

# Third IPCC Expert Meeting on Short-lived Climate Forcers

Report of IPCC Expert Meeting  
11 – 15 April 2022, Virtual Meeting

Task Force on National Greenhouse Gas Inventories

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INTERGOVERNMENTAL PANEL ON  
climate change



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The Third IPCC Expert Meeting on Short-lived Climate Forcers was organised by the IPCC Task Force on National Greenhouse Gas Inventories (TFI). It was held through ZOOM and MS Teams platforms.

This meeting report was prepared jointly by the Co-Chairs of the IPCC TFI (Eduardo Calvo Buendia and Kiyoto Tanabe) as well as the Technical Support Unit (TSU) of the TFI (Sandro Federici, Baasansuren Jamsranjav, Eduard Karapoghosyan, Pavel Shermanau, Valentyna Slivinska) and the consultant of the Institute for Global Environmental Strategies (Takeshi Enoki), and subjected to review by the meeting participants.

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## Preface

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We are pleased to present this report of the 3<sup>rd</sup> Expert Meeting on Short-lived Climate Forcers held on 11-15 April 2022 as a virtual meeting.

At the 45<sup>th</sup> Session of the IPCC in Guadalajara, Mexico in March 2017, the need for methodology to estimate emissions of Short-lived Climate Forcers (SLCFs) was brought up for discussion, because of the potential importance of reducing emissions of such climate forcers for climate change mitigation as well as for air quality improvement. Following the discussion and decision by the IPCC at its 46<sup>th</sup> Session in Montreal, Canada (Decision IPCC/XLVI-6), the Task Force on National Greenhouse Gas Inventories (TFI) jointly with Working Group I held an expert meeting on SLCFs in Geneva, Switzerland, in May 2018 to discuss issues on estimation of emissions and climate effects. This expert meeting in 2018 concluded, among others:

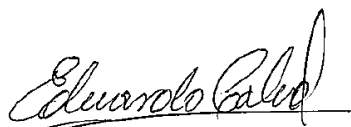
- *Improved emission inventories of SLCFs are necessary to enhance scientific understanding and assessment of their role in climate change as well as to inform climate policy at the national and international levels.*
- *Internationally-agreed, globally applicable methodologies and emission factors for SLCF emission inventories are necessary, and the IPCC TFI is in a good position to do that work.*

Taking the conclusions and recommendations of this expert meeting in 2018 into consideration, the IPCC decided, at its 49<sup>th</sup> Session in Kyoto, Japan in May 2019, to develop a Methodology Report on SLCFs during the IPCC's 7<sup>th</sup> Assessment Cycle (Decision IPCC-XLIX-7).

The Joint 1<sup>st</sup> and 2<sup>nd</sup> Expert Meeting on Short-lived Climate Forcers was held in October 2021 to begin the preparatory work for the Methodology Report on SLCFs. Participating experts listed the relevant source categories of SLCF emissions, aggregated according to inventory sectors (i.e., Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), Waste), and identified knowledge gaps in the available methodological guidance and datasets needed to estimate SLCFs emissions by all countries in the world.

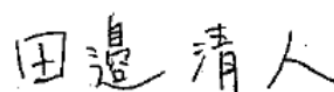
This 3<sup>rd</sup> Expert Meeting on Short-lived Climate Forcers continued the preparatory work for the Methodology Report on SLCFs. It brought together scientists and inventory experts identified and selected by the Bureau of TFI (TFB) in accordance with the procedures set out in Section 7.1 of Appendix A to the Principles Governing IPCC Work. Discussion and conclusions of this Expert Meeting are described in this report. The Expert Meeting reports is not to preempt the future work for production of the Methodology Report, but to serve as input to that process. We believe they will inform the scoping as well as the writing of the Methodology Report during the IPCC's 7<sup>th</sup> Assessment Cycle.

We would like to thank all those involved in this meeting, namely, the scientists and experts who participated, the members of TFB and the TFI Technical Support Unit, for their contribution, that enabled to make this meeting a success.



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## List of Acronyms and Abbreviations

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AD	Activity Data
AP-42	US EPA Compilation of Air Pollutant Emission Factors
AR6	Sixth Assessment Report
AR7	Seventh Assessment Report
BC	Black Carbon
BOG	Break-Out Group
BVOC	Biogenic Volatile Organic Compounds
CH <sub>4</sub>	Methane
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
CLRTAP	Convention on Long-range Transboundary Air Pollution
EBC	Effective Black Carbon
EC	Elemental Carbon
EEA	European Environment Agency
EF	Emission Factor
EV	Electric Vehicle
EMEP	European Monitoring and Evaluation Programme
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
KCA	Key Category Analysis
LPG	Liquified Petroleum Gas
LTO	Landing and Take-Off
N <sub>2</sub> O	Nitrous Oxide
NH <sub>3</sub>	Ammonia
NMVOG	Non-Methane Volatile Organic Compounds
NO <sub>x</sub>	Nitrogen Oxides
NTCF	Near-term Climate Forcers
OA	Organic Aerosol
OC	Organic Carbon
OM	Organic Matter
PM <sub>10</sub>	Particulate Matter with aerodynamic diameter ≤ 10 µm (micrometer)
PM <sub>2.5</sub>	Particulate Matter with aerodynamic diameter ≤ 2.5 µm (micrometer)
RF	Radiative Forcing

SCR	Selective Catalytic Reduction
SLCF	Short-lived Climate Forcers
SLCP	Short-lived Climate Pollutants
SO <sub>2</sub>	Sulphur Dioxide
SOA	Secondary Organic Aerosols
TFI	Task Force on National Greenhouse Gas Inventories
TSP	Total Suspended Particles
TSU	Technical Support Unit
UNECE	United Nations Economic Commission for Europe
UNEP	UN Environment Programme (United Nations Environment Programme)
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WG	Working Group

## Executive Summary

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At the 49th Session held in May 2019 (in Kyoto, Japan) the IPCC approved that the TFI produces an IPCC Methodology Report on SLCFs during the seventh IPCC assessment cycle (AR7 cycle) and that preparatory work is carried out during the sixth IPCC assessment cycle (AR6 cycle).

Accordingly, the IPCC TFI held the Joint 1<sup>st</sup> and 2<sup>nd</sup> IPCC Expert Meeting on SLCFs (Joint Meeting) on 11 – 22 October 2021 virtually to list all relevant source categories of SLCF emissions, aggregated according to inventory sectors (i.e., Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), Waste), and to identify knowledge gaps in the available methodological guidance and datasets needed to estimate SLCFs emissions by all countries in the world.

The IPCC TFI held the 3<sup>rd</sup> IPCC Expert Meeting on SLCFs on 11 – 15 April 2022 virtually to take stock of the information on SLCF provided in the IPCC Working Group I (WGI) I and Working Group III (WGIII) contributions to AR6 and have consideration of cross-cutting issues in methodologies to estimate SLCF emissions.

To facilitate and support the work at Expert Meeting, the Task Force on National Greenhouse Gas Inventories (TFI) Technical Support Unit (TSU) prepared the following materials based on previous Expert meetings and feedback from expert questionnaires carried out prior to the 3<sup>rd</sup> Expert meeting:

- Technical note for each break-out group (BOG) including participants' feedback to the questionnaire.
- Consideration for the Key Category Analysis of SLCF sources.
- Gaps list compiled from previous Expert Meetings.
- List of SLCF Categories and Species from the Joint Meeting.
- Note on allocation issues of SLCF emissions between different sectors from the Joint Meeting.

At the 3<sup>rd</sup> Expert Meeting, informative presentations were made on WGI and WGIII contributions to AR6 and general issues, and national or international emissions inventories experiences on general methodological issues, including on data collection/measurements. After this plenary session, experts split up into three BOGs to discuss the following topics:

- SLCF species definitions and their relevance for a climate-related inventory.
- Applicability of general inventory guidance provided in Volume 1 of the 2006 IPCC Guidelines and the 2019 Refinement to the inventories of SLCFs, including, but not limited to, key category analysis, uncertainty analysis, verification, etc.
- Gaps that need to be addressed in the future work for a new Methodology Report on SLCFs.

The BOG discussions and conclusions were presented and discussed at the closing plenary. Without drawing any conclusions, their relevance for the preparation of the Methodology Report was noted and further consideration of those was observed to be desirable.

In summary, this expert meeting concluded that:

- Most Black Carbon (BC)/Organic Carbon (OC) emission estimates start with particulate matter (PM<sub>2.5</sub>), so PM information is generally available. Reporting PM<sub>2.5</sub> would improve transparency of the BC and OC estimates.
- The priority for NMVOC reporting is to report the total mass of VOC. The value of total mass can depend on the methodology used for measurement so current data is not always consistent. Semi-volatile VOCs (SVOCs) are a separate category of emissions that should not be included in NMVOC. Anthropogenic emissions of biogenic VOCs can be reported following existing definitional frameworks for reporting biogenic sources of GHGs.
- Unlike GHGs, air-pollutant SLCF emission estimates will be needed for other purposes so priority for inventory development at the country level will depend on both needs for GHG reporting and country needs for air pollution emissions data. Prioritization should be conducted by source category considering all "air pollutant SLCFs" (at this expert meeting it was classified that the relevant compounds are BC, OC, NO<sub>x</sub>, SO<sub>2</sub>, NH<sub>3</sub>, NMVOCs, CO).

- It is not recommended to use metrics to compare long-lived GHGs with short-lived air pollutant SLCFs (criteria air pollutants not including CH<sub>4</sub>, HFCs). The large difference in atmospheric lifetimes makes any such metric non-unique and unreliable. Air pollutant SLCFs can be compared to each other using forcing metrics that incorporate the multiple forcing impacts of any given emission species.
- SLCF and direct GHGs should not be combined in the Key category analysis (KCA). The KCA can be carried out in two steps: First, apply KCA quantitative approach on a pollutant-by-pollutant basis for SLCF as a first step towards improvement identification and prioritization. Then, apply health impact and radiative (non-GWPs) metrics where applicable, as a second step to support identification and prioritization of improvements. IPCC/EMEP qualitative approaches can be applied on a pollutant-by-pollutant basis for SLCF.
- SLCF information should be reported at minimum national and on an annual basis. National circumstances (e.g., regulatory activities) can influence the need for finer regional or localized emissions data along with seasonal impact. Also, the scientific community needs more accurate information on the magnitude of BC emissions and where emissions are localized to better understand the impact of these emissions on radiative forcing and human health. Application of general methods followed by additional methods are needed for higher spatial and temporal resolution due to regional implication of SLCF.
- In terms of data collection, IPCC guidelines on Approach for Data Collection is a good starting point. Guidance should be provided to address data gaps and accessibility for SLCF sources. There is no need to prescribe a long time series, for example, no need to go back to 1990. Guidance should recognize time series step change due to various factors from AP/SLCF regulations, to change to common practices.
- Atmospheric observation and satellite data can be useful in identifying gaps and hot spots to support improvement and research. However, there is limited verification usage of current atmospheric observation and satellite data currently.
- Guidance on SLCF emissions should take into consideration applicability for new SLCF inventory compilers such as of ease of implementation, data and information accessibility.
- There are differences between GHG Inventory and SLCF Inventory, especially in terms of activity data collection/availability and time dependency of SLCF emissions. Sources of SLCF emissions are inherently variable and consideration of regional and in some cases climatic factors will be important in developing representative emission factors and methodologies. Higher tiers, or more granular development of Tier 1 emission factors might therefore be needed to capture SLCF emissions accurately for some sources across all regions of the globe.
- Capacities of small/developing countries need to be considered where information and country specific data is maybe not available to accurately estimate SCLF emissions or developing emissions inventories. Sharing of information is important on types of emissions sources and on relevance of EFs that are developed.



# 1. Introduction

- **Relevant IPCC decision, and planning of preparatory work for a Methodology Report on SLCFs during IPCC AR6 cycle**

At the 49th Session (IPCC-49) held in May 2019 (in Kyoto, Japan) the IPCC approved that the TFI produces an IPCC Methodology Report on SLCFs following the Appendix A to the Principles Governing IPCC Work (Decision IPCC-XLIX-7). In Annex 1 to the decision, the approach, output and timeline, and required activities are defined as follows.

## Approach

- The preparatory work for the Methodology Report (including supporting materials and scoping) is completed as soon as possible, starting in the AR6 cycle. Followed by further methodological development in the AR7 cycle.

## Output and Timeline

- Expert meetings will produce a series of supporting materials to be published after each meeting but no later than 2022.
- These supporting materials will be used to inform the scoping of methodological work for SLCFs.
- The scoping meeting will take into consideration the work on SLCFs underway in the reports of WG I (April 2021) and WG III (July 2021).
- The outline will be presented for approval to the Panel soon after the scoping meeting.

## Required Activities

- Technical analysis work by TSU with other experts.
- 3-4 Expert meetings.
- Scoping Meeting.
- Approval of outline by the Panel.

According to Decision IPCC-XLIX-7, the TFB planned originally to have two expert meetings in 2020, for which selected the invitees and defined the main aim as to list all relevant source categories of SLCF emissions, aggregated according to inventory sectors (i.e., Energy, IPPU, AFOLU, Waste), and with the secondary aim to identify knowledge gaps in the available methodological guidance for their assessment. The meetings had focus on source categories of SLCF emissions, the first in the AFOLU and Waste sectors and the second in the Energy and IPPU sectors.

However, due to the COVID-19 pandemic TFB first decided to postpone to 2021 the expert meetings originally planned for 2020, with the aim to hold those meetings in person. Subsequently, given the persistent impossibility to hold in-person meetings, TFB decided to hold those jointly in a virtual format (online) for all sectors: Energy, IPPU, AFOLU and Waste, as the Joint 1<sup>st</sup> and 2<sup>nd</sup> Expert Meeting on SLCF (Joint Meeting).

Further, as consequence of COVID-19 pandemic IPCC decided, at session 53bis, to postpone to the next assessment cycle (AR7) the scoping approval for the SLCF Methodology Report. Thus, during the current IPCC cycle (AR6) the joint expert meeting will be followed by a third expert meeting in the year 2022 (April) with the aim to take stock of the information on SLCF provided in the WGI and WGIII contributions to AR6 and have consideration of cross-cutting issues in methodologies to estimate SLCF emissions.

- **Materials prepared to inform discussion at the 3<sup>rd</sup> Meeting on SLCFs**

To serve the work at the 3<sup>rd</sup> Expert Meeting, questionnaire feedbacks from participants were collected by TSU and elaborated in documents for each BOG (see Annex 1):

- Technical note for each BOG including participants' feedback to the questionnaire.
- Consideration for the Key Category Analysis of SLCF sources.
- Gaps list compiled from previous Expert Meetings.
- List of SLCF Categories and Species from previous Expert Meeting.
- Note on allocation issues of SLCF emissions between different sectors from previous Expert Meeting.

- **Organization of the 3<sup>rd</sup> Expert Meeting on SLCFs**

The 3<sup>rd</sup> Expert Meeting was held on 11 – 15 April 2022 virtually via ZOOM and MS Teams platforms. At the opening plenary, following the welcome address and explanation of background of the 3<sup>rd</sup> Expert Meeting by TFI Co-Chairs, presentations were delivered to inform the discussion at this meeting. After the opening plenary, the meeting split into three BOGs and held two sessions of each BOG. At the closing plenary, each of three BOG reported on its discussion and conclusions, which was followed by plenary discussion on the BOG topics. The 3<sup>rd</sup> Expert Meeting was closed by expression of appreciation by TFI Co-Chairs to all the participants and TSU. (See Agenda of the 3<sup>rd</sup> Expert Meeting in Annex 2 and List of Participants in Annex 3).

