEP model results: -2.3 %/y, -2.3 %, -2.4%/y).

14. Only modest reductions of ammonia emissions have been achieved since 2000 compared to other pollutants. As a result, ammonium in precipitation has declined marginally (median of -0.08 %/y from 2000-2018 at long term EMEP sites). However, the formation of particulate ammonium in air depends not only on the availability of ammonia, but also on the availability of nitric acid (formed from NOx) and sulphate (formed from SOx). With large reductions in SOx and NOx emissions during the last decades, ammonia is to a large extent in excess and the availability of nitric acid and sulphate limit the formation of ammonium, resulting in a decline of ammonium in air of on average -2.8 %/y at long term EMEP sites. Total reduced nitrogen in air (ammonia + particulate ammonium) is reduced less (-1 %/y from 2000-2018), as a larger fraction of total reduced nitrogen being ammonia (but with a shorter lifetime than ammonium aerosol). The majority of sites for ammonia in air show no significant trends.

15. Since 2000, there has been significant reductions in PM_{10} and $PM_{2.5}$ (on average -1.7 and -2.3 %/y at EMEP long term observational sites, and slightly more in EMEP model calculations (-2.0 and -2.6 %/y). SIA (particulate sulphate, nitrate and ammonium) has decreased significantly since 2000, with sulphate showing the largest decrease (SO4: -2.9 (-4.0) %/y, NO3:-1.9 (-2.3) %/y, NH4: -2.8 (-2.9) %/y, EMEP model in parenthesis). For the natural components (sea salt and dust), less long-term observational sites exist, and only few of them show significant trends. For carbonaceous aerosol there are very few sites with long term, consistent measurements. One study show a 4 %/yr decrease in elemental carbon since

[7] See background technical report on shipping developed by TFTEI https://unece.org/environmental-policy/events/working-group-strategies-and-review-fifty-eighth-session.

2001, indicating a reduction from anthropogenic sources, whereas trends in organic carbon is (more) influenced by natural sources, and thus more difficult to assess (**OM/EC: This will be further assessed and can be answered better during Fall 2021)**.

16. At EMEP regional sites, exceedances of the WHO air quality guidelines (AQG) for PM10 and PM2.5 are in the later years seen at around ⅓ and ½ of the observational sites respectively. EMEP MSC-W model simulations show a decrease in the area with (rural and urban background) daily PM_{10} and $PM_{2.5}$ exceedances of WHO AQG from 2000 to 2018.

17. Overall, the trends of sulphur and nitrogen compounds in air and precipitation follow the emission trends within Europe and the influence of transcontinental transport is negligible. For PM, wildfires and wind-blown dust originating outside Europe influence concentration levels substantially during episodes (typically a few times a year). **For ozone, see TFHTAP answer**.

18. **Regarding future trends,** emission projections in Europe indicate that future ammonia emission reductions will be relatively small compared to the emission reductions of sulphur dioxide, nitrogen oxides and primary particulate matter. The depositions of sulphur and nitrogen are projected to change similarly to emissions of SOx, NOx and NH3. Assuming that NEC 2030 will be met (-19%, -77%, -63% compared to 2005 for NH3, SOx and NOx emissions, respectively), deposition of oxidized nitrogen will decrease much more than deposition of reduced nitrogen - leading to an increased fraction of reduced versus total deposition of nitrogen, expected to reach more than 60% in large parts of Europe by 2030. For ammonium, the much larger reductions of SOx and NOx emissions compared to NH3 emissions are projected to lead to reductions in particulate ammonium of around the same magnitude as the SOx/NOx emission reductions. Reductions of primary PM emissions, together with precursors of the secondary inorganic aerosols are projected to lead to reduced PM2.5 and PM10 concentrations by 2030. (Jonson et al, in prep, EMEP Report I/2020). Even so, WHO limit values for $PM_{2.5}$ (yearly and daily) are expected to be exceeded in some areas also in 2030. In the longer term, some processes may promote higher PM levels again, e.g. higher temperature may increase biogenic VOC emissions (and hence SOA formation), or soil-NO and NH3 emissions

19. Comment about the monitoring network: the observational network is dominated by sites in EU+EEA and has hardly any coverage in the EECCA & western Balkan area, thus the trends reported here are not representative for these regions. Furthermore, the lack of (consistent and high quality) emission reporting for these areas, and especially long-term emission data sets, makes it very difficult to model trends in this area. The improved resolution in the EMEP model results (and in the emissions) has in general improved the comparison to observations, especially for the primary components. While model results in the old resolution (50kmx50km) were representative for the regional background, the model results in the new resolution can represent urban background scale as well.

20. Exceedances of critical loads are slightly higher in the high-resolution model results (0.1x0.1) than in the old 50x50km results for acidification (EMEP Status Report 1/2018, page 33). The high exceedance area in and around the Netherlands is slightly more extended with the 0.1×0.1 deposition, both for acidification and eutrophication. The overall pattern, however, is very similar. The overall exceedances of eutrophication CLs are slightly smaller under the 0.1×0.1◦ depositions. A reason for this could be that the high-resolution deposition resolves the population centres much better. These areas generally have higher depositions but less (semi-)natural ecosystems. This may be an additional argument for the use of high-resolution depositions for exceedance calculations. Overall, the changes are small, e.g. 5.28% vs 5.25% area exceeded for acidification and 62.5% vs 61.2% for eutrophication for Europe for 2015 (Based on EMEP Status Report 1/2017).

21. The overall differences in blame matrices due to different model resolutions for the country-to-itself contribution are small for depositions (a few percent), but somewhat larger for PM and ozone (up to 11%). For the individual transboundary contributions, differences can be larger, especially when the pollution is transported across mountain areas and/or is very small. Changes in the chemical atmosphere also influence the effectiveness of emission reductions for air quality improvement. The much larger decrease in SOx and NOx emissions than NH3 emissions during the last decades (and which is projected to continue) impact the

efficiency of reducing NH3 emissions to curb PM2.5 concentrations. EMEP MSC-W model calculations indicate that reductions in PM2.5 per gram of ammonia emissions mitigated in 2030 versus 2005 are significantly reduced (Jonson et al, in prep).

22. There are hardly any (long term) EMEP observations in the EECCA & western Balkan area. Combined with the lack of consistent, high quality (and long term) emissions for countries in the eastern part of the EMEP domain, it is very difficult to assess and project air pollution and its effects in these areas. Condensable organics have been highlighted as one such problem (Simpson et al., 2020), and so-called intermediate volatility organics may also emerge as an important issue. Further discussion is needed between the EMEP Task Forces, Parties, and in conjunction with the Emission Inventory Guidebook. There are also issues with the consistent inclusion or exclusion of some other emission components, e.g. emissions from agricultural soil-NO, waste-burning, or VOC emissions. Additional measurements of nitrogen deposition in sea areas (islands or on ships) would be beneficial for better monitoring of eutrophication trends in marine ecosystems and to evaluate/constrain models.

2.1, 2.2, 2.3(a), 2.6, 2.7 (EMEP-MSC-W[8], TFMM[9], WGE[10])

- ➔ See above for 2.1
- ➔ See attached file from the EMEP centers for 2.2 (marine ecosystems)
- ➔ 2.3 (ozone exposure) will be answered in fall 2021 with updated data based on work done for EMEP summer 2021 (updated EMEP emissions, updated model calculations, updated CLs, updated obs trends).
- ➔ See above for 2.6 and EMEP centers note
- ➔ See above for 2.7

6.3(c) (TFEIP, TFIAM)

- ➔ Trends in methane emission and their impact: will be documented in Spring 2022

1. The observed and projected trends in urban air quality. Contribution of long-range transport to air pollutant concentrations in cities. The distance to the WHO air quality guideline values

23. Observed trends in urban air quality (at traffic stations and urban background stations) can be derived from EMEP/CCC, TFMM, EEA, WMO and WHO (and US/CAN?) can probably be made available in spring 2021. Studies by CIAM and JRC indicate the main sources of urban air pollution. Declining trends in average exposure of the urban population are to a large part the result of national and European wide emission reductions. Concentrations at urban traffic sites decline due to the penetration of newer vehicles that apply stricter emission limit values. However due to traffic increase, high shares of old cars, other sources than transport and the contribution of non-urban sources in many cities current WHO air quality guideline values and even EU air quality limit values are not yet met. An indicative baseline projection could be made available by CIAM in *spring 2022* using the new source receptor matrix developed by MSC-W. The SHERPA PM2.5 atlas will be updated in autumn 2021. Studies for 12 pilot cities in Russia are under way under the Russian air quality programme with 12 pilot cities. See: https://rpn.gov.ru/activity/fresh-air/info/ in Russian

24. An important question is whether a local air quality approach could be a stimulating driver for additional air quality policy, both in countries that signed the protocol and countries that are not parties to the protocol. CIAM works jointly with MSC-W to extend the domain, update source-receptor relationships for all species and include PPM tracking (enabling fine scale 0.1-degree analysis) and updated downscaling by MSC-W (100-250m). *See also 4.3: formation of PM2.5 including condensables – MSC-W/CIAM spring 2022.* A Nordic Council

8 The Meteorological Synthesizing Centre-West.
9 The Task Force on Measurements and Modelling.
10 The Working Group on Effects.

of Ministers-project ends in Dec 2021 (TNO, NILU, SYKE, EMEP, IIASA) which delivers new emission factors, the impact of mitigation measures, and a review of spatial emission and concentration patterns. The updated analysis will include condensables.

2. The change in exceedance of critical loads between 1990 and 2018/2019 and projected changes up to 2030 and beyond

25. The Chemical Coordinating Centre (CCE) will perform exceedance calculation for critical loads for acidification and eutrophication in the perspective of the review process. Updated Critical Loads will be available by summer. Updates may comprise updated national submissions and critical loads calculated with the newly updated background database of CCE The calculation of exceedances will be based on deposition data provided by MSC-West, CEIP, MSC-West This work still needs to be coordinated for data timing specification and availability until September 2021. Its purpose is the comparison of exceedance calculation between years 2000 and 2019.

