United Nations ECE/EB.AIR/2021/4

Economic and Social Council

Distr.: General
24 September 2021

Original: English

Economic Commission for Europe

Executive Body for the Convention on Long-range Transboundary Air Pollution

Forty-first session
Geneva, 6–8 December 2021
Item 5 of the provisional agenda
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, as amended in 2012

Submitted by the Gothenburg Protocol review group

Summary

At its thirty-ninth session (Geneva, 9–13 December 2019), the Executive Body initiated the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (the Gothenburg Protocol), as amended in 2012. At its fortieth session (Geneva , 18 December 2020), the Executive Body decided that the scope of the review should remain broad and that the review should focus on information-gathering, scientific and technical inputs and assessing the information collected (Executive Body decision 2020/2).

The Executive Body is invited to consider the present preliminary report on the review prepared by the Gothenburg Protocol review group. The report is based on the scientific and technical information provided by subsidiary bodies in accordance with decision 2020/2 following the annotated outline of the report (ECE/EB.AIR/WG.5/2021/4 and Corr.1). The full text of the inputs provided by subsidiary bodies is contained in an accompanying informal document entitled "Supplementary information for the review of the Gothenburg Protocol". The final report on the review, based on all required inputs and any new information that becomes available after the submission of the present document, will be presented for consideration by the Executive Body at its forty-second session (Geneva, provisional dates 12–16 December 2022).

I. Introduction

1. Following the entry into force of the 2012 amendment[1] to the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) on 7 October 2019, the Executive Body initiated the review of the Protocol at its thirty-ninth session (Geneva, 9–13 December 2019) (ECE/EB.AIR/144/Add.1, decision 2019/4) pursuant to article 10 of the Protocol, which stipulates that Parties shall keep under review the obligations set out in the Protocol, including the adequacy of the obligations and the progress made towards the achievement of the objective of the Protocol. The 2016 scientific assessment of the Convention on Long-range Transboundary Air Pollution (Air Convention),[2] its policy response (ECE/EB.AIR/WG.5/2017/3 and Corr.1) and the Long-term Strategy for the Convention for 2020–2030 and beyond (decision 2018/5, annex)[3] form the basis of the key elements that were taken into consideration for the review.

2. At its fortieth session (Geneva, 18 December 2020), the Executive Body decided that the scope of the review should remain broad and that the review should focus on information-gathering, scientific and technical inputs and assessing the information collected.[4]

3. The present document has been prepared by the Gothenburg Protocol review group convened by the Chair of the Working Group on Strategies and Review. This draft report is based on the scientific and technical information received to date from subsidiary bodies in accordance with decision 2020/2 following the annotated outline of the report (ECE/EB.AIR/WG.5/2021/4 and Corr.1). The full text of the inputs provided by subsidiary bodies is contained in an accompanying informal document entitled "Supplementary information for the review of the Gothenburg Protocol".[5] The final report on the review based on all required inputs will be submitted for consideration by the Executive Body at its forty-second session (Geneva, provisional dates 12–16 December 2022).

4. This document outlines: the legal requirements for the review; emission reduction commitments; flexibility provisions; approaches by countries outside the geographical scope of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP); hemispheric transport; integrated approaches; and synergies with other policy areas. It will conclude with recommendations/proposals for further action.

5. The Gothenburg Protocol review group will continue its work on this review and further input will be introduced into the next draft, which will be an official document for the sixtieth session of the Working Group on Strategies and Review (Geneva, 11–14 April 2022).

II. Legal requirements for the review

6. Article 2 of the Gothenburg Protocol sets out the treaty's objective, which is to control and reduce emissions of specific pollutants that are caused by anthropogenic activities and that are likely to cause adverse effects on human health and the environment, natural ecosystems, materials, crops and the climate in the short and long term. Article 2 also covers the implementation of measures by Parties to achieve their national targets for particulate matter (PM), in particular giving priority, to the extent considered appropriate, to emission reduction measures, which also significantly reduce black carbon (BC).

[1] The amendment of the text and annexes II–IX to the Protocol and the addition of new annexes X and XI, adopted by Executive Body decision 2012/2.

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

[3] All Executive Body decisions referred to in the present document are available at https://unece.org/decisions.

[4] Executive Body decision 2020/2, para. 1.

[5] Available at https://unece.org/info/Environmental-Policy/Air-Pollution/events/350953.

7. Article 10 requires that Parties keep under review and assess the obligations of the Protocol, which are meant to achieve the objectives set out in article 2. Article 10 also broadly specifies the modalities of such reviews.

8. The broader elements to be included are those assessing the obligations of Parties in relation to their calculated and internationally optimized allocations of emission reductions; as well as the adequacy of the obligations and whether sufficient and efficient progress has been made towards the achievement of the objectives of the Protocol as described above. The review includes an evaluation of the emission reduction commitments for 2020, not the fixed emission ceilings in the original Protocol for 2010.

9. Article 10 (3) and (4) refer to specific elements that must be included in the review. These elements include an evaluation of mitigation measures for BC emissions and an evaluation of NH_3 control measures and consideration of the need to revise annex IX. Included in these paragraphs is a timeline for the completion of these evaluations (by the second session of the Executive Body after the entry into force of the amendment contained in Executive Body decision 2012/2). It was decided by the Executive Body (decision 2020/2) that these evaluations would be subsumed by the broader review of the Gothenburg Protocol.

10. The best available scientific information on the effects of acidification, eutrophication and photochemical pollution, including assessments of all relevant human health effects, climate co-benefits, critical levels and loads, the development and refinement of integrated assessment models, technological developments, changing economic conditions, progress made on the databases on emissions and abatement techniques, especially related to PM, NH_3 and volatile organic compounds (VOCs), and the fulfilment of the obligations on emission levels were taken into consideration.

III. Emissions

11. The emission inventories submitted by Parties differ in quality, and technical reviews have identified those Parties that need improvement regarding their submissions. There have been significant improvements in the completeness of reporting in recent years, with 48 Parties submitting inventories in 2020. However, submissions from 17 Parties were incomplete,[6] and 11 Parties did not provide an Informative Inventory Report.

12. Emission inventories typically follow a similar trajectory as they are developed. Initially, there is a focus on the need for completeness, and then attention shifts to ensuring higher levels of accuracy. Even if completeness issues are addressed, substantial improvements will be needed in numerous national emissions inventories before the accuracy of emission estimates across Parties can be considered to be at "good practice" quality levels.

13. Reported emissions entail uncertainty margins of 10 per cent to over 100 per cent. In general, the trend in emissions is less uncertain than the absolute levels. The trend in emissions is comparable to the trend in measured concentrations (see section IV below). In some cases, there are unexplained divergences, for instance, for the nitrogen oxides (NO_x) trends after 2008, where reported emissions decline much faster than measured concentrations.