- **Outcome of the 3<sup>rd</sup> Expert Meeting on SLCFs**

Discussion and conclusions of the 3<sup>rd</sup> Expert Meeting are summarized in Chapter 2 of this meeting report. In addition, all meeting presentations and the meeting report are published on the IPCC TFI website.

## 2. Meeting discussion and conclusions

### 2.1 SLCF species (definitions and relevance)

The following experts participated in the General Inventory Issues BOG: Maria de Fatima Andrade, Bill Collins, Monica Crippa, Laura Dawidowski, Stefano Decesari, Aminata Mbow Diokhané, Detlev Helmig, Amara Holder, Yugo Kanaya, Patricia Krecl, Leonidas Ntziachristos, Kim Oanh, Naga Oshima, Xavier Querol, Steven Smith, Sophie Szopa, Toshihiko Takemura, Mohd Talib Latif, Vigdis Vestreng, Noureddine Yassaa, Xunhua Zheng.

The following TFB members participated in the General Inventory Issues BOG: Eduardo Calvo (Co-chair), Kiyoto Tanabe (Co-chair), Batouli Said Abdallah, Dominique Blain, Darío Gómez, Yasna Rojas, Rob Sturgiss.

Facilitator: Laura Dawidowski  
Rapporteur: Steven J. Smith  
TSU: Sandro Federici and Eduard Karapoghosyan

#### I. Discussion and conclusions:

The experts considered materials prepared by IPCC TFI TSU as annexed to this report. During the BOG session the expert discussion was focused on:

##### a. Confirmation of validity of SLCF species

###### Context

- ✓ Definitional issues are more complicated for some SLCFs (BC/OC/VOC) than for GHGs.
  - The EFs available to inventory developers have a variety of definitions that are not necessarily consistent. Likewise, different methods for estimating emissions do not always agree. This leads to increased uncertainty.
  - Need to be clear on the expected units for reporting.
  - Units: C for BC and OC; NO<sub>x</sub> as NO<sub>2</sub>; full mass for NMVOC; SO<sub>2</sub> as mass SO<sub>2</sub>.
- ✓ Therefore, it is important for inventory submissions to specify key aspects of the methodology used to estimate their emissions.
- ✓ Some air pollutant SLCFs have varying definitions (e.g., VOCs including condensable or not).
- ✓ Note there are potentially new SLCFs to include in the future (e.g. H<sub>2</sub>) for which there is not sufficient scientific information to quantify at present.
  - This has happened before, so this is not a problem for the process.

###### Black Carbon/Organic Carbon/PM<sub>2.5</sub>

- ✓ Reporting PM<sub>2.5</sub> would improve transparency.
  - Most BC/OC emission estimates start with PM<sub>2.5</sub>. So is generally available. Reporting PM<sub>2.5</sub> would improve transparency of the BC and OC estimates.
- ✓ BC and OC in inventory reporting should be specified as being sub-micron (e.g., BC<sub>1</sub>, OC<sub>1</sub>).
  - Current scientific inventories report BC and OC as BC<sub>1</sub>/OC<sub>1</sub> (sub-micron). This is currently standardized and is a consistent input into models.
  - For combustion sources most BC and OC are sub-micron already, so this does not imply a major change to current practices.

- Not all data sources for BC/OC (and PM) estimation are specific about size (no size resolved data). There may need to be guidance provided on how to estimate BC<sub>1</sub>/OC<sub>1</sub> from these data.
- For some sources, e.g. tire wear, however, much of the emissions are of larger sizes.
- Particles larger than 1µm will have some climatic impact but have less impact per gram for physical reasons (optics, nucleation) and shorter lifetimes. These larger particles (including PM<sub>10</sub>) can be more important on regional and local scales.
- ✓ Recommend that OC be reported.
  - Context: OC emissions are needed to evaluate the net climate impact of emissions or their reductions by source where OC fraction is high (e.g. solid biofuel emissions).
  - Context: most OC (and PM<sub>2.5</sub>) in the atmosphere is secondary (except where biomass burning regions is dominant).
  - Recommend that condensables be included in the reporting of OC.
  - Context: Emission processes are very dynamic from combustion to the point when a measurement might take place to dispersion in the atmosphere (e.g. lab vs field measurements). Condensation and evaporation can occur throughout this process. Including condensables in the definition is meant to capture some aspects of the evolution, but its not always clear what this might represent for different measurement techniques.
  - OM/OC ratios should be discussed in methodology guidance and countries should report their assumptions for OM/OC ratios in their methodology reporting. This information of OM/OC ratios will be useful for climate model calculations.
- ✓ If reported, emissions for sources that have very different physical (particle) characteristics should be reported separately.
  - E.g., report non-combustion particles (tire and break wear, road abrasion, etc.) separately from combustion particles.

#### NMVOC

- ✓ The priority for NMVOC reporting is to report the total mass of VOC.
  - Note that the value of total mass can depend on the methodology used for measurement. Not all measurement procedures capture all sub-species so current data is not always consistent. Harmonization of EF would be useful.
  - A sub-group has agreed to report back on what sub-species or species classes should be expected/prioritized to be included as part of total NMVOC. The note is provided as Appendix 1 to this Section 2.1.
- ✓ SVOCs (semi-volatile VOCs) are a separate category of emissions that should not be included in NMVOC
  - Note that there can be potential overlap with OC depending on how measured.
  - SVOCs are commonly estimated by scaling from OC inventory data.
  - Acknowledge that IVOCs (intermediate volatility VOCs) are also an active area of research – not ready for inventory yet.
- ✓ The group flagged the need for improved speciation profiles and methods as a research need and gap
  - The research community already does this by sector and region (e.g., EDGAR recently updated their VOC assumptions, ref.: Huang, G., Brook, R., Crippa, M., Janssens-Maenhout, G., Schieberle, C., Dore, C., Guizzardi, D., Muntean, M., Schaaf, E., and Friedrich, R.: Speciation of anthropogenic emissions of non-methane volatile organic compounds: a global gridded data

set for 1970–2012, Atmos. Chem. Phys., 17, 7683–7701, <https://doi.org/10.5194/acp-17-7683-2017>, 2017. EDGAR website: [https://edgar.jrc.ec.europa.eu/dataset\\_ap432\\_VOC\\_spec](https://edgar.jrc.ec.europa.eu/dataset_ap432_VOC_spec)).

- There is significant uncertainty and potential gaps in existing profile data for some sectors.
- ✓ Anthropogenic emissions of BVOCs (biogenic VOCs) can be reported following existing definitional frameworks for reporting biogenic sources of GHGs.
  - Context: Models increasingly incorporate LULUCF modules that can potentially generate consistent BVOC emissions. (May be what happens practically in scientific contexts.)
  - Context: Natural emissions as such are not included now, but natural environment is being strongly impacted and changed by anthropogenic activities.
  - Emissions from land that is significantly influenced by anthropogenic activities are included in the inventory as managed land. So could include anthropogenically influenced BVOC (land considered "managed") consistent with what is reported for GHGs.
  - Would ideally want to compare anthropogenically influenced BVOCs with that from natural vegetation in the same area.
  - Where would fire emissions go? Is an issue of active debate.
  - Note that in IPCC guidance it is up to countries to determine what is managed land.
- b. Providing a prioritization of each SLCF in emission inventory, considering the relevance in term of climate impact
  - ✓ Context: Unlike GHGs, air-pollutant SLCF emission estimates will be needed for other purposes so priority for inventory development at the country level will depend on both needs for GHG reporting and country needs for air pollution emissions data. The WG is only addressing prioritization for purposes of quantifying the impact of emissions on the climate system.
  - ✓ Note that quantitative methodologies for prioritization of air pollutant SLCFs is subject to change as: 1) local and global background conditions change into the future and 2) scientific understanding advances. (While this is true also for GHGs, such changes can be larger for some air pollutant SLCFs.)
  - ✓ Prioritization should be conducted by source category considering all air pollutant SLCFs.
- c. Common metric applicable across all GHGs and SLCFs to assess the relative importance, in terms of climate impacts.
  - ✓ Context: are considering metrics that quantify impacts on climate for purposes of prioritizing inventory development. Metrics for this use may not be appropriate for other uses.

We do not recommend using metrics to compare long-lived GHGs with short-lived air pollutant SLCFs (defined as criteria air pollutants not including CH<sub>4</sub>, HFCs).
  - ✓ The large difference in atmospheric lifetimes makes any such metric non-unique and unreliable.
  - ✓ Air pollutant SLCFs can be compared to each other using forcing metrics that incorporate the multiple forcing impacts of any given emission species.
  - ✓ There are a number of possibilities for a metric that could be used to compare air pollutant SLCFs.
    - In all cases, the BOG recommends that both positive and negative forcers be prioritized equally by using the absolute value of any metric.
    - One possible metric is to compare integrated radiative forcing from a unit emissions pulse.
    - Another proposal was to use global radiative forcing of each species (absolute value) as a weighting for prioritization (ref.: AR6 WG I Report, Figure 6.12, Table 6.SM.1).

- This can be useful for prioritization even if the comparison is uncertain (uncertainties are often factor of 2 or more). Uncertainties are larger for regional results (in part since there is limited modelling data).
  - ✓ A default global metric could be calculated for each species to use for emissions prioritization for all source regions.
  - ✓ In some cases, there is robust scientific evidence that sector (aviation, shipping) or emission region-specific metrics (Arctic, latitude) would be more appropriate to use than a global metric value.
  - ✓ Can CH<sub>4</sub> be compared to air pollutant SLCFs?
    - Context: There is no unique method for comparing different emissions forcing agents with significantly different lifetimes, but for purposes of key category analysis there is an established practice to do so for GHGs.
    - The BOG did not come to consensus on comparing air pollutant SLCFs with CH<sub>4</sub>.
- d. Assessment of constraints on instruments/monitoring-system availability and operativity that may prevent countries' capacity to prepare national emission estimate of specific SLCF species/sources.
- ✓ There is no report on this topic.

## II. Comments/Notes on the BOG report

- ✓ The experts highlighted that there was no consensus regarding the need to compare methane and air pollutant SLCF.
- ✓ Experts acknowledged that OC/BC/VOCs measurements will contain uncertainties and that they may be more salient than for GHG emissions. Experts also noted that small sources contain inherent variability which will affect any measurement results or emission factors. Even with potentially high uncertainties, the time series changes of SLCF emission levels may be observed in the country/region through improved SLCF inventories which is why this exercise is important.
- ✓ The future Methodology Report authors need to keep in mind of the balance of specificity of emission factors and the ability to collect the matching activity data, and that practical default values need to be set.

## Appendix 1 – Note on NMVOCs

Inventories usually provide estimates of bulk NMVOC emissions, which are total NMVOC by mass. These bulk emissions are then split into species (or, more commonly, species groups) using speciation profiles that are applied by sector. As there is no standard definition of what defines exactly a NMVOC (see below), it would be useful to do a survey across major country-level inventories regarding what definitions they use for bulk NMVOC and what criteria for categorization have been employed.

Because it is impractical to include all possible VOCs in chemical models, a “lumping” approach is often used where specific groups of species are treated together in the model. Indeed, as country-specific inventories of lumped NMVOC, or the output of different speciation schemes, can still comprise many classes of compounds, global models then re-group those to their internal speciation categories.

NMVOCs comprise chemical species including isoprene, terpenes, and other terpenoid biogenic emissions, formaldehyde, acetaldehyde, other aldehydes and ketones, methanol, ethanol, acetone, and other alcohols, ethane, propane, butane isomers, and other higher straight chain and branched alkanes, ethene, propene, acetylene, benzene, and other alkenes, acetylene, alkynes and higher alkyl aromatics, methyl chloride, acetonitrile, alkyl nitrates, acetic acid and other volatile carboxylic acids, etc. In air chemistry/pollution modelling studies, NMVOCs that are commonly included are those that contribute to regional ozone production (see e.g. Venecek et al (2018)) and those producing higher rates of secondary organic aerosols (SOA) (see e.g. Derwent et al., (2010)) are prioritized. That then may not include methanol, methyl chloride, acetone, etc., therefore care should be

given to understand whether the major national inventories cover only the reactive compounds or, more broadly, all volatile organic species including oxygenated and halogenated NMVOCs.

NMVOCs with high SOA formation potential include aromatic compounds, branched or cyclic unsaturated aliphatic hydrocarbons and all high-molecular weight volatile organics, such as: benzene and alkylated aromatics, benzaldehyde, higher semi-volatile alkanes, and biogenic terpenoid VOCs such as monoterpenes and sesquiterpenes (Derwent et al., (2010)).

Possible approaches for speciating and lumping the gaseous precursors of anthropogenic SOA are still matter of debate in the scientific community. Very recently, a SAPRC-based approach has been proposed for SOA precursors including high-molecular weight compounds (Manavi and Pandis, 2022), which may set the basis for a common frame of reporting the NMVOCs relevant for either ozone or SOA formation in simplified compositions. As reviewed by Huang et al. (2017) there are commonly used speciation databases for some specific regions, such as the IER database (Theloke and Friedrich 2007), for Europe and the SPECIATE database for the United States (Hsu et al., 2014). Von Schneidmesser et al. (2016) have demonstrated that variations between speciation profiles can have a significant impact on modeling results. The extent to which speciation profiles are physically distinct for specific sectors between different regions is unclear.

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Manavi, S. E. I. and Pandis, S. N.: A lumped species approach for the simulation of secondary organic aerosol production from intermediate volatility organic compounds (IVOCs): Application to road transport in PMCAMx-iv (v1.0), *Geosci. Model Dev. Discuss.* [preprint], <https://doi.org/10.5194/gmd-2022-90>, in review, 2022.

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Theloke, J. and Friedrich, R.: Compilation of a database on the composition of anthropogenic VOC emissions for atmospheric modeling in Europe, *Atmos. Environ.*, 41, 4148–4160, <https://doi.org/10.1016/j.atmosenv.2006.12.026>, 2007.

Hsu, Y., Divita, F., and Dorn, J.: SPECIATE Version 4.4 Database Development Documentation, Washington, DC, 2014.

von Schneidmesser, E., Coates, J., van der Gon, H.D., Visschedijk, A.J.H. and Butler, T.M., 2016. Variation of the NMVOC speciation in the solvent sector and the sensitivity of modelled tropospheric ozone. *Atmospheric Environment*, 135, pp.59-72

## 2.2 General Inventory Issues

The following experts participated in the General Inventory Issues BOG: Didin Agustian Permadi, Hiroko Akiyama, Tami Bond, Bofeng Cai, Paula Castesana, Richard Claxton, Qingxian Gao, Sophie Générumont, Veronika Ginzburg, Kentaro Hayashi, Francis Jeong, Guadalupe Martinez, Erin McDuffie, Rob Pinder, Enrique Puliafito, Gao Qingxian, Francisco Salazar.

The following TFB members participated in the General Inventory Issues BOG: Eduardo Calvo (Co-chair), Kiyoto Tanabe (Co-chair), Fahmuddin Agus, Fatma Betül Demirok, Dario Gomez, Riitta Pipatti, Rob Sturgiss, Thomas Wirth and Irina Yesserkepova.

Facilitator: Ole-Kenneth Nielsen  
Rapporteur: Chia Ha  
TSU: Baasansuren Jamsranjav and Valentyna Slivinska

The BOG members considered the applicability of general guidance provided in the 2006 IPCC Guidelines and its 2019 Refinement to emission inventories that includes SLCF species.