26. . The temporal developments of the exceedance of the CLs at ICP IM sites indicated the more effective reductions of S deposition compared to N . The monitoring data confirm that emission abatement actions are having their intended effects on CL exceedances and ecosystem impacts. The results also provided evidence on the link between CL exceedances and empirical impacts, increasing confidence in the methodology used for the European-scale CL calculations.

3. The change in water, soil and ecosystem quality indicators between 1990 and 2018/2019 and projected changes up to 2030 and beyond

27. According to ICP monitoring data, Sulphate concentrations show more than 40% decline for the period 1990-2016. Changes were more prevalent in the 90s than after 2000, indicating smoother trends in recent years. The trajectories of sulphate, ANC and pH indicate that the recovery was slowing down in Europe and accelerating in North America since the early 2000s. (ICP Waters report 142/2020).

28. Monitoring data show that the pronounced increase in diversity at ICP-Waters sites with the most pronounced chemical recovery and the strong correlation between sulphate and/or ANC and diversity suggest that a reduction in acidifying components of the water has had a strong influence on species diversity of aquatic invertebrates. Year-to-year variation in temperature was negatively correlated with diversity, suggesting that temperature has a secondary influence on diversity since the diversity is increasing, despite the negative correlation with temperature. Still, the effects from temperature suggest that these communities will be sensitive to long-term climate change. The strong correlation between acid components of the water and species diversity suggests that biodiversity will continue to increase when acid deposition decreases. The widespread response of aquatic diversity resulting from emission reductions of acidifying components to the atmosphere demonstrates the potential of international policy for achieving positive effects on the state of the environment.

29. Projected changes: Projections extended to 2030, require new projections for deposition from EMEP. this work could be done for chemical parameters by the summer, if the deposition data are available by then. No projections for biology

30. The ICP Forests long-term measurements show that there is a long-time lag between emission abatement and changes in soil solution acidity. Moreover, eutrophying or acidifying effects of inorganic N and S deposition led to imbalances in tree nutrition across Europe as briefly discussed in the following. In many parts of Europe positive tree growth were observed during the last decades. Among other things, the increased nitrogen deposition contributed to the observed tree growth stimulation. An increased tree growth will result in an increased nutrient demand and an excess of nitrogen due to air pollution may have an impact on the tree nutrient status. The analysis of foliar data collected at ICP Forests sites showed that due to the enhanced nitrogen deposition, there is a shift from nitrogen limitation to phosphorus limitation at many forests Europe. It is supposed that nutrient imbalances can affect the resilience of the European forests to a changing climate.

31. Results of the ICP IM monitoring network confirm the positive effects of the continuing emission reductions (Vuorenmaa et al. 2018; 2020, Forsius et al. 2020). ICP IM sites showed dominantly negative trend slopes of total inorganic nitrogen (TIN) in concentrations (95% of the sites; mean slope -1.08 μeq L−1 yr−1) and fluxes (91% of sites, mean slope -0.84 meq m−2 yr−1) of bulk/wet deposition between years 1990 and 2017, . Concentrations of TIN in runoff water for years 1990-2017 exhibited dominantly downward trend slopes (76% of sites, mean slope -0.48 μeq L−1 yr−1), and for fluxes 69% of the sites (mean slope -0.21 meq m−2 yr−1), respectively. Decrease of NO_3 and NH_4 in concentrations was significant at 59% (-0.36 μeq L−1 yr−1) and 36% (-0.05 μeq L−1 yr−1) of the sites, and but the decrease in fluxes was significant only at 25% (-0.18 meq m−2 yr−1) and 31% (-0.04 meq m−2 yr−1) of the sites, respectively. Decreasing trends for S and N emissions and deposition reduction responses in runoff water chemistry tended to be more gradual since the early 2000s.

33. Dynamic models are needed in order to assess the times scales of impacts and recovery from changes in air pollution emissions. Interaction with changes in climate variables is also of key importance. Decreases in N deposition under the CLE scenario will most likely be insufficient to allow recovery from eutrophication. Model predictions indicated that oligotrophic /favouring nutrient-poor conditions) forest understory plant species will further decrease. This result is partially due to confounding processes related to climate effects and to major decreases in S deposition and consequent recovery from soil acidification. Emissions reductions of oxidized and reduced N compounds need to be considerably greater to allow recovery from chronially high N deposition.

4. Observed and projected trend in ozone exposure of the population above critical levels

35. Information about the past and current population exposure to ozone is available from the European Environment Agency (summarised for example, in the Air quality in Europe - 2020 report). This information is available primarily for the EU-28, for population in areas exposed to ozone (O_3) concentrations in relation to the EU target value threshold and in reference to the WHO air quality guidelines (WHO AQGs). The estimates of the exposure of total European population (not only urban) in 2018 and changes over time are also available. To extract relevant information, interaction with the EEA will be needed. Recent analysis of ozone have shown that reductions in emissions have reduced the peak ozone concentrations but ozone concentrations have not really decreased in all the countries and rural areas show higher levels than urban areas. In mid-2021, new WHO AQGs are expected to be published, including also new guideline values for ozone. Question will also be discussed within the TFH, including at the annual TFH meeting in early May 2021[11].

5. Monitoring and modelling system of the Convention

36. Ecosystem effects, which were the main reason for the establishment of the Convention, are to some extent reduced, but the acidification effects of historical emissions will remain for decades and the emissions of ammonia have so far only been reduced by 20–30% in Europe and even less in North America. Looking at health effects, it is difficult to talk about success, when hundreds of thousands of inhabitants on both continents are predicted to meet an earlier death due to air pollution. The research communities within air pollution and climate change need to work more closely together. Basic questions still need further investigations to develop the best policies. Such areas include: better understanding of health effects from air pollution, nitrogen effects to ecosystems, and air pollution interactions with climate through carbon storage in ecosystems and impacts on radiation balances.

37. A combination of long-term monitoring and research is needed to document and understand complex interactions of air pollutants, climate change and other disturbances. Disturbance interactions can have unpredictable and surprising consequences which are as yet insufficiently studied. There is a need to extend the current ecosystem monitoring system

[11] https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report: In 2018, about 34 % of the EU-28 population in urban

to include more sites representing other sensitive habitats such as heathlands, grasslands and wetlands. The “IM light” initiative of ICP IM is an important process in this respect.

38. Increased cooperation with developing research infrastructures under the EU, such as eLTER, ICOS and ACTRIS would provide possibilities to extend the site networks and increase scientific competence. Coordination with ecosystem monitoring efforts of the EU National Emission Ceilings Directive (NEC) would provide similar benefits.

39. Regarding health effects, the monitoring and modelling system has really improved along the years. Some efforts are needed to integrate the knowledge on transboundary air pollution and local sources. Source apportionment studies to detail the contribution of each sector are welcome in their diffusion and refinement because they can indicate solutions that can have relevant health impacts.

40. Regarding modelling of the impact of air pollution on biodiversity, the challenges with the existing monitoring are representativity of non-forest ecosystem and availability of data on biodiversity. Expansion of the ICP IM system to include more types of ecosystems should be followed by other initiatives in the same direction. For data on biodiversity, the modelling work relies heavily on national data and national modelling expertise. The newly established CDM must continue efforts to bring the outcomes of the national efforts together and, to some extent, make use of these in the work of the Convention.

41. At present stage, the ICP Materials network in sufficient to observe and assess air pollution and its effects related to the Gothenburg Protocol in the ECE region. However, regarding projections of air pollution and its effects there are currently no system in place and projections are made when asked for and relies on input data to dose-response functions from other sources.

43. There is currently very little recording of ozone impacts in the ECE region. s. Within ICP Vegetation there is an opportunity to record visible leaf-damage on crops and semi-natural vegetation. However, in reality very little data is collated. This is partly because visible leaf-damage is becoming more rare in the ECE region due to the reduction in episodic peaks of ozone, and it is the peaks that cause the most visible leaf-damage . Based on current scientific knowledge of cumulative fluxes of ozone (including from low ozone concentrations) affecting growth and flowering of crops, trees and ecosystems, a more suitable observation and assessment method for the impacts could be the use of filtered-air chambers, to filter out ambient ozone pollution over a small area to show the yield/growth benefits of cleaned air compared to ambient air. However, the cost of these facilities is very expensive and this is only currently carried out at very few institutions as part of their ongoing experiments.

44. Accurate modelling ozone impacts to vegetation requires parameterisation of the dose-response relationship for each individual species, and there are many species (both crop, tree and semi-natural vegetation) for which such information does not currently exist, even for some of the common and commercially important species This is currently limited by the availability of experimental data to parameterise both the stomatal uptake component and the yield-response component.

45. Water chemical monitoring of surface waters for air pollution responses is well-developed, but in some countries the monitoring is under threat from reductions in funding. The planned monitoring under NECD can help to sustain water chemical monitoring but monitoring of biological recovery is in many countries not very well supported, and it has not been defined as a priority under other monitoring frameworks such as the NECD. Biological monitoring should preferably be done at the same sites as where water chemical monitoring is done. In addition, Climate change might lead to more variation in surface water chemistry, and it is important to maintain sufficient sampling frequency and long-term monitoring programmes.

6. Projected future trend in methane emissions and subsequent improvements in air quality, human health effects and ecosystems impacts

46. In addition to the response by HTAP on question 3.3: Global emission scenarios for methane, NOx, NMVOC, and CO are available in the ECLIPSE-emission scenario datasets

developed with the GAINS model (CIAM). They show the policy envelope between current legislation and maximum feasible reduction. These scenarios can be used to calculate the future trend in (European) background levels of ozone with models, such as the global EMEP-model and other models used by HTAP. These trends should be added to contributions from national emissions to ozone levels in European countries. The results of EMEP and/or GAINS calculations can be used to estimate trends in accumulated exceedances over ozone threshold values, and in premature mortality or expected crop damage.