14. BC emissions are reported on a voluntary basis, but the number of Parties providing emission estimates has increased to 40. Significant inconsistencies exist between national BC emission estimates, suggesting that the accuracy and completeness of the submissions need to be improved. Emission trends are expected to be more reliable, and data for the European Union 27 show emissions halving from 1990 to 2018. With continued reduction of BC emissions from diesel vehicles, the residential sector is becoming the main source (the United

[6] Katerina Mareckova and others, "Inventory Review 2020: Review of emission data reported under the LRTAP Convention and NEC Directive – Stage 1 and 2 review– Status of gridded and LPS data", Technical Report CEIP 4/2020 (Vienna, Centre on Emission Inventories and Projections (CEIP/Environment Agency Austria, 2020). Available at www.ceip.at/review-of-emission-inventories/technical-review-reports/rr2020.

States of America and Canada will provide similar information on BC for the second draft of the present report).[7]

15. Throughout the 1990s, emission reductions for a number of pollutants arose from fuel switching from coal to natural gas fuels, particularly in the residential sector in European countries. The impact of reduced use of coal in electricity generation is ongoing and is accentuated by the increased use of renewables. By contrast, emission reductions over the past 20 years have primarily been driven by targeted emissions reduction policies.

16. Further emission reductions are considered possible in international shipping. Within the United Nations Economic Commission for Europe (ECE) region, further abatement options are available, inter alia, to reduce NH_3 emissions from agriculture, fine particulate matter ($PM_{2.5}$) emissions from residential solid fuel burning and agricultural waste burning, and methane (CH_4) emissions from waste treatment, the fossil fuel sector and agriculture.

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

18. The EMEP/European Environment Agency (EEA) Air Pollutant Emission Inventory Guidebook is considered to be comprehensive in its scope and content. However, there are a number of improvements that could be made, in particular, regarding funding mechanisms, collaboration and methodologies for lower priority pollutants. There are also decisions that must be made on metrics for BC and inclusion of condensables before guidance can be updated. In addition, emissions methodologies in the Guidebook need to better account for the influences of climate change.

19. No decision has been made regarding the metric to be used for reporting BC emissions. Moreover, it is not known whether future PM emissions reporting will include the condensable and/or the semi-volatile component. The EMEP scientific community is still discussing the options for including condensables, but no decision has been made. Therefore, guidance cannot be updated/developed accordingly.

IV. Measured and modelled atmospheric concentrations and deposition levels

20. Ground-level ozone (O_3) is a secondary pollutant that results from complex physico-chemical mechanisms. Therefore, observed average concentrations do not change at the same rate as reductions in regional precursor emissions (NO_x and non-methane volatile organic compounds (NMVOCs)), and are influenced by other factors such as climatic parameters, hemispheric transport and global CH_4 emissions. In Europe, O_3 peaks have declined systematically (by around 10 per cent between 2000 and 2019). The health-related SOMO35 (for O_3, the sum of means over 35 ppb (daily max. 8-hour)) indicator decreased by about the same magnitude. The annual average O_3 concentrations remained constant and tended to increase in urban areas.

21. All other pollutant concentration trends generally followed the decreasing emission trends in the EMEP region. Annual average concentrations of sulfur dioxide (SO_2) and particulate sulfate, and wet deposition of oxidized sulfur, declined by, respectively, 74 per cent, 61 per cent and 60 per cent between 2000 and 2019 (the United States of America and Canada will provide trends for SO_2 for the second draft of the present document).

22. From around 1990 onwards, the total emissions of NOx declined significantly in Europe, followed by a 24 per cent reduction in nitrogen dioxide (NO_2) concentrations from 2000 to 2019, a 38 per cent reduction in total nitrate (nitric acid plus particulate nitrate) in air and a 26 per cent decrease of oxidized nitrogen (N) deposition at EMEP background sites. After 2008, measured and calculated trends diverge, which might indicate that the effectiveness of abatement measures is overestimated (the United States of America and Canada will provide trends for NOx in the second draft).

[7] To be presented to the Working Group on Strategies and Review at its sixtieth session.

23. Only modest reductions of NH_3 emissions in the EMEP region have been achieved since 2000 compared to other pollutants. Ammonium measured in precipitation declined by 6 per cent. Due to the limited availability of nitric acid and sulfate, ammonium particles in air declined by 49 per cent between 2000 and 2019. In the EMEP region, total reduced N in air (ammonia + particulate ammonium) was reduced by 28 per cent, but the majority of sites in air show no declining trend for NH_3 (the United States of America and Canada will provide trends for NH_3 for the second draft of the present document).

24. Since 2000, there have been significant reductions in total $PM_{2.5}$ concentrations (46 per cent between 2000 and 2019) at EMEP long-term observational sites. Secondary inorganic aerosols, particulate sulfate, nitrate and ammonium, decreased between 2000 and 2019 by 61 per cent, 38 per cent and 49 per cent respectively. For carbonaceous aerosols, including BC, observed and modelled trends for 15 EMEP stations show an average reduction of 4 per cent per year (the United States of America and Canada will provide trends for $PM_{2.5}$ for the second draft of the present document).

25. Around half of the EMEP sites have recorded exceedances of the 2005 World Health Organization (WHO) air quality guidelines for $PM_{2.5}$ in recent years. EMEP Meteorological Synthesizing Centre-West model simulations show a decrease in exceedances from 2000 to 2018. As local air quality is strongly influenced by regional and even transboundary air pollution processes, urban exceedances and associated health risks can be a stimulating driver for additional air quality policy, including for countries that are not parties to the Protocol (average population weighted exposure still has to be calculated).

26. The influence of transcontinental transport of PM on European sulfur (S) and N concentrations and deposition is negligible. Wildfires and wind-blown dust originating outside Europe substantially influence concentration levels during episodes (typically a few times a year) (the United States of America and Canada will provide similar information).

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

28. Current monitoring and modelling systems used under the Convention to calculate ambient concentrations and deposition levels should be assessed further (more information coming next year) to see if they are fit for use in optimized reduction allocations and dealing with the increased variation in highly and less polluted regions that becomes visible from finer resolution approaches.

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

29. Population exposure and health risks: updated WHO air quality guideline values, relative risk factors, as well as no-effect/counterfactual values, will become available in autumn 2021 and will form the basis for new assessments of mortality and morbidity risks for $PM_{2.5}$, NO_2 and O_3 in the EMEP region. Preliminary EMEP assessments show a relatively high population exposure to $PM_{2.5}$ in large cities and in industrial areas, in particular in countries of Eastern Europe, the Caucasus and Central Asia. Health risks of $PM_{2.5}$ will include exposure to secondary inorganic particles, as well as secondary organic particles caused by emissions of NH_3 and VOCs.

30. Protection of ecosystems against acidification and eutrophication: Aquatic and terrestrial ecosystems have shown evidences of recovery from acidification since the 1990s. Moreover, many sites covered by the International Cooperative Programme on Assessment

and Monitoring of the Effects of Air Pollution on Rivers and Lakes show an increase in biodiversity at sites with the most pronounced chemical recovery. Empirical results are in line with the exceedances of the critical load for acidification, which were reduced between 1990 and 2019 to only 5 per cent of the ecosystem area in Europe.