### I. Discussion

#### 1. Consideration of key category analysis (KCA).

- ✓ SLCF and direct GHGs should not be combined in the KCA
  - o due to differing objectives and usages. For example, GHG inventories – Paris Agreement
  - o primary impact differs – climate change vs health impact
  - o no common criteria
  - o will limit usability of KCA results
- a. *How quantitative approaches will be applied (see KCA note) if applicable common metric is not available for all SLCF gases?*
  - ✓ Apply KC quantitative approach on a pollutant-by-pollutant basis for SLCF as a first step towards improvement identification and prioritization – Step 1.
  - ✓ Apply health impact and radiative (non-GWPs) metrics where applicable, as a second step to support identification and prioritization of improvements – Step 2
    - o Identify appropriate dataset for use in guidance
    - o Consider regional health metrics
  - ✓ Available KC approaches
    - o IPCC and EMEP KCA guidance would be a good starting point
    - o EMEP presents an approach to rank and combine pollutants
      - must take into consideration regional and local differences
      - What regional and local criteria are needed as a minimum?
    - o Consider guidance for combining pollutants.
  - ✓ Consider EMEP threshold of 80% as compared to 95% presented in IPCC KCA guidelines
    - o Consider applicability by species, by sources and by regions
    - o Direct improvement efforts to large contributors
  - ✓ Explore facility level data to support both quantitative and qualitative analysis
    - o Facility level data should be of good quality for KCA and comparative usage across similar industry. For example, does emission estimate follow specified approaches taking into account facility specific operation, the use of Continuous Emissions Monitoring, the use of general default emission factors or a mix of approaches?
      - As a starting point for consideration of facility data usage and its quality, refer to the 2019 IPCC, Volume 1, Section 2.3 Use of Facility Data in Inventories. Reference:



- b. *Should a qualitative criterion be applied as provided in the KCA note or should it be revised or new one be added?*
- ✓ Apply IPCC/EMEP qualitative approaches on a pollutant-by-pollutant basis for SLCF.
  - ✓ General overview text of KCA should also discuss qualitative options as additional guidance for identification and prioritization of improvements (by source and pollutant).
    - o Consider additional approaches and guidance on how to identify and prioritize what is key
      - Health, environmental, air quality impact along with other metrics should be consider.
      - National circumstances on AP/SLCF may impact improvement prioritization
      - Use mathematical tools for ranking/prioritization rather than policy measures
  - ✓ Identification of additional information sources to support qualitative analysis, such as:
    - o impact of mitigation techniques and abatement technologies, with implication on time series
    - o other factors that contribute to growth or decline in emissions, for example: pollution regulation, supply and demand changes, change in operational and management practices, etc.
    - o non-quantitative uncertainty criteria
    - o proxy dataset from other regions/countries
  - ✓ Keep in mind regional factors and differences when comparing proxy dataset such as abatement technologies and regulations, across emission sources (industry, non-industry (transport, residential, agriculture etc.) and across regions.
  - ✓ Consider guidance on how best to allocate financial resource across pollutant and category.

## 2. Consideration of approaches to data collection and time series consistency.

The experts considered materials prepared by IPCC TFI TSU as annexed to this report. During the BOG session, the expert discussion was focused on:

- a. *How to address finer temporal and spatial distribution?*
- ✓ Annual GHG inventories normally presented at the national level.
  - ✓ SLCF information should at minimum be national and on an annual basis.
    - o National circumstances can influence the need for finer regional or localize emissions data along with seasonal impact (i.e., increase agricultural activities during summer months)
  - ✓ Start with general methods follow by additional methods for higher spatial and temporal resolution due to regional implication of SLCF.
    - o Area and line sources need more consideration compare to point sources
      - Consider proxy data for spatial distribution
      - A common basis (i.e. 0.1 or 0.5 degree) for modelling purposes
    - o Consult with end-users prior to developing guidance
      - Guidance to support inventory development, keeping in mind end-users' needs where applicable
    - o Consult with IPCC scientists and modellers to assess what level of detail would suffice for temporal and spatial distribution
      - Noting that SLCF at point of release by species will differ from atmospheric concentration
    - o Consider Tier 1 approach for spatial allocation – refer to survey feedback on spatial approach suggestions
      - Spatial distribution presented in EMEP guidebook may be consider for use in developing a Tier 1 spatial guideline
      - New guidance should focus on ease of use and applicability for those that are new to SLCF inventory compilation with limited detail data as compare to well established inventories

- Advice on Tier 2 and Tier 3 spatial resolution while recognizing that there will be differences across countries for similar sector due to national circumstances
          - Combine top-down bottom-up approach – hyper approach, if applicable
  - ✓ Temporal distribution guidance should at minimum be annually.
    - o Provide general guidance –with achievable temporal resolution method
      - Start with a simple approach for country with limited dataset
    - o Consider monthly temporal distribution when proxy dataset is available
      - In addition, some species of SLCF may need to be on a monthly depending on their impact, for example winter months for BC and summer months for NO<sub>x</sub> along with other seasonal implication like wet and dry seasons for agricultural sources
      - Monthly data would be of use for modellers
- b. *What are the implications in terms of good practice for data collection?*
  - ✓ Provide general data quality guidance
    - o Consider minimum quality requirement
    - o IPCC guidelines on Approach for Data Collection is a good starting point
      - Also, for facility level data, consider quality criteria presented in Section 2.3 Use of Facility Data in Inventories from the 2019 IPCC Refinement for the collection and use of point source or facility data.
  - ✓ Provide guidance to address data gaps and accessibility for SLCF sources
    - o Example of data gaps and challenges range from lack of information on abatement technology such as low NO<sub>x</sub> and desulphurisation technology to common country practices such as land management and cooking fuels.
    - o Consider use of proxy data
  - ✓ Provide general data collection and direct measurement methods for point source data.
  - ✓ Consider the need for additional guidelines to ensure quality of surface, point source (stack) and road measurement results and its potential for comparison purposes or to identify further improvements.
- c. *What are the implications on time series consistency?*
  - ✓ 2006 IPCC and 2019 Refinement guidelines on Time Series Consistency are applicable
  - ✓ No need to prescribe a long time series. For example, will not require SLCF inventory back to 1990
  - ✓ Guidance should recognize time series step change due to various factors from AP/SLCF regulations (i.e., vehicle emission abatement technologies), to change to common practices (i.e., industrial process, cooking fuel, land management, etc.)

### 3. Use of in situ and remote sensing data to inform SLCF inventory development and verification

- a. *Should verification with atmospheric observation data be further promoted?*
  - ✓ Recognise limited verification usage of current atmospheric observation and satellite data
    - o Due mainly to the nature of SLCFs – There can be uncertainty in the relationship between air concentration and emissions due to variability in atmospheric mixing, chemical reactions, and removal by dry deposition.
    - o High uncertainty associated with atmospheric and satellite information at this time
  - ✓ Atmospheric and satellite data can be useful to:
    - o Identify gaps and large sources/hot spots
    - o Identify and support additional activity data collection
  - ✓ Guidelines on atmospheric concentration is outside the scope of work for SLCF inventories
    - o New guidance should note that inventory base SCLF emissions/releases are not comparable to atmospheric concentration. Atmospheric concentrations of SLCF are influenced by atmospheric conditions such as seasonal weather changes, temperature, wind speed, mixing, location, etc.
      - . Concentrations are the relevant metric for air quality monitoring and regulation, and are not the responsibility of this emissions work group

b. *Is there any regional/global independent monitoring system/dataset to be suggested for verification of SLCF emissions?*

- ✓ Verification through direct measurement
  - o consider guideline for in-situ measurement and correlation methods for comparison purposes
- ✓ Compare with other independent data sources (examples – local and regional research findings)
- ✓ Consider the use of global inventory/databases for biomass burning for certain countries (local and regional research)
  - o Take note that global inventories such as EDGAR and CEDS and existing research emission inventories at the regional or county level may be used as a starting point for comparison purposes only, not for verification purposes. Noting that inventory improvements contribute to refinement of some global inventories. In addition, it may take a few years for global inventories to reflect national inventories' improvements in their dataset.

## II. Conclusions

During the BOG sessions, the experts concluded on how general guidance provided in the 2006 IPCC Guidelines and its 2019 Refinement can be applied to emission inventories that includes SLCF species:

### 1. Key category analysis (KCA)

- ✓ SLCF and direct GHGs should not be combined
- ✓ SLCF should be on a pollutant-by-pollutant basis and in mass unit
- ✓ Apply at minimum a two-step KCA process to help with improvement prioritisation of SCLF species
  - o Step 1: Mass unit analysis (quantitative analysis)
  - o Step 2: Health impact and radiative forcing metrics
- ✓ Include in general overview discussion, guidance on the use of qualitative analysis options as an additional step to help identify and prioritize areas of improvements

### 2. Approaches to data collection and time series consistency

- ✓ SLCF information should at minimum be national and on an annual basis
  - o National circumstances may require finer temporal and spatial distribution.
- ✓ Consult with IPCC scientists and modellers to determine relevant level of detail of SLCF data relating to spatial and temporal resolution
- ✓ Consider tiered approach for spatial allocation taking into account that Tier 1 should be applicable to all countries
- ✓ Provide general data quality guidance, data collection and use of proxy data
  - o Chapter 2 Approach to Data Collection from Volume 1 of the 2019 IPCC Refinement is a good starting point
- ✓ No need for SLCF inventory to have a long timeline (i.e., back to 1990). The lack of availability of consistent activity data can make estimating SLCF emissions with a consistent method back to 1990 both uncertain and burdensome, and so other methods, rather than requiring national reporting, may still be needed to estimate emission trajectories for earlier years (this may be needed from the perspective of scientists trying to quantify the trends in regional radiative forcing).
- ✓ Recognise the impact of AP/SLCF regulations and country specific practices on emission trends and time series consistency guidelines

### 3. Verification

- ✓ Recognise limited verification usage of current atmospheric observation and satellite data
- ✓ Atmospheric observation and satellite data can be useful in identifying gaps and hot spots to support improvement and research

### 4. Additional elements for consideration

- ✓ New guidance should take into consideration applicability for new SLCF inventory compilers such as of ease of implementation, data and information accessibility (i.e., activity data, proxy data, AP release regulation and management)

- ✓ Challenge comparing SLCF-AP across inventories
- ✓ Identification of SLCF from all sources is a challenge
- ✓ AP-SLCF higher uncertainty relative to GHGs
- ✓ General guidelines present in the 2006 and 2019 IPCC documents for GHGs on; Approaches to Data Collection, Time Series Consistency, Comparison with atmospheric measurement (covered in QA/QC and Verification chapter) are available for consideration as to their applicability for SCLF guideline development.

### **III. Comments/Notes on the BOG report**

- ✓ Continuous emission monitoring systems (CEMS) are observational data but are not included in conclusion regarding verification with atmospheric observation data.
- ✓ Experts noted that global inventories have a time lag and may not necessarily reflect national assumptions (use global default).
- ✓ Experts noted that SLCP are defined as short-lived components that have positive radiative forcing (methane, black carbon, tropospheric ozone, hydrofluorocarbons). Experts noted that compounds that have cooling effects should be reported also to evaluate the net forcing effect.
- ✓ Stepwise air quality regulations may have a more pronounced impact on the level of SCLF emissions compared to GHG emissions.
- ✓ National air pollutant inventories not necessarily coordinated with the GHG inventory reporting or consistent with results submitted to the UNFCCC due to multiple reporting requirements and different institutional arrangements.

## 2.3 List of data gaps and List of SLCF categories

The following experts participated in the List of data gaps and List of SLCF categories BOG: Tami Bond, Bofeng Cai, Eduardo Calvo, Vincent Camobreco, Premakumara Dickella Gamaralalage, Amit Garg, Savitri Garivait, Francis Jeong, Julia Drewer, Sergey Kakareka, Puji Lestari, Doug MacDonald, Meimalin Moreno, Kim Oanh Nguyen, Omkar Patange, Cecilia Penengo, Mohd Talib Latif, Vigdis Vestreng, Damian Zasina.

The following TFB members participated in the List of data gaps and List of SLCF categories BOG: Kiyoto Tanabe (Co-chair), Darío Gómez, Rob Sturgiss, Irina Yesserkepova

Facilitator: Amit Garg  
Rapporteurs: Julia Drewer and Savitri Garivait  
TSU: Pavel Shermanau and Takeshi Enoki

### I. Background

As outcome of the Joint 1st and 2nd IPCC Expert Meeting, sectoral BOGs developed the list of data gaps and the list of SLCF categories. The list of data gaps has been further complemented with those gaps identified at the IPCC meeting on SLCFs held in Geneva in 2018. Although the list of data gaps does not necessarily detail each source's gaps, as it highlights the major areas, it aims at identifying the lack of data or methodological information that may prevent the development a robust Tier 1 methodological approach for the relevant source category and associated SLCF species.

Lists should be assessed with the view that those may be used for preparation to the scoping meeting of a new Methodology report on SLCFs.

### II. Discussion

BOG considered the list of data gaps and discussed the following:

- ✓ The elements of a Tier methodology need to be reconsidered. Sometimes simple regional Tier 1 is not sufficient or might have to be more specific, considering more variables than GHGs. For some sources (e.g., combustion emissions) there are parallels with developing SLCF Tier 1 EFs with non-CO2 GHG emissions, for example technology and industry specific EFs. However, there are some sources where the Tier 1 approach might not be sufficient to capture the differences in SLCF emissions due to temporal, spatial and technology dependent factors. For example, it is difficult to capture mobile source SLCF emissions with a Tier 1 methodology, see Table 1 created as part of the 1st and 2nd Expert Meetings for more details on each source category.
- ✓ There are data gaps for specific regions/countries and/or knowledge gaps in terms of calculations of EF. For example, existing SLCF methodologies (EMEP/AP-42) don't cover a lot of smaller source categories that could be important in developing countries.
- ✓ In developing Tier 1 EFs it will be important to understand if they include controlled technologies/abatement. For example, brickworks can range from facilities with inefficient and highly polluting technologies to modern plants with appropriate emission control. The Tier 1 method should be able to reflect the wide variety of emissions associated with the different manufacturing technologies and emission abatement systems or explain what is included.
- ✓ Uncertainty in SLCFs is high, making more regional or technology specific EFs important to develop. Methodology might become complex and care will be required to assure that Tier 1 and 2 emission factors are consistent with reasonable expectations of data availability.
- ✓ In developing countries (e.g. in Asia, Africa), the small industries and small combustion sources can contribute large amount of SLCF. These sources will need higher tier EFs to quantify emissions.
- ✓ Dust is a large source of uncertainty. We need to focus on BC/OC content of the dust.

- ✓ Gaps on VOCs and speciation from manure, size/magnitude of the source uncertain due to data paucity, for VOCs from pesticides there is complexity of carrying out calculations to estimate emissions at a global scale.
- ✓ Burning. Wildfires occur as a part on natural ecological cycles in many regions of the globe and focus should be on anthropogenic emissions. Emissions from open biomass burning are highly dependent on climatic conditions as well as the land use and land management objective of the action. Emission factors should consider burn intensity associated with specific types of burning. EF for crop residue open burning depends very much on the burning practice. The EF of PM<sub>2.5</sub> from rice straw spread burning (after combine harvester) is about 1/3 of that of the pile burning (after the manual harvesting). Pile burning versus broadcast burning or prescribed burning for fuel control in forestry applications may have very different emission profiles.
- ✓ Burning of manure to be allocated to in Energy not AFOLU – allocation should be clear in methodological development, considering objectives of combustion. Manure used to produce energy should be covered by the Energy sector
- ✓ Transfers of products of biological treatment of Waste can occur between various sources and allocations should be carefully documented in methodological development. For example, waste may be transferred to agricultural locations or manure transferred to waste treatment and then the treated waste returned to agricultural fields. Clarity in the allocation of emissions will be required. Activity data should be developed to track both biomass and N in feedstock (NH<sub>3</sub>) and manure recognizing that data will be limited on these transfers.