E. Measured and modelled effects on natural ecosystems, materials and crops and assessment of human health effects

47. The main ozone metric recommended by ICP vegetation is now the phyto-toxic ozone dose over threshold Y (PODY). For EMEP and integrated assessment modelling purposes, two key metrics are the 3-monthly POD3-IAM-CR being used for crops and POD1-IAM-DF for deciduous forests. Model results suggest that POD1-IAM-DF has declined over the period 2000-2016 by ca. 0.7%/yr at EMEP's ozone stations, though again site-to-site variability is large, and the high O3 summers of 2003 and 2006 may account for some of this trend. For POD3-IAM-CR declines are also simulated, but trends are non-significant for the majority of sites. Two major difficulties with this type of metric though is that (a) we cannot compare with observations, and (b) the POD calculations are very sensitive to meteorology. Over the next months, MSC-W will explore the impact of the meteorological factors on the modelled POD trends. **NOTE: trend numbers are preliminary, and will likely be revised by Fall 2021**

48. The AOT40 index as used in earlier assessments is less biologically meaningful than POD, but has the advantage that we can compare modelled and measured values across the EMEP network. Mills et al. (2018) estimated the trends in 3-months and 6-months AOT40 over the period 1995-2014. They found a clearer signal of reduced levels in the 6-months AOT40 compared to 3-months AOT40 in Europe. For the latter, only 10 % of the sites showed significant decreases ($p<0.05$). Chang et al. (2017) calculated a statistically significant downward trend in the 6-months AOT40 over the period 2000-2014 for both rural and urban European sites. For the rural sites they estimated reductions in 6-months AOT40 of ca. 300-400 ppb.h/yr and less for urban sites. **Note: Based on trend calculations for the period 2005-2019, we will provide more detailed info on ozone statistics in September**.

49. **Contribution of the condensable in the PM population exposure** cannot be assessed before next year (2022). Indeed, at present the emission data reported by the countries includes condensables for some countries (& some sectors), and for some not/partly. Therefore, it is at present not possible to quantify in a consistent way across the countries the effect of condensables. Ongoing work within EMEP, CAMS, and a new project financed by Nordic Council of Ministers (led by MSC-W, with CIAM as partner) should be (partly) able to give an answer to this by spring 2022, and is expected to result in better consistency of emissions for use in EMEP modelling.

1. Observed and projected trends in vegetation risk of damage due to ozone

50. The model runs to answer this question will be completed over the coming months. ICP Vegetation are waiting for the EMEP scenario data to be finalised and distributed. This also needs the model to be run for 1990 and 2018/19 (in addition to 2030) to ensure internal consistency with the predictions of impacts. Parameterisations, dose-response relationships and critical levels for ozone are all up to date (last update of Critical Levels was 2017), meaning that no additional work is needed on this part. This question will be answered for crops, trees and semi-natural vegetation. The analysis will calculate a) impacts and b) exceedance of critical levels. Although exceedance of critical levels based on AOT40 can be calculated, the analysis will focus on critical levels based on ozone fluxes (POD) as this reflects the most recent scientific advances and knowledge. The analysis will provide a) maps and b) tables of extracted data per country.)

A preliminary estimate of the results shown following this analysis would be that there is a large difference in predictions depending on which metrics are used. Likely there appears to be a large reduction in effect of ozone on all vegetation types if analysis is based on AOT40 and a concentration-based analysis. Likely there would be a moderate reduction in effect of ozone on all vegetation types if analysis is based on M7 (there are no current critical levels for vegetation based on M7). Likely there would be little or no change in effect of ozone on all vegetation types since 1990 if analysis is based on ozone fluxes (POD). These changes between scenarios and differences in the extent of change between the different metrics are because the ozone profile has changed since 1990. The 'peak' concentrations have reduced, whereas the 'background' concentrations have increased. Concentration-based metrics, particularly AOT40, put greatest emphasis on peak concentrations. Scientific evidence has shown that vegetation responds to cumulative ozone uptake, reflected in the flux-based (POD) metrics, and that the response is the same when this is delivered as an 'elevated backgound' or 'episodic peak' profile[12] . Evidence has shown that impacts of ozone are observed when low to moderate ozone concentrations coincide with meteorological conditions favouring ozone uptake, whereas the concentration-based metrics do not reflect this newer evidence. This means that ozone impacts on vegetation can be found where the critical level for AOT40 is not exceeded [13] . For semi-natural vegetation, together with accurate modelling of impacts, the difference in sensitivity to ozone means that there could be changes in relative species abundance and possible impacts on biodiversity[14].

51. Although the analysis is not yet complete, an estimate based on current knowledge is that the Gothenburg Protocol will not have eliminated the negative impacts of ozone on vegetation, even by 2030. Based on current knowledge, ozone pollution is calculated to have reduced wheat grain yield by a mean of 9.9% in the northern hemisphere in 2010-2012[15]. Projections show that ozone risks to biodiversity will still occur by 2050, as ozone exposure will remain similar using RCP4.5 compared to that experienced in 2000[16]. Similarly, projections show that there will still be a significant effect of ozone on the biomass increment of trees.

52. Despite a slight but significant reduction of ozone levels during the vegetative period, large-scale studies conducted at the ICP Forests plots revealed that the concentration-based Critical Levels (AOT40) have been exceeded on the majority of the investigated sites, especially in East and Southern Europe. On these sites, foliar injury attributable to ozone has been detected on several species, mostly broadleaves. No consistent ozone effect has been detected on growth and defoliation at the ICP Forests sites, regardless the ozone metric adopted. We do expect that interaction with climate change and biotic agents (pests and disease) may substantially alter the above results: this will be however dependent on site-specific condition.

2. Observed and projected trend in life years lost due to exposure to ozone, particulate matter and nitrogen dioxide

53. For particulate matter (PM2.5), mortality (premature deaths) estimates are available based on the WHO ambient air quality database; the most recent estimates are available based on 2016 data and they include DALYs estimation. There has been a trend of reduced attributable deaths driven by air pollutants decrease, but there is still peaks in some cities, for example for NO2 in areas close to traffic. New estimates will be generated later this year, as part of the SDG reporting (indicator on mortality due to air pollution). The estimates of premature mortality and years of life lost are available from the reports of the European Environment Agency. The demographic data and life expectancy data are from Eurostat and the mortality data from WHO; the exposure-response relationship and the population at risk follow recommendations from the Health Risks of Air Pollution in Europe (HRAPIE) project.

3. Observed and projected trends for other health metrics

[12] Harmens et al., 2018 doi.org/10.1016/J.ATMOSENV.2017.10.059
[13] Mills et al., 2011 doi.org/10.1111/J.1365-2486.2010.02217.X
[14] van Goethem et al., 2013 DOI: 10.1016/j.envpol.2013.02.023; Hayes et al., 2007 doi.org/10.1016/J.ENVPOL.2006.06.011; Hayes et al., 2009 DOI: 10.1016/j.envpol.2008.07.002
[15] Mills et al., 2018 doi.org/10.1111/GCB.14157
[16] Fuhrer et al., 2016 doi.org/10.1002/ECE3.2568

54. With regard to other health metrics, such as morbidity, a new project has been initiated on the estimation of morbidity from air pollution and its economic costs (EMAPEC). The project is to deliver a method to estimate costs of morbidity from air pollution (for locations with the available appropriate health statistics) and morbidity-related concentration-response functions. The results are expected in 2022. The Second Clean Air Outlook includes projected trends of morbidity, with data from CIAM. Follow up action is needed to check feasibility of getting access to scenarios. This work needs to be coordinated by several TFs.

55. From the (past and future) trends in average national/urban population exposure to PM2.5 and ozone, developments of premature mortality and life years lost can be estimated by CIAM and EEA. Estimates for the non-Parties, e.g. Balkan, EECCA are likely available only early 2022; additionally the updated source-receptor relations which CIAM/MSC-W develops will be also available only February 2022 (MSC-W, completes by the end of the year 2021 and then CIAM needs time for processing and implementation – based on the discussion with MSC-W). It is expected that TFH gives additional guidance on updated relative risks and the counterfactual values to be used in modelling. Provided that an updated WHO-HRAPIE-document will become available in time (*spring 2022*) that would give guidance on the calculation method of morbidity impacts (such as asthma and sickness leave) and the health impacts of NO2-exposure (*fall 2022*). Alternatively, estimates could be based on methods used by EMRC for the Clean Air Outlook of the EU https://ec.europa.eu/environment/air/pdf/CAO2-MAIN-final-21Dec20.pdf. *See also 4.3; inclusion of condensables in PM2.5 exposure, and 6.3c influence of methane trends.*

4. Observed and projected trend in damage to materials and cultural heritage due to air pollution above threshold levels

56. When looking at observed trends, corrosion and pollution have decreased significantly since the early 1990s and a shift in the magnitude was generally observed around 1997 from a sharp decrease to a more modest decrease or to a constant level without any decrease[17]. SO_2 levels, carbon steel and copper corrosion have decreased even after 1997, which is more pronounced in urban areas, while corrosion of the other materials shows no decrease after 1997, when looking at one-year values. When looking at four-year values, however, there is a significant decrease after 1997 for zinc, which is not evident when looking at the one-year values. There are still occurrences of corrosion values above acceptable levels at some places in Europe. For soiling, there is no decreasing trend after 1997 and consequently larger areas in Europe are above acceptable levels, so therefore the focus of future development of the programme is on exposure of new soiling materials, for example coil coated materials and stone materials. The main pollutant responsible for soiling of materials is particulate matter. For projected trends, it is possible to make an analysis based on existing dose-response functions using pollution and climate data for different scenarios. However, this information is not available at present and need to be collected for all ICPs together based on pending decisions from the working group on strategies and review and the executive body.

