United Nations ECE/EB.AIR/WG.5/2022/3

Economic and Social Council

Distr.: General
31 January 2022

Original: English

Economic Commission for Europe

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

Working Group on Strategies and Review

Sixtieth session
Geneva, 11–14 April 2022
Item 4 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

Following the entry into force of the 2012 amendment 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).

The present document prepared by the Gothenburg Protocol Review Group is based on the initial draft it presented to the Executive Body at its forty-first session (Geneva, 6–8 December 2021) (ECE/EB.AIR/2021/4). The document contains scientific and technical information provided by subsidiary bodies in accordance with Executive Body decision 2020/2. The full text of the inputs of subsidiary bodies is contained in an accompanying informal document entitled “Supplementary information for the review of the Gothenburg Protocol”.

The Working Group on Strategies and Review is invited to consider the updated draft report on the review. The final report, incorporating any comments by the Working Group, as well as 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, 12–16 December 2022, tentatively).

* The present document is being issued without formal editing.

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. 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 using scientific and technical information received to date from subsidiary bodies in accordance with decision 2020/2. 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, 12–16 December 2022, tentatively). The final report will be extended by the documents entitled "Scientific information for the review of the Gothenburg Protocol" and "Technical information for the review of the Gothenburg Protocol".

II. Legal requirements for the review

4. 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).

5. 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.

6. 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.

7. 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 ammonia (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

[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.

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 Protocol.

8. The review addresses 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. Emission reductions and emission reporting

9. Throughout the 1990s, emission reductions for a number of pollutants were realized due to 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.

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

11. 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.

12. The emission inventories submitted by Parties differ in quality, and technical reviews have identified those Parties whose submissions need improvement. 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,[5] and 11 Parties did not provide an Informative Inventory Report.

13. 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.

14. 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 of oxidised nitrogen compounds.

15. 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 27 European Union member States show emissions halving from 1990 to 2018. With continued reduction of BC emissions from diesel vehicles, the residential sector is becoming the main

[5] 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.

source. In the United States of America, BC emissions are projected to decline 30 per cent by 2028 relative to 2016 emissions. The largest reductions are due to emission standards for diesel engines in on-road and off-road vehicles. In the United States of America, it is estimated that approximately 8 per cent of black carbon emissions are from residential solid wood burning. Canada began reporting its black carbon emissions in 2013. Since then, black carbon emissions have decreased by 15 per cent. Canada is on track to meet its Arctic Council commitment to reduce emissions of black carbon by 25–33 per cent below 2013 levels by 2025. This decline can be attributed to a decrease in emissions from the transportation and residential heating sectors.[6]

16. The Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)/European Environment Agency (EEA) Air Pollutant Emission Inventory Guidebook is widely used and 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. Updated guidance, including for residential wood heating should aim at properly characterizing the emissions of condensables and real-world emissions for the different appliances and operating conditions. In addition, emissions methodologies in the Guidebook need to better account for the influences of climate change. A policy decision on the inclusion of condensables must take due account of the policy implications involved, information that may only become fully available after the review phase.

17. 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, emissions and deposition levels

18. 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 parts per billion (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.

19. 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. In the United States of America and Canada, SO_2 emissions have declined between 2005 and 2019 by 86 and 66 per cent respectively. In the United States of America pollution emission management area (PEMA), sulfate deposition declined between 2000–2019 by more than 77 per cent. In the eastern half of Canada, sulfate deposition declined by 68 per cent between 1990 and 2016.[7]

20. 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.

[6] Canada's Black Carbon emissions inventory: https://open.canada.ca/data/en/dataset/d00dd235-d194-4932-9ec0-45011d2bd347/resource/96bd9853-81e4-4599-a84b-3d97d8efe5ec?inner_span=True.

[7] Feng et al., available at https://www.sciencedirect.com/science/article/pii/S1352231021001850.

After 2008, measured and calculated trends diverge, which might indicate that the effectiveness of abatement measures is overestimated. In the United States of America PEMA region and in Canada, between 2005–2019. NO_x emissions have declined by 58 and 29 per cent percent respectively. The total nitrogen deposition in the United States of America PEMA region declined between 2000-2019 by around 35 per cent, but increased in the North Central region, due to increased deposition of reduced nitrogen. In Canada, nitrate deposition decreased between 1990 and 2016 by 50 per cent.

21. 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 monitoring concentrations in air show no declining trend for NH_3. In the United States of America and Canada, there is no declining trend in NH_3 emissions. In the North-Central region of the United States of America, deposition of reduced nitrogen increased. In Canada, emissions from animal production peaked in 2005, decreased between 2006–2012 and remained then stable, while emissions from crop production have been steadily increasing since 2006.