#### Discussion of priorities in the list of data gaps

##### **Potentially Large Sources with Limited Data**

- ✓ Small scale stationary combustion sources (e.g., small industries, cookstoves, etc.) are not well represented in existing SLCF methodologies and there is a lack of information on collection of AD and EFs.
- ✓ Transport off-road combustion encompasses a wide variety of off-road vehicles and other machinery used across the different combustion categories and the methodology for SLCFs should contemplate and be consistent with the widespread distribution of off-road combustion. The emissions of SLCFs are highly dependent on the type of equipment and technology and guidance on the collection and/or estimation of AD is required as this may constitute the main challenge in estimating these emissions.

##### **New Sources**

- ✓ There is limited data on SLCF emissions from existing non-traditional fuels (e.g., quality, type, and moisture content of solid fuels may have a large effect on emission factors). There could also be more use of non-traditional fuels in the future (e.g., biomass, waste, hydrogen) that warrant further research.

##### **Missing data**

- ✓ Availability of BC and OC EFs across all sectors and regions.
- ✓ Solvents AD (various sources of emissions, activity data is difficult to collect).
- ✓ Differentiation of technologies and EFs in all sectors.

##### **Allocation/uncertainties**

- ✓ Burning in AFOLU, waste in general – high uncertainties and challenges in allocation to the correct source as a result of complex and poorly documented transfers between waste, agriculture and uses of feedstocks for energy.
- ✓ Manure management – emissions factors are uncertain and data collection is challenging in the case of VOCs and speciation from manure, size/magnitude of the source is uncertain due to data paucity. same for VOCs from pesticides.

### Discussion of the list of categories

Categories list is reviewed by experts and considered to reflect the current status of SLCF sources and species, future authors of a new Methodology report on SLCFs will analyse literature for a particular category and SLCF species in terms of evaluating methods and available EFs. Other considerations:

- ✓ The treatment of memo items – bunker fuels, were not specifically discussed in the list of categories. Would treatment of memo items for SLCFs follow the same guidelines as for GHG emission inventories?
- ✓ The SLCF methodology should account for future transitions: electric vehicles, biofuels, hydrogen, waste that may become more important categories in the future.
- ✓ Shale gas and coal fires (they can be included in Gas production and Coal production categories, subcategorization can be considered due to unique properties of emissions).

### Discussion of the list of allocation issues

- ✓ Do we need a different allocation for SLCFs? How to measure and allocate SLCFs on a stack which may include process and energy emissions? The type of measurement approach used to develop emission factors should be considered in the allocation approach.
- ✓ Control technologies allocation which can include process and energy emissions. If Tier 1 factors are developed for industries that have combustion (Energy) and process (IPPU) emissions in terms of product output, it will be important to understand allocation and double counting issues, e.g., if all reported under IPPU the need to subtract some emissions from energy.
- ✓ Can we use the Decision tree type approach for allocation?
- ✓ Temporal variability needs to be considered.
- ✓ Ammonia production and Iron and Steel production are important categories in terms of allocation issues
- ✓ Recycling of waste to produce products – nature of emissions and allocation.
- ✓ Dust sources of emissions (which include BC/OC), accounting, mitigation technologies.
- ✓ Pellet production.
- ✓ Energy balance may not capture all small sources of different fuels/wastes/bio-sources. Many solid fuels are collected rather than marketed and estimates of activity data would benefit from diverse inputs. There are issues concerning the reconciliation of AD with the energy balance.
- ✓ Informal combustion in Energy and Waste may be challenging to monitor.
- ✓ The allocation of the emissions in the production of biogas will be challenging to monitor due to the lack of tracking of the movement and quantities of feedstocks.
- ✓ Waste, Manure AFOLU, Energy sector - circular nature needs to be considered, good description needed to identify pathways for waste and agricultural products, international movement (cross border, e.g. Drax importing woodchips from wood exporting countries). Avoiding of double counting will be important.

Some references to SLCF inventories or local pollutant data:

- ✓ USA <https://archive.epa.gov/emap/archive-emap/web/html/index-37.html>
- ✓ EU <https://www.eea.europa.eu/themes/air/explore-air-pollution-data>
- ✓ China  
[https://dataverse.harvard.edu/dataverse/cga\\_aqi;jsessionid=ea21ddabee064bf1cbdc54056de1?q=&types=datasets&sort=dateSort&order=desc&page=1](https://dataverse.harvard.edu/dataverse/cga_aqi;jsessionid=ea21ddabee064bf1cbdc54056de1?q=&types=datasets&sort=dateSort&order=desc&page=1)
- ✓ India <https://cpcb.nic.in/namp-data/>
- ✓ Japan <https://www.iqair.com/us/japan>

### **III. Conclusions**

- ✓ There are differences between GHG Inventory and SLCF Inventory, especially in terms of activity data collection/availability and time dependency of SLCF emissions.

- ✓ Sources of SLCF emissions are inherently variable and consideration of regional and in some cases technological and climatic factors will be important in developing representative emission factors and methodologies.
- ✓ Higher tiers, or more granular development of Tier 1 emission factors might therefore be needed to capture SLCF emissions accurately for some sources across all regions of the globe.
- ✓ Capacities of small/developing countries need to be considered where information and country specific data is maybe not available to accurately estimate SCLF emissions or developing emission inventory.
- ✓ Sharing of information is important on types of emissions sources and on relevance of EFs that are developed.

#### **IV. Comments/Notes on the BOG report**

- ✓ Future authors of the Methodological Report should keep in mind that the capabilities of countries are different. Also, GHG inventory preparation knowhow may not necessarily be transferred to SLCF inventory work, with will add to the challenge especially in developing countries. Regional technical cooperation is desirable to further science and inventory work.



## Annex 1: Materials for the Meeting

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### Note for BOG1 <SLCF species> (including participants' feedback to the questionnaire)

BOG1 is asked to provide clarification on SLCF species definitions and relevance<sup>1</sup> for a climate-related inventory. A joint TFI and WGI IPCC Expert Meeting held in Geneva in 2018 concluded that SLCF species to focus in a national emission inventory are:

- Aerosols:
  - ✓ Black Carbon (BC, also as fraction of  $PM_{2.5}$ ),
  - ✓ Organic Carbon (OC, also as fraction of  $PM_{2.5}$ )
- Precursors (ozone precursors and aerosol precursors):
  - ✓  $NO_x$
  - ✓ CO
  - ✓ NMVOC (including BVOC)
  - ✓  $SO_2$
  - ✓  $NH_3$

With reference to the above list, could expert:

- a. Confirm its validity?
- b. Provide for a prioritization in an emission inventory, considering the relevance, in term of climate impact, of each SLCF species?

Further, the key category analysis is a fundamental element of an emission inventory that allows inventory compilers to efficiently use available resources as well as to evaluate the quality of estimates prepared for each source category with reference to the significance of each of those sources. To do so, the good practice established in the 2006 IPCC Guidelines uses a common metric to allow to “weight” the contribution of every and each source and associated GHG. The Geneva’s meeting on SLCFs concluded that SLCF emissions should not be converted into  $CO_2$  equivalent based on GWP100 (as currently done for GHGs), thus:

- c. Is there a common metric applicable across all GHGs and SLCFs to assess the relative importance, in terms of climate impacts, of each and every GHG/SLCF source and of  $CO_2$  sinks within a national total of emissions?

Considering single SLCF species emission from single sources, the availability of operational methods and instruments to measure/scale SLCF emissions may impact the practicability to derive a national annual estimate.

- d. Could experts assess if for any of the SLCF species listed above constrains in instruments/monitoring-system availability and operativity may prevent countries’ capacity to prepare national emission estimate unless a disproportionate<sup>2</sup> amount of resources is to be applied?

Hereafter information provided by experts through the questionnaire on species definitions, and on measurement methods for those species for which the necessity of further consideration was found by the participants in the Joint 1<sup>st</sup> and 2<sup>nd</sup> Expert Meeting on Short-lived Climate Forcers (SLCF) held virtually in October 2021 (Joint Meeting) has been compiled.

Original information submitted by experts is provided below.

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<sup>1</sup> Where the relevance is defined by the combination of climate impact of the SLCF species and the practicability of its inventorying

<sup>2</sup> With reference to the climate impact of the SLCF emission assessed

Compilation of Information received from participants

<b>Organic Aerosol (OA)</b>	
<p>Atmospheric organic aerosols (OA) are either directly emitted from biogenic and anthropogenic sources (e.g., fossil fuel combustion, biomass burning, and industrial processes) or formed in the atmosphere (secondary organic aerosol, SOA) by condensation and heterogeneous and homogeneous reactions<sup>34</sup>.</p> <p>OA measurement methods exist, although not yet comprehensively used across all source categories</p>	
<u>1. Definition:</u>	“Total mass of organic species including hydrogen and oxygen” in unit of air volume
<u>2. Measurement methods:</u>	<p>Aerosol Mass Spectrometers (AMS), is the most commonly applied method</p> <p>Among AMSs, the aerosol chemical speciation monitor (ACSM) represents the most suitable application for monitoring, although instruments with a 2.5 µm were let available only recently</p> <p>OC/EC analysers</p> <p>PM speciation profiles can be used to estimate OA for emission sources</p> <p>Research OA measurement methods exist, but not comprehensively used across all source categories.</p>
<u>Reference/Source:</u>	<p>1. IPCC AR6 WG1 Chapter 6  <a href="https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_06.pdf">https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_06.pdf</a></p> <p>In Europe, ACTRIS (<a href="https://www.actris.eu/">https://www.actris.eu/</a>) provides intercomparisons of ACSM systems on a routine basis</p> <p>COST Action CA16109 Chemical On-Line cOmpoSition and Source Apportionment of fine aerosol, COLOSSAL - <a href="https://www.costcolossal.eu/">https://www.costcolossal.eu/</a></p> <p>An et al. 2021 <a href="https://www.sciencedirect.com/science/article/pii/S2666911021000010">https://www.sciencedirect.com/science/article/pii/S2666911021000010</a></p> <p>Freney et al. 2019  <a href="https://www.tandfonline.com/doi/full/10.1080/02786826.2019.1608901">https://www.tandfonline.com/doi/full/10.1080/02786826.2019.1608901</a></p> <p>Cain et al. 2017 <a href="https://amt.copernicus.org/articles/10/4865/2017/">https://amt.copernicus.org/articles/10/4865/2017/</a></p> <p>May et al. 2014 <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014JD021848">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014JD021848</a></p> <p>Dallmann et al. 2014 <a href="https://acp.copernicus.org/articles/14/7585/2014/acp-14-7585-2014.pdf">https://acp.copernicus.org/articles/14/7585/2014/acp-14-7585-2014.pdf</a></p> <p>Heringa et al. 2011 <a href="https://acp.copernicus.org/articles/11/5945/2011/acp-11-5945-2011.pdf">https://acp.copernicus.org/articles/11/5945/2011/acp-11-5945-2011.pdf</a></p> <p>Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a></p> <p>Jimenez et al. 2009 <a href="https://www.science.org/doi/10.1126/science.1180353">https://www.science.org/doi/10.1126/science.1180353</a></p> <p>Zhang et al. 2007 <a href="https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2007GL029979">https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2007GL029979</a></p> <p>Murphy et al. 2006 <a href="https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JD007340">https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2006JD007340</a></p> <p>Kanakidou et al. 2005 <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a></p>

<sup>3</sup> Jimenez et al. (2009). DOI: 10.1126/science.1180353

<sup>4</sup> Cain et al. (2017). DOI: 10.5194/amt-10-4865-2017

<b>Primary Organic Aerosols (POA)</b>	
<p>Primary organic aerosols (POA) is the fraction of Organic Aerosol directly emitted from a source in the air -in particulate form or condensed into the particle phase- without undergoing chemical reactions in the atmosphere. POAs are emitted by processes such as combustion, spray, erosion of biological/soil material. Measurement approaches are challenged by the fact that apparently POA has not a purely conservative behaviour in the atmosphere since evaporation of SVOC take place upon dilution of the emission in the atmosphere; consequently, emission factors must be accurately documented for the conditions in which they were estimated.</p>	
<u>1. Definition:</u>	Primary organic aerosols (POA) is the fraction of Organic Aerosol directly emitted from a source in the air -in particulate form or condensed into the particle phase- without undergoing chemical reactions in the atmosphere.
<u>2. Measurement methods:</u>	<p>In laboratory, combustion facilities provide comprehensive information about the emission factors of POA by varying combustion conditions and fuel type through measurements at stack or at the pipe.</p> <p>In the field, measurements taken in proximity of combustion sources such as prescribed fires and agricultural fires using both ground-based and airborne instrumental platforms have provided large datasets on POA emissions factors.</p> <p>Aerosol mass spectrometry (AMS), similar with SOA and OM</p> <p>Aerodyne aerosol mass spectrometer</p> <p>PM speciation profiles can be used to estimate POA for emission sources</p>
<u>Reference/Source:</u>	<p>de Gouw et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es9006004">https://pubs.acs.org/doi/pdf/10.1021/es9006004</a>.</p> <p>Kanakidou et al. 2005 <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a></p> <p>Bhattu D. (2018) Primary Organic Aerosols. <a href="https://doi.org/10.1007/978-981-10-7185-0_7">https://doi.org/10.1007/978-981-10-7185-0_7</a></p> <p>Jathar et al. (2020). DOI: 10.1016/j.atmosenv.2019.117221</p> <p>Seinfeld, J. H. and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley</p> <p>Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a></p> <p>Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a></p>