31. Critical loads for eutrophication by N deposition remained exceeded for 60 per cent of the ecosystem area in Europe in 2019. Exceedances are expected to decrease only moderately in the coming decade (the Coordination Centre for Effects will provide estimates for exceedances in 2030 (and beyond)), but emission reductions of N deposition need to be greater to allow ecosystems recovery and prevent, inter alia, effects on nutrient imbalances in trees, on surface water and groundwater quality, on biodiversity, as well as on the resilience of forests to stress factors such as drought or insect infestation.

32. The results from the ecosystems monitoring network under the Working Group on Effects provide evidences on the link between critical load exceedances and empirical impacts, and confirm that emission abatement actions are having effects on critical load exceedances and therefore reduce impacts.

33. To assess the potential recovery of ecosystems, according to future emission scenarios, the use of dynamic modelling tools can be considered in the coming years. To assess biodiversity and the loss of specific species that are sensitive for eutrophication, new models will have to be explored.

34. An ad-hoc marine group, led by Germany, was recently established to develop options to include marine ecosystem protection in future emission reduction strategies in cooperation with the Baltic Marine Environment Protection Commission and the Convention for the Protection of the Marine Environment of the North-East Atlantic.

35. Ozone damage to crops and forests: Model results suggest that the phytotoxic O_3 dose for deciduous forests declined over the period 2000–2016 by approximately 0.7 per cent per year at EMEP O_3 stations. The phytotoxic O_3 dose for crops shows no significant decline for the majority of sites. Increased CH_4 emissions and climate change are influencing O_3 concentrations. Based on current knowledge, O_3 pollution was responsible for a reduced wheat grain yield of, on average, 9.9 per cent in the northern hemisphere in the period 2010–2012.[8] Projections based on current climate and energy policies (Representative Concentration Pathway 4.5) show that O_3 risks to biodiversity will still occur by 2050, as O_3 exposure will remain similar to that in 2000.[9] Similarly, projections show that there will still be a potential risk for a significant effect of O_3 on the biomass increment of trees.

36. Damage to materials and cultural heritage: corrosion has decreased significantly since the early 1990s due to the decrease of SO_2 levels. After 1997, the decrease in corrosion became more modest; currently a constant level seems to have been reached.[10] Carbon steel and copper corrosion decreased more pronouncedly in urban areas even after 1997. For soiling, there is no decreasing trend after 1997 and, consequently, many areas in Europe are above acceptable levels. The main pollutant responsible for soiling of materials is PM.

VI. Emission reduction commitments for Parties

37. This section provides an answer on status in terms of and barriers to meeting the 2020 emission reduction commitments in annex II to the amended Gothenburg Protocol and to whether these emission reduction commitments are adequate or not. It includes answers to

[8] Gina Mills and others, "Ozone pollution will compromise efforts to increase global wheat production", *Global Change Biology*, vol. 24, No. 8 (August 2018), pp. 3560–3574.

[9] Jürg Fuhrer and others, "Current and future ozone risks to global terrestrial biodiversity and ecosystem processes", *Ecology and Evolution*, vol. 6, No. 24 (December 2016), pp. 8785–8799.

[10] Johan Tidblad and others, ICP Materials Trends in Corrosion, Soiling and Air Pollution (1987–2014), *Materials*, vol. 10, No. 8 (August 2017).

the following questions in annex I to the preparatory review document:[11] 1.1, 1.3, 1.5.e, 4.4 and 6.5.

A. Status of meeting the 2020 emission reduction commitments

38. Tables 2–6 of annex II to the amended Gothenburg Protocol set out the emission reduction commitments for SO_2, NO_X, NH_3, VOCs and $PM_{2.5}$ for 2020 and beyond, expressed as percentage reductions from the 2005 emission level. Thirty-four Parties are currently listed in tables 2–6 (twenty-seven European Union member States, the European Union, the United Kingdom of Great Britain and Northern Ireland, Canada, the United States of America, Norway, Switzerland and Belarus), of which twenty-four have already ratified the amended Gothenburg Protocol (status as of 20 August 2021). Belarus and nine European Union member States are still in the process of ratification and may soon join, as possibly will other Parties, at which time, emission reduction commitments for these Parties will be proposed and adopted in accordance with the procedures of article 13 of the amended Protocol. European Union member States are also bound by the 2020 emission reduction commitments under the European Union National Emission reduction Commitments Directive.[12]

39. An assessment of the current status of meeting the 2020 emission reduction commitments of the amended Gothenburg Protocol based on a comparison with the last reported emissions (2019) and 2020–2030 projections by Parties (reporting year 2021), provides the following key findings:

(a) The collective efforts of all 34 Parties resulted in combined emission reductions between 2005 and 2019 that already exceed the combined emission reductions envisaged by the Parties' emission reduction commitments for 2020, except for $PM_{2.5}$. However, at the level of individual Parties, there is a significant difference in the progress made towards meeting the emission reduction commitments;

(b) The majority of the 34 Parties did not meet their 2020 emission reduction commitments for one or more pollutants in 2019. More recently, reported emission projections based on current legislation ("with measures" projections) for the period 2020–2030 show that, in 2030, 15 out of 34 Parties will still not meet their 2020 emission reduction commitments for one or more pollutants, in particular for NH_3;

(c) Additional policies and measures will be required for NH_3 and, to a lesser extent, VOC, NO_X and $PM_{2.5}$, in order for Parties to make faster progress towards meeting all their emission reduction commitments in 2020 and beyond. According to the latest reported "with measures" projections, emission levels corresponding to the 2020 relative targets for NH_3, VOC, NO_X and $PM_{2.5}$ will still be exceeded in 2030 by up to 30 per cent for several Parties;

(d) The main reasons for not meeting the reduction commitments are lack or delayed implementation of policies and measures, higher activity levels than foreseen at the time when the emission reduction commitments were set, slower replacement of old stock, and adjustment and improvement of the emission inventories. Additional action may be needed in the agricultural sector (NH_3), the energy sector (NO_X), road transport (NO_X and VOCs), shipping (NO_X), solvent use (VOCs), domestic wood burning ($PM_{2.5}$ and VOCs) and agricultural residue burning ($PM_{2.5}$) to meet the 2020 emission reduction commitments.

40. Other Parties that have not yet ratified the amended Gothenburg Protocol and for which no emission reduction commitments are proposed in tables 2–6 of annex II to the amended Gothenburg Protocol show mixed emission trends for the main pollutants between 2005 and 2019. For some of these Parties, and for one or more pollutants, emissions have increased.

[11] Preparations for the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, as amended in 2012 (ECE/EB.AIR/2020/3–ECE/EB.AIR/WG.5/2020/3).