22. 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. In the United States of America, $PM_{2.5}$ emissions have declined 17 per cent from a 2005 baseline year to 2019 reported emissions in the PEMA. In Canada, $PM_{2.5}$ emissions (excluding emissions from road dust, crop production and construction operations) have declined by 29 per cent from a 2005 baseline year to 2019.

23. Around half of the EMEP sites have recorded exceedances of the 2005[8] 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).

24. 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 reductions in pollutants, such as SO_2 and NO_x, within the United States of America are the result of domestic emissions reductions. The Unites States Environmental Protection Agency reports show that emissions associated with National Ambient Air Quality Standard (NAAQS) pollutants have also decreased over this time period. High short-term (i.e., 1-hour or 8-hour max) concentrations in most areas of the United States of America tend to be attributable to domestic emissions. The main exceptions include near- border where international transport may be substantial. High concentrations relevant to long-term averaging times (i.e., seasonal or annual) tend to have a greater relative contribution from long-range international transport. Due to prevailing winds and large emission sources of pollutants such as PM and key PM precursors, the United States of America is a significant contributor of PM for certain regions of Canada. Southern areas of Ontario and Quebec are particularly impacted by transboundary flows of PM, ozone and precursor species from the United States of America. Most of the United States of America contribution was limited to areas near the border.

[8] Next step in the review is to update taking into account the updated WHO guidelines (WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021).

25. 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.

26. While the 50x50 EMEP-model resolution was representative for the regional background, the new high-resolution model can also represent urban background concentrations. Exceedances of critical loads are slightly higher in the new model. The observational network is dominated by sites in the European Union and EEA-countries and has hardly coverage in Eastern Europe, the Caucasus, Central Asia and Western Balkan area. Thus, measured trends are less representative for these sub-regions.

27. Current monitoring and modelling systems used under the Convention to calculate ambient concentrations and deposition levels should be assessed further (more information expected in 2022–2023) 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

28. Updated WHO air quality guideline values, relative risk factors, as well as no-effect/counterfactual values, became available in late 2021. These 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.

29. Aquatic and terrestrial ecosystems have shown evidence 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 from 14 per cent of the sensitive terrestrial and aquatic ecosystem area in Europe in 2000 to only 4 per cent in 2019.

30. Critical loads for eutrophication by N deposition remained exceeded for 64 per cent of the sensitive ecosystem area in Europe in 2019, down from 75 per cent in 2000. Exceedances are expected to decrease only moderately in the coming decade (the Coordination Centre for Effects will provide estimates (expected by April 2022) for exceedances in 2030 (and beyond)).

31. Both acidification and eutrophication are dominated by ammonia emissions from agricultural sources. Additional emission reductions especially of nitrogen compounds are necessary 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 evidence 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 under the Working Group on Effects, 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. 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. 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.[9] 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.[10] 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. Corrosion and other damage on materials and cultural heritage 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.[11] 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 the following questions in annex I to document ECE/EB.AIR/2020/3–ECE/EB.AIR/WG.5/2020/3 entitled "Preparations for the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, as amended in 2012 " (preparatory document): 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 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-five have already ratified the amended Gothenburg Protocol (status as of January 2022). Belarus and eight European Union member States are still in the process of ratification and may soon join. Other Parties currently not yet listed in tables 2–6 of annex II may also be considering ratification.

39. An assessment of the current status of meeting the 2020 emission reduction commitments of the amended Protocol based on a comparison with the last reported

[9] 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.

[10] 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.

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

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 Protocol and for which no emission reduction commitments are proposed in tables 2–6 of annex II to the amended 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.

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: forthcoming.

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 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 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 emission inventory adjustment procedure from 2022 onwards.

D. Use of the adjustment procedure

44. An analysis of the approved emission inventory 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. The inclusion of condensables in reporting particulate matter emissions allows for a more representative explanation of the population exposure to $PM_{2.5}$ and could better define the effectiveness of measures for health protection. This could shift the optimal policy strategy towards addressing 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 national emission reduction commitment for $PM_{2.5}$, without additional measures for residential heating or for other sectors/activities;

(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, as part of or after the review phase. The final version of the Protocol review report will report on results that will be available at that time (inter alia from new modelling work).