<b>Secondary Organic Aerosols (SOA)</b>	
<p>Secondary organic aerosols (SOA) originate in the atmosphere through oxidative or acid/base reactions. Condensation of volatile and semi-volatiles organic compounds, either of biogenic or anthropogenic origin or through nucleation, at low temperatures (or/and high relative humidity) is also commonly considered a source of SOA.</p> <p>SOA formation is normally tested and simulated in reaction chambers. Formation yields are expressed as mass of SOA formed per mass of gaseous precursors that has reacted, given SOA yields are a function of precursor concentrations and the level and type of oxidant. For some precursors (e.g. isoprene), the composition of the aerosol onto which SOA condenses is also key, and probably important – though not well studied – for all SOA systems.</p>	
<u>1. Definition:</u>	<p>Secondary organic aerosols (SOA) is the fraction of organic aerosol formed in the atmosphere by conversion of organic gases into particulate material through chemical-physical processing.</p> <p>Secondary organic aerosols (SOA) is the organic aerosol that is produced in the atmosphere from the chemical reaction and condensation of volatile organic compounds (Black Carbon Report to Congress, 2012).</p>
<u>2. Measurement methods:</u>	<p>In Europe, the EUROCHAMP network provides standards and guidelines for performing reaction chamber experiments for SOA studies.</p> <p>In the field, SOA can be estimated using aerosol mass spectrometers (AMS).</p> <p>Indirect methods: Quantifying total secondary organic aerosols as the difference between the measured total OA and estimated POA.</p> <p>Off-line high complexity secondary organic aerosols measurements, e.g., gas chromatography/mass spectrometry (GC/MS), liquid chromatography/MS (LC/MS), nuclear magnetic resonance (NMR) and Fourier transform infrared (FTIR) spectroscopy, Smog chamber experiments, Potential Aerosol Mass (PAM) reactor, Aerodyne aerosol mass spectrometer</p> <p>On-line techniques (e.g., aerosol mass spectrometry, AMS)</p> <p>Tracer or positive matrix factorization (PMF) methodologies along with speciated OA measurements</p>
<u>Reference/Source:</u>	<p><a href="https://www.eurochamp.org/">https://www.eurochamp.org/</a></p> <p>Al-Naiema et al. 2018 <a href="https://acp.copernicus.org/articles/18/15601/2018/">https://acp.copernicus.org/articles/18/15601/2018/</a></p> <p>Black Carbon Report to Congress, 2012</p> <p><a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a></p> <p>Chow et al. 1994</p> <p><a href="https://www.sciencedirect.com/science/article/abs/pii/S135223109490474X?via%3Dihub">https://www.sciencedirect.com/science/article/abs/pii/S135223109490474X?via%3Dihub</a></p> <p>de Gouw et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es9006004">https://pubs.acs.org/doi/pdf/10.1021/es9006004</a></p> <p>Hallquist et al. 2009 <a href="http://www.atmos-chem-phys.net/9/5155/2009/">www.atmos-chem-phys.net/9/5155/2009/</a></p> <p>Hayes et al. 2013 <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50530">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50530</a></p> <p>Kostenidou et al. 2009 <a href="https://pubs.acs.org/doi/10.1021/es803676g">https://pubs.acs.org/doi/10.1021/es803676g</a></p> <p>Kanakidou et al. 2005 <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a></p> <p>Seinfeld, J. H. and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley</p> <p>Stewart et al., 2021 <a href="https://acp.copernicus.org/articles/21/2383/2021/">https://acp.copernicus.org/articles/21/2383/2021/</a></p> <p>Srivastava et al. 2021</p> <p><a href="https://www.sciencedirect.com/science/article/abs/pii/S0048969720366985?via%3Dihub">https://www.sciencedirect.com/science/article/abs/pii/S0048969720366985?via%3Dihub</a></p> <p>Turpin et al. 1995</p> <p><a href="https://www.sciencedirect.com/science/article/abs/pii/S135223109400276Q">https://www.sciencedirect.com/science/article/abs/pii/S135223109400276Q</a></p>

<b>Organic Material (OM)</b>	
Organic Material or Organic Matter is a synonym of Organic Aerosol Organic material (OM) is defined in modern chemistry as carbon-based compounds, originally derived from living organisms but now including lab-synthesized versions as well, of which most are combinations of a few of the lightest elements, particularly hydrogen, carbon, nitrogen, and oxygen.	
<u>1. Definition:</u>	Total mass of organic material (Black Carbon Report to Congress, 2012). Organic material includes organic carbon and associated hydrogen and oxygen <sup>5</sup> . The calculation or measurement method for organic material may include the contribution from organic nitrogen and sulfur <sup>6</sup> .
<u>2. Measurement methods:</u>	On-line techniques Aerosol Mass Spectrometers Off-line high complexity techniques air and filter analysis e.g. through Gas Chromatography/Mass Spectrometry (GC/MS), liquid chromatography/MS (LC/MS), nuclear magnetic resonance (NMR) and Fourier transform infrared (FTIR) spectroscopy, which provide detailed information on individual chemical species or functional groups in secondary organic aerosols but generally require large amounts of samples, resulting in low time resolution (hours to days) and low size resolution
<u>Reference/Source:</u>	IPCC AR6 WG1 Chapter 6 <a href="https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_06.pdf">https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_06.pdf</a> Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a> Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a> Aiken et al. 2008 <a href="https://pubs.acs.org/doi/10.1021/es703009q">https://pubs.acs.org/doi/10.1021/es703009q</a> Hallquist et al. 2009 <a href="http://www.atmos-chem-phys.net/9/5155/2009/">www.atmos-chem-phys.net/9/5155/2009/</a> Turpin et al. 2001 <a href="https://doi.org/10.1080/02786820119445">https://doi.org/10.1080/02786820119445</a>

<sup>5</sup> Reff et al. 2009 <https://pubs.acs.org/doi/pdf/10.1021/es802930x>

<sup>6</sup> Reff et al. 2009 <https://pubs.acs.org/doi/pdf/10.1021/es802930x>  
Aiken et al. 2008 <https://pubs.acs.org/doi/10.1021/es703009q>

## Organic Carbon

Two significantly different definitions have been provided:

- A broad definition of Organic Carbon (OC) in the atmosphere includes hydrocarbons, oxygenated or halogenated compounds and multifunctional compounds, as well as particulate matter i.e. the carbon found in any organic compound (which are generally considered to be any chemical compounds that contain carbon-hydrogen bond). An immediate consequence of such a broad definition is that CH<sub>4</sub> is then OC. Consequently, in atmospheric chemistry OC is often separated, between CH<sub>4</sub> and other Atmospheric Organic Carbon (AOC) excluding methane.

- The carbon mass fraction of Organic Aerosol

### 1. Definition:

- Mix of compounds containing carbon bound with other elements (e.g. hydrogen or oxygen). This can include primary organic carbon formed from incomplete combustion or secondary organic carbon formed in the atmosphere (Black Carbon Report to Congress, 2012).  
- The carbon mass fraction of Organic Aerosol

### 2. Measurement methods:

It is determined using thermal-optical methods (TOT), hence from a measurement of total carbon (TC) in multiple steps of temperature and oxygen level allowing to differentiate (EC/OC analysers) between elemental carbon (EC, proxy for black carbon) and organic carbon (OC). The methodology is sensitive to chemical composition, the amount of BC in the samples and the method applied to account for BC<sup>7</sup>.

OC can be measured through solvent extraction from quartz filters<sup>6</sup> followed by combustion, b. Continuous temperature ramping in inert pure helium atmosphere and oxidising to CO<sub>2</sub> using a catalyst (e.g., MnO<sub>2</sub>), c. measuring by either CO<sub>2</sub> analyzer or by flame ionization detector (FID) after reducing to CH<sub>4</sub>]

OC emissions can be sampled on quartz filters<sup>8</sup> and analyzed using thermal optical analysis. Varying temperature protocols may be used, but the most common are the NIOSH 5040 protocol or the IMPROVE-A protocol<sup>9</sup>.

Chemical speciation ambient monitoring stations (see PM<sub>2.5</sub> speciation below for more information) measure OC using an IMPROVE protocol specifying the temperature ramp and a TOR method to account for BC (SOP #402).

### Reference/Source:

IPCC AR6 WG1 Chapter 6  
[https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC\\_AR6\\_WGI\\_Chapter\\_06.pdf](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_06.pdf)  
Karanasiou et al. 2015 <https://amt.copernicus.org/preprints/amt-2015-217/>  
Bond et al. 2013 <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171>  
Chow et al 2004 <https://pubs.acs.org/doi/10.1021/es034936u>  
Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley  
Black Carbon Report to Congress, 2012  
<https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf>  
Khan et al. 2012 <https://www.tandfonline.com/doi/full/10.1080/02786826.2011.609194>  
University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer [https://www.epa.gov/sites/default/files/2019-11/documents/ucd\\_sop402\\_tor\\_carbon\\_analysis\\_final\\_srsedit.pdf](https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf)

<sup>7</sup> It may be accounted for with a laser measurement of filter transmittance (TOT) or reflectance (TOR) during the temperature ramp

<sup>8</sup> From WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations: "Quartz fiber filters should be used for organic carbon measurements. The currently accepted analytical method for organic carbon is thermal desorption and evolution that requires such a specific filter medium. The quartz fiber filters must be fired before use, at a recommended temperature range of 850-900oC, to reduce the OC content of the filters. As a QA/QC procedure, it is recommended that randomly selected filters from the fired filter batches be tested for organic carbon blanks, before the batches are used for field sampling; if organic carbon blanks exceed a set limit (such as 2σ of the average blank values over all blank tests), then the batch of filters may be rejected for sampling."

<sup>9</sup> Khan et al. 2012 Khan et al. 2012 <https://www.tandfonline.com/doi/full/10.1080/02786826.2011.609194>



## Black Carbon

Black carbon (BC) is the most strongly light-absorbing component of particulate matter, and is formed by the incomplete combustion of fossil fuels, biofuels and biomass<sup>10</sup>.

Properties are: absorbing visible light at all wavelength and with a mass absorption coefficient (MAC) of \*5–15 m<sup>2</sup> g<sup>-1</sup> at 550 nm; insoluble in water -and common organic solvents, acids and bases-, refractory to thermal decomposition at 4000 K, aggregate morphology (carbon spherules).

Many analytical protocols exist for determining BC content by thermal, chemical, molecular marker or optical methods. The choice of method depends on the nature of the matrix being analysed and on the equipment available in the laboratory.

Further, matrix-specific methods are needed for soils or sediments (to access historical deposition and reconstruct past emissions)<sup>11</sup>

Many common measurement methods do not quantify this material specifically, instead reporting a proxy like light absorption or refractory component, with names like “effective black carbon” (eBC) or “elemental carbon” (EC). EPA’s National Emissions Inventory and SPECIATE particulate matter composition database use EC to represent BC.

Analytical differences create uncertainty in emission factors and predicted light absorption<sup>12</sup>

<u>1. Definition:</u>	A solid form of mostly pure carbon that absorbs solar radiation at all wavelengths and is produced by incomplete combustion (Black Carbon Report to Congress, 2012).
<u>2. Measurement methods:</u>	<p>Different methods applied to measure BC provides for different BC types:</p> <ul style="list-style-type: none"> <li>✓ <i>Based on light absorption (equivalent black carbon<sup>13</sup> - eBC<sup>14</sup>): Aethalometers, Light absorption/reflectance (MAAP), CLAP, PSAP, denuder/light absorption (COSMOS<sup>15</sup> or BCM); Photo-acoustic (PASS)</i></li> <li>✓ <i>Based on r refractory<sup>16</sup> properties (refractory black carbon - rBC): Laser induced incandescence, SP2;</i></li> <li>✓ <i>Based on combustion properties: (elemental carbon - EC): Thermo-optical (TOT);</i></li> </ul> <p>Or as a fraction of PM<sub>2.5</sub></p>
<u>Reference/Source:</u>	<p>Caria et al. 2011 <a href="http://dx.doi.org/10.1111/j.1475-2743.2011.00349.x">http://dx.doi.org/10.1111/j.1475-2743.2011.00349.x</a></p> <p>Bond et al. 2006 <a href="https://www.tandfonline.com/doi/full/10.1080/02786820500421521">https://www.tandfonline.com/doi/full/10.1080/02786820500421521</a></p> <p>Chow et al. 2004 <a href="https://pubs.acs.org/doi/10.1021/es034936u">https://pubs.acs.org/doi/10.1021/es034936u</a></p> <p>Chow et al. 2007 <a href="https://www.tandfonline.com/doi/pdf/10.3155/1047-3289.57.9.1014">https://www.tandfonline.com/doi/pdf/10.3155/1047-3289.57.9.1014</a></p> <p>Gysel et al. 2011 <a href="https://amt.copernicus.org/articles/4/2851/2011/">https://amt.copernicus.org/articles/4/2851/2011/</a></p> <p>Kondo et al. 2011 <a href="https://www.tandfonline.com/doi/full/10.1080/02786826.2010.533215">https://www.tandfonline.com/doi/full/10.1080/02786826.2010.533215</a></p> <p>Petzold et al. 2013 <a href="https://acp.copernicus.org/articles/13/8365/2013/acp-13-8365-2013.html">https://acp.copernicus.org/articles/13/8365/2013/acp-13-8365-2013.html</a>; <a href="https://acp.copernicus.org/preprints/13/9485/2013/acpd-13-9485-2013.pdf">https://acp.copernicus.org/preprints/13/9485/2013/acpd-13-9485-2013.pdf</a></p> <p>Pileci et al. 2021 <a href="https://amt.copernicus.org/articles/14/1379/2021/">https://amt.copernicus.org/articles/14/1379/2021/</a></p>

<sup>10</sup> In the absence of a method for uniquely determining the mass of BC, the term “BC” should be used as a qualitative and descriptive term when referring generally to material that shares some of the characteristics of BC, in particular its carbonaceous composition combined with its light-absorbing properties; “BC” is already used this way in atmospheric modeling and assessment studies

<sup>11</sup> Caria et al. 2011 <http://dx.doi.org/10.1111/j.1475-2743.2011.00349.x>

<sup>12</sup> The different types of BC measurements (EC, eBC, and rBC) usually agree with each other within a factor of two”. Ohata et al. (AMT 2021) also supports this conclusion

<sup>13</sup> A number of commercial instruments that measure the absorption coefficient of absorbing particles derive a mass concentration of “BC” using a conversion constant referred to as a mass absorption coefficient (MAC). In order to clarify that what is being measured may not be 100 % BC

<sup>14</sup> It is defined on the basis of absorption coefficient which is converted to mass concentration using a constant value of mass absorption coefficient (MAC). However, with the known contribution of brown carbon (absorption in visible wavelength: 300–600 nm), the bias in estimating the equivalent BC due to constant MAC value can be reduced

<sup>15</sup> COSMOS does not fit to eBC/rBC definitions, as a pre-heater evaporates the co-existing non-refractory species and then the filter absorbance is measured (i.e., the measured absorbance is not the quantity for the ambient particles)

<sup>16</sup> It is the carbon mass which is stable at ~ 4300 K and measured by thermal emission of carbon component of the particle absorbing laser energy



