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Progress in the implementation of the 2020-2021 workplan
Review of sufficiency and effectiveness of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone

Prioritizing reductions of particulate matter from sources that are also significant sources of black carbon - analysis and guidance

Summary

The present document was prepared by the Task Force on Integrated Assessment Modelling in cooperation with the Task Force on Techno-economic Issues, in accordance with item 2.2.1 of the 2020-2021 workplan for the implementation of the Convention (ECE/EB.AIR/144/Add.2). It is aimed to help guide actions to reduce emissions of particulate matter that are also effective in reducing black carbon emissions. The document contains an evaluation of mitigation measures for black carbon emissions in line with the requirements of article 10 (3) of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone as amended as part of the review of the Protocol.

The current document is being presented to the Working Group on Strategies and Review for consideration. It is expected that a final draft will then be forwarded to the Executive Body for adoption at its session in December 2021.

I. Summary for policymakers

1. The Intergovernmental Panel on Climate Change has determined that all pathways to limiting global temperature increase to 1.5°C above pre-industrial levels require substantial reductions in short-lived climate pollutants, in addition to reductions in long-lived greenhouse gases. Black carbon (BC), a short-lived climate forcer, is a component of fine particulate matter ($PM_{2.5}$) emitted from certain types of combustion. It is estimated that the warming impact on climate of BC is 460–1,500 times greater than that of carbon dioxide (CO_2) per unit mass. Not only is mitigating BC emissions necessary to achieve the Paris Agreement goals, it is also key to slowing the thawing and melting of polar and high-altitude ecosystems, where black carbon emissions can settle and darken the surface of ice and snow. Reductions of BC emissions will have near-immediate benefits in these vulnerable areas of the globe, and help mitigate the far-reaching consequences of melting glaciers, permafrost thaw and decreased sea ice. This is in addition to the well-established air quality benefits. BC mitigation represents a major opportunity to implement policies that will have co-beneficial effects on climate change and air quality.

2. Under article 2.2 of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol), Parties should, in implementing measures to achieve their national targets for particulate matter, give priority, to the extent they consider appropriate, to emission reduction measures which also significantly reduce BC in order to provide benefits for human health and the environment and to help mitigation of near-term climate change. Furthermore, under article 3.1, in taking steps to reduce emissions of particulate matter, each Party should seek reductions from those source categories known to emit high amounts of BC, to the extent it considers appropriate.

3. Given that not all sources of $PM_{2.5}$ are sources of BC, this guidance is meant to help guide actions to reduce emissions of $PM_{2.5}$ that are also effective in reducing emissions of BC. The guidance is based on previously reported emission scenarios available in the Greenhouse Gas-Air Pollution Interaction and Synergies (GAINS) model developed by the Centre for Integrated Assessment Modelling.[1] The results of the scenario comparison are aggregated for three regions. The first region consists of Belarus, the Republic of Moldova, the Russian Federation (European part only) and Ukraine, the four Eastern European countries available for analysis with the European online version of the GAINS model. The second region consists of Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia and Turkey, as well as Kosovo.[2] The third group consists of the States members of the European Union and Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland. For all regions, the overall guidance is that measures to reduce $PM_{2.5}$ emissions from domestic wood burning in boilers and stoves and agricultural waste burning should be prioritized to also achieve reduction of BC emissions.

4. The scenarios for each region suggest that, when seeking reductions beyond current legislation of particulate matter from sources that are also significant sources of BC, the priority sectors are:

(a) In the first region: (1) agricultural waste burning; (2) wood-fuelled heating stoves; (3) coke production in coke ovens; (4) flaring in refineries; and (5) gas pipeline compressors;

(b) In the second region: (1) wood-fuelled heating stoves; (2) agricultural waste burning; (3) brown coal-fuelled heating stoves; (4) hard coal-fuelled heating stoves; and (5) diesel-fuelled vehicles in agriculture;

[1] A.Stohl and others, "Evaluating the climate and air quality impacts of short-lived pollutants", *Atmospheric Chemistry and Physics*, vol. 15, No. 18 (September 2015), pp. 10529–10566; Zbigniew Klimont and others, "Global anthropogenic emissions of particulate matter including black carbon", *Atmospheric Chemistry and Physics*, vol. 17, No. 14 (July 2017), pp. 8681–8723; and M. Amann and others, *Progress Towards the Achievement of the EU's Air Quality and Emissions Objectives* (Laxenburg, International Institute for Applied Systems Analysis, 2018).

[2] References to Kosovo shall be understood to be in the context of Security Council resolution 1244 (1999).

(c) In the third region: (1) wood-fuelled heating stoves; (2) agricultural waste burning; (3) wood-fuelled single house boilers; (4) hard coal-fuelled heating stoves; and (5) meat frying, barbecues in households.

5. Measures in the sectors listed above do not cover all conceivable options for further emission reductions. Potential fuel shifts and behavioural change measures are not included in the modelling supporting the present guidance. Such measures may also effectively reduce emissions of both $PM_{2.5}$ and BC. Although planned introduction of advanced engine exhaust standards for diesel-fuelled road and off-road vehicles is a high priority measure included in the baseline scenario for the period 2020–2030 in all three regions, accelerated implementation of advanced standards for road transport is not an included potential measure in 2030. Analysis of historical emission reductions indicates that this $PM_{2.5}$ emission control measure effectively reduces BC.

6. The baseline emission scenarios supporting this guideline are not always aligned with officially reported emission inventories for every region but, given data limitations, the scenarios still constitute the best available information for the question at hand. It is also worth highlighting that BC emission factors are still uncertain, and future research might alter the results slightly.

7. The baseline scenario results for the first region indicate that, between 2020 and 2030, implementation of emission control measures in industry would abate 7 kilotons of $PM_{2.5}$ emissions, but almost no BC emission abatement is anticipated. By 2030, it would be technically feasible to apply other measures that would combine PM-reduction with reduction of BC emissions, including increased control of agricultural waste burning and replacement of older wood-fuelled stoves. A comparison of the baseline scenario with technically feasible emission levels suggest a technical potential to further control 2030 $PM_{2.5}$ emissions with more than 300 kilotons of $PM_{2.5}$ with measures that ensures high priority to BC emission control.

8. The baseline scenario results for the second region indicate that 22 kilotons of $PM_{2.5}$ emissions would be abated between 2020 and 2030 through controlling emissions from cement production, without much BC emission abatement. Measures technically available by 2030 that also ensure high priority to BC emission abatement include cleaner coal-fuelled heating stoves and bans on trash burning. All in all, between 2020 and 2030, the scenarios suggest a technical potential to further control 128 kilotons of $PM_{2.5}$ emissions whilst still ensuring high priority to BC emission control.

9. The scenario results for the third region suggest that current legislation to a large extent enables climate and health co-benefits during $PM_{2.5}$ and BC emission reduction. However, about 20 per cent of the total modelled 246 kilotons of $PM_{2.5}$ emission reduction for the period 2020–2030 does not imply any noticeable change in BC emissions. There is significant remaining technical potential for measures ensuring high priority to BC emission reduction. A full-scale effective ban on agricultural waste burning, and increased utilization of new wood-fuelled stoves and pellet stoves, are two important measures ensuring high BC priority.

10. The present guidance document complements the "Review on Black Carbon (BC) and Polycyclic Aromatic Hydrocarbons (PAHs) emission reductions induced by PM emission abatement techniques" – a background informal technical document presented by the Task Force on Techno-Economic Issues at the fifty-eighth session of the Working Group on Strategies and Review (Geneva, 14, 15 and 17 December 2020),[3] which provides an in-depth analysis of capacities of techniques to reduce BC and PAH.

II. Black carbon abatement - a win-win for human health and climate change

11. BC – carbonaceous particulate matter that absorbs light – is composed of small particles which are a component of $PM_{2.5}$ and are therefore linked to severe effects on human

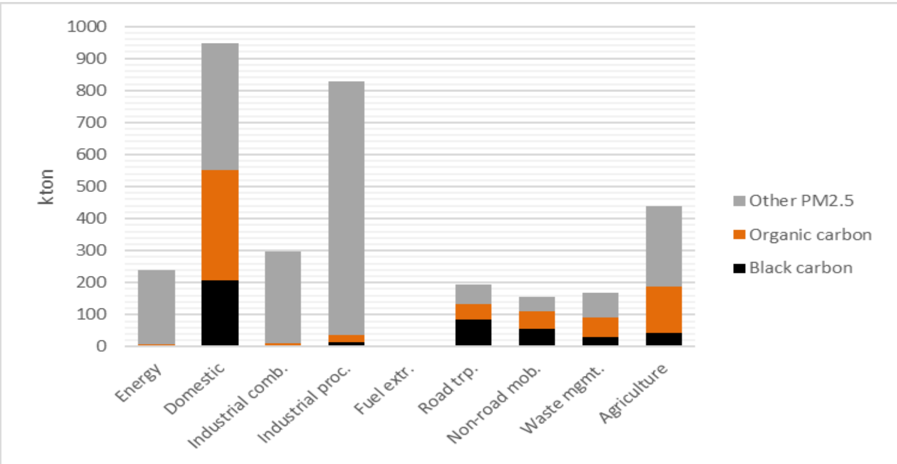
[3] Bertrand Bessagnet and Nadine Allemand.

health such as respiratory disease and reduced life expectancy. Although the final numbers vary between studies and methods, a ballpark assessment is that human exposure to $PM_{2.5}$ around 2010 was linked to ~3-4 million preterm fatalities each year, and in Europe ~400 000 – 500 000.[4] There are even indications that BC might be more toxic than other $PM_{2.5}$ components.[5]

12. In adopting the Paris Agreement to limit warming to well below 2°C above pre-industrial levels, the Parties to the United Nations Framework Convention on Climate Change recognized that reductions in the emission of CO_2 are the backbone of any meaningful effort to mitigate climate forcing. But in order to slow the pace of warming over the next two to three decades, both globally and in the Arctic, countries must also reduce emissions of short-lived climate forcers, such as BC and methane, as a complement to reductions of CO_2 and other long-lived greenhouse gas emissions.