[12] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, *Official Journal of the European Union*, L 344 (2016), pp. 1–31.

41. The above assessment will be extended in a subsequent draft of the review report to include a comparison of the emission reduction commitments with the reported emissions for 2020 (reporting year 2022) and the updated Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) scenarios for the Parties involved.

B. Barriers to meeting the 2020 emission reduction commitments

42. Key messages: to be completed at a later stage based on the Parties' responses to question 1.5 (e) and the subsequent discussion at the next session of the Working Group on Strategies and Review.

C. Updates of the base year 2005 emission estimates

43. Key messages from an analysis of how the most up-to-date 2005 emission estimates, as reported by Parties in 2021, compare to the 2005 estimates listed in tables 2–6 of annex II to the amended Gothenburg Protocol are the following:

(a) There are many significant changes in the reported 2005 emission estimates between 2012 and 2021 (last reporting year), especially for $PM_{2.5}$ and VOCs, and less so for NO_X and SO_2. Most changes remain within the range of +50 per cent and -50 per cent compared to the 2005 emission estimates listed in tables 2–6 of annex II to the amended Gothenburg Protocol, but with some outliers to over 100 per cent change;

(b) A comparison of the 2005 emission estimates reported in 2012 with the most recently reported updates for the year 2005 (reporting year 2021) shows that the basis for setting the 2020 emission reduction commitments significantly changed between 2012 and 2021. It underlines the importance and usefulness of moving from fixed (2010 ceilings) to relative targets (2020 emission reduction commitments);

(c) Relative targets are able to absorb many, but not all, of the effects of inventory developments and improvements. The transition from the 2010 fixed targets to the 2020 relative targets will therefore most likely also reduce, but not eliminate, the need for and use of the adjustment procedure from 2022 onwards.

D. Use of the adjustment procedure

44. An analysis of the approved adjustment applications to date provides the following key messages:

(a) A total of 11 Parties submitted eligible adjustment applications in the period 2014–2021 for one or more pollutants. Adjustments of national emission inventories were submitted for NH_3, NO_X and VOCs, and concern adjustments to account for new emission source categories, as well as significant changes in emission factors or methodologies used. The majority of the adjustment applications were submitted for the following categories: road transport, agricultural soils, manure management and cultivated crops;

(b) The approved adjusted emission totals represent 2–20 per cent of the unadjusted national emission totals for NH_3, 10–30 per cent of the unadjusted national emission totals for NO_X, and 10–40 per cent of the unadjusted national emission totals for VOCs;

(c) All adjustment applications approved so far relate to adjustments to emission inventories for the purpose of assessing compliance with the 2010 fixed ceilings (provisional application since 2014). Approved adjustments so far will not be applicable for use with respect to the 2020 emission reduction commitments. New applications and reviews (based on a new reference point and including adjustments for the base year 2005) will be required for the post-2020 scheme.

E. Inclusion of condensables in reporting particulate matter emissions for residential heating

45. Including condensables would give a more representative explanation of the population exposure to $PM_{2.5}$ and could better define the effectiveness of measures for health protection. Including condensables could shift the optimal policy strategy more in the direction of tackling residential solid fuel burning.

46. At the time when the 2020 emission reduction commitments were set (2012), many Parties had not yet included condensables in their PM reporting for residential (wood) heating:

(a) 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 commitment for $PM_{2.5}$, without additional measures for residential heating. The adjustment procedure could be used for this circumstance;

(b) For other Parties, including condensables could undermine the set emission reduction commitment for $PM_{2.5}$: this would be the case if the use of wood for residential heating had not significantly increased between 2005 and 2020 and the share of old stock had decreased during this period. The inclusion of condensables for this specific situation would inflate PM emissions in the base year 2005 much more than in 2020 (given that the share of the condensables in PM from old stoves with poorer combustion conditions is much higher than for new stoves).

47. Key messages are to be further completed. A description of the policy implications of including condensable particles in reporting of emissions of PM also should be discussed.

F. Adequacy of 2020 emission reduction commitments

48. To be further completed on the basis of input from the Centre for Integrated Assessment Modelling (CIAM)/the Task Force on Integrated Assessment Modelling (TFIAM). To be decided whether the assessment of the adequacy of the 2020 emission reduction commitments should be dealt with in section VI or section XVI below.

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

49. This section will include an assessment of the implementation rate and adequacy of the technical obligations of the amended Gothenburg Protocol and related guidance documents (their contribution in meeting the emission reduction commitments), identification of gaps or redundancies, and technical requirements and guidance that are obsolete (i.e. assessment against new legislation and updated best available techniques since 2012), identification of technical requirements that are too demanding or too detailed and should best be adapted to overcome barriers for ratification, identification of additional implemented or available measures, and a specific focus on BC (as a component of PM) and NH_3.

50. The Task Force on Techno-economic Issues (TFTEI) is conducting an in-depth analysis of annexes IV, V, VI, VIII, X and XI to the amended Gothenburg Protocol, and their associated guidance documents, to identify the emission limit values and other technical requirements in the technical annexes that could potentially be updated as a consequence of the evolution of technology since 2012. At the same time, potential adaptations of the annexes, to better address key sectors in Eastern Europe, the Caucasus and Central Asia, are being investigated. Gaps, complexity, and how demanding these requirements are will be assessed in collaboration with experts from Eastern Europe, the Caucasus and Central Asia. The outcome of the review, which will be completed by mid-November 2021, will highlight the critical sections of the annexes and associated guidance documents, along with the

existence of the latest technological solutions, without expressing preferences on specific emission limit values (ELVs). Preliminary results (collected in August 2021) show a number of significant updates available in several pollutant/technology/sector combinations. The information the Parties are invited to submit by 30 September 2021 on technical annexes and related guidance documents, with priority given to BC and NH_3 measures, and barriers to implementing obligations, will provide further elements of analysis for the final report on the Gothenburg Protocol review.

51. The United States of America and Canada can provide information on implementation of emission reductions measures identified in technical annexes, as appropriate.

52. Although many options to update annex IX in the 2012 process to amend the Gothenburg Protocol were discussed,[13] Parties did not agree on an amended text; instead, its review was prioritized for the present review via article 10 (4) of the amended Protocol. Thus, annex IX is over 20 years old and can no longer be considered state-of-the-art. Even so, many Parties appear not to have fully implemented its requirements. Its implementation is not technically demanding, as has been demonstrated by actions taken by a few Parties. Considering substantial progress in technical capability, availability of cost-effective measures, and recognition that measures are needed to meet NH_3 emission reduction commitments, a comprehensive revision of annex IX is overdue. When doing so, it is recommended to take into account sustainable management practices in the context of the wider N cycle.