5. Expected impacts of new scientific findings on environmental and health effects assessments

57. The main input related to the new scientific evidence will be the publication of the new WHO global air quality guidelines, which will contain a set of updated guideline values for PM, NO2, SO2, ozone and CO. Publication of the new WHO guidelines is expected in mid-2021. Another input would be a technical report on the health effects of PAHs.

58. Main new findings regarding modelling and mapping issues are:

- N empirical Critical Loads (CLempN): The work to update CLempN is currently under progress. It will be finalised in 2022 only, but a final scientific workshop will be hold in October 2021 already. First results of this process can therefore be included in the GP report version due in February 2022.

[17] Tidblad et al, Materials 2017, 10, 969; doi:10.3390/ma10080969

- By providing scenario assessments of the expected state of ecosystems in the future, Dynamic Modelling complements the critical loads calculations. In the context of the GP review, Dynamic Modelling could provide outputs as what the state of ecosystems will be so that the policy will reflect not only if the air pollution is not causing further damage (non-exceedance of critical loads) but also what the state of ecosystems in any given year is expected to be. Dynamic Modelling has the potential to provide a picture of such relevant and easy to understand factors as e.g. quality of surface waters, tree health, ozone damage to crops or biodiversity in a given future year. Given that delivering such information has been so far rather underexplored in the political process, a dialogue between the GP review group and ICP M&M would be beneficial for designing how the CDM could help in the review process.

59. The focus of the new development of the program is on soiling effects on different materials. The reason is the strong link to particulate matter concentrations, where there has been no significant decreasing in soiling in the recent years. New materials assessing effects on soiling has been included in the program, for example coil coated materials and stone materials and this will result in new data on the effect of particulate matter on materials and cultural heritage.

60. The ICP Vegetation will provide a summary text with the impact of new scientific findings relevant to ozone impacts on crops and ecosystems, including the interactions with climate change and nitrogen. A brief summary of the main points (to be further updated) is included below. There are potential interactive effects between ozone pollution and nitrogen. Ozone pollution can reduce the nitrogen use efficiency of some crops e.g. wheat, soybean and rice[18] . As a result of lower nitrogen fertilization efficiency, ozone causes a risk of increased losses of nitrogen from agroecosystems, e.g. through nitrate leaching and nitrous oxide emissions. Tropospheric ozone thus has the potential to cause elevated nitrogen in streams and rivers compared to clean air conditions, but the potential magnitude of this has not been quantified. A similar pattern can be seen for semi-natural vegetation, as the stimulating effect of nitrogen on growth can be progressively lost with increasing ozone concentrations . For crops, it has only been possible to investigate changes in ozone sensitivity at different nitrogen application rates for wheat, as there is insufficient data for other crops. A comprehensive meta-analysis of the available wheat data showed that there was no significant relationship between ozone sensitivity and nitrogen application rate, indicating that there is no requirement to adjust critical levels for ozone for crops according to nitrogen load (Pleijel et al., SBD-B chapter 11).

61. The relationship between ozone sensitivity and nitrogen application rate is less consistent for semi-natural vegetation. However, this heterogeneous response means that there can be changes in species composition of semi-natural vegetation communities with elevated ozone and additional nitrogen deposition co-occur . In addition, as elevated nitrogen deposition can alter species composition (notably of grasslands), this can in turn influence the ozone-sensitivity of the community, with studies suggestion that vegetation communities in pristine environments with low nitrogen deposition are most sensitive to tropospheric ozone . Current critical levels for ozone do not currently take account of the local nitrogen deposition rate.

62. There are also interactions between ozone pollution and climate change. Some interactions alter the exposure of vegetation to ozone, such as accelerated phenological development with increasing temperature resulting in bud-break earlier in the year and consequent exposure of the plant to ozone earlier in spring than current models predict[19] . Changes in meteorological conditions and soil moisture due to climate change will alter ozone fluxes to vegetation via influence on stomatal opening, however, the direction and extent of change will depend on the difference between perceived conditions and optimum

[18] Pleijel et al., SBD-B chapter 11, Broberg et al., 2017 DOI: 10.1016/j.scitotenv.2017.07.069)
(Mills et al., 2016 doi.org/10.1016/J.ENVPOL.2015.09.038)
[19] Calvete-Sogo et al., 2016 DOI: 10.1007/s00442-016-3628-z)
(Hayes et al., 2019 doi.org/10.1016/J.ENVPOL.2019.07.088)
Menzel et al., 2006 doi: 10.1111/j.1365-2486.2006.01193.x; SBD-B chapters 6-8)
(Hayes et al., 2019 doi.org/10.1007/S11270-018-4057-X)

conditions for each meteorological and soil moisture parameter . In addition to interactions between ozone and climate that affect exposure to ozone and fluxes of ozone, there can be additional ‘non stomatal’ physiological interactions affecting plant physiology with consequences that can include alterations in crop yield. Such interactions that do not involve ozone fluxes are not currently accounted for in existing models used within the Convention.

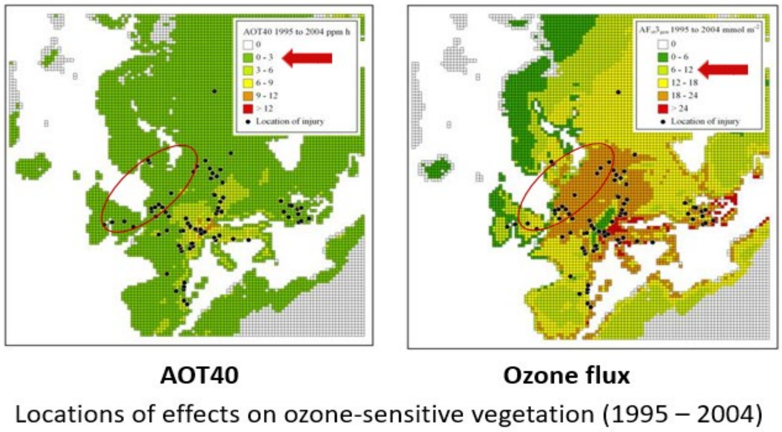


Figure B: Risk maps based on the AOT40 metric do not give a good prediction of the location of ozone impacts on crops and ecosystems, whereas risk maps based on the POD (ozone flux) metric are better at predicting the locations of ozone impacts.

63. ICP waters is currently working on effects of N deposition on surface water biology. Other topics will be discussed at the Task Force meeting (among which interactions of climate, land cover and N deposition on surface waters). ICP Waters will be able to deliver some more inputs before the summer.

64. ICP IM studies have shown that a systems approach is useful in addressing the question of future integrated impacts of climate and air pollution on ecosystem processes and biodiversity responses Simulated future soil conditions improved under projected decrease in deposition and current climate conditions: When climate change projections were included pH increased in most cases, while BS and C:N increased in about half of the cases. Hardly any climate warming scenarios led to decrease in pH. Modelling results also indicated that decreases in N deposition under the CLE current legislation scenario will most likely be insufficient to allow recovery of forest understory vegetation from eutrophication. Oxidized and reduced N emission reductions would need to be considerably greater to allow recovery from chronically high N deposition (Dirnböck et al. 2018).These studies illustrate the value of long-term integrated monitoring sites for applying models that can predict soil, vegetation and species responses to multiple environmental changes.

65. The target load concept is an extension of the critical load concept of air pollution inputs to ecosystems (Posch et al. 2019). The advantage of target loads over critical loads is that one can define the deposition and the point in time (target year) when the critical (chemical) limit is no longer violated. This information on the timing of recovery requires dynamic modeling. Target loads on a large regional scale can inform effects-based emission reduction policies. The assessment of Posch et al. (2019) suggested that reductions beyond the Gothenburg Protocol are required to ensure surface water recovery from acidification by 2050.

66. In a recent study by ICP IM, Weldon and Grandin (2021) showed that epiphytic lichens which are known to be good indicators of air quality, are of limited indicative ability of recovery after large scale disturbances such as air pollution. In a twenty-year time series of the epiphytic lichen community in a forested IM catchment (mainly Norway spruce, Picea abies), only very limited recovery was detected despite a drastic decrease in sulphur deposition, from high to low levels. This has implications for the use of epiphytic lichens as

indicators of improved air quality. However, we argue that monitoring of epiphytic lichens should continue as they still are good and rapid indictors of decreasing air quality.

67. An Ad-hoc Marine Group (AMG), led by Germany, was established in order to investigate options to answer the question 2.8 concerning inclusion of marine ecosystem protection. The ad-hoc group will present the issue in a presentation at the 14th Meeting of the HELDOM Working Group PRESSURE, 13 - 16 April 2021, seeking to establish a first contact." ["A concept and time schedule, which contribution can be delivered to which point in time in order to answer the question can only be provided after this first meeting with HELCOM experts."]

F. Emission reduction commitments for Parties

1.5 (e). What barriers have been identified by the Parties to meet the 2020 emission reduction obligations?

Proposal for Parties to submit information to the Secretariat by 30 September 2021 to answer this question. WGSR then could then have an agenda item in April 2022 to discuss and provide input into the Review.

Spring 2022 - CIAM, CEIP:

1. Inclusion of condensables in reporting of particulate matter

68. CIAM and TNO/CAMS started to improve the default database of condensable emissions (TNO Ref2 database). Crucial uncertainties are the number and type of appliances. Such information has to come from the parties. Meanwhile more parties started to report residential PM2.5 emissions with and without condensables to CEIP. This input is needed on order to properly answer question 4.4. A new initiative, funded by the Nordic Council of Ministers, will allow for a development of a new consistent set of technology specific emission factors for PM2.5 including condensables. This work focuses also on the assessment of the efficiency of mitigation of PM emissions, when condensable PM are taken into account. Including condensables would give a more complete explanation of the population exposure to PM2.5 and could better define the effectiveness of measures for health protection. Including condensable could shift the optimal policy strategy more into the direction of tackling residential solid fuel burning. For some parties, including condensables could prove to be problematic, as even with adjustment of their 2005 emission data, they would not be able to deliver the emission reduction obligation for PM2.5, without additional measures for residential heating.