13. BC emissions originate mainly from the incomplete combustion of fuel. However, the share of BC in $PM_{2.5}$ emissions varies between emission source sectors and fuels combusted (see figure I below). Furthermore, BC is often co-emitted with other particulates that have a cooling effect, such as organic carbon, non-carbonaceous particles and coarser particles. As a result, not all measures aimed at reducing $PM_{2.5}$ from combustion will have the same climate benefits. Reductions in $PM_{2.5}$ from sources with low shares of BC are likely to have minimal climate benefits. Correspondingly, reductions in sources that have a large share of cooling particles likely unmask the climate warming induced by anthropogenic greenhouse gas emissions and, to a varying degree, diminish the climate benefit of associated BC reductions. Most reductions in $PM_{2.5}$ have benefits to human health, though targeted reductions from $PM_{2.5}$ sources with high BC content and minimal cooling species content maximize co-benefits for climate and human health.

Figure I
Modelled emissions of fine particulate matter/black carbon/organic carbon in the United Nations Economic Commission for Europe area in 2015



Source: Klimont, "Global anthropogenic emissions".

[4] World Health Organization (WHO), "Burden of disease from Ambient Air Pollution for 2012: Summary of results" (Geneva, 2014); European Environment Agency (EEA), "Air quality in Europe – 2015 report", EEA report No. 5/2015 (Luxembourg, Publications Office of the European Union, 2015); J. Lelieveld and others, "The contribution of outdoor air pollution sources to premature mortality on a global scale", *Nature*, vol. 525, No. 7569 (September 2015), pp. 367–371.

[5] Nicole A. H. Janssen and others, *Health effects of black carbon* (Copenhagen, WHO Regional Office for Europe, 2012); Thomas J. Grahame, Rebecca Klemm and Richard B. Schlesinger, "Public health and components of particulate matter: The changing assessment of black carbon", *Journal of the Air and Waste Management Association*, vo. 64, No. 6 (May 2014), pp. 620–660; Nicole A. H. Janssen and others, "Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM_{10} and $PM_{2.5}$", *Environmental Health Perspective*, vol. 119, No. 12 (December 2011), pp. 1691–1699.

14. Given the potential for co-benefits between human health and climate change, and the variability of BC-fractions in $PM_{2.5}$ emissions, it is necessary to give guidance to Parties to the Convention on Long-range Transboundary Air Pollution (Air Convention) on which specific sectors and abatement measures provide the greatest opportunities to capture these co-benefits.

III. Purpose and approach of the guidance document

A. Purpose of the guidance document

15. The present guidance document is meant to clarify in which sectors Parties to the Air Convention can implement $PM_{2.5}$ emission reduction measures that will enable reductions of BC. The goal is to increase awareness among the Parties to the Convention of the fact that $PM_{2.5}$ emission abatement can have various effects on BC emissions reductions. More specifically, the document strives to give guidance on the following issues:

(a) Have $PM_{2.5}$ emission abatement measures implemented since 2010 resulted in significant reductions in BC emissions?

(b) Given current air quality policies and legislation, will anticipated $PM_{2.5}$ emission reductions also result in BC emission abatement?

(c) If $PM_{2.5}$ emissions were to be reduced below anticipated levels, would there be potential to achieve even more ambitious BC emissions reduction by targeting specific $PM_{2.5}$ sources? If so, which sectors and control measures would be most important?

B. Approach of the guidance document

16. The work leading to the present guidance document has been made possible by using the detailed data presented in openly available GAINS model[6] scenarios. For the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland, the Climate and Energy Policy (CEP)_post2014_current legislation (CLE)_v.Dec.2018 scenario was used as the current legislation scenario and the CEP maximum technically feasible reduction (MTFR) as the maximum technically feasible reduction scenario. Since the CEP scenario set didn’t include any MTFR-estimates for regions outside the European Union region, the ECLIPSE v5a_MTFR_base was used to represent current legislation scenarios and ECLIPSE_MTFR to represent MTFR scenarios. All these scenarios have been previously presented.[7] It has not been possible to collect information on relevant data supporting the emission trends and scenarios reported by the Parties, so the guidance given in the present document might not exactly match the Parties’ own estimation of their emission trends and scenarios. The applicability of the guidelines thereby needs to be estimated by the Parties themselves.

17. The analysis supporting this guidance document focuses on emission control measures included in the GAINS model database. The analysis excludes $PM_{2.5}$ and BC emission reductions from behavioural or structural change measures in, for example, the energy and transport system. Examples of omitted measures are fuel shifts and energy efficiency in the transport sector, energy-efficiency improvements or changing heating systems in houses, or changes in combustion behaviour or indoor temperature. Therefore, the emission reductions presented are likely underestimates of the total potential for BC emissions reductions from $PM_{2.5}$ mitigation measures. Harvesting this total potential would likely require improved integration of climate change and air quality policies.

18. Constrained by data and scenario availability, the ECE member States in focus for this guidance document are those on the European continent and represented in the GAINS

[6] https://gains.iiasa.ac.at/gains/EUN/index.login?logout=1&switch_version=v0.

[7] M. Amann, *Progress Towards the Achievement*; Stohl “Evaluating the climate”; and Klimont “Global anthropogenic emissions”.

model, and the time horizon is 2010–2030. Given that the model emission trends and scenarios were made publicly available by 2018, the effects on 2020 emissions of the ongoing coronavirus disease (COVID-19) pandemic are not included. This guidance document considers 2020 as an "historical" year since 2020 is the GAINS model year that lies closest to the last reported historical year (2018). An update of the support to the European Union Clean Air Outlook report[8] was published in December 2020.[9] The model scenarios developed in that update have not yet been made publicly available and are therefore not used as basis for the scenarios in this report.

IV. Methodological overview and terminology

A. Methods used to provide guidance

19. The overarching method used to support the guidance was to compare sector specific $PM_{2.5}$ and BC emission trends and scenarios for different policy scenarios available in the GAINS model (a baseline scenario and an MTFR scenario). The comparison considered trends and scenarios for: emissions; emission control and relationship between $PM_{2.5}$ and BC. The separation between emission scenarios and emission control scenarios is needed to decompose the modus with which emissions have been changed and are expected to change. The analysis was grouped geographically in three regions. The first region consists of the parties commonly grouped as Eastern Europe, the Caucasus and Central Asia, in this document represented by Belarus, the European part of the Russian Federation, the Republic of Moldova and Ukraine, since these four are represented in the GAINS model. The second region consists of the areas of South-Eastern Europe referred to in paragraph 3 above and Turkey. The third region consists of the Convention Parties that have already ratified the amended Gothenburg Protocol and have emission reduction commitments for $PM_{2.5}$ for 2020 and beyond (European Union-27 plus Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland).

20. The relationships between $PM_{2.5}$ and BC emissions are irregular across sectors and depend on applied emission control. It is not enough to only identify sectors with high shares of BC in $PM_{2.5}$ emissions, it is also necessary to identify which $PM_{2.5}$ control measures ensure large BC emission reduction. For example, if a potential abatement measure effectively removes $PM_{2.5}$ but not BC (as, for instance, coarse particle filters do), the BC/$PM_{2.5}$ share in the emissions remaining after abatement will increase, but the share of BC in the emission reductions (removed emissions) will be small.

21. The analysis underlying this guidance is focused on $PM_{2.5}$/BC relationships in emission reductions for three cases: (a) 2010 vs. 2020; (b) 2020 vs. 2030 (baseline); and (c) baseline scenario vs. MTFR scenario for 2030. When comparing emission trends and scenarios, we first determined whether emission changes were driven by changes in fuel activities or by use of abatement measures. For emission changes driven by abatement, we quantified the share of BC in the removed $PM_{2.5}$: this share was further used to characterize the measures in relative terms. We also identified whether the measure was important for emission abatement of $PM_{2.5}$ and BC in absolute terms (i.e. in kilotons of removed emissions). Based on BC shares and absolute removal, we characterized the measures as indicating high/mid/low or no priority to BC emission reduction.

22. The support for measure prioritization was then compiled by comparing how much of the $PM_{2.5}$ emission abatement in the three cases implied prioritization of BC emission abatement, and to what degree. The quantitative results present, per region, sectors in which $PM_{2.5}$ emission reduction favours BC prioritization. The results also present the control measures with highest potential.

23. The relationships between BC and $PM_{2.5}$ emissions in our analysis depend on the past, current, future and potential levels of abatement as implied in the GAINS model scenarios

[8] M. Amann, *Progress Towards the Achievement*.

[9] M. Amann and others, *Support to the development of the Second Clean Air Outlook: Final report* (Laxenburg, European Commission/International Institute for Applied Systems Analysis, 2020).

used. These relationships are not always in good consistency with BC/$PM_{2.5}$ shares as assumed in the EMEP/EEA Emission Inventory Guidebook 2019,[10] that provides default emission factors for emission inventories. Emission factors provided in the Guidebook 2019 and emission factors used in the GAINS model are not fully harmonized. They are developed with different methodologies and based on different sources. Default emission factors in the Guidebook 2019 most often imply a certain state-of-the-art current abatement level for a sector and region, whereas in GAINS, emission factors are technology-specific and technology levels are scenario-specific. Typically, GAINS scenarios for future years would imply higher application rate of efficient $PM_{2.5}$ control (whilst BC emissions might not be reduced with the same efficiency) than the Guidebook 2019 does for the current year. This means that the GAINS model BC/$PM_{2.5}$ ratio for a sector might be higher in 2030 than in 2020, and naturally less consistent with the shares implied in the Guidebook 2019.