53. The following guidance documents related to NH_3 and the wider N cycle need to be kept up-to-date as follows, with details provided in the informal document:[14]

(a) The Guidance document on preventing and abating ammonia emissions from agricultural sources (ECE/EB.AIR/120);

(b) The United Nations Economic Commission for Europe Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions (ECE/EB.AIR/129);

(c) The Guidance document on national nitrogen budgets (ECE/EB.AIR/119);

(d) The Guidance document on integrated sustainable nitrogen management (ECE/EB.AIR/149).

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

54. This section will focus on key sectors that require specific attention in further reducing their emissions and impacts on human health and the environment. It will include a review of emission reporting, future trends, available measures and emission reduction potential. It will focus on the following pollutants: PM and BC (residential solid fuel burning), NH_3, CH_4, NO_x, VOCs (agriculture) and NO_x (shipping).

55. In a number of background technical documents developed by TFTEI,[15] key sources are identified, and main measures are suggested.

56. Fossil fuel consumption, both in stationary and mobile sources, and biomass burning are key sources of BC and associated polycyclic aromatic hydrocarbon (PAH) emissions into the atmosphere. The reduction of BC and PAHs is linked to the reduction of PM.

[13] See informal document entitled “Supplementary information for the review of the Gothenburg Protocol”, to be made available at https://unece.org/info/Environmental-Policy/Air-Pollution/events/350953, footnote 22, containing the list of documents related to revision of annex IX.

[14] See informal document entitled “Supplementary information for the review of the Gothenburg Protocol”, to be made available at https://unece.org/info/Environmental-Policy/Air-Pollution/events/350953.

[15] Informal documents for the fifty-eighth session of the Working Group on Strategies and Review, available at https://unece.org/environmental-policy/events/working-group-strategies-and-review-fifty-eighth-session.

57. Residential solid fuel burning remains a major issue, and many efforts still need to be made to reduce emissions, in particular those of $PM_{2.5}$, BC and PAHs. The Code of good practice for wood-burning and small combustion installations (ECE/EB.AIR/2019/5), developed by TFTEI and adopted by the Executive Body at its thirty-ninth session, may help end users to implement a more efficient use of appliances.

58. In the transport sector, tyre and brake emissions are becoming dominant sources and are also a source of BC, even though these particles are mainly in the coarse mode (diameter > 2.5 µm).

59. PM resuspension from the road should be better addressed. In some regions, this emission source already dominates total road transport emissions; its relevance will further increase when exhaust emissions are effectively reduced.

60. Gas flaring from the oil and gas industry is an important source of BC emissions, particularly in areas surrounding the Arctic. Steam-assisted flares are clearly the most efficient measure in terms of soot emission reductions. However, high pressure-assisted flares can also be an efficient technique if water is not available on site.

61. CH_4 emissions from waste landfills are the most important non-agricultural source of CH_4 emissions in Europe and are responsible for around 20 per cent of overall emissions. Globally, this share is assumed to be even higher.

62. In the shipping sector, a relevant study, conducted by the International Institute for Applied Systems Analysis,[16] shows that the designation of the Mediterranean as a NO_x emission control area would be efficient in reducing secondary $PM_{2.5}$, and related premature deaths, especially in the southern parts of the ECE region. Camilla Geels and others[17] 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 S emission control regulations.

63. Agricultural residue burning is addressed in the Draft guidance document on reduction of emissions from agricultural residue burning (ECE/EB.AIR/2021/5) developed by TFTEI and the Task Force on Reactive Nitrogen (TFRN), in collaboration with International Cryosphere Climate Initiative experts. The document, agreed at the fifty-ninth session of the Working Group on Strategies and Review (Geneva, 18–21 May 2021), is expected to be adopted by the Executive Body at its forty-first session.

64. The main barrier to NH_3 reduction by Parties and non-Parties appears to be a lack of political will. However, this will has improved recently as Parties realize that implementation of measures is needed to meet emission reduction commitments. In addition, confidence in measures to control NH_3 emissions has increased greatly since these were first discussed by the Convention in the 1990s, with control of NH_3 emissions now seen as part of a wider strategy to reduce large amounts of otherwise-wasted valuable reactive N resources.[18]

65. TFRN has identified the "Top five" priority areas for NH_3 emission abatement (ECE/EB.AIR/WG.5/2011/16):

(a) Low emission application of manures and fertilizers to land;

(b) Animal feeding strategies to reduce N excretion;

[16] Janusz Cofala and others, *Final report: The potential for cost-effective air emission reductions from international shipping through designation of further Emission Control Areas in EU waters with focus on the Mediterranean Sea* (Laxenburg, International Association for Applied Systems Analysis, 2018).

[17] Camilla Geels and others, "Projections of shipping emissions and the related impact on air pollution and human health in the Nordic region", *Atmospheric Chemistry and Physics*, vol. 21, No. 16 (2021), pp. 12495–12519.

[18] Activities linked to the International Nitrogen Management System have drawn attention to a global loss of reactive nitrogen worth $200 billion per year, pointing to the opportunity to "halve nitrogen waste" by 2030, saving $100 billion per year globally, as embraced as part of national action plans under the Colombo Declaration on Sustainable Nitrogen Management.

(c) Low emission techniques for all new stores for cattle and pig slurries and poultry manure;

(d) Strategies to improve N use efficiencies and reduce N surpluses;

(e) Low emission techniques in new and largely rebuilt pig and poultry housing.[19]

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

66. The technical annexes to the revised Gothenburg Protocol include ELVs for installations, vehicles and products based on best available techniques during the preparation of the revised Protocol. Due to technical progress, some of these ELVs require an update. More recent best available techniques to reduce emissions are presented in guidance documents from TFTEI and TFRN.[20]

67. Implementation of ELVs is not always sufficient to meet national emission reduction obligations or air quality targets. In such cases, additional actions in the form of "non-technical" measures could be considered at the national or local level. This could include encouraging faster substitution of old and polluting technologies by new and cleaner technologies, facilitating use of cleaner fuels or feedstocks, or stimulating greener consumer behaviour, for example, through a modal shift from private to public transport, dietary changes or domestic energy saving. Often, such measures prove to be more efficient and less costly than implementing stricter ELVs. The common feature of structural and behavioural changes is that they cannot easily be implemented via permitting of specific activities. They often require a combination of actions by producers and consumers and a wider set of policy instruments, including financial incentives, infrastructural investments and awareness-raising.[21]

68. The draft document entitled "Prioritizing reductions of particulate matter from sources that are also significant sources of black carbon – analysis and guidance" (ECE/EB.AIR/2021/6) identifies "non-technical" measures as the main measures that would reduce PM-emissions and also significantly reduce BC (and PAH) emissions: (a) reduction of residential burning of coal and wood; (b) reduction of open field (agricultural) residue burning; and (c) scrapping of old diesel vehicles and old, non-road mobile machinery.