Simpson et al, How should condensable emissions be included in PM emission inventories? emep_mscw_technical_report_4_2020.pdf

G. Emission limit values, technical annexes and related guidance documents of the Protocol (with priority given to black carbon and ammonia measures)

1.5 (a). To what extent have best available techniques and emission limit values and other technical provisions in annexes IV, V, VI, VIII, IX, X and XI been implemented by the Parties? Spring 2022l WGSR

1.5 (b). Have Parties implemented additional or newer source- oriented measures? What are the contributions of these measures? Spring 2022; WGSR

1.5(c). Have Parties implemented other (non-technical or structural) measures that contribute in meeting the 2020 emission reduction obligations? What are the expected contributions of these measures in 2020 and beyond? Spring 2022; WGSR

1.5(d). What barriers have been identified by Parties and non-Parties to implement the obligations in the technical annexes? Spring 2022; WGSR

Proposal for Parties to submit information to the Secretariat by 30 September 2021 to answer these questions. WGSR could then have an agenda item in April 2022 to discuss and provide input into the Review Document.

1.5(a), 1.5(b), 1.5(d) (TFTEI[20], TFRN[21], Parties) Spring 2022

69. The questionnaire organized by TFTEI with the support of the UNECE Secretariat was answered by many EECCA Countries as result of the 2019 Berlin meeting (see note 19) to answer the above questions. A number of barriers to implementation/ratification by EECCA Countries have been identified, along with possible actions to overcome the barriers. The joint meeting TFTEI/EECCA_CG workshop scheduled on April, 26-27, 2021, may add new elements for the evaluation. The action of TFTEI on this is limited to the EECCA countries, thanks to the long term cooperation relationship. TFTEI in NOT in the position to ask Parties what they have implemented at national level. In the past this task was carried out by the WGSR Chair with the support of the Secretariat and use of a questionnaire.

1.6(a), 1.6(b), 1.6(c), 1.6(d) (TFTEI, TFRN) Spring 2022

70. According to the revised mandate of the task force, TFTEI will perform an accurate and details analysis of the Annexes IV, V, VI, VIII, X and XI, and the associated guidance documents, in 2021, to identify the emission limit values and other technical requirements in the technical annexes, which could be potentially updated, because of the evolution of the technology since 2012. At the same time, potential adaptations of the annexes, to better address key sectors in the EECCA regions, will be investigated, along with possible gaps, complexity, excessive demanding, in collaboration with the EECCA experts (see the mentioned joint TFTEI-EECA_CG workshop), The outcome of the review will highlight the critical sections of the Annexes and associated guidance documents, along with the existence of the newest technological solutions, however, without expressing preferences or specific ELVs values.

Spring 2022 - TFIAM/CIAM/TFTEI:

1. To what extent have the measures implemented to meet the emissions reduction obligations for particulate matter contributed to reduce black carbon and polycyclic aromatic hydrocarbons emissions

71. Additional modelling will be needed. CIAM can construct a backcasting scenario that provides information on the PM-reduction with and without compliance to emission limit values as defined in the technical annexes of the amended Gothenburg Protocol and the associated reductions of black carbon and polycyclic aromatic carbon. *For all GPG-questions on black carbon and polycyclic aromatic carbon, we assume that for modelling purposes, black carbon is represented by 'elemental carbon' and polycyclic aromatic hydrocarbons by 'organic carbon'.*

2. Best available techniques to reduce black carbon emissions. Additional particulate matter measures that are also effective for reducing black carbon and PAH-emissions

72. In all countries, reduction of emissions from agricultural waste burning and from residential solid fuel burning are the most effective PM-reduction measures that would also reduce emissions of black carbon. See: Prioritizing reductions of particulate matter from sources that are also significant sources of black carbon – analysis and guidance ECE/EB.AIR/WG.5/2021/8 (unece.org) , ECE/EB.AIR/2020/6 (unece.org) and: 2 (unece.org).

[20] The Task Force on Techno-economic Issues.
[21] The Task Force on Reactive Nitrogen.

73. Sectoral projections of black carbon and organic carbon emissions will be made with the GAINS-model, considering existing legislation where several current important PM and BC sectors are included)e.g., transport, residential wood combustion). Development of the MTFR scenario will allow to demonstrate remaining PM2.5 and BC & OC potential and key technical measures. These will be different across the countries since potential will depend on structure of emissions, e.g., heavy reliance on solid fuels in residential sector, old fleet of diesel vehicles, or still poorly executed policies banning open burning of waste, including agricultural residue burning. While, non-technical measures offer potentially significant contribution to overall reduction their analysis will be limited to using only an alternative future scenario (i.e., strong climate mitigation, sustainable development) where certain transformation take place, including for example rapid decarbonization, structural changes in transport system, vehicle fleet electrification.

74. The above questions have found some answers in the background technical documents made available by TFTEI to WGSR, at its 58 session, in December 2020.

75. Fossil fuel consumption both in stationary and mobile sources, biomass burning are key sources of BC and associated PAHs (Polycyclic Aromatic Hydrocarbons) into the atmosphere. Gas Flaring (GF) is also an important source of BC and PM with both air quality and climate impact in the Artic regions as example. PM presents a large spectrum of components such as dust, BC, organic compounds, sulphates, nitrates, ammonium, etc… These different components may have a warming or cooling effect in the atmosphere. The reduction of BC and PAHs is linked to the reduction of PM.

76. **Residential wood burning** remains a major issue, and many efforts still need to be made to reduce emissions. The use of advanced or eco-design stoves should be promoted. The use of modern stoves implementing advanced methods to limit the emission of pollutants like catalytic combustors, wood pellets and masonry stoves enables to reach the emission standards as defined in the EU.

- Automatic fuel feeding and improvement of air staging combustion clearly improve the combustion efficiency. Low cost strategies of retrofit air injection on traditional stoves can reduce PM and BC emissions.
- Wood pellet stoves have 2 to 3 times lower PM, BC and PAH emissions than wood logs in advanced wood stoves.
- Additional strategies like Thermal Energy Storage can help to optimize the heating cycle from the start-up and the shutdown.
- Installation of an ESP (electrostatic precipitator) and the installation of a catalyst can help to reduce emissions from existing appliances.

77. The following technologies can be used[1]: New advanced stoves equipped with improved air control, reflective materials and two combustion chambers; New smart stoves with automated control of air supply and combustion, thermostatic control, Wi-Fi-connected to collect and send combustion data to the manufacturer for better service; New advanced masonry stoves, operating at high efficiencies and low emissions; New advanced pellet boilers: fully automated boilers (electronic control of air supply, lambda sensors), condensing boilers, using standardized pellets; Wood carburettor boilers using log wood or chip wood; Heat accumulating equipment with heat accumulating reducing stop/start frequencies and operation at partial load, which generates higher emissions than operation at full load; Other: flue gas recirculation, reverse combustion, gasifier. Correct installation and use of appliances, as well as maintenance and service/inspection of appliances and flue gas pipes are also essential to reduce emissions. The quality and the type of wood is also important.

78. Start-up is a critical phase with high emissions of pollutants. Currently, test procedures for delivering labels are not able to characterise real conditions of use of domestic appliances. New normalised test procedures should be developed and set-up, to better account for real utilisations of small-scale combustion appliances (starting phases, closing phases).

79. Harmonized methods to better account for the real emission factors of PM and BC would be necessary for accounting for condensables like dilution tunnels are recommended.

Road Traffic

80. PM produced by combustion emitted at the exhaust pipe are mostly fine particles below 2.5 µm and are mainly composed of carbonaceous species. PM, BC, PN, and PAH emissions are effectively reduced using tailpipe aftertreatment systems as Diesel Particulate Matter (DPF) or Gasoline Particulate Matter (GPF). Decreases from 90 to 100% are commonly observed for most particulate pollutants. Diesel particulate filters (DPFs) have been widely used in the motor vehicle industry for decades and found to be cost-effective. As an order of magnitude of $PM_{2.5}$ emission factors, changes from Conventional to Euro VI for Heavy Duty Vehicles (HDV) from 333-491 to 0.5-1.3 mg km^{-1} can be observed. The fraction of BC in PM ranges from 10 to 20% in Euro VI HDV vehicles.

81. Recent research findings show that different after-treatment technologies have an important effect on the level and the chemical composition of the emitted particles and highlight the importance of the particle filter devices condition and their regular checking to maintain the best performances.

82. Tyre and brake emissions are turning dominant sources and they are also a source of BC even if these particles are mainly in the coarse mode (diameter > 2.5 µm). There is no widely used after-treatment system to control brake, tire and road wear emissions. The choice of pad material is the main technical way to decrease emissions even some suction devices could be used to remove most particles from brakes. The behaviour of the driver is often cited as a key to reduce emissions (non-technical measure). Some companies have developed brake particles collection system that would reduce by 80% to 90 % respectively the brake mass and number emissions.

83. PM resuspension from the road should be better addressed. This emission is responsible for a large fraction of total road traffic emissions. It depends on meteorology (wind, temperature, humidity, precipitation) and the site climatology (land use in the vicinity).

Gas Flaring (GF)

84. Black carbon emissions from the oil & gas industry by Gas Flares is an important source of black carbon and particularly in areas surrounding the Artic zone. Russia, USA, Africa and some Middle East countries are among the largest emitting countries.