B. Terminology used in the guidance document

24. This Guidance document uses some terms adapted for its purpose:

(a) "Activity data" refers to fuel use, transport use or production quantities: i.e. the basic driver of emissions. Changes in emissions driven by changes in the activity data were identified by also applying emission factors for the starting year to the activity data for the last year of the same period and recalculating emissions as "frozen emission factor" emissions. The difference between starting year (for example, 2010) emissions and "frozen emission factor" emissions in the target year (for example, 2020) is thus due to changes in activity data. The residual difference between the "frozen emission factor" emissions and the original scenario emissions in the same target year is driven by use of control measures. Activity data is relevant as a driving force for emission changes only for the two cases where historical and future baseline emissions are considered. When we compare baseline and potential emissions in 2030, all emission changes are due to use of abatement measures;

(b) "BC/$PM_{2.5}$ emission reduction ratio" is a relationship between absolute BC reduction (kilotons of BC) and absolute $PM_{2.5}$ reduction (kilotons of $PM_{2.5}$) within a certain sector (for example, wood-fuelled heating stoves) caused by use of $PM_{2.5}$ control measures. We use BC/$PM_{2.5}$ emission reduction ratio as one of the criteria for further classification of sectors with respect to BC priority in emission control. The ratio is scenario-specific since it depends on the abatement levels before and after emission reduction. It can thus vary between GAINS scenarios, regions and years;

(c) "Co-benefits" is a general concept and is used in this document to refer to a situation when $PM_{2.5}$ emission reduction benefiting people's health also implies "significant" BC emission reductions mitigating climate change. Given the sector- and measure-specific BC/$PM_{2.5}$ emission reduction ratios, measures can have varying degrees of significance. Consequently, their "priority**"** should differ. Here, the different degree of significance is represented with "high BC priority", "mid BC priority", "low BC priority" and "no BC priority". In this document, these priority classes are specified as follows:

(i) If the BC emission reductions are "significant" in absolute terms (kilotons of emissions reduced), the term "high BC priority" is used. To identify high BC priority measures, sectorial $PM_{2.5}$ emission reductions measures were first sorted with respect to quantity reduced. Second, sectors and measures that have BC/$PM_{2.5}$ emission reduction ratios over 0.1 were identified. Out of these, the five sectors with the largest BC emission reduction were classified as being a high BC priority sector;

(ii) The term "mid BC priority" is used if the BC emission reductions are significant in relative terms. We arbitrarily picked 0.5 as the minimal value of the BC/$PM_{2.5}$ emission reduction ratio for a sector to be classified as a mid BC priority sector (unless classified as a high BC priority);

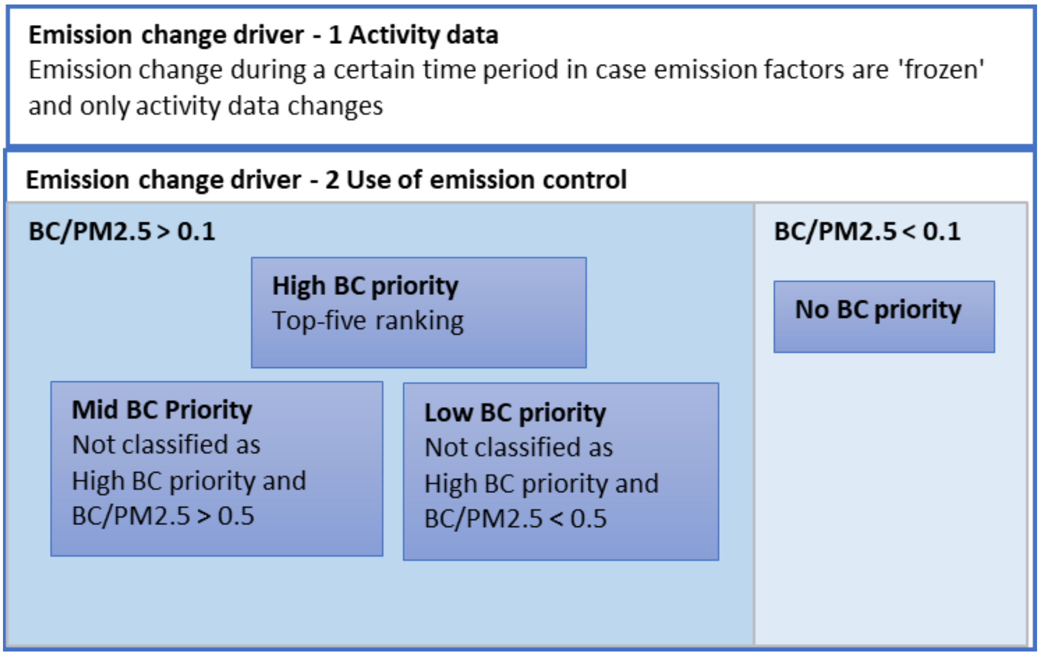
[10] EEA, "EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories", EEA report No. 13/2019 (Luxembourg, Publications Office of the European Union, 2019).

(d) Unless classified as a high BC priority, If the BC/$PM_{2.5}$ emission reduction ratio is between 0.1 and 0.5, the sector is classified as a “low BC priority”;

(e) If the BC/$PM_{2.5}$ emission reduction ratio is lower than 0.1, the sector is classified as a “no BC priority” sector, because this is the approximate ratio where one unit of European $PM_{2.5}$ emission no longer provides climate co-benefits (as indicated by common climate metrics for particulate matter and BC presented by the Intergovernmental Panel on Climate Change).[11]

25. The sector and measure classification described above is summarized in figure II below. Note that both BC/$PM_{2.5}$ emission reduction ratios and top-five ranking used for definition of high BC priority sectors are scenario-specific, depend on the current and target level of activity and emission control, and can vary between regions and years. The distribution of the fixed set of sectors available in the GAINS model between high-, mid-, low- and no BC priority is therefore not rigid but also scenario specific. The same sector can be defined as a low BC priority sector for one region and scenario case, and as a high BC priority sector for another one.

Figure II
Types of emission changes based on their driving forces, and black carbon priority classification of sectors



Source: Figure II was created for the present document.
Notes: BC/$PM_{2.5}$ indicates the BC/$PM_{2.5}$ emission reduction ratio.

V. Guidance to decision-makers

26. This guidance document gives guidance on which $PM_{2.5}$ emission control can be prioritized to also achieve significant BC emission reductions. In general, measures to reduce $PM_{2.5}$ emissions from domestic wood burning and agricultural waste burning are the most effective measures to also reduce BC. The guidance is supported by quantitative analysis of GAINS modelling results. The quantitative support starts with presenting results for Eastern Europe, followed by South-Eastern Europe and Turkey and lastly the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland. For all subregions, the overall picture is first presented, followed by a detailed description of the

[11] Gunnar Myhre and others, “Anthropogenic and Natural Radiative Forcing”, in *Climate Change 2013: The Physical Science Basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change*, T. F. Stocker and others, eds. (Cambridge and New York, Cambridge University Press, 2013).

modelled development for the period 2010–2020, the planned emission change for the period 2020–2030, and the potential for further emission reductions by 2030.

A. Black carbon prioritization of particulate matter control in Eastern Europe

27. For the countries representing Eastern Europe in this Guidance document, the guidance baseline ECLIPSE_v5a_CLE_base scenario assumes that both $PM_{2.5}$ and BC emissions increase due to structural changes in the period 2010–2020, a tendency that continues until 2030. Correspondingly, there remains a significant $PM_{2.5}$ emission reduction potential in 2030 if implementing all available control measures (see table 1 and figure III below). Detailed scenario information on the use of measures in the baseline and ECLIPSE_MTFR_base (MTFR) scenario is available in annex I below.

Table 1

Changes in fine particulate matter and black carbon emissions from Belarus, the Russian Federation, the Republic of Moldova and Ukraine

Emission change by driver, kilotons	*Activity data changes*	*High BC priority control measures*	*Mid BC priority control measures*	*Low BC priority control measures*	*No BC priority control measures*	*Net total change*
Historical change (2010–2020)						
$PM_{2.5}$	195	-23	-0.2	-3	-25	144
BC	21	-12	-0.1	-1	-0.4	7
Planned changes (2020–2030) with measures according to current legislation						
$PM_{2.5}$	204	-8	-1	-1	-12	182
BC	9	–	-1	-0	-0.5	4
Potential in 2030 from additional emission abatement measures beyond current legislation						
$PM_{2.5}$	-	-350	-4	-43	-820	-1 217
BC	-	-68	-3	-11	-3	-85

Source: Stohl, "Evaluating the climate"; and Klimont, "Global anthropogenic emissions".

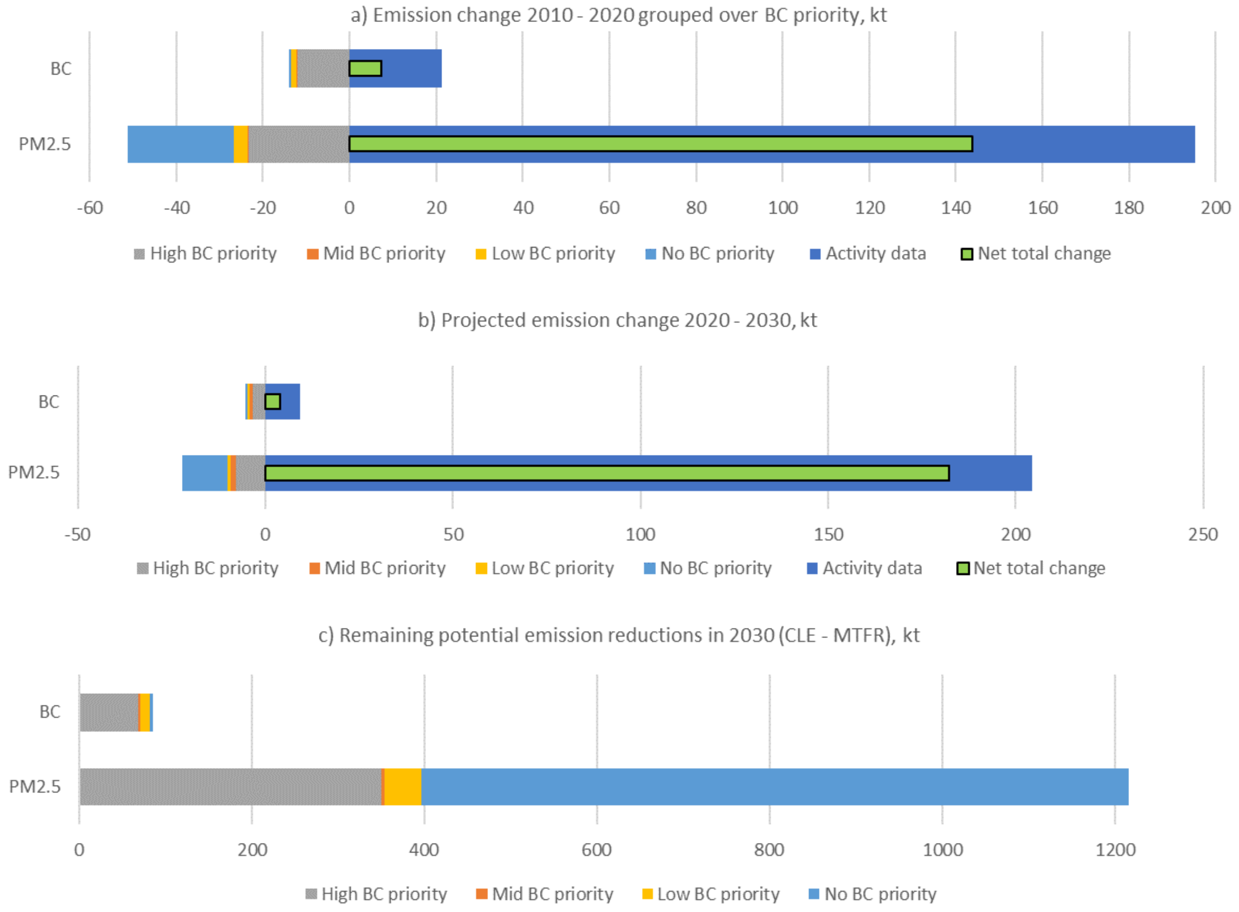
Abbreviations: a hyphen (-) indicates that the item is not applicable. An en-dash (–) indicates that the amount is nil or negligible.