69. According to TFRN, a wide range of cost effective and reliable measures are available to Parties to achieve their national emissions reduction commitments for NH_3. These include measures on animal housing, storage of manure, spreading of solid and liquid manures and of urea and other inorganic fertilizers to land, together with measures to promote recovery and reuse of N and other resources, with an emphasis on reducing pollution and developing the circular economy with innovation opportunities. Control of NH_3 emissions can be seen as part of a wider strategy to reduce the huge amount of valuable reactive N resource that is wasted (reference required). Several TFRN documents give additions to the measures in the revised annex IX (ECE/EB.AIR/WG.5/2011/16) that is now 10 years old.[22] The challenge will be to avoid trade-offs between NH_3 emission reduction and CH_4 emission reduction.

70. Dietary change has huge potential to influence N losses to the environment, including NH_3, nitrous oxide, NO_x, nitrate and di-nitrogen, as well as to reduce CH_4 emissions. In Europe, meat and dairy consumption in excess of dietary needs contributes substantially to pollution and waste of N resources.

[19] A more comprehensive list of ammonia and nitrogen mitigation options is listed in the informal document accompanying the present one, available at https://unece.org/info/Environmental-Policy/Air-Pollution/events/350953, subsection entitled "Which elements of annex IX and guidance documents need to be updated?"

[20] ECE/EB.AIR/2019/5.

[21] See "Informal document on non-technical and structural measures", available at https://unece.org/fileadmin/DAM/env/documents/2020/AIR/WGSR/Note_on_non-technical_and_structural_measures_-201120.pdf.

[22] United Nations publication, Sales No. E.16.II.E.16.

71. Analysis by TFRN has shown that halving meat and dairy intake in Europe (demitarian scenario) would reduce NH_3 emissions by around 40 per cent, with co-benefits for health and climate.[23]

X. Flexibility provisions

72. The amended Gothenburg Protocol contains a wide range of flexibility provisions, some of which are addressed to all Parties in order to facilitate full implementation of all requirements and some of which are specifically intended to facilitate ratification by countries of Eastern Europe, the Caucasus and Central Asia and other countries that have not yet ratified the Protocol. The flexibility provisions vary in type, scope and impact.

73. Some flexibility provisions were already available in the 1999 Gothenburg Protocol. Several new flexibility provisions were added to the amended 2012 version of the Gothenburg Protocol. In addition, the amended Gothenburg Protocol, like the original Protocol, contains separate provisions for Canada and the United States of America to address the different air quality management systems in North America. These provisions include obligations that are equivalent in terms of stringency and level of ambition. The use of a designated pollutant emission management area is also available, and is intended for the large countries (Canada, the Russian Federation and the United States of America).

74. The 2012 amendment to the Gothenburg Protocol introduced several flexibility provisions to specifically accelerate/encourage ratification by non-Parties (e.g., countries of Eastern Europe, the Caucasus and Central Asia): see in particular articles 3 bis (flexible transitional arrangements) and 7 (6) (reporting of limited emission inventories) and annex VII (4) (longer timescales for application of limit values). The flexibility provisions in articles 3 bis and 7 (6) have expired in the meantime. The expiry date in annex VII (4) was extended by decision 2019/23. None of these provisions have been used so far nor have they led to further ratifications. Another important provision for non-Parties to the present Protocol is given in article 13 (1), which allows any Party to the Convention to add its name and emission reduction commitments to annex II to the Protocol at a later stage, when a Party is ready to ratify (and it is able to propose meaningful emission reduction commitments on the basis of further developed emission inventories of sufficient quality). The adjustment procedure is also a new flexibility mechanism that was introduced in the amended Gothenburg Protocol (see article 3 (11) quinquies) and, since 2014, provisionally applied for compliance with the 2010 ceilings of the original Gothenburg Protocol. Although now used by current Parties to the Protocol for implementation and compliance purpose, it may also be an important flexibility mechanism for current non-Parties to be able to ratify.

75. Preliminary key findings:

(a) The amended Gothenburg Protocol only recently entered into force (7 October 2019). Consequently, there is limited insight into the extent to which the new flexibility provisions are considered useful, used and potentially effective, making their review difficult. Experience gained and knowledge about the use of the flexibility provisions of the original Gothenburg Protocol is helpful in this context. Parties' replies to the questionnaire on the review of current flexibilities, which are due by 30 September 2021, may provide further insight into the use and usefulness of the current flexibility provisions;

(b) Several of the new flexibility provisions introduced in the amended Gothenburg Protocol to facilitate further ratifications (flexible arrangements, limited reporting) have already expired and were never used;

(c) Article 7 (1) (a) requires reporting on the use of equivalent emission reduction strategies and derogations from limit values. No such reporting has ever taken place. This means that the flexibility provisions allowed under article 3 (2), (3) and (7) are either not applied or not reported. Again, the Parties' replies to the questionnaire may provide further

[23] H. Westhoek and others, *Nitrogen on the table: The influence of food choice on nitrogen emissions and the European environment* (Edinburgh, Centre for Ecology & Hydrology, 2015).

insight into this issue. The lack of reporting on the use of these flexibility provisions impedes proper monitoring and enforcement;

(d) The adjustment procedure is a widely used and resource intensive mechanism and seems (for certain Parties) indispensable;

(e) Some of the new flexibility provisions have not yet been applied (e.g., 3-year average) because the amended Protocol only recently entered into force and demonstration of compliance with the 2020 emission reduction commitments will take place for the first time only in 2022.

76. Preliminary key conclusions:

(a) To date, the current flexibility provisions have not proven adequate and/or effective in facilitating further ratifications. In particular, the additional flexibility mechanisms introduced in the amended Protocol to increase the number of ratifications (arts. 3 bis and 7 (6) and annex VII (4)) have not met expectations;

(b) For the time being, however, a cautious approach should be taken to drawing firm conclusions on the usefulness and effectiveness of the current flexibility provisions, as the amended Protocol only recently entered into force. Parties' replies to the questionnaire may provide further useful information;

(c) A primary reason for the persistent non-ratification of the amended Protocol by countries of Eastern Europe, the Caucasus and Central Asia and other countries could be that the Protocol and its 11 technical annexes are complicated and may be too demanding on a country;

(d) Options for discussion for addressing flexibility in the future are needed as part of and after the review process. The thematic session on barriers to ratifying and implementing the Gothenburg Protocol, currently scheduled for spring 2022, will include a broad discussion on potential options to further improve ratification.

77. Possible recommendations:

(a) Increase the effectiveness of the Protocol and facilitate ratification and implementation by considering and implementing improvements to the current flexibility provisions that could be pursued under the 2012 amended Protocol. These could include: operational improvements to flexibility provisions to facilitate implementation/compliance such as improved reporting and monitoring of the use of current flexibility provisions; adjustments of existing guidance or Executive Body decisions; development of new implementing guidance or Executive Body decisions; and reduction of the workload and administrative burden of the adjustment procedure;

(b) Consider and discuss new options for a potential revision of the 2012 amended Gothenburg Protocol that could help non-Parties overcome barriers and move towards ratification and implementation.