	<p>Whaley et al 2021 <a href="https://acp.copernicus.org/preprints/acp-2021-975/">https://acp.copernicus.org/preprints/acp-2021-975/</a></p> <p>Ohata et al 2021 <a href="https://amt.copernicus.org/articles/14/6723/2021/amt-14-6723-2021.html">https://amt.copernicus.org/articles/14/6723/2021/amt-14-6723-2021.html</a></p> <p>Khan et al. 2011 <a href="https://www.tandfonline.com/doi/pdf/10.1080/02786826.2011.609194?needAccess=true">https://www.tandfonline.com/doi/pdf/10.1080/02786826.2011.609194?needAccess=true</a></p> <p>Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a></p> <p>Bond et al. 2013 <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171</a></p> <p>Lack et al. 2014 <a href="https://link.springer.com/article/10.1007/s00216-013-7402-3">https://link.springer.com/article/10.1007/s00216-013-7402-3</a></p> <p>University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer <a href="https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf">https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf</a></p> <p>Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley</p> <p>Sharma et al. 2017 <a href="https://acp.copernicus.org/articles/17/15225/2017/acp-17-15225-2017.html">https://acp.copernicus.org/articles/17/15225/2017/acp-17-15225-2017.html</a></p> <p>EEA/EMEP (2019) <a href="https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/download">https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/download</a></p>
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<b>PM<sub>2.5</sub></b>	
Particulates of aerodynamic diameter size up to 2.5 µm. Need of distinguishing the inclusion or not of condensable <sup>17</sup> components when calculating emission factors.	
<u>Speciation methods:</u>	<p>The main instruments and methods of measuring concentration (gravimetric, optical, and microbalance) and size distribution are: Scanning Mobility Particle Sizer (SMPS), Electrical Low Pressure Impactor (ELPI)</p> <p>Others: Beta-attenuation, TEOM-FDMS, GC/MSn, HPLC/MSn, PIXE, ICP-MS, IC, IC-MS, TOT</p> <p>Measurements of aerosol particle<sup>18</sup> and chemical analysis<sup>19</sup>:</p> <p>i) mass concentration with gravimetric analysis; continuous measurements with Tapered Element Oscillating Microbalance (TEOM) or Aerosol mass spectrometer (e.g., Aerodyne Aerosol Chemical Speciation Monitor) for organic aerosol, NO<sub>3</sub>, SO<sub>4</sub>, NH<sub>4</sub>, Cl</p> <p>ii) major ionic species (sulfate, nitrate, chloride, sodium, calcium, ammonium, potassium, magnesium, and calcium) using ion chromatography (e.g., URG ambient ion monitor;</p> <p>iii) elemental composition (Na through Pb on the periodic table). Multiple analytical techniques available including PIXE, INAA, X-Ray fluorescence XRF, AAS and ICP-MS;</p> <p>iv) carbonaceous components. Total particulate carbon mass (TC) can be divided into three fractions: inorganic carbonates, organic carbon (OC), and a third fraction referred to variously as elemental carbon, equivalent black carbon (EBC), soot, or refractory carbon. Some of these terms are related to the measurement method used</p>
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	<p>Nozière et al. 2015 <a href="https://pubs.acs.org/doi/abs/10.1021/cr5003485">https://pubs.acs.org/doi/abs/10.1021/cr5003485</a></p> <p>Grover et al. 2006 <a href="https://www.tandfonline.com/doi/pdf/10.1080/02786820600615071">https://www.tandfonline.com/doi/pdf/10.1080/02786820600615071</a></p> <p>Pfeiffer 2005 <a href="https://digitalcommons.unl.edu/usdaarsfacpub/1393/">https://digitalcommons.unl.edu/usdaarsfacpub/1393/</a></p> <p>Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley</p> <p>Amaral et al. 2015 <a href="https://www.mdpi.com/2073-4433/6/9/1327/htm">https://www.mdpi.com/2073-4433/6/9/1327/htm</a></p> <p>Alfano et al. 2021 <a href="https://www.mdpi.com/1424-8220/21/9/3060">https://www.mdpi.com/1424-8220/21/9/3060</a></p> <p>EEA/EMEP (2019) <a href="https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/download">https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/download</a></p> <p><a href="https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter">https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter</a></p> <p><a href="https://www.intechopen.com/chapters/52206">https://www.intechopen.com/chapters/52206</a></p> <p>EPA PM speciation guidelines: <a href="https://www.epa.gov/sites/default/files/2017-01/documents/final_draft_pm2.5_speciation_guidance_1999.pdf">https://www.epa.gov/sites/default/files/2017-01/documents/final_draft_pm2.5_speciation_guidance_1999.pdf</a></p> <p>EPA designated reference instruments/samplers: <a href="https://www.epa.gov/system/files/documents/2021-12/designated-referene-and-equivalent-methods-12152021.pdf">https://www.epa.gov/system/files/documents/2021-12/designated-referene-and-equivalent-methods-12152021.pdf</a></p> <p>EPA stationary source methods: <a href="https://www.epa.gov/emc/emc-promulgated-test-methods">https://www.epa.gov/emc/emc-promulgated-test-methods</a></p> <p>University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer <a href="https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf">https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf</a></p> <p><a href="https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter">https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter</a>;</p> <p><a href="https://www.intechopen.com/chapters/52206">https://www.intechopen.com/chapters/52206</a></p>

<sup>17</sup> Thus, it is highly important to evaluate the presence of condensable material in the measured data

<sup>18</sup> For mass measurements and chemical analyses, except organic carbon, filtration with a Teflon filter is recommended for aerosol collection

<sup>19</sup> GAW Report No. 227, WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations, 2<sup>nd</sup> Edition, 2016

<b>PM<sub>10</sub></b>	
Particulate matter with a diameter less than 10 micrometer. Need of distinguishing the inclusion or not of condensable components when calculating emission factors	
<u>Speciation methods:</u>	See info for PM2.5
<u>Measurement methods:</u>	See info for PM2.5
<u>Reference/Source:</u>	See info for PM2.5

<b>NMVOCs</b>	
<p>Non-methane volatile organic compounds (NMVOCs) are a set of organic compounds that are typically photochemically reactive in the atmosphere, which are marked by the exclusion of methane.</p> <p>Relevant species will be dependent<sup>20</sup> on the source and the atmospheric conditions and chemistry into which they are emitted</p> <p>Semivolatile organic compounds (SVOCs) and intermediate volatile organic compounds (IVOCs) are important SOA precursors<sup>21</sup></p>	
<u>Relevant species</u> <sup>22</sup> :	<p>Isoprene (relevant for both ozone and SOA production)</p> <p>C2-C10 hydrocarbons (especially ozone precursors with aromatic species also SOA-forming)</p> <p>C11-C20 hydrocarbons (relevant for SOA formation)</p> <p>25 GEIA species through the application of speciation profiles<sup>23</sup></p> <p>Some examples of important chemical classes for specific sources are:</p> <ul style="list-style-type: none"> <li>- aromatics, cyclic alkanes in mobile source emissions,</li> <li>- oxygenated organic compounds and heterocyclic compounds in biomass burning,</li> <li>- non-oxygenated IVOCs in volatile chemical products</li> </ul> <p>In CMIP6 anthropogenic emission inventory, there are 25 speciated-VOC types</p>
<u>Speciation methods</u> :	<p>Gas chromatography/mass spectrometry GC/MS systems of varying complexity for an in-depth speciation</p> <p><a href="https://www.epa.gov/air-emissions-modeling/speciate">https://www.epa.gov/air-emissions-modeling/speciate</a>.</p>
<u>Measurement methods</u> :	<p>GC/FID can be implemented as automatic systems suitable for monitoring of the simplest compounds (up to C10)</p> <p>Proton transfer reaction mass spectrometer (PTRMS)</p> <p>Gas Chromatograph (GC)- Mass Spectrometry (MS)</p> <p>Speciation of VOC emission from solid fuel combustion uses PTR-ToF-MS, a technique well suited to species released in significant quantities such as small oxygenated species<sup>24</sup>, phenolics and furanics.</p>
<u>Reference/Source</u> :	<p><a href="https://www.epa.gov/amtic/compendium-methods-determination-toxic-organic-compounds-ambient-air">https://www.epa.gov/amtic/compendium-methods-determination-toxic-organic-compounds-ambient-air</a></p> <p>Blas et al. 2011 <a href="https://pubmed.ncbi.nlm.nih.gov/21978614/">https://pubmed.ncbi.nlm.nih.gov/21978614/</a></p> <p>Jathar et al. 2014 <a href="https://www.pnas.org/doi/10.1073/pnas.1323740111">https://www.pnas.org/doi/10.1073/pnas.1323740111</a></p> <p>Huo et al. 2021 <a href="https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD035835?af=R">https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD035835?af=R</a></p> <p>Nozière et al. 2015 <a href="https://pubs.acs.org/doi/abs/10.1021/cr5003485">https://pubs.acs.org/doi/abs/10.1021/cr5003485</a></p> <p>Heald et al. 2020 <a href="https://www.science.org/doi/10.1126/sciadv.aay8967">https://www.science.org/doi/10.1126/sciadv.aay8967</a></p> <p>Nozière et al. 2015 <a href="https://pubs.acs.org/doi/10.1021/cr5003485">https://pubs.acs.org/doi/10.1021/cr5003485</a></p> <p>Ahkerati et al. 2020 <a href="https://pubs.acs.org/doi/10.1021/acs.est.0c01345">https://pubs.acs.org/doi/10.1021/acs.est.0c01345</a></p>

<sup>20</sup> A recent approach to address this complexity is to estimate total reactive organic carbon, which includes VOCs, semi-volatile organic compounds (SVOCs), and intermediate volatility organic compounds (IVOCs) - Heald et al. 2020 <https://www.science.org/doi/10.1126/sciadv.aay8967>

<sup>21</sup> VOCs are compounds with effective saturation concentrations (C\*) between 103 and 106 µg/m<sup>3</sup>; this roughly corresponds to the volatility range of C12–C22n-alkanes

<sup>22</sup> EPA does maintain a list of compounds that are not considered VOCs, because their rate of reaction with OH is sufficiently small that they are considered negligible for the formation of ozone on local and regional scales

<sup>23</sup> Specific profiles are available in the EMEP/EEA Guidebook 2019 (e.g. for gasoline evaporative emissions from road transport, see Table 3-16)

<sup>24</sup> These species are often missed by GC measurement alone

Lu et al. 2020 <a href="https://acp.copernicus.org/articles/20/4313/2020/">https://acp.copernicus.org/articles/20/4313/2020/</a>
Pennington et al. 2021 <a href="https://acp.copernicus.org/articles/21/18247/2021/acp-21-18247-2021.pdf">https://acp.copernicus.org/articles/21/18247/2021/acp-21-18247-2021.pdf</a>
Robinson et al. 2007 <a href="https://www.science.org/doi/10.1126/science.1133061">https://www.science.org/doi/10.1126/science.1133061</a>
Compounds exempted from VOC regulations: <a href="https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-51/subpart-F/section-51.100">https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-51/subpart-F/section-51.100</a>
Gareth et al. 2021 <a href="https://doi.org/10.1016/j.aeaoa.2021.100115">https://doi.org/10.1016/j.aeaoa.2021.100115</a>
Stewart et al. 2021 <a href="https://doi.org/10.5194/acp-21-2383-2021">https://doi.org/10.5194/acp-21-2383-2021</a>
Cai et al. 2019 9269-9278 <a href="https://pubmed.ncbi.nlm.nih.gov/31288521/">https://pubmed.ncbi.nlm.nih.gov/31288521/</a>
Stewart et al. 2021 <a href="https://pubs.rsc.org/en/content/articlelanding/2021/fd/d0fd00087f">https://pubs.rsc.org/en/content/articlelanding/2021/fd/d0fd00087f</a>
Nourian et al. 2021 <a href="https://doi.org/10.1016/j.envint.2020.106152">https://doi.org/10.1016/j.envint.2020.106152</a>

Submitted information from participants

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	OA mass includes the mass of OC and relevant atom, such as hydrogen, oxygen, etc. (In our ESM calculation, if the emissions are given as OA, we convert OA to OC assuming OA/OC ratios.)
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	Total mass of organic species including hydrogen and oxygen
<u>Measurement methods:</u>	Aerosol Mass Spectrometers
<u>Reference/Source:</u>	IPCC AR6 WG1 Chapter 6

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	Organic fraction of the particulate matter
<u>Measurement methods:</u>	Aerosol Mass Spectrometer (AMS), Aerosol Chemical Speciation Monitor (ACSM), OC/EC analysers
<u>Reference/Source:</u>	Scientific literature

<b>Organic Aerosols (OA)</b>	
<u>Definition:</u>	Organic aerosols (OA) is a broad term indicating carbon-containing compounds that also contain hydrogen and, usually, oxygen.
<u>Measurement methods:</u>	Same as OM
<u>Reference/Source:</u>	Kanakidou, M., Seinfeld, J.H., Pandis, S.N., Barnes, I., Dentener, F.J., Facchini, M.C., van Dingenen, R., Ervens, B., Nenes, A., Nielsen, C.J., Swietlicki, E., Putaud, J.P., Balkanski, Y., Fuzzi, S., Horth, J., Moortgat, G.K., Winterhalter, R., Myhre, C.E.L., Tsigaridis, K., Vignati, E., Stephanou, E.G., Wilson, J., 2005. Organic aerosol and global climate modelling: a review. <i>Atmos. Chem. Phys.</i> 5,1053–1123, <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a>

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	Mass concentration of total particulate organic compounds
<u>Measurement methods:</u>	OA can be derived indirectly from a measurement of organic carbon (OC) using a thermal-optical method (TOT) and an assumption for conversion coefficients (OM/OC ratio). OA can be measured directly by aerosol mass spectrometer (AMS) technologies. Among these, the aerosol chemical speciation monitor (ACSM)

	represents the most suitable application for monitoring, although instruments with a 2.5 $\mu\text{m}$ were let available only recently (while PM10 versions are not available at all). ACSMs remain sophisticated instruments requiring careful calibration protocols. In Europe, ACTRIS ( <a href="https://www.actris.eu/">https://www.actris.eu/</a> ) provides intercomparisons of ACSM systems on a routine basis for better QA/QC.
<u>Reference/Source:</u>	<a href="https://www.costcolossal.eu/">https://www.costcolossal.eu/</a> Freney et al. 2019 (10.1080/02786826.2019.1608901)

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	Aerosol consisting of organic material (see definition below).
<u>Measurement methods:</u>	EPA does not have any promulgated or proposed measurement methods for OA. OA is not measured in EPA's ambient monitoring network or from emission sources. Organic Carbon (OC) is measured. EPA's National Emissions Inventory estimates organic material (OM) using an OM/OC ratio (Reff et al. 2009 Supplemental Information). This value is dependent upon the emission source and varies from 1.2 (motor vehicles) to 1.7 (wood combustion sources), with 1.4 for sources without a well-defined OM/OC ratio.  Research OA measurement methods exist and are often used in scientific studies, but not comprehensively used across all source categories. The most common method is the aerosol mass spectrometer (AMS). Some specific examples can be seen for open burning in May et al. 2014, wood stoves in Heringa et al. 2011, and mobile sources in Dallmann et al. 2014.
<u>Reference/Source:</u>	Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a> May et al. 2014 <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014JD021848">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014JD021848</a> Heringa et al. 2011 <a href="https://acp.copernicus.org/articles/11/5945/2011/acp-11-5945-2011.pdf">https://acp.copernicus.org/articles/11/5945/2011/acp-11-5945-2011.pdf</a> Dallmann et al. 2014 <a href="https://acp.copernicus.org/articles/14/7585/2014/acp-14-7585-2014.pdf">https://acp.copernicus.org/articles/14/7585/2014/acp-14-7585-2014.pdf</a>

<b>Organic Aerosol (OA)</b>	
<u>Definition:</u>	Atmospheric organic aerosols (OA) are either directly emitted from biogenic and anthropogenic sources (e.g., fossil fuel combustion, biomass burning, and industrial processes) or formed in the atmosphere (secondary organic aerosol, SOA) by condensation and heterogeneous and homogeneous reactions [7].  Organic aerosol (OA) is traditionally classified either as primary (POA) or secondary (SOA) [11].
<u>Measurement methods:</u>	Measuring techniques used for investigation of the chemical composition of particles enumerated in [1] (PL EMEP emission inventory – no data): filter sampling, and ion chromatograph measurements of extracts from filter samples, subsequent thermal analysis of carbon released from filter samples, infrared spectroscopy of concentrated impactor samples, electron microscope.  Gas chromatography [9].
<u>Reference/Source:</u>	[1] Murphy et al. (2006). DOI: 10.1029/2006JD007340. [2] Zhang et al. (2007). DOI: 10.1029/2007GL029979. [7] Jimenez et al. (2009). DOI: 10.1126/science.1180353.