85. Routine flaring from a lack of gas utilisation sources is the most important and largest source of BC emissions from flaring, however, intermittent flaring and continuous flaring for operational reasons can also be significant sources. At least 90% of particulate carbonaceous species in the gas flare flue gas is made of black carbon.

86. Steam-assist Flares are clearly the most efficient in terms of soot emission reductions. However high pressure-assisted flares can be an efficient technique if water is not available on site. New model based on neural networks (advanced statistical methods) could help to better assist the flaring operations to better control soot formation.

87. The optimization of flare design and combustion conditions is an option thanks to the use of Computational Fluid Dynamic (CFD) model. Model and control systems can be used to monitor the flue gas characteristics and control the input data.

3. Appropriate definitions and calculation methods (emission factors) for black carbon and the condensable part of particulate matter

88. The joint activity (funded by the Nordic Council of Ministers) between MSC-W, TNO, NILU, SYKE, CIAM will review the Scandinavian experience and assimilate new data to establish consistent technology specific emission factors for solid particles (including BC) and total PM2.5 emissions including condensables. There will be a need for TFEIP to follow up with updating the emission inventory guidebook, and for TFTEI to update emission limit values including condensables in technical annexes.

4. Guidance documents

89. The guidance documents associated with the Annexes, are reviewed for the part of competence of TFTEI. The guidance document on "Agricultural Residue Burning" is submitted for consideration of WGSR, at its session 59th (May 2021). The development of further guidance documents might be considered, in example, for methane or shipping emissions, on the basis of the technical documents, already developed by TFTEI in 2020.

90. There is a proposal for Parties and task force chairs to give views on which guidance documents need to be updated as a priority and if there need to be any new guidance documents in response to the Review. Responses are to be sent to the Secretariat by 30 September 2021. WSGR could also take views on whether a guidance document is needed on non-technical measures. See informal document from WSGR58 re-posted for WGSR 59. [Note_on_non-technical_and_structural_measures_-201120.pdf (unece.org). Note: there is a standing mandate for TFTEI to update and assess information on technologies on a regular basis. All guidance documents should be updated on a regular basis. This is a priority question as well as a question for new documents that do not yet exist but that would be helpful in implementing the requirements of the existing protocol.

H. Specific sector approaches (such as residential solid fuel, agriculture, shipping)

1. Best available emission abatement techniques and measures for the reduction of methane emissions from key sources

The IIASA study evaluates mitigation potential for key sources, highlighting the available measures.

[TFTEI] Some answers are provided in the background technical document on methane emissions from the natural gas production and distribution network and emissions from solid waste landfills, made available by TFTEI to WGSR, at its 58th session, in December 2020.

90. Methane emissions from waste landfills are the most important non-agricultural source of methane emissions in Europe and are responsible for around 20% of overall emissions. Globally, this share is assumed to be even higher. In landfills, methane is formed through anaerobic digestion of hydrocarbon waste. To avoid theses emissions the most important measure is the reduction of landfilled waste. This can be achieved through composting of biodegradable waste, more efficient separation and recycling, or incineration of non-biological hydrocarbon waste (e.g. for combined heat and power generation). For the reduction of methane emissions from existing landfills, the most relevant options are:

- Gas collection and utilization: The implementation of an active landfill gas extraction system using vertical wells or horizontal collectors is the single most important mitigation measure to reduce emissions. This gas may be further used in different manners such as electricity generation, direct gas use for heat generation, gas grid injection or flaring if further utilisation is not possible.
- Oxidation of methane in biocovers or through biofiltration based on methanotrophic organisms (bacteria) that transfer methane into CO_2 and H_2O. This requires a final soil-based biocover of the landfill.
- Landfill aeration to avoid anaerobic digestion and to enhance biological processes to inhibit methane production.

91. A further important source of methane emissions is the natural gas production and distribution network. As production technologies, compression and pressure regulation partly show regional differences, not all options listed hereafter are relevant for all countries. Furthermore, a general distinction between production, transmission and distribution to final end-users has to be made, because e.g. from an EU perspective, production and transmission mainly takes place outside of the EU (Russia as the most important natural gas supplier). Generally, these measures can be categorized as technical measures by replacing existing equipment and organizational or management measures by modifying common practices e.g.

for maintenance and inspection. In summary, the following measures have been identified to be the most relevant:

- Reduction of operating emissions: Use of low or zero emitting pneumatic and compressor systems with re-use of the gas instead of venting. This may include the replacement of centrifugal compressor seal oil systems (recover methane from seal oil), the installation of low bleed pneumatic devices, etc.
- Reduction of maintenance emissions by using mobile compressors to pump gas from a section to be vented into a neighbouring section or the use of a mobile flare unit to burn vented gas at pipeline maintenance works etc.
- Inspection and maintenance programs: Organizational measures to detect emissions earlier and stop them, also referred to as leak detection and repair (LDAR).

2. Policy implications of including particles formed from condensable compounds in particulate matter reporting

- [TFTEI] TFTEI works in collaboration with MSC_W on deepening the technical aspects condensable part of PM. The policy implications are discussed in the frame of WGSR

3. Shipping sector

92. Projections of future emissions from international shipping in Europe have been made by the International Institute for Applied Systems Analysis (IIASA) and the Finnish Meteorological Institute (FMI). According to the FMI projections, NOx emissions from shipping in Europe will continue to decrease, despite the growth in traffic volumes (Repka et al., 2019). IIASA projects NOx emission reductions by up to 40% in 2030 and 79% in 2050, with respect to 2015 emissions (Cofala et al. 2018, their Table 5.3).

93. Based on a single model study roughly 10% of the ozone in Europe of anthropogenic origin can be attributed to international shipping (Jonson et al. 2020). Regulations of NOx emissions from shipping in emission control areas are likely to reduce ozone levels by 2030 (Jonson et al. 2019). Exceptions are regions with very high NOx levels, where reductions in NOx emissions can lead to increases in ozone during winter time. However, as ozone levels are low during winter, this will not have a major effect on exceedances of Air Quality Guidelines.

94. Cofala et al. (2018) have shown that the designation of the Mediterranean as a NOx emission control area (NECA) would be efficient in reducing PM2.5, and related premature deaths, especially in the southern parts of the ECE region. Geels et al. (2021) conclude similarly for Northern Europe that the number of premature deaths due to shipping emissions can be significantly reduced by 2050 through a heavy fuel oil ban in addition to the sulphur emission control regulations.

95. Critical loads of nitrogen depositions are exceeded in much of Europe. In particular in countries with long coastlines, a substantial portion of the nitrogen deposition is from shipping (Jonson et al. (2020) and EMEP, 2020 (their Table C.2)). Repka et al. (2021) have shown that shipping emissions contribute to critical load exceedances in land areas but that this contribution will decrease due to emission regulations, in particular in emission control areas as already implemented in the North Sea and the Baltic Sea.

I. Non-technical measures, best available techniques and energy-efficiency requirements

1.5(a), 1.5(b), 1.5(c) (CIAM, TFIAM, TFTEI, TFRN)

[TFTEI] These answers are mainly due by the Parties. TFTEI may contribute as in the case of the questionnaire for the EECCA Countries.

Fall 2021 - TFIAM, CIAM, TFTEI:

1. Best available non-technical measures, effective policy instruments to trigger behavioural change and their contribution to environmental and health improvement

[TFTEI] Behavioural changes can be triggered by ad hoc guidance documents like the Code of good practice for wood-burning and small combustion installations. The effectiveness and costs of non-technical and structural measures are currently analysed in several countries, e.g. Sweden, Italy, Portugal, UK, Germany[22], Ireland, Belgium, the Netherlands as well as the European Commission's Joint Research Centre, and is also the subject of work under the Expert Panel on Clean Air in Cities and the Task Force on Reactive Nitrogen.

95. Shifting car mobility to more active mobility (walking, cycling and public transport use) as well as changing diets (less meat, more vegetables) could have multiple benefits for environment and individual health. Pricing, regulation and infrastructural measures (fewer parking places and car lanes, better facilities for cycling and fast public transport) proved to be effective in several cities. CIAM analysis of dietary (low meat) and improved nitrogen use efficiency measures showed significant environmental and health benefits due to reduced air pollution at a regional scale and also climate co-benefits owing to reduction of methane emissions; such measures are part of the clean air portfolio in Amann et al (2020).

96. The COVID-19 induced lockdown periods taught us some relevant lessons on the impact of reduced car use and the shift to walking and cycling. A big uncertainty is which of the behavioural changes will have a lasting effect after the pandemic. There is a potential for negative feedbacks on air quality if more people will avoid public transport and use cars instead and move to larger dwellings. Additionally, the actual impacts on air quality will depend on the indicator, i.e., reduced NO_2 concentrations but not so clear picture for PM concentrations and even increase in ozone. There is a need to complement the information on non-technical measures with information on policy instruments that will be effective to implement this group of measures (e.g. regulation, economic instruments, infrastructural investments, nudges, etc). See: Note_on_non-technical_and_structural_measures_-201120.pdf (unece.org)

J. Flexibility provisions

97. Description of the complexity of the amended Gothenburg Protocol and its main barriers to ratification. Assessment of the adequacy and effectiveness of current flexibility provisions to facilitate further ratifications. Proposals for alternative solutions and new approaches, with pros and cons, to overcome barriers and increase ratification.

98. There is an informal document on flexibility provisions for the WGSR59 meeting. There will be a proposal to take general comments on the informal document on flexibility provisions, discuss the possibility for an informal session in Spring 2022 and continue discussion on this topic during the Review. Parties and non-Parties could send comments on the informal document on flexibility provisions to the secretariat by 15 July 2021.