78. This section will be updated on the basis of Parties' replies to the questionnaire, the outcome of the planned thematic session on barriers and other relevant information (e.g., findings of emission inventory capacity workshops).

XI. Convention Parties that are not Parties to the Protocol

79. Given the high importance of increasing ratification and implementation of the Gothenburg Protocol, this separate section for non-Parties to the Gothenburg Protocol summarizes the key findings for these Parties resulting from the other sections as an aid to arriving at appropriate recommendations.

80. Only 24 Parties among the 51 Parties to the Convention ratified the 2012 amended Gothenburg Protocol (29 Parties ratified the 1999 Gothenburg Protocol). The fundamental principles of the Convention assume that a Party will protect human health and the environment from air pollution through development of national policies and strategies. Implementation of the Protocol's requirements by the Parties is strongly linked to national

systems. Awareness of policymakers of the need to improve air quality and to implement best available techniques and emission limit values is a prerequisite for any action. The technical aspects should be introduced at the national level under the Party's own legislation.

81. Air pollution monitoring, to be checked for compliance with (new) WHO air quality guidelines, is also a key element to improving awareness. However, this task requires significant efforts from various national stakeholders. In order to ensure that the process of ratification and implementation of the Protocol is accomplished in the most effective and efficient manner, a detailed national action plan is required. This action plan will identify the sources and the key sectors, including corresponding statistics of activities applicable to a number of sectors and sources. It is also imperative for the national Government to work on this action plan with stakeholders and partners, including the business community. Improvement will also be made possible through the existing benefits of climate and energy policies on air quality. Greater efforts will provide greater benefits to human health and the environment, to be summarized as a win/win situation.

XII. Canada and the United States of America

82. 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 (AQA), which includes commitments by both countries to reduce emissions of SO_2, NO_x, and VOCs. Although the review report will integrate inputs from both countries into the relevant sections, as appropriate to national circumstances, this section will include all other relevant information.

83. Canada and the United States of America have ratified the 1999 Gothenburg Protocol (in December 1999 and December 2018 for the United States of America and Canada respectively) and its 2012 amendments (in January 2017 and November 2017 for the United States of America and Canada respectively), and, 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 AQA. In early 2021, both countries initiated work on a joint review and assessment of the AQA, examining whether it is meeting its environmental objectives as well as its sufficiency in addressing transboundary air pollution. The review and assessment focus on pollutants/issues covered by the AQA that cause acid rain and O_3 formation, as well as their transboundary impacts. The review also examines pollutants/issues not currently addressed by the AQA, such as fine PM, including concentrations and trends, as well as transboundary flows and impacts. The review is scheduled for completion in late 2022.

84. Although not covered by the AQA, NH_3 is also of concern to Canada and the United States of America, as atmospheric NH_3 is a key precursor to the formation of fine PM and contributes to acid deposition and eutrophication. Additional assessments are needed to quantify the impacts. Discussions are ongoing. In the context of the Gothenburg Protocol review, neither country is currently incorporated into the provisions of annex IX (under art. 8 of the Protocol).

XIII. Hemispheric transport

85. The role of hemispheric transport is important in the ECE region as global background levels of O_3 and PM and their precursors, including CH_4 emissions, contribute to air pollution within the ECE region, which has impacts on public heath, ecosystems and biodiversity.

86. The hemispheric contribution to ground-level O_3 is larger than the hemispheric contribution to PM or its components due to the longer atmospheric lifetime of O_3. The concentration of O_3 experienced at any given location is the combination of O_3 and O_3 precursors transported from distant sources on hemispheric to regional scales and, depending on the photochemical regime, local photochemical O_3 production or local O_3 loss due to

titration with nitrogen oxide. Since 1990, decreases in precursor emissions in the ECE region have increased the relative influence of background O_3, including O_3 from hemispheric transport, on local concentrations of O_3 experienced in the ECE region, especially in Europe.

87. The contribution of anthropogenic emission sources outside the ECE region to PM species and their associated impacts within the ECE region is negligible compared with the impact of local anthropogenic sources. Wildfires and wind-blown dust emanating from outside the ECE region, however, do influence PM levels and deposition in the ECE region and are sensitive to changes in climate.

88. The absolute contribution of NO_x and VOC emissions outside the ECE region to annual average ground-level O_3 in Europe and North America is not expected to change significantly under a business-as-usual scenario to 2050. In addition, expected increases in global CH_4 are expected to more than offset projected reductions of NOx and VOC emissions in Europe and at least partially offset reductions of NOx and VOC emissions in North America (more information is forthcoming on CH_4 for the sixtieth session of the Working Group on Strategies and Review).

89. If NOx and VOC emissions were reduced everywhere by the same percentage, the emission reductions outside of Europe would have a bigger impact on European O_3 levels than the emission reductions within Europe. In North America, equal percentage emission reductions of NO_X and VOC outside of North America would contribute significantly to decreases of O_3 in North America, but not more than the equal percentage emission reductions in North America itself.

90. Projected trends in anthropogenic CH_4 emissions span a very wide range, between a factor of two smaller or a factor of two larger than present-day emissions by the end of the century, depending on assumptions made about economic development and the use of emission control technology.

91. O_3 formation is strongly influenced by the atmospheric CH_4 burden, with model studies consistently showing that higher mixing ratios of CH_4 lead to higher background mixing ratios of ground-level O_3.

92. This is a placeholder for conclusions that address the need for CH_4 reductions globally; links to the work of the forum for international cooperation on air pollution, and further work by the Air Convention as per the Long-term Strategy for 2020–2030 and beyond.

XIV. Integrated multi-pollutant multi-effect approach

93. The robust science and technical base within the Convention lays the groundwork for the continued support of a comprehensive multi-pollutant, multi-effect approach to managing air quality. An integrated multi-pollutant approach is more cost effective than the original flat rate emission reduction agreements for individual pollutants; it increases the synergies in policy measures, makes the most efficient use of available resources, and increases the benefits associated with air quality management, such as reducing risk to public health. A primary goal of multi-pollutant planning is to identify and evaluate control strategies targeting acidification, eutrophication, O_3 and $PM_{2.5}$ and their precursors. However, a multi-pollutant definition is far broader and can also incorporate other pollutants and environmental concerns such as climate change and biodiversity loss, as discussed in the Long-term Strategy.

94. The Convention's tools and technical expertise have the potential to support cities and air agencies in developing risk-based multi-pollutant air quality management plans and implementing multilevel strategies that reduce air pollution emissions and improve public health. For example:

(a) Identifying local and regional emission reduction measures that address multiple pollutants;

(b) Developing multilevel policy strategies to achieve long-term targets of the Gothenburg Protocol and the WHO air quality guidelines;

(c) Demonstrating the importance of selected policy measures for reducing health risks from exposure to O_3, PM and their precursors;

(d) Using and further developing an integrated approach to address air pollution through a multi-pollutant and multi-effect approach (e.g., GAINS model) that: takes into account, for example, climate, energy and agricultural policies and measures; considers interactions with climate change, biodiversity loss and other environmental problems; and can achieve multiple benefits and avoid trade-offs.