Notes: Changes are presented separately for the main drivers of emission changes. Negative values imply emission reduction.

28. Despite the 182 kilotons of $PM_{2.5}$ and 4 kilotons of BC emission increase between 2020 and 2030 assumed in the baseline scenario, there remains even greater technical potential to reduce emissions to well below the 2010 emission levels. Although most of this potential consists of no BC priority control measures, the potential for emission reduction with high BC priority measures is still higher than the assumed baseline scenario emission increase between 2010 and 2030.

Figure III

Graphical illustration of emission changes separated into changes due to variations in activity data, high-, mid-, low-, and no black carbon priority measures



Source: Stohl, "Evaluating the climate"; and Klimont, "Global anthropogenic emissions".

Abbreviations: kt, kiloton.

Notes: The green bar represents the net total change of emissions. (a) Changes over the period 2010–2020. (b) The emission scenario representing current legislation. (c) Remaining technical potential for further emission control. Notice the difference in scale and sign of emission control in (c) compared to (a) and (b). The figures are based on the GAINS model scenarios ECLIPSE v5a_base and ECLIPSE_MTFR base scenarios.

29. The detailed analysis of the baseline scenario shows that, although increased economic activity drives up actual emissions, the control measures with highest effect on $PM_{2.5}$ and BC emissions in the period 2010–2020 are stricter emission control (Euro-standards) in diesel-fuelled road and rail transport (trucks, cars, buses and trains). In all, 46 per cent of the $PM_{2.5}$ emission reductions in the period 2010–2020 were realized using high BC priority measures (86 per cent of BC emission reductions). In all, 0.3 per cent of the emission reductions come from using mid BC priority measures. The low and no BC priority measures are those used to reduce $PM_{2.5}$ emissions from new hard-coal fuelled power plants.

30. Increased economic activity is in the baseline scenario continuing to drive up $PM_{2.5}$ emissions for many emitting sectors during the period 2020–2030. But 36 per cent of the drive towards reduced $PM_{2.5}$ emissions (64 per cent of BC) is induced using high BC priority measures. More specifically, continuous introduction of advanced engine exhaust cleaning technologies in the diesel-fuelled heavy-duty vehicle fleet, trains and agricultural machinery stocks is the most important of these measures. Also, the use of cyclones and one-field electrostatic precipitators to reduce $PM_{2.5}$ emissions from black liquor combustion in the paper and pulp industry is important. The expected mid BC priority measures are renewal of diesel-fuelled bus and light-duty vehicle fleets. The low- and no BC priority measures are mainly measures used to reduce $PM_{2.5}$ emissions from biomass fuel combustion in chemical- and paper and pulp industries, and renewal of fuelwood household heating stoves. In all, 1

kiloton of $PM_{2.5}$ emission reductions is in the baseline scenario expected from low BC priority measures and 12 from no BC priority measures. The above-mentioned examples of no BC priority measures account for 9 kilotons. All in all, the baseline scenario shows that most of the expected $PM_{2.5}$ emission abatement until 2030 can be expected from measures that miss opportunities for effective BC abatement.

31. The MTFR scenario indicate a large technical potential by 2030 to further the reduction in emissions of $PM_{2.5}$ and BC. The high BC priority control measures still available for implementation in 2030 are found in the control of emissions from agricultural waste burning, small-scale household wood burning, iron and steel coke ovens, oil refinery gas flaring and from non-road mobile machineries. High BC priority measures constitute 29 per cent of the technical potential for $PM_{2.5}$ emission reduction and 80 per cent of the BC emission reduction potential. Remaining mid BC priority control measures only constitutes 0.3 per cent and 3 per cent of the remaining potential for $PM_{2.5}$ and BC emission reduction, respectively. The largest part (70 per cent) of the remaining potential is however from use of no BC priority measures, such as those available to reduce $PM_{2.5}$ emissions from steel production and cement production.

32. Guidance: the modelling results indicate that, beyond the current legislation 2020–2030, the $PM_{2.5}$ reduction measures with highest BC priority are (kilotons of potential $PM_{2.5}$ emission reduction in parenthesis):

(a) A full implementation of a ban on open agricultural burning (~200 kilotons);

(b) Quicker introduction and use of pellets stoves and renewal of other wood-fuelled household stove stocks (~70 kilotons);

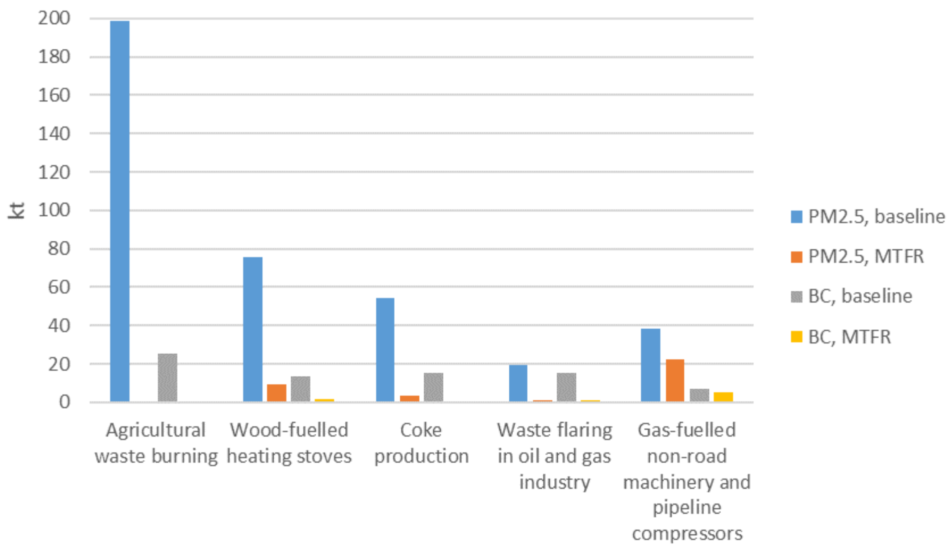
(c) Increased use of high-efficiency de-dusters to reduce emissions from coke oven processes (~50 kilotons);

(d) Good flaring practices in oil and gas industries (~18 kilotons);

(e) Renewal of gas-fuelled non-road mobile machinery fleet, and emission control for gas pipeline compressors (~16 kilotons).

33. The potential effects of these measures on $PM_{2.5}$ and BC emissions are illustrated in figure IV below.

Figure IV
Modelled Eastern Europe emissions from high **black carbon priority sectors in 2030 – baseline vs maximum technically feasible reduction**



Source: Stohl, “Evaluating the climate”; and Klimont, “Global anthropogenic emissions”.
Notes: The difference between the baseline and MTFR emissions indicates emission reduction potential.

B. Black carbon-prioritization of particulate matter control in South-Eastern Europe and Turkey

34. For South-Eastern Europe and Turkey, the guidance baseline scenario suggests that $PM_{2.5}$ emissions for the entire period 2010–2030 are driven up by increased use of coal-fired power plants. For the period 2010–2020, this emission driver is counteracted by increased emission control, resulting in a net reduction in emissions. But for 2020–2030, the increase in emission control is not enough to reduce $PM_{2.5}$ emissions. For BC emissions the situation is different, where changes in activity data as well as implementation of control measures both help reduce emissions for the entire period 2010–2030 (see table 2 and figure V below). Detailed scenario information on the use of control measures in the baseline and MTFR scenario is available in annex II below.

Table 2
Changes in fine particulate matter and black carbon emissions from South-Eastern Europe and Turkey

Emission change by driver, kilotons	*Activity data changes*	*High BC priority control measures*	*Mid BC priority control measures*	*Low BC priority control measures*	*No BC priority control measures*	*Net total change*
Historical change (2010–2020)						
$PM_{2.5}$	41	-15	-0.5	-0.5	-49	-24
BC	-18	-8	-0.4	-0.2	-1.4	-28
Planned changes (2020–2030) with measures according to current legislation						
$PM_{2.5}$	95	-15	-0.3	-0.5	-22	57
BC	-1	-4	-0.2	-0.2	-0.1	-6
Potential in 2030 from additional emission abatement measures beyond current legislation						