F. Adequacy of 2020 emission reduction commitments

48. Further information from the Centre for Integrated Assessment Modelling (CIAM)/the Task Force on Integrated Assessment Modelling (TFIAM) is forthcoming. 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. The Task Force on Techno-economic Issues (TFTEI) conducted the in-depth analysis of annexes IV, V, VI, VIII, X and XI to the amended 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. The review was completed at the end of November 2021, and the main message, as result of the analysis from a technological point of view was that "potential new ELVs[12] have been identified as technically feasible/consistent with the new/upgraded technologies, now available, which would allow significant emission reductions, including black carbon, in many of the sector/fuel(activity)/technology combinations". Summary conclusions of the analysis carried out by the TFTEI are included in its report to the Working Group on Strategy and Review (ECE/EB.AIR/WG.5/2022/1), which provide answers to the questions in section 1.6 of annex I to the preparatory document.

50. Gaps, complexity, and how demanding the requirement in the technical annexes are, have been examined in collaboration with the Coordinating Group on the promotion of actions toward implementation of the Convention in Eastern Europe, the Caucasus and Central Asia. In particular, the issue of possible adaptation of the annexes to better address key sectors in South-Eastern Europe, Eastern Europe, the Caucasus, Central Asia and Turkey (question 1.6.b), may find a better answer in the review of the flexibility mechanism of the Protocol[13]. A more extensive report, with detailed information on the TFTEI review, is available as an informal document for the sixtieth session of the Working Group on Strategies and Review.

51. The United States of America and Canada have strong, structured, and rigorous air quality management systems. The United States' rigorous regulatory program under the Clean Air Act significantly reduces emissions of NOx, sulfur, VOCs and PM. The United States Environmental Protection Agency has established national ambient air quality standards for SO_2, NO_2, PM and O_3. Under the Clean Air Act, state and local governments must implement programs to reduce these pollutants by specific deadlines. Failure to take steps to do so can result in sanctions and, potentially, imposition of federal controls to achieve the required emission reductions. The implementation dates for the application of emission limit values for new and existing sources in these regulations meet the timescales included in Annex VII. Canada's comprehensive air quality programme includes its Air Quality Management System, which is a collaborative effort implemented by federal, provincial and territorial governments, who each have distinct roles and responsibilities under the system. The system includes ambient standards and emissions requirements for industrial sectors. Canada's Air Quality Program also includes measures to address short-lived climate pollutants, such as black carbon as well as measures to reduce emissions from transportation and from consumer and commercial products used in daily life; monitoring, modelling and data collection; science and reporting; regularly keeping Canadians informed on air quality and indoor air quality. The United States of America and Canada implement their commitments under the applicable technical annexes through emission reduction measures

[12] Emission limit values.

[13] Report of the Chair of the Coordinating Group to the Executive Body at its forty-first session available at https://unece.org/sites/default/files/2021-12/Speaking%20points%20CG%202021.pdf.

that are part of their respective air quality programs, which contain best available technology and emission limit values.

52. Although many options to update annex IX in the 2012 process to amend the Protocol were discussed,[14] 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:[15]

(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 is focused on key sectors that require specific attention in further reducing their emissions of pollutants under the Protocol and their impacts on human health and the environment. It is focused on the following pollutants: PM and BC (residential solid fuel burning), NH_3, CH_4, NO_x, VOCs (agriculture) and NO_x (shipping).

55. A number of background technical documents developed by TFTEI[16] identify key sources, including shipping, and measures to address them, in relation to the sectors identified in paras 10-11 and the pollutants indicated in para 55. Sectors, for which specific guidance documents have been developed by TFTEI, are indicated below.

56. Agricultural residue burning and residential solid fuel burning remain major issues, and efforts are still needed to reduce emissions, in particular those of $PM_{2.5}$, BC and PAHs. The guidance document on reduction of emissions from agricultural residue burning (ECE/EB.AIR/2021/5) and the code of good practice for wood-burning and small combustion installations (ECE/EB.AIR/2019/5) may help end users to implement more efficient uses of appliances.

57. Non-exhaust emissions from the transport sector needs more attention, in the future, because of PM resuspension and emissions from tyres and brakes which are becoming dominant sources and are also source of BC.

58. 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

[14] See informal document entitled “Supplementary information for the review of the Gothenburg Protocol”, footnote 22, containing the list of documents related to revision of annex IX.

[15] See informal document entitled “Supplementary information for the review of the Gothenburg Protocol”.

[16] 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.

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.

59. 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.

60. 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.[17]

61. The Task Force on Reactive Nitrogen (TFRN) has identified the "Top five" cost-effective and reliable measures 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;

(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.[18]

62. The importance of linking across the nitrogen cycle for multiple co-benefits has been recognized in new Guidance document on integrated sustainable nitrogen management. In addition, a 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 Protocol as amended in 2012, resources to provide national budgets, and resources for awareness-raising on the benefits of such an approach).