	<p>[9] An et al. (2021). DOI: 10.1016/j.hazl.2021.100013.</p> <p>[11] Cain et al. (2017). DOI: 10.5194/amt-10-4865-2017.</p> <p>In [1] many measurement methods are enumerated.</p> <p>No information in Polish emission inventory (LRTAP/NEC).</p>
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<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	Fraction of OA directly emitted
<u>Measurement methods:</u>	POA is not tied to measurement methods.
<u>Reference/Source:</u>	

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	Organic aerosols directly emitted in the air (without undergoing atmospheric processing).
<u>Measurement methods:</u>	Measurements at the stack or at the pipe, etc. with filters, impactors (e.g. Dekati).
<u>Reference/Source:</u>	Scientific literature

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	Organic particulate matter emitted directly as particles from sources (but most of the POA may be sufficiently volatile and then experience evaporation-reaction-recondensation cycle in urban areas).
<u>Measurement methods:</u>	Aerodyne aerosol mass spectrometer
<u>Reference/Source:</u>	Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	Organic aerosol originating directly from an emissions source (Black Carbon Report to Congress, 2012).
<u>Measurement methods:</u>	As with OA, EPA has not promulgated a primary organic aerosol measurement method. PM speciation profiles can be used to estimate POA for emission sources, as described above for OA and detailed in Reff et al. 2009 Supplemental Information.
<u>Reference/Source:</u>	Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a> Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a>

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	Primary organic aerosols (POA) is defined as organic compounds that are emitted directly in particulate form.



<u>Measurement methods:</u>	Online method: aerosol mass spectrometry (AMS), similar with SOA and OM.
<u>Reference/Source:</u>	de Gouw, J., Jimenez, J.L., 2009, Organic Aerosols in the Earth's Atmosphere. Environ. Sci. Technol 43, 7614–7618, <a href="https://pubs.acs.org/doi/pdf/10.1021/es9006004">https://pubs.acs.org/doi/pdf/10.1021/es9006004</a> . Kanakidou, M., Seinfeld, J.H., Pandis, S.N., Barnes, I., Dentener, F.J., Facchini, M.C., van Dingenen, R., Ervens, B., Nenes, A., Nielsen, C.J., Swietlicki, E., Putaud, J.P., Balkanski, Y., Fuzzi, S., Horth, J., Moortgat, G.K., Winterhalter, R., Myhre, C.E.L., Tsigaridis, K., Vignati, E., Stephanou, E.G., Wilson, J., 2005, Organic aerosol and global climate modelling: a review. Atmos. Chem. Phys. 5, 1053–1123, <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a> .

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	OA emitted in the atmosphere in particulate form by processes such as combustion, spray, erosion of biological/soil material.
<u>Measurement methods:</u>	In laboratory, combustion facilities provide comprehensive information about the emission factors of POA by varying combustion conditions and fuel type. In the field, measurements taken in proximity of combustion sources such as prescribed fires and agricultural fires using both ground-based and airborne instrumental platforms have provided large datasets on POA emissions factors. Both approaches are challenged by the fact that apparently POA has not a purely conservative behaviour in the atmosphere: evaporation of SVOC take place upon dilution of the emission in the atmosphere, therefore emission factors must be accurately documented for the conditions in which they were estimated.
<u>Reference/Source:</u>	

<b>Primary Organic Aerosols (POA)</b>	
<u>Definition:</u>	<ul style="list-style-type: none"> <li>- Organic aerosol released directly into the air [3].</li> <li>- Primary organic aerosol (POA) constitutes the emissions from both natural (vegetation and micro-organisms) and anthropogenic sources such as combustion of fossil fuels and biofuels, and open biomass burning (forest fire) [4].</li> <li>- Organic compounds directly emitted in the particulate form or condensed into the particle phase without undergoing chemical reactions are known as POA... [4].</li> <li>- POA being the crucial part of carbonaceous aerosols requires further targeted and coherent observations for accurate emission estimates. This needs standardization of measurement methods for both BC and OC. [4].</li> </ul>
<u>Measurement methods:</u>	Measuring of POA from a modern non-road diesel engine [8].
<u>Reference/Source:</u>	[3] de Gouw, and Jimenez (2009). DOI: 10.1021/es9006004. [4] Bhattu (2017). DOI: 10.1007/978-981-10-7185-0_7. [8] Jathar et al. (2020). DOI: 10.1016/j.atmosenv.2019.117221. No information in Polish emission inventory (LRTAP/NEC).

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	OA formed in the atmosphere by conversion of organic gases into particulate material. Such processes can be mediated by oxidative or acid/base reactions. Condensation of semivolatiles (SVOCs) at low temperatures (or/and high relative humidities) is also commonly considered a source of SOA.
<u>Measurement methods:</u>	SOA formation is normally tested and simulated in reaction chambers. Formation yields are expressed as mass of OA formed per mass of gaseous precursors that has reacted. SOA yields are a function of precursor concentrations and the level and type of oxidant. For some precursors (e.g. isoprene), the composition of the aerosol onto which SOA condenses is also key, and probably important – though not well studied – for all SOA systems. In Europe, the EUROCHAMP network provides standards and guidelines for performing reaction chamber experiments for SOA studies. In the field, SOA can be estimated using aerosol mass spectrometers (AMS).
<u>Reference/Source:</u>	<a href="https://www.eurochamp.org/">https://www.eurochamp.org/</a>

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	Fraction of OA secondarily produced in the atmosphere
<u>Measurement methods:</u>	SOA is not tied to measurement methods
<u>Reference/Source:</u>	

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	Secondary organic aerosols (SOA) refers to the organic components of particulate matter that transfers to the aerosol phase from the gas phase as products of gas-phase oxidation of parent organic species.
<u>Measurement methods:</u>	<ol style="list-style-type: none"> <li>a. Indirect methods: Quantifying total secondary organic aerosols as the difference between the measured total organic aerosols and estimated primary organic aerosols.</li> <li>b. Off-line high complexity secondary organic aerosols measurements, e.g., gas chromatography/mass spectrometry (GC/MS), liquid chromatography/MS (LC/MS), nuclear magnetic resonance (NMR) and Fourier transform infrared (FTIR) spectroscopy.</li> <li>c. On-line techniques (e.g., aerosol mass spectrometry, AMS).</li> </ol>
<u>Reference/Source:</u>	<p>de Gouw, J., Jimenez, J.L., 2009, Organic Aerosols in the Earth's Atmosphere. Environ. Sci. Technol 43, 7614–7618, <a href="https://pubs.acs.org/doi/pdf/10.1021/es9006004">https://pubs.acs.org/doi/pdf/10.1021/es9006004</a>.</p> <p>Hallquist, M., Wenger, J.C., Baltensperger, U., Rudichm, Y., Simpson, D., Claeys, M., Dommen, J., Donahue, N.M., George, C., Goldstein, A.H., Hamilton, J.F., Herrmann, H., Hoffmann, T., Iinuma, Y., Jang, M., Jenkin, M.E., Jimenez, J.L., Kiendler-Scharr, A., Maenhaut, W., McFiggans, G., Mentel, Th.F., Monod, A., Prévôt, A.S.H., Seinfeld, J.H., Surratt, J.D., Szmigielski, R., Wildt, J., 2009, The formation, properties and impact of secondary organic aerosol: current and emerging issues. Atmos. Chem. Phys., 9, 5155–5236, <a href="http://www.atmos-chem-phys.net/9/5155/2009/">www.atmos-chem-phys.net/9/5155/2009/</a>.</p>

	Kanakidou, M., Seinfeld, J.H., Pandis, S.N., Barnes, I., Dentener, F.J., Facchini, M.C., van Dingenen, R., Ervens, B., Nenes, A., Nielsen, C.J., Swietlicki, E., Putaud, J.P., Balkanski, Y., Fuzzi, S., Horth, J., Moortgat, G.K., Winterhalter, R., Myhre, C.E.L., Tsigaridis, K., Vignati, E., Stephanou, E.G., Wilson, J., 2005, Organic aerosol and global climate modelling: a review. Atmos. Chem. Phys. 5, 1053–1123, <a href="http://www.atmos-chem-phys.org/acp/5/1053/">www.atmos-chem-phys.org/acp/5/1053/</a> .
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<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	Organic aerosols formed through secondary atmospheric chemical-physical processing (gas to particle conversion, condensation of gases on seeds, etc.)
<u>Measurement methods:</u>	Smog chamber experiments, Potential Aerosol Mass (PAM) reactor
<u>Reference/Source:</u>	Scientific literature

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	Aerosol produced by the oxidation of VOCs to low-volatility condensable products
<u>Measurement methods:</u>	Aerodyne aerosol mass spectrometer
<u>Reference/Source:</u>	Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	<ul style="list-style-type: none"> <li>- (Aerosol) formed by chemical transformation and condensation of volatile and semivolatile species [2].</li> <li>- Aerosol formed in the atmosphere from gas-phase precursors [3].</li> <li>- (...) whereas the ones with sufficiently low vapor pressure, formed by gas-phase oxidation of precursor volatile organic compounds (VOCs), either of biogenic or anthropogenic origin or through nucleation are known as SOA [4].</li> <li>- SOA is formed by condensation of low-volatility products of the oxidation of volatile organic compounds (VOCs) on pre-existing particles and is an important contributor to ambient particulate matter in urban, rural, and remote areas [10,12,13].</li> </ul>
<u>Measurement methods:</u>	AMS (mass spectrometry) [10]
<u>Reference/Source:</u>	<p>[10] Kostenidou et al. (2009). DOI: 10.1021/es803676g.</p> <p>[12] Chow et al. (1994). DOI: 10.1016/1352-2310(94)90474-X.</p> <p>[13] Turpin, and Huntzinger (1995). DOI: 10.1016/1352-2310(94)00276-Q.</p> <p>No information in Polish emission inventory (LRTAP/NEC).</p>

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	Organic aerosol that is produced in the atmosphere from the chemical reaction and condensation of volatile organic compounds (Black Carbon Report to Congress, 2012).

<u>Measurement methods:</u>	EPA does not measure secondary organic aerosols as part of its ambient monitoring network. There are several research approaches to measuring secondary organic aerosol including using tracer or positive matrix factorization (PMF) methodologies along with speciated OA measurements (Srivastiva et al. 2021). Often online aerosol mass spectrometer (AMS) along with PMF is used to apportion organic aerosol to primary or secondary sources (e.g., Hayes et al. 2013), which can be compared to chemical mass balance models (e.g., Al-Naiema et al. 2018).
<u>Reference/Source:</u>	Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a> Srivastiva et al. 2021 <a href="https://www.sciencedirect.com/science/article/abs/pii/S0048969720366985?via%3Dihub">https://www.sciencedirect.com/science/article/abs/pii/S0048969720366985?via%3Dihub</a> Hayes et al. 2013 <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50530">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50530</a> Al-Naiema et al. 2018 <a href="https://acp.copernicus.org/articles/18/15601/2018/">https://acp.copernicus.org/articles/18/15601/2018/</a>

<b>Secondary Organic Aerosols (SOA)</b>	
<u>Definition:</u>	
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	Stewart et al., 2021, G.J. Stewart, B.S. Nelson, W.J.F. Acton, A.R. Vaughan, J.R. Hopkins, S.S.M. Yunus, C.N. Hewitt, E. Nemitz, N. Mullinger, R. Gadi, A.R. Rickard, J.D. Lee, T.K. Mandal, J.F. Hamilton; Comprehensive organic emission profiles, secondary organic aerosol production potential, and OH reactivity of domestic fuel combustion in Delhi, India; Environ. Sci.: Atmosphere, 1 (2021), pp. 104-117, 10.1039/D0EA00009D

<b>Organic Material</b>	
<u>Definition:</u>	= OA
<u>Measurement methods:</u>	Aerosol Mass Spectrometers
<u>Reference/Source:</u>	IPCC AR6 WG1 Chapter 6

<b>Organic Material</b>	
<u>Definition:</u>	Or Organic Matter.
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	

<b>Organic Material</b>	
<u>Definition:</u>	Synonym of organic aerosol (OA)
<u>Measurement methods:</u>	

Reference/Source:	
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<b>Organic Material</b>	
<u>Definition:</u>	Organic matter corresponds to the material formed by organic compounds which are those including carbon.
<u>Measurement methods:</u>	Chemical analysis of filters, Aerosol Mass Spectrometer measurements and Fourier transform infrared absorption (FT-IR) spectrometry.
<u>Reference/Source:</u>	Scientific literature

<b>Organic Material</b>	
<u>Definition:</u>	Total mass of organic material (Black Carbon Report to Congress, 2012). Organic material includes organic carbon and associated hydrogen and oxygen (Reff et al. 2009). Although not stated in the reference, the calculation or measurement method for organic material may include the contribution from organic nitrogen and sulfur (see Reff et al. 2009 supplemental information and Aiken et al. 2008)
<u>Measurement methods:</u>	See information for organic aerosol
<u>Reference/Source:</u>	Black Carbon Report to Congress, 2012 <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a> Reff et al. 2009 <a href="https://pubs.acs.org/doi/pdf/10.1021/es802930x">https://pubs.acs.org/doi/pdf/10.1021/es802930x</a> Aiken et al. 2008 <a href="https://pubs.acs.org/doi/10.1021/es703009q">https://pubs.acs.org/doi/10.1021/es703009q</a>

<b>Organic Material</b>	
<u>Definition:</u>	No data
<u>Measurement methods:</u>	No data
<u>Reference/Source:</u>	No information in Polish emission inventory (LRTAP/NEC).

<b>Organic Material</b>	
<u>Definition:</u>	Organic material (OM) is defined in modern chemistry as carbon-based compounds, originally derived from living organisms but now including lab-synthesized versions as well, of which most are combinations of a few of the lightest elements, particularly hydrogen, carbon, nitrogen, and oxygen.
<u>Measurement methods:</u>	a. Off-line high complexity techniques, e.g., gas chromatography/mass spectrometry (GC/MS), liquid chromatography/MS (LC/MS), nuclear magnetic resonance (NMR) and Fourier transform infrared (FTIR) spectroscopy, which provide detailed information on individual chemical species or functional groups in secondary organic aerosols but generally require large amounts of samples, resulting in low time resolution (hours to days) and low size resolution. b. On-line techniques (e.g., aerosol mass spectrometry, AMS).
<u>Reference/Source:</u>	<a href="https://www.conservation-wiki.com/wiki/Organic_Materials">https://www.conservation-wiki.com/wiki/Organic_Materials</a>

	<p>Hallquist, M., Wenger, J.C., Baltensperger, U., Rudichm, Y., Simpson, D., Claeys, M., Dommen, J., Donahue, N.M., George, C., Goldstein, A.H., Hamilton, J.F., Herrmann, H., Hoffmann, T., Iinuma, Y., Jang, M., Jenkin, M.E., Jimenez, J.L., Kiendler-Scharr, A., Maenhaut, W., McFiggans, G., Mentel, Th.F., Monod, A., Prévôt, A.S.H., Seinfeld, J.H., Surratt, J.D., Szmigielski, R., Wildt, J., 2009, The formation, properties and impact of secondary organic aerosol: current and emerging issues. <i>Atmos. Chem. Phys.</i>, 9, 5155–5236, <a href="http://www.atmos-chem-phys.net/9/5155/2009/">www.atmos-chem-phys.net/9/5155/2009/</a>.</p> <p>Turpin, B.J., Lim, H.-J., 2001, Species contributions to PM2.5 mass concentrations: revisiting common assumptions for estimating organic mass. <i>Aerosol Sci. Technol.</i> 35, 602-610, <a href="https://doi.org/10.1080/02786820119445">https://doi.org/10.1080/02786820119445</a>.</p>
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<b>Organic Carbon</b>	
<u>Definition:</u>	The carbon mass fraction of OA
<u>Measurement methods:</u>	ECOC analysers
<u>Reference/Source:</u>	IPCC AR6 WG1 Chapter 6

<b>Organic Carbon</b>	
<u>Definition:</u>	Mass of carbon in organic form
<u>Measurement methods:</u>	It is determined using thermal-optical methods (TOT), hence from a measurement of total carbon (TC) in multiple steps of temperature and oxygen level allowing to differentiate between elemental carbon (EC, proxy for black carbon) and organic carbon (OC). The methodology is sensitive to chemical composition and to the amount of BC in the samples.
<u>Reference/Source:</u>	Karanasiou et al. <i>Atmos. Meas. Techn.</i> 2015 (doi:10.5194/amtd-8-9649-2015);