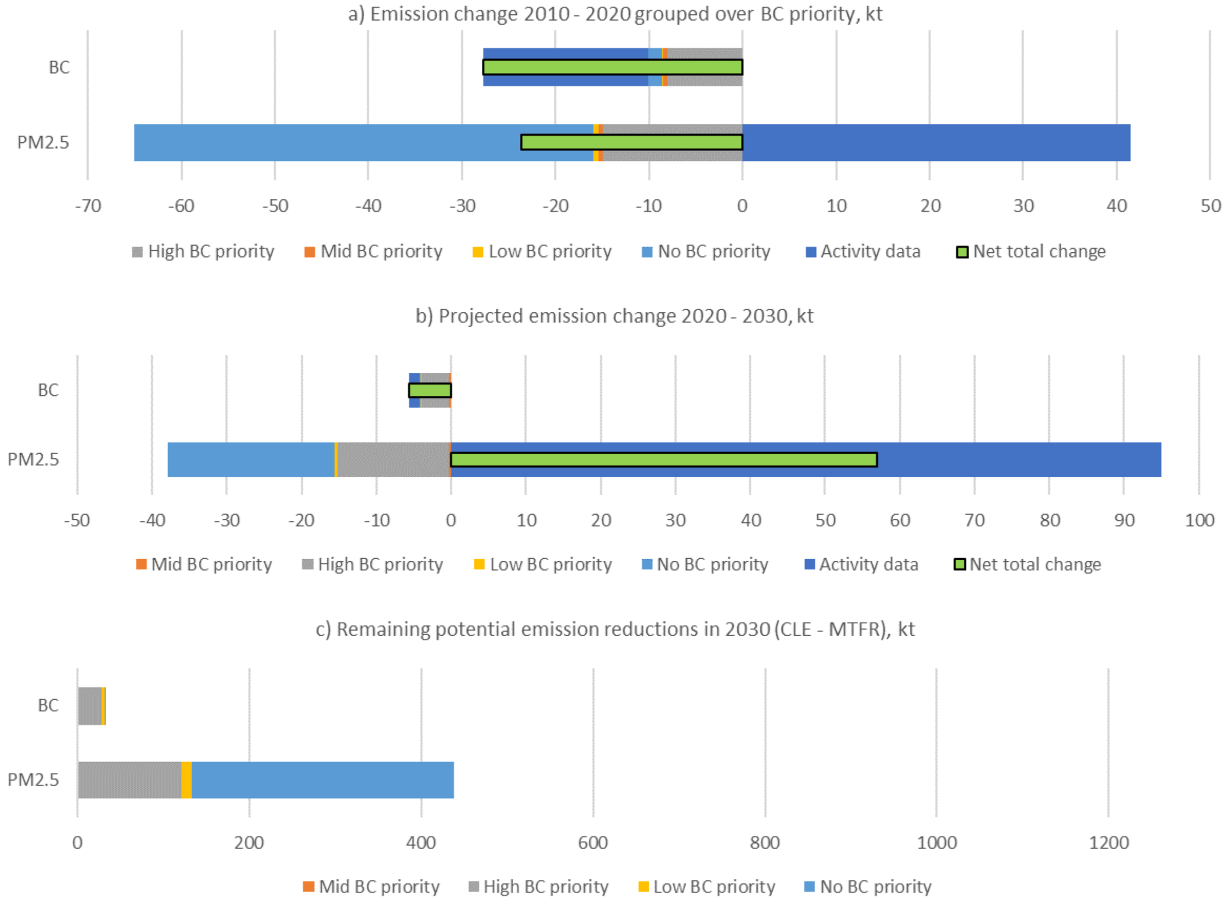
Emission change by driver, kilotons	*Activity data changes*	*High BC priority control measures*	*Mid BC priority control measures*	*Low BC priority control measures*	*No BC priority control measures*	*Net total change*
$PM_{2.5}$	-	-121	-0.4	-12	-304	-438
BC	-	-28	-0.3	-3	-2	-34

Source: Stohl, "Evaluating the climate"; and Klimont, "Global anthropogenic emissions".
Notes: Changes are presented separately for the main drivers of emission changes. Negative values imply emission reduction.

35. For South-Eastern Europe and Turkey, the baseline scenario indicates that, even though increased fuel use activity drives $PM_{2.5}$ and BC emissions up, the countervailing increased use of control measures ensures an emission reduction between 2010 and 2020. For the period 2020–2030 though, current legislation as represented in the baseline scenario shows that $PM_{2.5}$ emissions will increase due to increased fuel use activity. The same is not the case for BC. As was the case for the countries representing Eastern Europe, the remaining technical potential for control measures that reduce $PM_{2.5}$ emissions is substantially greater than the emission reduction achieved with measures expected to be implemented in the period 2020–2030.

Figure V

Graphical illustration of emission changes separated into changes due to variations in activity data, high-, mid-, low-, and no black carbon priority measures



Source: Stohl, "Evaluating the climate"; and Klimont, "Global anthropogenic emissions".

Notes: The green bar represents the net total change of emissions. (a) Changes over the period 2010–2020. (b) The emission scenario representing current legislation. (c) Remaining technical potential for further emission control. Notice the difference in scale and sign of emission control in (c) compared to (a) and (b). The figures are based on the GAINS model scenarios ECLIPSE v5a_base and ECLIPSE_MTFR_base scenarios.

36. During the period 2010–2020, High BC priority measures ensured 23 per cent and 80 per cent respectively of total $PM_{2.5}$ and BC emissions reduction from emission abatement in the baseline scenario. The most important high BC priority measures for the period were renewal of the diesel vehicle and mobile machinery fleets and the corresponding introduction of advanced emission control technologies. Also important was the implementation of newer and improved installation of wood-fuelled household boilers. Mid BC priority measures were responsible for 2 per cent and 1.2 per cent of $PM_{2.5}$ and BC emission reductions, respectively. The most important no BC priority measures were those used to reduce $PM_{2.5}$ emissions from brown coal-fuelled power plants, cement production and newer and improved biomass-fuelled household heating stoves.

37. For the period 2020–2030 in the baseline scenario, the most important high priority BC measures are the same as for the period 2010–2020, with the addition that new and improved wood-fuelled stoves in single households contribute. This group of measures will achieve 39 per cent and 87 per cent of the $PM_{2.5}$ and BC emission reductions respectively over the period. The most important no BC priority measures are those used to reduce $PM_{2.5}$ emissions from cement production. The mid BC priority measures have a limited effect on emissions.

38. When studying the technically remaining potential for emission reductions by 2030, and the potential for co-benefits, there are several technically available high BC priority

measures. These measures constitute 28 per cent and 84 per cent of the remaining technical potential to reduce $PM_{2.5}$ and BC emissions, respectively. Mid BC priority measures constitute only a small proportion of the remaining technical emission reduction potential in 2030. The most important no BC priority measures are the ones used to reduce $PM_{2.5}$ emissions from cement production, steel production and coal-fired power plants.

39. Guidance: the modelling results indicate that, beyond the current legislation 2020–2030, the $PM_{2.5}$ reduction measures with highest BC priority are (kilotons of potential $PM_{2.5}$ emission reduction in parenthesis):

(a) Quicker introduction and use of pellets stoves and renewal of other wood-fuelled household stove stocks (~50 kilotons);

(b) A full implementation and enforcement of a ban on open agricultural burning (~40 kilotons);

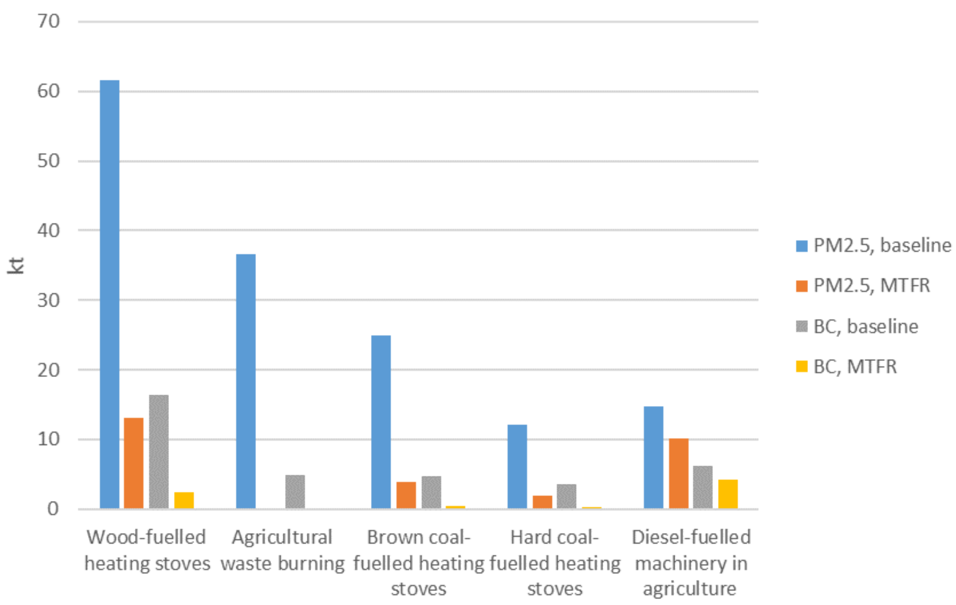
(c) Use of briquette stoves and increased replacement rate of existing installation for newer ones for brown coal-fired heating stoves (~20 kilotons);

(d) Use of briquette stoves and increased replacement rate of existing installation with newer ones for hard coal-fired heating stoves (~10 kilotons);

(e) Renewal of diesel-fuelled machinery stock in agriculture (~5 kilotons).

40. The potential effects of these measures on $PM_{2.5}$ and BC emissions are illustrated in figure VI below.

Figure VI
Modelled emissions in South-Eastern Europe and Turkey from high black carbon priority sectors in 2030 – baseline vs maximum technically feasible reduction



Source: Stohl, "Evaluating the climate"; and Klimont, "Global anthropogenic emissions".
Notes: The difference between the baseline and MTFR emissions indicates emission reduction potential.

C. Black carbon prioritization of particulate matter control in the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland

41. For the Western European countries, represented by the European Union member States and Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland, both $PM_{2.5}$ and BC emissions have decreased since 2010 and are expected to continue to decrease until 2030. The decrease in emissions is driven by reduced fuel use activities, as

well as by direct implementation of control measures, mainly high BC priority measures. By 2030, the remaining technical potential is also dominated by high BC priority measures (see table 3 and figure VII below). Detailed scenario information on the use of measures in each scenario is available in annex III below.