IX. Best available techniques, non-technical measures, and energy efficiency requirements

63. The technical annexes to the revised Protocol include emission limit values (ELVs) for installations, vehicles and products based on best available techniques during the preparation of the revised Protocol. More recent best available techniques (BAT) are presented in guidance documents from the TFTEI and the TFRN.[19] The emission levels associated with the use of updated BAT show a higher reduction potential than the current emission limit values in the technical annexes.

64. Implementation of emission limit values for installations and products 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. Often, such measures prove to be more efficient

[17] 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.

[18] 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?"

[19] Code of good practice for wood-burning and small combustion installations.

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.[20] A guidance document on best practices is recommended to be produced after the review phase.

65. "Prioritizing reductions of particulate matter from sources that are also significant sources of black carbon – analysis and guidance" (ECE/EB.AIR/2021/6) report 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.

66. 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. 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.

X. Flexibility provisions to facilitate ratification and implementation

67. The amended 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.

68. 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.

69. The 2012 amendment to the Protocol introduced several flexibility provisions to specifically accelerate/encourage ratification by non-Parties (for example, countries of Eastern Europe, the Caucasus and Central Asia). None of these provisions have been used so far nor have they led to further ratifications.

70. The amended 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.

71. There is an overall lack of reporting on the use of some of the flexibility provisions, impeding proper monitoring and enforcement.

72. 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 and insufficient information on their use is available;

[20] 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.

(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;

73. 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;

(b) Consider and discuss new options and/or additional/different flexibilities for a potential revision of the 2012 amended Gothenburg Protocol that could help non-Parties overcome barriers and move towards ratification and implementation. The thematic session on flexibilities and barriers to ratification and implementation of the Gothenburg Protocol, currently scheduled for 2022, should include a broad discussion on potential options to further improve ratification.

74. More information on the review of the flexibility provisions to facilitate ratification and implementation can be found in document ECE/EB.AIR/WG.5/2022/5 entitled “Review of the flexibility provisions to facilitate ratification and implementation”. This section will be further updated on the basis of the discussions on this document by the Working Group on Strategies and Review at its sixtieth session and the outcome of the planned thematic session on barriers and other relevant information (for example, findings of emission inventory capacity workshops).

XI. Convention Parties that are not Parties to the Protocol

75. Only 25 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.

76. 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

77. This section recognizes that Canada and the United States of America, having ratified the Protocol and its amendments, are also 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. The review report will include inputs from both countries into the relevant sections as appropriate.

78. 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.

79. 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. In the context of the Protocol review, neither country is currently incorporated into the provisions of annex IX (under art. 8 of the Protocol). The ammonia workshop (Ottawa, 10 October 2018) held with participants from Canada, the United States of America and Europe, concluded with a number of key messages regarding the health and environmental impacts of ammonia, as well as tools and approaches available for mitigation.

XIII. Hemispheric transport

80. Although the ECE region covers most of the Northern hemisphere, global background levels of O_3 and PM, including emissions of their precursors, including methane, from outside the ECE region contribute to air pollution within it, which has impacts on public health, ecosystems and biodiversity.

81. Specifically, 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 is the result of O_3 precursors emitted in the region and precursors transported from distant sources on hemispheric to regional scales. Since 1990, decreases in precursor emissions in the ECE region have increased the share of background O_3, including O_3 from hemispheric transport, on concentrations of O_3 experienced in the ECE region, especially in Europe, meaning that further hemispheric action on O_3 precursors, including methane, would be needed to reduce the background concentration and health and ecosystem impacts of long-term exposure to O_3. However, reduction of precursor emissions (NO_x and VOC) within the region remains important to reduce peak concentrations and health and ecosystem impacts of short-term exposure to high levels of O_3.

82. Evidence shows that for PM, the contribution of anthropogenic emission sources outside the ECE region and its associated impacts within the ECE region is negligible compared with the impact of anthropogenic sources within the ECE region. Non-anthropogenic sources like 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.

83. 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, without new measures, expected increases in global methane emissions 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.

84. If NOx and VOC emissions outside Europe were to be reduced by the same percentage as implied by the Protocol for the European region, 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, such a scenario would contribute significantly to decreases of O_3 in North America, but not more than the percentage emission reductions in North America itself.

85. Various 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.

86. O_3 formation is strongly influenced by methane, with model studies consistently showing that higher levels of methane lead to higher background levels of ground-level O_3.