K. Convention Parties that are not parties to the Protocol

1.5 (d) What barriers have been identified by Parties and non-Parties to implement the obligations in the technical annexes? **Spring 2022; WGSR**

Proposal for non-Parties to submit information to the Secretariat by 30 September 2021 to answer this question. WGSR could then have an agenda item in April 2022 to discuss and provide input into the Review Document. Clarify non-Parties are only to answer 1.5(d) and Parties 1.5 (a-e).

[22] https://www.umweltbundesamt.de/publikationen/oekonomische-instrumente-in-der-luftreinhaltung (a summary is available in English)

Fall 2021/spring 2022 - TFEIP/TFIAM/CIAM:

1. Key sectors with large emission reduction potential in EECCA/SEE

98. CEIP (Fall 2021) – major emitting sectors based on current emission reporting or current implementation in GAINS, if other data missing. CIAM (Spring 2022) – MTFR for future scenario defining mitigation potential and identifying key sectors. For item 3.1 c & e – see chapter on progress towards achieving objectives.

L. Canada and the United States of America

99. This section recognizes that the amended Gothenburg Protocol includes a number of commitments for parties outside the geographical scope of EMEP, which in most cases includes Canada and the United States of America, unless otherwise specified. It also recognizes that Canada and the United States are bilaterally addressing cross-border air pollution under the Canada-United States Air Quality Agreement, which includes commitments by both countries to reduce emissions of sulphur dioxide, nitrogen oxides, and volatile organic compounds. Although the review report will integrate inputs from Canada and the United States of America into the relevant chapters/sections, as appropriate to national circumstances, this section will include all other relevant information.

100. Canada and the United States of America have ratified the 1999 Gothenburg Protocol (in December 1999 and December 2018 for the United States and Canada respectively) and its 2012 amendments (in January 2017 and November 2017 for the United States and Canada respectively), and have, upon ratification, submitted their respective emission reduction commitments to annex II and relevant emission limit values into annexes IV, V, VI, VIII, X and XI. Canada and the United States of America have a long history of bilateral cooperation on transboundary air pollution through the 1991 Canada-United States Air Quality Agreement. The two countries plan to undertake a review of the effectiveness of the agreement in terms of meeting its environmental objectives as well as its sufficiency in addressing transboundary air pollution. The scope and content of the review are being finalized. It is expected to focus on issues covered by the Air Quality Agreement including acid rain and ozone and their transboundary impacts, while discussions are underway on how and whether to address fine particulate matter, as well as other appropriate additional topics. Although the work schedule for the review of the Air Quality Agreement is not yet confirmed, it is expected to begin in the first half of 2021, with a tentative completion date in 2022.

101. Ammonia is not covered by the Air Quality Agreement, but it is also of concern in Canada and the United States of America as atmospheric ammonia is a key precursor to the formation of fine particulate matter and contributes to acid deposition and eutrophication. Additional assessments are needed to quantify the impacts. Discussions are ongoing.

M. Hemispheric transport

102. Description of the role of hemispheric transport. Assessment of current and future contributions of emission sources outside the ECE region to ecosystems and health impacts in the ECE region. Assessment of emission reduction potentials outside the ECE region. Special focus on ozone and particulate matter (black carbon) and their precursors.

Preliminary contribution: QuestionsForGPReview210228.pdf (kaskada.tk)

N. Integrated multi-pollutant multi-effect approach

Fall 2021 - CIAM:

103. The GAINS model has been continuously updated including revisions of key assumptions about installation structure (especially in residential sector), emission factors, cost coefficients. A larger systematic update of the GAINS framework has been released in

Spring 2021 where several updates were introduced, including: allocation of wood and coal combustion in the residential sector into urban and rural population, new waste management sector allocating waste generation and management activities into urban/rural population, possibility to include explicit representation of high emitting vehicles. Further updates will be performed in 2021 in collaboration with MSC-W, including extension of the GAINS Europe domain to cover the whole extended EMEP domain; this will encompass also additional model capacity through so called Primary Particulate Matter (PPM) tracking, enabling downscaling beyond 10x10km, sectoral transfer coefficients allowing for improved source attribution (e.g., cities) and potentially adjusting for significant spatial shifts (due to improved data or mitigation efforts) in source distribution. Furthermore, GAINS will include consistent inclusion of condensables, new data for selected EECCA, West Balkan, Turkey (both past and future) based on the ongoing activities within EU and World Bank projects.

O. Synergies and interactions with other policy areas

6.3 (b) What is the contribution of implemented and new climate measures for reduction of methane? Spring 2021; TFIAM lead with TFTEI and TFRN

TFIAM/CIAM will present on air and climate synergies, including methane. See also Höglund-Isaksson et al. (2020). Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model. Environ. Res. Commun. 2 (2020) 025004 https://doi.org/10.1088/2515-7620/ab7457

6.3 (d) Addressing methane in a future instrument Spring 2022; WGSR lead

- WGSR could discuss options to address, activities to focus on, but not on the technical aspects
- Likely link to discussion on International Forum for Collaboration on Air Pollution
- Potentially discuss progress and how to include methane

1. Impact of climate and energy measures on emissions reductions in the long term. Impact of new policies and measures on biodiversity, bioeconomy, circular economy, nitrogen management, etc.

104. For the EU as whole a 2050-scenario including climate policy is available, but country specific data are still confidential. Lessons (or indicative answers) on the impact of climate policy could be drawn from the EU-wide analysis (as already available in the 2nd Clean Air Outlook study for the EU), single country analysis when the EU-data is released, or from analyses made by (some) individual countries. Qualitative answers on the potential contribution to reducing ammonia emissions of promoting the bioeconomy and circular economy as well as integrated nitrogen management, will be formulated in co-operation with TFRN. Studies presented at TFIAM48 reconfirm the potential co-benefits for air quality of reaching the 2 degrees climate target (Task Force on Integrated Assessment Modelling - TFIAM - IIASA). The Task Force noted that these co-benefits will not be enough for reaching the long-term objectives of the Air Convention. Remaining nitrogen problems would require additional action. An integrated design of climate and air quality policy is needed to deal with policy trade-offs: fuel switch for climate reasons should not worsen (local or regional) air quality, and air pollution strategies should aim to be at least climate neutral. GAINS analyses[23] showed that a wider perspective on air pollution control (considering more than end-of-pipe measures and involving policies aimed at various sustainable development goals including also measures in agriculture addressing reduced meat consumption and improving nitrogen use efficiency) would be needed to reach WHO air quality targets. This also

[23] Amann M et al. (2020) Reducing global air pollution: the scope for further policy interventions. Phil. Trans. R. Soc. A 378: 20190331. http://dx.doi.org/10.1098/rsta.2019.0331

confirms the need for an integrated approach to air pollution taking into account other environmental issues.

2. Contribution of implemented and new climate measures on the reduction of methane emissions

105. A peer-reviewed studies are available by IIASA[24] and JRC (Rita van Dingenen, et al) on emission trends (including climate policy) and available additional measures to reduce methane emissions. Current policy focusses on emission reduction from waste and gas exploration. Gas recovery from landfills and reduced use of fossil fuels are important measures. Additional measures would have to focus on emissions from cattle, with a combination of changes in cattle feed, as well as reduced livestock and reduced meat consumption, as the technical potential to reduce methane emissions seems low.

3.5(a) (CIAM, TFIAM, TFTEI)

[TFTEI] the work carried out by TFIAM (lead body) in collaboration with TFTEI on cost of inaction will provide elements to answer the question

6.3(b) (TFIAM, TFTEI)

[TFTEI] The effects of the implemented measures are mainly matter of Integrated Assessment Modelling. Additional elements may come from background studies like that carried out by TFTEI, mentioned above

P. Progress towards achieving the objectives of the Protocol

Fall 2021 - CIAM/TFIAM, TFTEI, CEIP, TFRN:

1. The latest emission projections by Parties compared with the latest GAINS -scenarios, taking into account recent climate, energy and agricultural policies, new source legislations and latest updated emission inventories

106. For EU-countries, an updated set of GAINS-scenarios including existing policies as well as National Air Pollution Control Programmes (NAPCP) has been developed for the baseline scenario and a scenario with climate policies; these are available in: https://ec.europa.eu/environment/air/pdf/CAO2-MAIN-final-21Dec20.pdf. Comparable analyses for non-EU countries are dependent on the completeness of national projections delivered to CEIP and the updated GAINS scenarios for these countries. Model calculations for EU-countries show that full implementation of emission limit value regulations would enable parties to meet national emission reduction obligations for SO_2, NO_x, NMVOC and $PPM_{2.5}$, assuming an average lifetime of existing installations and vehicles. Slower than average replacement could be a reason to miss the deadline. Many parties have difficulties to meet the ammonia reduction obligation, even with implementation of emission limit values for new large stables (https://iiasa.ac.at/web/home/research/researchPrograms/air/policy/past_meetings.html.

2. Will the Protocol obligations be met based on latest emission projections?

107. The latest CAO2 analysis for EU countries shows that all countries will meet the 2005-2020 reduction obligations for SO_2. Four out of 27 countries will only meet the 2020 obligation for NO_x a few years later (among which France and Germany), two countries will meet the NMVOC target later than 2020 and seven countries will meet the primary $PM_{2.5}$ obligation only after 2020 (without correcting for condensable PM-emissions). The NH_3 obligation seems to be the most challenging one: ten countries will miss the 2020-target.

[24] Höglund-Isaksson et al. (2020). Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model. Environ. Res. Commun. 2 (2020) 025004 https://doi.org/10.1088/2515-7620/ab7457

Even with additional measures in the NAPCP and additional climate policies up to 2030, Denmark, Estonia, Finland, Ireland, Latvia and Lithuania will not meet the ammonia obligation. Also see: Assessment report on ammonia ECE_EB.AIR_WG.5_2021_7-2102624E.pdf (unece.org), in French: ECE/EB.AIR/WG.5/2021/7 (unece.org) and in Russian: ECE/EB.AIR/WG.5/2021/7 (unece.org); and: Ammonia_inf_doc_for_WGSR58__note_from_TFRN__TFIAM_.pdf (unece.org).