Table 3

Changes in fine particulate matter and black carbon emissions from the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland

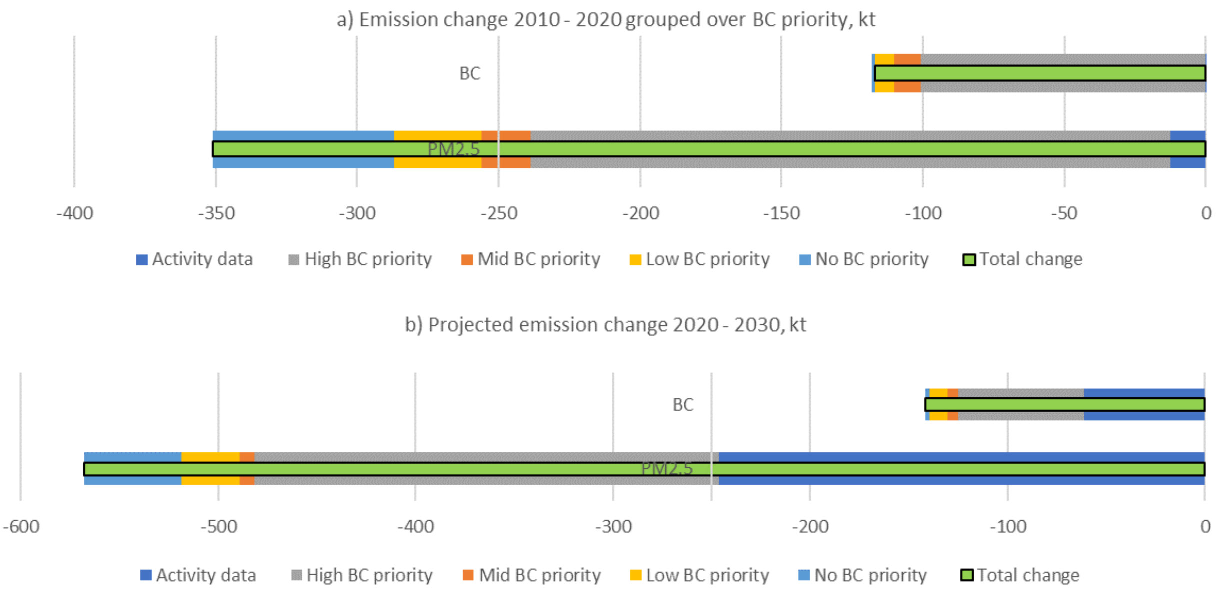
Emission change by driver, kilotons	*Activity data changes*	*High BC priority control measures*	*Mid BC priority control measures*	*Low BC priority control measures*	*No BC priority control measures*	*Net total change*
Historical change (2010–2020)						
$PM_{2.5}$	-13	-226	-17	-31	-64	-351
BC	1	-101	-9	-7	-1	-117
Planned changes (2020–2030) with measures according to current legislation						
$PM_{2.5}$	-246	-236	-7	-30	-49	-568
BC	-61	-64	-6	-9	-2	-142
Potential in 2030 from additional emission abatement measures beyond current legislation						
$PM_{2.5}$	-	-172	-1	-17	-103	-294
BC	-	-38	-0.8	-4	-1	-44

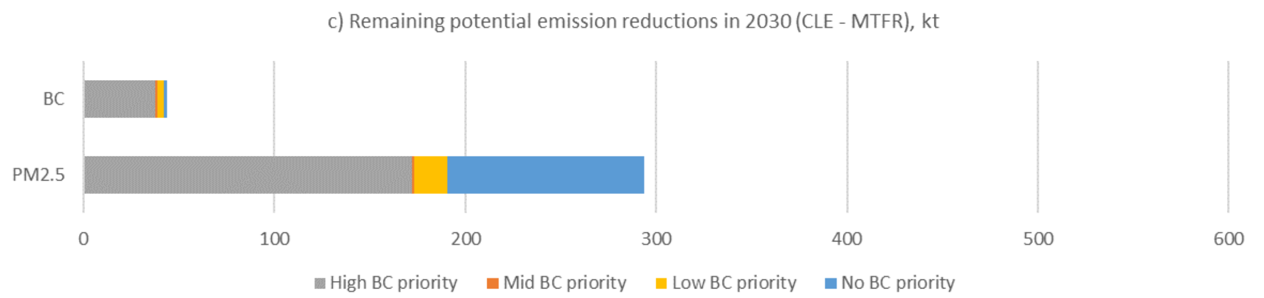
Source: Amann, Progress Towards the Achievement.

Notes: Changes are presented separately for the main drivers of emission changes. Negative values imply emission reduction.

Figure VII

Graphical illustration of emission changes separated into changes due to variations in activity data, high-, mid-, low-, and no black carbon priority measures





Source: Amann, Progress Towards the Achievement.

Notes: The green bar represents the net total change of emissions. (a) Changes over the period 2010–2020. (b) The emission scenario representing current legislation. (c) Remaining technical potential for further emission control. Notice the difference in scale and sign of emission control in (c) compared to (a) and (b). The figures are based on the GAINS model scenarios CEP_post2014_CLE_v.Dec.2018 and CEP_MTFR.

42. For the period 2010–2020, 67 per cent of the $PM_{2.5}$ emission reduction and 85 per cent of the BC reduction came from high BC priority measures. As for the other regions, the emission reductions came mainly from the introduction of new and improved wood-fuelled stoves in households (including pellets stoves) as well as from newer vehicle fleets in diesel-driven road and non-road mobile machinery. BC emissions from household stoves increased, though due to increased use of wood fuels. Mid BC priority measures constituted 5 per cent and 3 per cent of $PM_{2.5}$ and BC emission reductions. Those measures were mainly newer types of engine exhaust control on diesel-driven machinery and buses. The no BC priority measures were those controlling emissions from cement production and from household fireplaces.

43. According to the baseline scenario, $PM_{2.5}$ and BC emissions measures will decrease with 73 per cent and 79 per cent between 2020 and 2030 by high BC priority measures. Again, it is the introduction of new installations (including pellet stoves) to control emissions from household stoves and boilers that induces the largest emission reductions. The improved engine exhaust measures in diesel-fuelled vehicles and machinery are also important in this category. Mid BC priority measures contribute with 2 per cent of the emission reduction for both $PM_{2.5}$ and BC. Most important in this category are engine exhaust measures in diesel engines and high-grade coal in stoves. The most important no priority measure for this period is newer installations in household fireplaces.

44. On top of current legislation, there are still several control measures that could be utilized more to reduce emissions further by 2030. High BC priority measures ensure 59 per cent and 87 per cent of the $PM_{2.5}$ and BC emission reduction potential, respectively. Mid BC priority measures have relatively limited potential, whilst measures to reduce $PM_{2.5}$ emissions from industrial processes, fireplaces and biomass combustion in industrial furnaces are the most important no BC priority measures.

45. Guidance: the modelling results indicate that, beyond the current legislation 2020–2030, the $PM_{2.5}$ reduction measures with the highest BC priority are (kilotons of potential $PM_{2.5}$ emission reduction in parenthesis):

(a) Quicker introduction and use of pellets stoves and renewal of other wood-fuelled household stove stocks (~100 kilotons);

(b) A full implementation of a ban on open agricultural burning (~50 kilotons);

(c) Renewal of wood-fuelled household boiler stock (~13 kilotons);

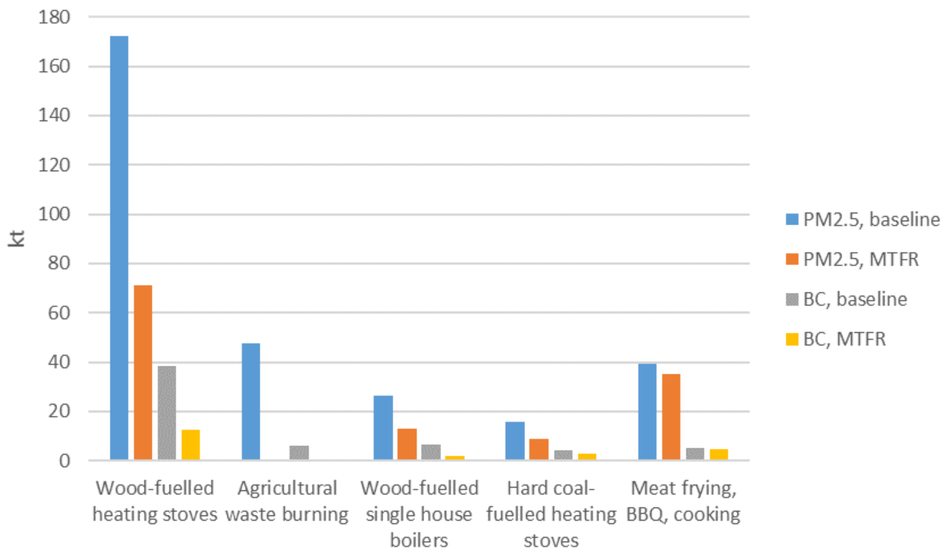
(d) Use of briquette stoves and increased replacement rate of existing installation with newer ones for hard coal-fired heating stoves (~7 kilotons);

(e) Installation of kitchen filters to reduce emissions from coking/barbecue (~4 kilotons).

46. The potential effects of these measures on $PM_{2.5}$ and BC emissions are illustrated in figure VIII below.

Figure VIII

Modelled emissions in the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland from high black carbon priority sectors in 2030 – baseline vs maximum technically feasible reduction



Source: Amann, Progress Towards the Achievement.

Notes: The difference between the baseline and MTFR emissions indicates emission reduction potential.

47. In contrast to the other regions, $PM_{2.5}$ emission reductions in the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland are driven both by changes in activity data and by use of high BC priority measures. A large majority of $PM_{2.5}$ emission reductions in the period 2010–2020 were achieved by use of high BC priority measures, and for the period 2020–2030 changes in activity data and use of high BC priority measures are responsible for most emission reductions. Still, almost two thirds of the remaining technical potential by 2030 is made up of high BC priority measures. The technical potential for high BC priority measures is 172 kilotons by 2030. Just ensuring an effective ban on agricultural waste burning would reduce $PM_{2.5}$ emissions by 47 kilotons whilst also ensuring 6 kilotons of BC emission reductions. If just half of the technical potential to increase the use of new wood-fuelled stoves and pellet stoves were to be ensured, $PM_{2.5}$ emissions would be reduced by 50 kilotons, with simultaneous reduction of BC emissions by 13 kilotons.