XV. Synergies and interactions with other policy areas

95. There are several synergies and interactions with, inter alia, climate change, energy, transport, agricultural and nitrogen management policies. CIAM calculations indicate that full implementation of policies and measures in these other areas could offer substantial and cost-effective emission reductions of air pollutants covered by the Gothenburg Protocol. Such measures would make attainment of air quality targets more likely.

96. To limit negative effects of air pollution on climate change, more focus is needed on reducing emissions of air pollutants that have a warming effect, such as BC and O_3 precursors. CH_4 reduction plays a key role in reaching synergetic effects, as CH_4 is both a greenhouse gas and an increasing determinant of O_3 formation.

97. The main anthropogenic sources of CH_4 emissions are agriculture (with cattle dominating in the ECE region), fossil fuel production and waste treatment. Cost-effective technical solutions are available to reduce CH_4 emissions from waste treatment and oil and gas production.[24] In order to reduce CH_4 emissions from cattle, fewer technological options are available. Here, behavioural change leading to less (over-) consumption of meat and dairy could offer synergetic impacts on health, climate, O_3 formation, as well as N pollution.

98. BC has multiple environmental effects. It contributes to health effects associated with $PM_{2.5}$ and absorbs light and heats the atmosphere, contributing to global warming. When deposited onto ice and snow, it accelerates melting – a significant issue in the Arctic and mountain glaciers. Emission scenarios that stabilize global warming at 1.5°C include global BC emission reductions of 40–60 per cent by 2030. BC is co-emitted with other particles that reflect light and contribute to cooling. Because BC is emitted in population centres, it contributes to highly localized air quality issues. BC concentrations are, on average, 2.5 times higher in populated areas compared to remote locations. The Convention should coordinate with the Arctic Council and the Climate and Clean Air Coalition to Reduce Short-lived Climate Pollutants to develop the best strategy to address BC.

99. NH_3 emissions are hardly influenced by energy policy measures. Reduction of NH_3 emissions can, however, play an important role in meeting N deposition targets and halting biodiversity loss as part of an integrated approach to reducing N pollution (i.e. including tackling other forms of N pollution, such as nitrate leaching and emissions of nitrous oxide).

100. At its sixtieth session, the Working Group on Strategies and Review plans to discuss the need, best approach and potential options to address CH_4 in a future instrument: e.g., if and how to include CH_4 in the Protocol, which emission sources to focus on, and how to link with the forum for international collaboration on air pollution, the United Nations Framework Convention on Climate Change and the Global Methane Initiative.

101. Considering agricultural sources, several measures are available to reduce CH_4 emissions. They are mostly related to dietary change of ruminants and storage/processing of manure.

[24] An informal paper will be produced by the Centre for Integrated Assessment Modelling for the sixtieth session of the Working Group on Strategies and Review. See also, e.g., Lean Höglund-Isaksson and others, "Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe – results from the GAINS model*", Environmental Research Communications*, vol. 2, No. 2 (February 2020).

102. N losses to the environment, including NH_3 emissions, are strongly dependent on agricultural and food policies. While abatement techniques offer a large reduction potential, agricultural funding schemes, pricing policies and other agricultural policies are also important to ensure cost-effective emission reductions. Though many climate and energy measures could have benefits for air quality, they will not significantly influence air quality issues related to N. One new way to address N is reporting of national nitrogen budgets, as this provides an opportunity to optimize for multiple benefits in relation to environment, climate, health and economy. However, nitrogen budgets have been only used by a few Parties (the main barriers appear to be the lack of any mandatory requirement of the Gothenburg Protocol as amended in 2012, resources to provide national budgets, and resources for awareness-raising on the benefits of such an approach).

103. Wider agricultural and integrated nutrient management policies offer great potential to reduce NH_3 and other N pollution, for example, through: the European Union reform of agricultural funding; the European Union Farm to Fork Strategy and Biodiversity Strategy for 2030 aiming to reduce nutrient pollution by 50 per cent by 2030, directly building on the Colombo Declaration on Sustainable Nitrogen Management; and the present global negotiations on biodiversity and climate to take into account the negative effects of N emissions.

XVI. Progress towards achieving the objectives of the Protocol

104. Assessment of the progress towards achieving the objectives of the amended Gothenburg Protocol. The section should provide an answer to the question of whether the Protocol obligations, if fully implemented, would lead to the desired results in reducing emissions of S, NO_x, NH_3, VOCs and PM, including BC, and their effects on human health and the environment, in view of the latest best available scientific knowledge.

105. Emissions of NO_x from soils are specifically excluded from the emission reduction commitments in the revised Gothenburg Protocol (for European Union member States). This represents a barrier to progress in further reducing total NO_x emissions, while not giving credit for progress with such measures. These measures also reduce total N waste, with co-benefits for climate, stratospheric O_3 and water quality.[25]

106. Work to be carried out and results to be expected by autumn 2021/spring 2022:

(a) GAINS optimized emission reduction calculations based on updated emission inventories and projections and using the same gap-closure ambitions as used in the preparation of the amended Gothenburg Protocol. Calculations may include the sensitivity for including condensable PM emissions, NOx and NMVOCs from agricultural land and deposition reduction targets for marine ecosystems;

(b) GAINS calculations to explore what emission reductions would be needed for attainment of critical loads and levels and the WHO air quality guidelines;

(c) GAINS calculations to estimate the remaining risks for health, ecosystems and crops, assuming: (a) full implementation of the 2020 emission reduction commitments as listed in tables 2–6 of annex II to the amended Gothenburg Protocol; (b) emission projections for 2030, including full application of the requirements (emission limit values) in the other annexes; and, possibly, (c) tentative emission projections for 2050, also including implementation of climate policies;

(d) Maximum technically feasible reduction scenarios, considering the best available techniques and ambitious ELVs as defined in the technical annexes, will be developed. Concentration and deposition calculations will be performed evaluating health and environmental impacts;

(e) In the absence of the harmonized projections for the non-Parties to the Protocol (non-European Union countries of the Western Balkans, Eastern Europe, the Caucasus and Central Asia), several alternative sources will be used and implemented in GAINS;

[25] ECE/EB.AIR/149.

(f) A TFIAM/TFTEI-report on the costs of inaction will be available by the end of 2021.

107. The Gothenburg Protocol review group requested information from Parties by 30 September 2021 on an assessment of adequacy and suitability of key articles (including, but not limited to, objectives in art. 2, reporting provisions in art. 7, review provisions in art. 10, adjustment provisions in art. 13, and amendments procedures in art. 13 bis) of the amended Gothenburg Protocol. A summary will be included in the second draft of the present report to be presented to the Working Group on Strategies and Review at its sixtieth session.

XVII. Conclusions

108. 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.