3. The optimized emission reduction obligations, given the updated emission inventories and projections and the same gap-closure ambitions as used in the preparation of the amended Gothenburg Protocol

108. Preliminary optimization calculations for 2020 and 2030 are planned to be made *late 2021* depending on the availability of updated emission inventories (for 2005) and projections for non-EU countries. Final optimization calculations are planned for *spring 2022*, including the sensitivity for including condensable PM-emissions, NOx and NMVOC from agricultural land, and deposition reduction targets for marine ecosystems (provided that credible targets are made available in time by the WGE). CIAM could recalculate ambition scenarios as used in 2011. Alternatively CIAM might explore what emission reductions would be needed for attainment of critical loads and levels and the WHO air quality guidelines.

4. Are emission reduction obligations adequate for meeting long term environmental and health protection targets of the protocol? E.g. what will be the outcomes for health risks from ozone and particulate matter and for nitrogen deposition in 2030 and 2050

109. With updated relative risk factors from TFH, updated critical load maps from CCE and updated damage functions for vegetation of ozone fluxes from ICP-Vegetation GAINS could estimate the remaining risks for health, ecosystems and crops, assuming 1) full implementation of the 2020 emission reduction obligations; 2) emission projections for 2030 based on national air pollution control programmes, and possibly: 3) tentative emission projections for 2050 assuming implementation of climate policies (currently only available for the EU as a whole). For non-EU countries that ratified the protocol similar projections exist in GAINS. GAINS will look at the share of ecosystems with exceedances of critical loads and excess ozone in countries and the remaining health risks. Deposition and air quality data from the three scenarios will also be shared with WGE-groups to further analyse the impacts for specific end points, such as biodiversity. Based on current difficulties and slow progress in reduction of ammonia emissions, the exceedance of nitrogen critical loads would likely stick out at as a remaining challenge, and probably also the high share of secondary aerosols (e.g., ammonium-nitrate) in population exposure to PM2.5.

5. The estimated reductions based on the best available emission projections for non-Parties to the revised protocol. Will these reductions contribute to meeting long term environmental and health protection targets?

110. In the absence of the harmonized projections for the non-parties to the Protocol (non-EU West Balkan and EECCA) several alternative sources will be used and implemented in GAINS; these include EU project on West Balkan and EECCA and the IEA/FAO projections. CEIP and TFTEI will be involved to get a most up-to-date picture of current legislation and actual current implementation of abatement technologies. Bilateral communication with the parties involved will depend on available co-funding and time (and should probable be postponed to the revision phase of the protocol. Uncertainties about the actual implementation of measures will probably remain significant. Based on the emission projections impacts for health and ecosystems will be estimated. CIAM/IIASA will develop emission trends for all species. CIAM/IIASA and MSC-W will jointly (in parallel) calculate the concentration and deposition as well as perform assessment of environmental impacts and distance to environmental and health targets.

6. Will implementation of best available techniques and emission limit values and other technical provisions be adequate for meeting long term environmental and health protection targets of the protocol beyond 2020?

111. CIAM/IIASA will develop the MTFR scenario considering the BAT and ambitious ELVs as defined in the technical annexes. IIASA and MSC-W will perform concentration and deposition calculation evaluating health and environmental impacts.

7. Contribution to meeting environmental and health protection targets if non-Parties to the revised protocol implemented best available techniques and the emission limit values and other technical provisions set in the technical annexes

112. CIAM is currently updating (best available) emission projections for several EECCA- and west-Balkan countries, including Turkey, for both current legislation and with maximum feasible technical measures. Based on these projections, an assessment will be made of the remaining risks for health and ecosystems. CEIP and TFTEI will be involved to get a most up-to-date picture of applicable technologies and their potential in the concerned countries. Based on the emission projections impacts for health and ecosystems will be estimated.

Fall 2022 - TFIAM/CIAM , TFTEI:

8. The costs of additional measures in the region that would not exceed the external costs of inaction, with due consideration of synergies and other interactions with and more cost-effective measures potentially available in other policy areas. In which sectors can such be found?

113. A TFIAM/TFTEI-report on the Costs of Inaction will be available in the coming months. See informal document: Cost_of_inaction_TFIAM_two_pager.pdf (unece.org). Identification of cost-effective actions to reduce ammonia emissions will be identified with TFRN. There are opportunities to reduce the costs of (end-of-pipe) abatement measures when air quality policy can be combined with policy measures to reduce the use of fossil fuels, the number of car kilometres driven and the production and consumption of meat and dairy. GAINS costs will be updated with the latest data from TFTEI and TFRN. The GAINS model will provide an optimized (either at the ECE level or country level) portfolio of additional measures whose cost will not exceed the cost of inaction at the regional or country level. The scenario will consider the synergies with other policies including climate targets as well as nitrogen use efficiency improvements. GAINS costs will be updated with the latest data from TFTEI and TFRN. The GAINS model will provide an optimized (either at the ECE level or country level) portfolio of additional measures whose cost will not exceed the cost of inaction at the regional or country level. The scenario will consider the synergies with other policies including climate targets as well as nitrogen use efficiency improvements.

Fall 2022: TFIAM/EPCAC:

9. Are additional local air quality measures sufficient and cost-effective to reduce health risks or strive towards WHO air quality guideline values (or to strive towards updated WHO values, if available on time)?

114. Local traffic measures are effective to reduce the health burden for people living along busy roads that are exposed to high pollution levels. Further, with local permitting of installations and equipment use, cities can stimulate early replacement of old installations, wood stoves and non-road mobile machinery in favour of newer ones, that comply with stricter emission limit values. In many cities (not only in Europe, but all over the world), to reduce the average exposure of the urban populations as a whole. Even in large cities like Berlin and London, there is a large regional and transboundary contribution to the concentration of particulate matter at traffic stations. Long-range transport of fine particulate matter, NO_2 and ozone contribute significantly to local air quality and related impacts on health and ecosystems. WHO guideline values could not be achieved unless those sources outside the city itself were also addressed, emphasizing the need for a multiscale governance approach. Nevertheless it is clear that all cities were net exporters of pollution (Task Force on Integrated Assessment Modelling - TFIAM - IIASA).

3.1 (CIAM, TFIAM, TFTEI, TFRN, TFEIP)

[TFTEI] The effects of the measures and other instruments (e.g. ELVs) are mainly matter of Integrated Assessment Modelling. CIAM could provide input on the effects of best available technology implemention in *spring 2022.*

3.5(a), 3.5(b), 3.5(c) (CIAM, TFIAM, TFTEI)

Work on the costs of inaction is carried out by TFIAM (lead body) in collaboration with TFTEI. Elements are provided by the upcoming Costs of Inaction (IVL), the EEA-report (INERIS/EMRC) on damage estimates of emissions and the OECD-report (The Economic Benefits of Air Quality Improvements in Arctic Council Countries | en | OECD).

3.6 (TFIAM)

Input on effective local measures is expected from the Expert Panel on Clean Air in Cities, the JRC, and several national experts including those from Italy and the UK.

4.2(a), 4.2(b), 4.4 (TFTEI, CIAM, TFIAM)

[TFTEI] The effects of the implemented measures on black carbon and PAH are mainly matter of Integrated Assessment Modelling. TFTEI contributes with the background technical documents on the abatement technologies. CIAM will include projections on elemental carbon and organic carbon in scenarios for current legislation and maximum technical feasible reductions.

Q. Additional policy issues

115. Assessment of adequacy and suitability of key articles (including but not limited to objectives in article 2, reporting provisions in article 7, review provisions in article 10, adjustment provisions in article 13, and amendments procedures in article 13bis) of the amended Gothenburg Protocol. Assessment of the need and best approach to include methane in a future instrument. Description of the policy implications of including condensable particles in reporting of emissions of particulate matter.

6.2 (a) Are key articles on inter alia objectives, reporting obligations and amendments still fit for purpose? **Fall 2022; WGSR Lead**

Proposal to collect preliminary views from Parties by 30 September 2021 and make clear that it concerns an evaluation of current articles, and whether or not they are effective to meet the objective of the Protocol and not yet in the context of a possible revision. The GPG will then make proposals in Draft 2 of the Review based on any views received. The following articles could be reviewed:

-Article 1. Any new/modified definitions?
-Article 2. Is 1. (a)-(f) sufficient to meet the objective?
-Article 3. Is implementation of the basic obligations sufficient to meet the objective of the Protocol? (Annex I answers will help inform)
-Article 4. Exchange of Information
-Article 5. Public Awareness
-Article 6. Strategies, Policies, Programmes, Measures and Information
-Article 7. Reporting
-Article 8. Research, Development and Monitoring
-Article 12. Annexes (TFTEI and TFRN Review) Others?
-Article 13. Adjustments

6.2(b) Do articles 4 (exchange of information) and 8 (research and development) adequately address international cooperation and integrated environmental policy as indicated in the LTS for 2020-2030 and beyond? **Fall 2022; WGSR lead**

Proposal for parties and subsidiary bodies to send in views on these Articles by 30 September 2021 to the Secretariat.

6.5: Policy Implications for condensables; **May 2021; WGSR lead with EMEP/WGE**

Include a paragraph in the draft review that gives an update/discussion from May WGSR59 (Section F. para 12 of outline).

- Basic science questions need answered first before policy discussions begin
- Not all information will be available for discussion in May – will just give an update on progress
- Need additional clarity on what policy implications would be if condensables are included in emissions inventories and projections, it would be useful to list those issues more clearly

R. Conclusions

116. Description of main review findings and conclusions on the adequacy of the obligations and the progress made towards the achievement of the objectives of the amended Gothenburg Protocol. Recommendations for next steps and further work.

Sources (to be further converted to footnotes)

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