Annex I

Most important measures implemented in the Eastern European scenarios

A. Historical development (2010–2020)

1. Key high BC priority sectors and measures:

(a) Diesel-fuelled heavy-duty vehicles; historical emission abatement due to introduced control measures is 9.8 kilotons of $PM_{2.5}$ and 5.3 kilotons of BC – there is large relative co-benefit in this sector as well (0.54 BC per 1 $PM_{2.5}$). Higher Euro standards;

(b) Diesel-fuelled cars; historical emission abatement due to introduced control measures is 7.7 kilotons of $PM_{2.5}$ and 3.7 kilotons of BC. Higher Euro standards;

(c) Diesel-fuelled light-duty vehicles; historical emission abatement due to introduced control measures is 2.2 kilotons of $PM_{2.5}$ and 1.3 kilotons of BC – there is large relative co-benefit in this sector as well (0.57 BC in $PM_{2.5}$). Higher Euro standards;

(d) Diesel-fuelled heavy-duty buses; historical emission abatement due to introduced control measures is 2.1 kilotons of $PM_{2.5}$ and 1.1 kilotons of BC – there is large relative co-benefit in this sector as well (0.54 BC in $PM_{2.5}$). Higher Euro standards;

(e) Diesel-fuelled railway; historical emission abatement due to introduced control measures is 1.6 kilotons of $PM_{2.5}$ and 0.7 kilotons of BC. Higher Control Stages.

2. The high BC priority emission control measures in five key sectors account for 46 per cent of the reduction of $PM_{2.5}$ and 86 per cent of the reduction of BC in Eastern Europe in the period 2010–2020 – these reductions due to control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector. In some cases, total emissions increased. Additional input in emission reductions from mid BC priority control measures is 0.3 per cent for both $PM_{2.5}$ and BC. This sector is carbon black production (0.99 BC in $PM_{2.5}$).

3. The most important sectors with low-, and no BC priority measures between 2010 and 2020 were:

(a) Hard coal combustion at new large power plants (9 kilotons of $PM_{2.5}$, 0.1 kilotons of BC);

(b) Hard coal combustion at existing large power plants (3 kilotons of $PM_{2.5}$, 0.02 kilotons of BC);

(c) Fuelwood in domestic heating stoves (3 kilotons of $PM_{2.5}$, 0.2 kilotons of BC).

B. Planned emission reductions (2020–2030, current legislation)

4. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in 2030):

(a) Diesel-fuelled heavy-duty vehicles; planned emission abatement due to control measures is 2.2 kilotons of $PM_{2.5}$ and 1.4 kilotons of BC – there is large relative co-benefit in this sector as well (0.63 BC in $PM_{2.5}$). Belarus: Euro II (100 per cent), the Republic of Moldova: Euro V (78 per cent), the Russian Federation: Euro V (100 per cent), Ukraine: Euro III (100 per cent);

(b) Black liquor combustion in pulp-and-paper industry boilers; planned emission abatement due to control measures is 2.0 kilotons of $PM_{2.5}$ and 0.3 kilotons of BC. Cyclones (30 per cent), One-field electrostatic precipitators ESP1 (70 per cent);

(c) Diesel-fuelled railway; planned emission reduction due to control measures is 1.5 kilotons of $PM_{2.5}$ and 0.7 kilotons of BC. Belarus, the Russian Federation: Control Stage 1 (100 per cent), the Republic of Moldova: Control Stage 1 (85 per cent);

(d) Diesel-fuelled vehicles in agriculture; planned emission reduction due to control measures is 1.2 kilotons of $PM_{2.5}$ and 0.5 kilotons of BC. Belarus, the Russian Federation: Control Stage 1 (100 per cent), the Republic of Moldova: Control Stage 1 (85 per cent);

(e) Diesel-fuelled cars; planned emission abatement due to control measures is 1 kiloton of $PM_{2.5}$ and 0.5 kilotons of BC. Belarus: Euro II (100 per cent), the Republic of Moldova: Euro IV (78 per cent), the Russian Federation: Euro IV (100 per cent), Ukraine: Euro III (100 per cent);

5. High BC priority control measures in five key sectors account for 36 per cent of expected emission reductions of $PM_{2.5}$ and 64 per cent of expected reductions of BC in Eastern Europe in the period 2020–2030 – these reductions due to technical control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector. Additional input in emission reductions from mid BC priority control measures is 6 per cent for $PM_{2.5}$ and 4 per cent for BC. These sectors include diesel-fuelled heavy-duty buses (0.63 BC in $PM_{2.5}$), and diesel-fuelled light-duty vehicles (0.79 BC in $PM_{2.5}$).

6. The most important sectors with low-, and no BC priority measures between 2020 and 2030 are:

(a) Biomass fuel combustion in chemical industry boilers (4 kilotons of $PM_{2.5}$, 0.2 kilotons of BC);

(b) Wood fuels in household heating stoves (3.4 kilotons of $PM_{2.5}$, 0.2 kilotons of BC);

(c) Biomass fuel combustion in pulp and paper industry boilers (1.5 kilotons of $PM_{2.5}$, 0.07 kilotons of BC).

C. Potential emission reductions (maximum technically feasible reduction-current legislation)

7. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in MTFR):

(a) Agricultural waste burning; emission reduction potential is 199 kilotons of $PM_{2.5}$ and 26 kilotons of BC. Effective ban on open burning (100 per cent);

(b) Wood fuels in household heating stoves; emission reduction potential is 66 kilotons of $PM_{2.5}$ and 12 kilotons of BC. Pellets stoves (65 per cent), new installations (35 per cent);

(c) Coke oven processes; emission reduction potential is 51 kilotons of $PM_{2.5}$ and 15 kilotons of BC. High efficiency de-dusters (99 per cent);

(d) Flaring in refineries; emission reduction potential is 18 kilotons of $PM_{2.5}$ and 14 kilotons of BC. Good practice in oil and gas industry (100 per cent);

(e) Gas-fuelled non-road 4-stroke engine machinery (small household and forestry machines, military vehicles, motorboats) and pipeline compressors; emission reduction potential is 16 kilotons of $PM_{2.5}$ and 1.8 kilotons of BC. Euro VI (50 per cent).

8. High BC priority control measures in five key sectors account for 29 per cent of the total potential reduction of $PM_{2.5}$ and 80 per cent of the total potential reduction of BC in Eastern Europe in 2030. Additional input from mid BC priority control measures is 0.3 per cent for $PM_{2.5}$ and 3 per cent for BC. These sectors include diesel-fuelled heavy-duty vehicles (0.74 BC in $PM_{2.5}$), diesel-fuelled heavy-duty buses (0.74 BC in $PM_{2.5}$), diesel-fuelled light-duty vehicles (0.82 BC in $PM_{2.5}$), diesel-fuelled cars (0.91 BC in $PM_{2.5}$), diesel-fuelled non-

road 4-stroke engine machinery (0.51 BC in $PM_{2.5}$), and carbon black production (0.99 BC in $PM_{2.5}$).

9. The most important sectors with low-, and no BC priority measures are:

(a) Steel production in basic oxygen furnaces (reduction potentials – 442 kilotons of $PM_{2.5}$, no BC);

(b) Steel production in electric arc furnaces (reduction potentials – 109 kilotons of $PM_{2.5}$, no BC);

(c) Cement production (53 kilotons of $PM_{2.5}$, 0.3 kilotons of BC).

Annex II

Most important measures implemented in the South-Eastern Europe and Turkey scenarios

A. Historical development (2010–2020)

1. Key high BC priority sectors and measures:

(a) Diesel-fuelled heavy-duty vehicles; Historical emission abatement due to introduced control measures is 7.2 kilotons of $PM_{2.5}$ and 3.9 kilotons of BC – there is large relative co-benefit in this sector as well (0.55 BC in $PM_{2.5}$). Higher Euro standards;

(b) Diesel-fuelled vehicles used in agriculture; Historical emission abatement due to introduced control measures is 4.6 kilotons of $PM_{2.5}$ and 1.9 kilotons of BC. Higher Control Stages;

(c) Diesel-fuelled light-duty vehicles; Historical emission abatement due to introduced control measures is 2.1 kilotons of $PM_{2.5}$ and 1.7 kilotons of BC – there is large relative co-benefit in this sector as well (0.83 BC in $PM_{2.5}$). Higher Euro standards;

(d) Diesel-fuelled heavy-duty buses; Historical emission reduction due to introduced control measures is 0.6 kilotons of $PM_{2.5}$ and 0.36 kilotons of BC – there is large relative co-benefit in this sector as well (0.59 BC in $PM_{2.5}$). Higher Euro standards;

(e) Wood fuels in single house boilers; Historical emission reduction due to introduced control measures is 0.5 kilotons of $PM_{2.5}$ and 0.1 kilotons of BC. New installations (5–7 per cent implementation in 2020), Improved installations (20–35 per cent implementation in 2020).

2. High BC priority control measures in five key sectors account for 23 per cent of the reduction of $PM_{2.5}$ and 80 per cent of the reduction of BC in the Balkans in the period 2010–2020 – these reductions due to technical control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector.

3. Additional input in emission reductions from mid BC priority control measures is 2 per cent for $PM_{2.5}$ and 1.2 per cent for BC. These sectors include diesel-fuelled cars (0.74 BC in $PM_{2.5}$), diesel-fuelled heavy-duty buses (0.59 BC in $PM_{2.5}$), and carbon black production process (0.99 BC in $PM_{2.5}$).

4. The most important sectors with low-, and no BC priority measures between 2010 and 2020 are:

(a) Cement production process (20 kilotons of $PM_{2.5}$, 0.1 kilotons of BC);

(b) Wood fuels in household heating stoves (14 kilotons of $PM_{2.5}$, 1.3 kilotons of BC);

(c) Brown coal combustion at existing large power plants (6.3 kilotons of $PM_{2.5}$, no BC).

B. Planned emission reductions (2020–2030, current legislation)

5. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in 2030):

(a) Wood fuels in household heating stoves; planned emission reduction due to control measures is 11.2 kilotons of $PM_{2.5}$ and 1.4 kilotons of BC. New installations (20 per cent). Improved installations (50 per cent);

(b) Diesel-fuelled heavy-duty vehicles; planned emission abatement due to control measures is 2.8 kilotons of $PM_{2.5}$ and 1.8 kilotons of BC – there is large relative co-benefit in this sector as well (0.64 BC in $PM_{2.5}$). Balkans - Euro V (80 per cent). Turkey - Euro VI (85 per cent);

(c) Wood fuels in single house boilers; planned emission abatement due to control measures is 0.4 kilotons of $PM_{2.5}$ and 0.13 kilotons of BC. New installations (10–15 per cent). Improved installations (30 per cent);

(d) Diesel-fuelled heavy-duty buses; planned emission reduction due to control measures is 0.22 kilotons of $PM_{2.5}$ and 0.15 kilotons of BC – there is large relative co-benefit in this sector as well (0.69 BC in $PM_{2.5}$). Balkans - Euro V (80 per cent). Turkey - Euro VI (90 per cent);

(e) Diesel-fuelled light-duty vehicles; planned emission reduction due to control measures is 0.19 kilotons of $PM_{2.5}$ and 0.17 kilotons of BC – there is large relative co-benefit in this sector as well (0.88 BC in $PM_{2.5}$). Balkans - Euro V (100 per cent). Turkey - Euro VI (96 per cent).