87. Preliminary conclusions: Even with full implementation of the Protocol, increasing background levels of O_3, mainly due to methane, and other precursor pollutants like NOx and VOCs, will remain. Further reductions of these precursor pollutants will be key to reduce the formation of tropospheric ozone. In addition, cooperation with other countries, organizations, and fora outside of the ECE will also be key. Options should be explored for how this cooperation could be realized, including through the work of the Forum for International Cooperation on Air Pollution, as appropriate within its mandate.

XIV. Integrated multi-pollutant multi-effect approach

88. 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.

89. The Convention’s tools and technical expertise have the potential to support cities and relevant agencies in developing risk-based multi-pollutant air quality management plans 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 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 (for example, 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

90. 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 Protocol. Such measures would make attainment of air quality targets more likely.

91. 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.

92. 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.[21] 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.

93. 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.

94. NH_3 emissions are hardly influenced by energy policy measures. Emissions could even increase due to increased use of biofuels. However, a wider agricultural and integrated nutrient management approach could play an important role in meeting N deposition targets, and halting biodiversity loss, while tackling other forms of N pollution, such as nitrate leaching and emissions of nitrous oxide as well as reducing CH4 emissions.

95. Further information on the best approach and potential options to address CH_4 in a future instrument like if and how to include CH_4 in the Protocol, which emission sources to focus on, and how (if) to link with the forum for international collaboration on air pollution, the United Nations Framework Convention on Climate Change and the Global Methane Initiative is forthcoming.

XVI. Objectives and key articles of the Protocol[22]

96. Assessment of the progress towards achieving the objectives, as well as the adequacy of other key articles, of the amended 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. It should also answer whether the key articles like reporting obligations, amendments, exchange of information, research development, amongst others, adequately address international cooperation and integrated environmental policy as per the long-term strategy for the Convention.

A. Progress towards achieving the objectives of the Protocol

97. Further information is forthcoming based on work to be carried out and results to be expected by summer 2022:

(a) GAINS optimized emission reduction calculations based on updated emission inventories and GAINS projections. Calculations shall include the sensitivity for including condensable PM emissions (on the basis of the TNO[23] Ref2 estimates), NOx and NMVOCs from agricultural land and (still to be determined) deposition reduction targets for marine ecosystems. It should be noted that NOX emissions from agricultural soils are currently excluded from the emission reduction commitments in the amended Protocol (for the European Union member States), which reduces the incentive to take measures to reduce

[21] 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).

[22] Section XVI and subsequent sections contain description of the text to be added there in the final report.

[23] The Netherlands organization for applied scientific research.

these emissions, while such measures would also reduce total N waste with co-benefits for climate and water quality;

(b) GAINS calculations to explore what emission reductions would be needed for attainment of critical loads and levels and the WHO air quality guidelines, including the 2021 WHO air quality guidelines and interim targets;

(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 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. The calculations will also include an assessment of the extent to which measures for particulate matter contribute to the reduction of black carbon;

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

(e) In the absence of 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;

(f) The cost of inaction (ECE/EB.AIR/WG.5/2022/4) report, compares the costs of inaction, defined as the damage to health, ecosystems and economy, with the costs of taking action, defined as the costs of abatement measures. The main message is that the abatement costs are significantly lower than the benefits (the avoided costs of inaction).

B. Adequacy of other key articles of the Protocol

98. Other key articles that should be taken into consideration in reviewing the Protocol, as amended in 2012 include, inter alia, the articles on definitions; objectives, exchange of information; public awareness, strategies and measures; reporting (not covered above); research and development; reviews by the Parties; adjustments; and amendments. Key articles should be assessed in terms of whether they (still) adequately and effectively contribute to the objectives of the Protocol (with due consideration of a possible need to update them) and the strategic priorities. The review of these articles was supported by a questionnaire to the Parties with responses due by 30 September 2021. Six Parties provided responses.

99. These other key articles continue overall to be relevant. However, given that they were developed and discussed over 10 years ago, some of these articles are no longer fully adequate and, in order to remain relevant and useful, merit further consideration of updates to reflect current evidence and new scientific developments and policymaking.

100. Strategic priorities of the Long-term strategy for the Convention for 2020–2030 and beyond, as they relate to the Gothenburg Protocol, that could be reflected in the other articles of the Protocol include the need for further strategies to reduce ammonia and black carbon emissions; as well as the need to further address precursor pollutants of tropospheric ozone including methane. Opportunities for integrated approaches and synergies with other policy areas like air and climate policies should be considered in the other articles, as well as the global and regional nitrogen cycles; the influence of long-range air pollution on local air pollution to emphasize increased cooperation between different levels of government, and reference to marine ecosystems and/or marine shipping, as appropriate. Further conclusions are forthcoming.

XVII. Conclusions

101. 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.