6. High BC priority control measures in five key sectors account for 39 per cent of expected reduction of $PM_{2.5}$ and 87 per cent of expected reductions of BC in the Balkans in the period 2020–2030 – these reductions due to technical control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector.

7. Additional input in emission reductions from mid BC control measures is 0.9 per cent for $PM_{2.5}$ and 0.6 per cent for BC. These sectors include diesel-fuelled cars (0.88 BC in $PM_{2.5}$), and diesel-fuelled construction machinery (0.51 BC in $PM_{2.5}$).

8. The most important sectors with low-, and no BC priority measures between 2020 and 2030. Cement production process (22 kilotons of $PM_{2.5}$, 0.13 kilotons of BC).

C. Potential emission reductions (maximum technically feasible reduction-current legislation)

9. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in MTFR):

(a) Wood fuels in household heating stoves; emission reduction potential is 48 kilotons of $PM_{2.5}$ and 14 kilotons of BC. Pellets stoves (65 per cent). New installations (35 per cent);

(b) Agricultural waste burning; emission reduction potential is 37 kilotons of $PM_{2.5}$ and 4.8 kilotons of BC. Effective ban on open burning (100 per cent);

(c) Brown coal in household heating stoves; emission reduction potential is 21 kilotons of $PM_{2.5}$ and 4.3 kilotons of BC. Briquette stoves (90 per cent). New installations (10 per cent);

(d) Hard coal in household heating stoves; emission reduction potential is 10 kilotons of $PM_{2.5}$ and 3.2 kilotons of BC. Briquette stoves (90 per cent). New installations (10 per cent);

(e) Diesel-fuelled vehicles in agriculture; emission reduction potential is 5 kilotons of $PM_{2.5}$ and 2 kilotons of BC. Control Stage 5 (25–44 per cent).

10. High BC priority control measures in five key sectors account for 28 per cent of the total potential reduction of $PM_{2.5}$ and 84 per cent of the total potential reduction of BC in the European Union in 2030. Additional input from mid BC priority control measures is 0.1 per cent for $PM_{2.5}$ and 1 per cent for BC. These sectors include flaring in refineries (0.78 BC in $PM_{2.5}$) and diesel-fuelled heavy-duty vehicles (0.76 BC in $PM_{2.5}$).

11. The most important sectors with low-, and no BC priority measures are:

(a) Cement production (reduction potentials – 77 kilotons of $PM_{2.5}$, 0.5 kilotons of BC);

(b) Steel production in electric arc furnaces (reduction potentials – 69 kilotons of $PM_{2.5}$, no BC);

(c) Brown coal combustion at large new power plants (63 kilotons of $PM_{2.5}$, no BC).

Annex III

Most important measures implemented in the European Union, Norway, Switzerland and the United Kingdom of Great Britain and Northern Ireland scenarios

A. Historical development (2010–2020)

1. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in 2020):

(a) Wood fuels in household heating stoves; historical emission abatement due to introduced control measures is 100 kilotons of $PM_{2.5}$ and 11 kilotons of BC. Pellets stoves (~7 per cent). New installations (~17 per cent). Improved installations (~44 per cent);

(b) Diesel-fuelled cars; historical emission abatement due to introduced control measures is 63 kilotons of $PM_{2.5}$ and 51 kilotons of BC – there is large relative co-benefit in this sector as well (0.82 BC in $PM_{2.5}$). Higher Euro standards;

(c) Diesel-fuelled heavy-duty vehicles; historical emission reduction due to introduced control measures is 24 kilotons of $PM_{2.5}$ and 15 kilotons of BC – there is large relative co-benefit in this sector as well (0.62 BC in $PM_{2.5}$). Higher Euro standards;

(d) Diesel-fuelled vehicles used in agriculture; historical emission reduction due to introduced control measures is 21 kilotons of $PM_{2.5}$ and 9.1 kilotons of BC. Higher Control Stages;

(e) Diesel-fuelled light-duty vehicles; historical emission reduction due to introduced control measures is 19 kilotons of $PM_{2.5}$ and 14 kilotons of BC – there is large relative co-benefit in this sector as well (0.77 BC in $PM_{2.5}$). Higher Euro standards.

2. High BC priority control measures in five key sectors account for 67 per cent of the reduction of $PM_{2.5}$ and 85 per cent of the reduction of BC in the European Union in 2010–2020 – these reductions due to technical control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector.

3. Additional input in emission reductions from mid BC priority control measures is 5 per cent for $PM_{2.5}$ and 3 per cent for BC. These sectors include diesel-fuelled construction machinery (0.52 BC in $PM_{2.5}$), diesel-fuelled heavy-duty buses (0.60 BC in $PM_{2.5}$), generator sets on heavy fuel oil (0.51 BC in $PM_{2.5}$), and carbon black production process (0.99 BC in $PM_{2.5}$).

4. The most important sectors with low-, and no BC priority measures between 2010 and 2020:

(a) Wood fuels in single house boilers (14 kilotons of $PM_{2.5}$, 3 kilotons of BC);

(b) Cement production (11 kilotons of $PM_{2.5}$, 0.07 kilotons of BC);

(c) Fireplaces (10 kilotons of $PM_{2.5}$, 0.4 kilotons of BC).

B. Planned emission reductions (2020–2030, current legislation)

5. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in 2030):

(a) Wood fuels in household heating stoves; planned emission reduction due to control measures is 181 kilotons of $PM_{2.5}$ and 36 kilotons of BC. Pellets stoves (~10 per cent). New installations (~59 per cent);

(b) Wood fuels in single house boilers; Planned emission reduction due to control measures is 23 kilotons of $PM_{2.5}$ and 6.5 kilotons of BC. New installations (~62 per cent);

(c) Diesel-fuelled cars; Planned emission reduction due to control measures is 14 kilotons of $PM_{2.5}$ and 12 kilotons of BC – there is large relative co-benefit in this sector as well (0.88 BC in $PM_{2.5}$). Euro VI (~79 per cent);

(d) Diesel-fuelled vehicles used in agriculture; Planned emission reduction due to control measures is 11 kilotons of $PM_{2.5}$ and 4.6 kilotons of BC. Control Stage 5 (~54 per cent);

(e) Diesel-fuelled heavy-duty vehicles; planned emission reduction due to control measures is 6.0 kilotons of $PM_{2.5}$ and 4.3 kilotons of BC. Euro VI (~86 per cent).

6. High BC priority control measures in five key sectors account for 73 per cent of expected reduction of $PM_{2.5}$ and 79 per cent of expected reductions of BC in the European Union in the period 2020–2030 – these reductions due to technical control measures are further affected by activity data development so that the actual emissions can be either higher or lower, depending on the sector.

7. Additional input in emission reductions from control measures in sectors with large relative co-benefits is 2 per cent for $PM_{2.5}$ and 2 per cent for BC. These sectors include diesel-fuelled heavy-duty buses (0.66 BC in $PM_{2.5}$), diesel-fuelled light-duty vehicles (0.80 BC in $PM_{2.5}$), hard coal grade 2 in household heating stoves (0.71 BC in $PM_{2.5}$), and oil-fuelled generator sets (0.53 BC in $PM_{2.5}$).

8. The most important sectors with low-, and no BC priority measures between 2020 and 2030:

(a) Fireplaces (34 kilotons of $PM_{2.5}$, 1.6 kilotons of BC);

(b) Hard coal in household heating stoves (11 kilotons of $PM_{2.5}$, 3 kilotons of BC);

(c) Diesel-fuelled inland waterways transport (4 kilotons of $PM_{2.5}$, 1.8 kilotons of BC).

C. Potential emission reductions (maximum technically feasible reduction-current legislation)

9. Key high BC priority sectors and measures (in parenthesis – implementation rates of listed control measures in MTFR):

(a) Wood fuels in household heating stoves; emission reduction potential is 101 kilotons of $PM_{2.5}$ and 26 kilotons of BC. Pellets stoves (~61 per cent);

(b) Agricultural waste burning; emission reduction potential is 47 kilotons of $PM_{2.5}$ and 6 kilotons of BC. Effective ban on open burning (100 per cent);

(c) Wood fuels in single house boilers; emission reduction potential is 13 kilotons of $PM_{2.5}$ and 4 kilotons of BC. Pellet boilers (~59 per cent);

(d) Hard coal in household heating stoves; emission reduction potential is 7 kilotons of $PM_{2.5}$ and 1 kiloton of BC. Briquette stoves (50 per cent). New installations (50 per cent);

(e) Meat frying, food preparation, barbecues; Emission reduction potential is 3.9 kilotons of $PM_{2.5}$ and 0.5 kilotons of BC. Filters in households (100 per cent).

10. High BC priority control measures in five key sectors account for 59 per cent of the total potential reduction of $PM_{2.5}$ and 87 per cent of the total potential reduction of BC in the European Union in 2030. Additional input from mid BC priority control measures is 0.4 per cent for $PM_{2.5}$ and 2 per cent for BC. These sectors include flaring in refineries (0.78 BC in $PM_{2.5}$), venting and flaring of associated petroleum gas during oil and gas production (0.76 BC in $PM_{2.5}$), and carbon black production (0.86 BC in $PM_{2.5}$).

11. The most important sectors with low-, and no BC priority measures are:

(a) Industrial processes (reduction potentials – 20 kilotons of $PM_{2.5}$, no BC);

(b) Fireplaces (reduction potentials – 16 kilotons of $PM_{2.5}$, 0.3 kilotons of BC);

(c) Biomass fuels in industrial furnaces (8 kilotons of $PM_{2.5}$, 0.7 kilotons of BC).