<b>Organic Carbon</b>	
<u>Definition:</u>	Organic carbon (OC) refers to the carbon mass within organic aerosol.
<u>Measurement methods:</u>	<ol style="list-style-type: none"> <li>a. Solvent extraction followed by combustion</li> <li>b. Continuous temperature ramping</li> <li>c. Two temperatures in oxidizing and non-oxidizing atmospheres</li> <li>d. Thermal/optical reflectance</li> <li>e. Thermal/optical transmittance</li> </ol>
<u>Reference/Source:</u>	<p>Bond, T.C., Doherty, S.J., Fahey, D.W., Forster, P.M., Berntsen, T., DeAngelo, B.J., Flanner, M.G., Ghan, S., Kärcher, B., Koch, D., 2013, Bounding the role of black carbon in the climate system: A scientific assessment. <i>J Geophys. Res.: Atmos.</i> 118, 5380–5552, <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171</a>.</p> <p>Chow, J.C, Watson, J.G., Chen, L.-W. A., Arnott, W.P., Moosmüller, H., Fung, K., 2004, Equivalence of elemental carbon by thermal/optical reflectance and transmittance with different temperature protocols. <i>Environ. Sci. Technol.</i> 38, 4414-4422, <a href="https://pubs.acs.org/doi/10.1021/es034936u">https://pubs.acs.org/doi/10.1021/es034936u</a>.</p>

<b>Organic Carbon</b>	
<u>Definition:</u>	OC mass is the mass of carbon in carbonaceous particles excluding EC, not include hydrogen, oxygen, etc.
<u>Measurement methods:</u>	Thermal optical method
<u>Reference/Source:</u>	Seinfeld, J. H., and S. N. Pandis (2006), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 2nd Edition, Wiley Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley

<b>Organic Carbon</b>	
<u>Definition:</u>	Carbonaceous component of the organic matter.
<u>Measurement methods:</u>	Thermal method analysis of filters where PM has been collected. OC is given by the difference between total carbon and elemental carbon. On site instruments are e.g. the Sunset OC-EC analysers.
<u>Reference/Source:</u>	Scientific literature

<b>Organic Carbon</b>	
<u>Definition:</u>	Organic carbon (OC): OC is made up of the molecules that are combined with hydrogen, oxygen and/or nitrogen, sulfur, etc. [4].
<u>Measurement methods:</u>	Thermal analytical method: evolved gas analyzer (EGA) - volatilizing the OC via ramping the temperature in steps in inert pure helium atmosphere and converting to CO <sub>2</sub> using a catalyst (e.g., MnO <sub>2</sub> ) and can be measured by either CO <sub>2</sub> analyzer or flame ionization detector (FID) after converting to CH <sub>4</sub> [4].
<u>Reference/Source:</u>	No information in Polish emission inventory (LRTAP/NEC).

<b>Organic Carbon</b>	
<u>Definition:</u>	A broad definition of Organic Carbon (OC) is the carbon found in organic compound, which are generally considered to be any chemical compounds that contain carbon-hydrogen bond. An immediate consequence of such a broad definition is that CH <sub>4</sub> is then OC. Consequently, often in atmospheric chemistry it is separated, between CH <sub>4</sub> and other atmospheric Organic Carbon excluding methane. When limited to Atmospheric Organic Carbon (AOC), a rather simple definition is "Organic carbon in the atmosphere includes hydrocarbons, oxygenated or halogenated compounds and multifunctional compounds, as well as particulate matter".
<u>Measurement methods:</u>	Depend of the Matrix, and if presence or not of inorganic carbon.
<u>Reference/Source:</u>	

<b>Organic Carbon</b>	
<u>Definition:</u>	Mix of compounds containing carbon bound with other elements (e.g. hydrogen or oxygen). This can include primary organic carbon formed from incomplete combustion or secondary organic carbon formed in the atmosphere (Black Carbon Report to Congress, 2012).
<u>Measurement methods:</u>	<p>Thermal optical analysis is used to quantify organic carbon. The amount of organic carbon can vary depending upon the temperature ramp specifications and the method used to account for charring (Khan et al. 2012). Charring is accounted for with a laser measurement of filter transmittance (TOT) or reflectance (TOR) during the temperature ramp.</p> <p>Organic carbon is measured at chemical speciation ambient monitoring stations (see PM2.5 speciation below for more information) using an IMPROVE protocol specifying the temperature ramp and a TOR method to account for char (SOP #402).</p> <p>EPA does not have a measurement method promulgated or proposed for measuring organic carbon from emission sources. Emissions can be sampled on quartz filters and analyzed using thermal optical analysis. Varying temperature protocols may be used, but the most common are the NIOSH 5040 protocol or the IMPROVE-A protocol (Khan et al. 2012).</p>
<u>Reference/Source:</u>	<p>Black Carbon Report to Congress, 2012  <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a></p> <p>Khan et al. 2012 <a href="https://www.tandfonline.com/doi/full/10.1080/02786826.2011.609194">https://www.tandfonline.com/doi/full/10.1080/02786826.2011.609194</a></p> <p>University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer <a href="https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf">https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf</a></p>

<b>Organic Carbon</b>	
<u>Definition:</u>	
<u>Measurement methods:</u>	From WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations: "Quartz fibre filters should be used for organic carbon measurements. The currently accepted analytical method for organic carbon is thermal desorption and evolution that requires such a specific filter medium. The quartz fibre filters must be fired before use, at a recommended temperature range of 850-900oC, to reduce the OC content of the filters. As a QA/QC procedure, it is recommended that randomly selected filters from the fired filter batches be tested for organic carbon blanks, before the batches are used for field sampling; if organic carbon blanks exceed a set limit (such as 2σ of the average blank values over all blank tests), then the batch of filters may be rejected for sampling."
<u>Reference/Source:</u>	GAW Report No. 227, WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations, 2nd Edition, 2016.

<b>Black Carbon</b>	
<u>Definition:</u>	Black carbon (BC) content corresponds to residues from incomplete combustion of fossil fuels, wood, coal and biomass in general.
<u>Measurement methods:</u>	Many analytical protocols exist for determining BC content by thermal, chemical, molecular marker or optical methods. The choice of method depends on the nature of the matrix being analysed and on the equipment available in the laboratory.



<u>Reference/Source:</u>	For methods without bias when the matrix is either soils or sediments (to access historical deposition and reconstruct past emissions for instance): Caria et al. 2011. Black carbon estimation in French calcareous soils using chemo-1 thermal oxidation method. <i>Soil Use Management</i> . 27, 3, 333-339. <a href="http://dx.doi.org/10.1111/j.1475-2743.2011.00349.x">http://dx.doi.org/10.1111/j.1475-2743.2011.00349.x</a>
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<b>Black Carbon</b>	
<u>Definition:</u>	Mass of carbonaceous aerosols absorbing visible light at all wavelength and with a minimum absorption of 5. m <sup>2</sup> /g in the mid-vis (500 nm). Other properties are: insoluble in water, refractory to thermal decomposition, aggregate morphology.
<u>Measurement methods:</u>	Optical (equivalent black carbon): Aethalometers, MAAP, CLAP, PSAP, COSMOS; Incandescence (refractory black carbon): SP2; Thermo-optical (elemental carbon): TOT; Photo-acoustic: PASS
<u>Reference/Source:</u>	Bond and Bergstrom, <i>Aerosol. Sci. Technol.</i> 2006, 41(1), 27– 47. Chow et al, <i>J. Air Waste Manage. Assoc.</i> 2007, 57, 1014–1023. Gysel et al., <i>Atmos. Meas. Tech.</i> 2011, 4, 2851–2858. Kondo et al. <i>Aerosol Sci. Tech.</i> 2011, 45, 295-312. Petzold et al. <i>Atmos. Chem. Phys.</i> 2013, 13, 8365–8379. Pileci et al. <i>Atmos. Meas. Tech.</i> 2021, 14, 1379–1403.

<b>Black Carbon</b>	
<u>Definition:</u>	(As Energy BOG discussed during last expert meeting in October 2021, which I participated) The material known as “black carbon” is identifiable by its particular properties: strong visible light absorption, refractory, insoluble, and composed of aggregated carbon spherules. Many common measurement methods do not quantify this material specifically, instead reporting a proxy like light absorption or refractory component, with names like “effective black carbon” or “elemental carbon.” This working group recognizes that these analytical differences create uncertainty in emission factors and predicted light absorption. However, the working group also acknowledges the need to constrain highly variable emissions and the small number of input measurements. Emission measurements, where any standard method is used to quantify black carbon, effective black carbon, or elemental carbon are considered equivalent in these recommendations.  Additional comment: Whaley et al. (ACPD 2021) for the AMAP report states “The different types of BC measurements (EC, eBC, and rBC) usually agree with each other within a factor of two”. Ohata et al. (AMT 2021) also supports this conclusion.
<u>Measurement methods:</u>	Light absorption/reflectance (MAAP), Laser induced incandescence (SP2), denuder/light absorption (COSMOS or BCM). Note that COSMOS does not fit to eBC/rBC definitions, as a pre-heater evaporates the co-existing non-refractory species and then the filter absorbance is measured (i.e., the measured absorbance is not the quantity for the ambient particles). ).  <a href="https://acp.copernicus.org/preprints/acp-2021-975/">https://acp.copernicus.org/preprints/acp-2021-975/</a> <a href="https://amt.copernicus.org/articles/14/6723/2021/amt-14-6723-2021.html">https://amt.copernicus.org/articles/14/6723/2021/amt-14-6723-2021.html</a>

Reference/Source:	
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<b>Black Carbon</b>	
<u>Definition:</u>	Black carbon (BC), in some cases also called elemental carbon (EC), is the most strongly light-absorbing component of particulate matter, and is formed by the incomplete combustion of fossil fuels, biofuels and biomass.
<u>Measurement methods:</u>	<ul style="list-style-type: none"> <li>a. Solvent extraction followed by combustion</li> <li>b. Continuous temperature ramping</li> <li>c. Two temperatures in oxidizing and non-oxidizing atmospheres</li> <li>d. Thermal/optical reflectance</li> <li>e. Thermal/optical transmittance</li> </ul>
<u>Reference/Source:</u>	<p><a href="https://www3.epa.gov/blackcarbon/basic.html">https://www3.epa.gov/blackcarbon/basic.html</a></p> <p>Bond, T.C., Doherty, S.J., Fahey, D.W., Forster, P.M., Berntsen, T., DeAngelo, B.J., Flanner, M.G., Ghan, S., Kärcher, B., Koch, D., 2013, Bounding the role of black carbon in the climate system: A scientific assessment. J Geophys. Res.: Atmos. 118, 5380–5552, <a href="https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171">https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/jgrd.50171</a>.</p> <p>Chow, J.C, Watson, J.G., Chen, L.-W. A., Arnott, W.P., Moosmüller, H., Fung, K., 2004, Equivalence of elemental carbon by thermal/optical reflectance and transmittance with different temperature protocols. Environ. Sci. Technol. 38, 4414-4422, <a href="https://pubs.acs.org/doi/10.1021/es034936u">https://pubs.acs.org/doi/10.1021/es034936u</a>.</p>

<b>Black Carbon</b>	
<u>Definition:</u>	Light absorbing component of carbonaceous matter (definition based on optical methods). Need to specify if emission factors are expressed as BC or Elemental Carbon.
<u>Measurement methods:</u>	Optical method, light absorption (e.g. using an aethalometer).
<u>Reference/Source:</u>	Scientific literature

<b>Black Carbon</b>	
<u>Definition:</u>	<p>From Petzold et al. (2013):</p> <p><i><u>“Black carbon (BC) is a useful qualitative description when referring to light-absorbing carbonaceous substances in atmospheric aerosol; however, for quantitative applications the term requires clarification of the underlying determination.</u></i></p> <p><i>In the absence of a method for uniquely determining the mass of BC, the authors recommend that the term “BC” should be used as a qualitative and descriptive term when referring generally to material that shares some of the characteristics of BC (see Table 1), in particular its carbonaceous composition combined with its light-absorbing properties “BC” is already used this way in atmospheric modeling and assessment studies. For quantitative applications like reporting data from observations or <b>building inventories</b>, we suggest using more specific terminology that refers to the particular measurement method (Table 2).”</i></p> <p>From Lack et al. (2014), definition of equivalent BC (eBC):</p>

	<p>“A number of commercial instruments that measure the absorption coefficient of absorbing particles derive a mass concentration of “BC” using a conversion constant referred to as a mass absorption coefficient (MAC). In order to clarify that what is being measured may not be 100 % BC, Petzold et al. (2013) recommend the use of eBC when reporting the carbon mass derived from the absorption coefficient.”</p>
<u>Measurement methods:</u>	<p>Based on light absorption (eBC):</p> <ul style="list-style-type: none"> <li>• <i>Filter-based optical methods</i></li> <li>• <i>Photo-acoustic techniques</i></li> <li>• <i>Photo-thermal interferometry</i></li> </ul> <p>Based on combustion properties; sp<sup>2</sup> bonded carbon; carbon content (EC):</p> <ul style="list-style-type: none"> <li>• <i>Thermal and thermal optical analysis</i></li> <li>• <i>Raman spectroscopy</i></li> <li>• <i>Aerosol mass spectroscopy</i></li> </ul> <p>Based on refractory properties (rBC):</p> <ul style="list-style-type: none"> <li>• <i>Incandescence methods</i></li> </ul>
<u>Reference/Source:</u>	<p>Petzold et al., 2013. doi:10.5194/acp-13-8365-2013</p> <p>Lack et al., 2014. doi:10.1007/s00216-013-7402-3</p>

<b>Black Carbon</b>	
<u>Definition:</u>	A solid form of mostly pure carbon that absorbs solar radiation at all wavelengths and is produced by incomplete combustion (Black Carbon Report to Congress, 2012).
<u>Measurement methods:</u>	<p>EPA’s National Emissions Inventory and SPECIATE particulate matter composition database use elemental carbon to represent black.</p> <p>Elemental carbon is measured at chemical speciation ambient monitoring stations and is analyzed using the same ambient measurement method as described above for organic carbon (SOP #402).</p> <p>EPA does not have a measurement method promulgated or proposed for measuring elemental carbon or black carbon from emission sources.</p> <p>Black carbon is also quantified by a variety of other methods (Petzold et al. 2013). Many emissions studies also quantify black carbon emissions through filter-based light attenuation, but these are not used in EPA’s National Emissions Inventory.</p>
<u>Reference/Source:</u>	<p>Black Carbon Report to Congress, 2012  <a href="https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf">https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf</a></p> <p>University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer  <a href="https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf">https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf</a></p> <p>Petzold et al. 2013 <a href="https://acp.copernicus.org/articles/13/8365/2013/acp-13-8365-2013.html">https://acp.copernicus.org/articles/13/8365/2013/acp-13-8365-2013.html</a></p> <p><a href="https://acp.copernicus.org/preprints/13/9485/2013/acpd-13-9485-2013.pdf">https://acp.copernicus.org/preprints/13/9485/2013/acpd-13-9485-2013.pdf</a></p>

<b>Black Carbon</b>	
<u>Definition:</u>	The term BC and EC depends on measurement methods. BC is distinguished from other carbonaceous material by the following physical properties: (1) strong visible

	light absorption, (2) refractory, (3) insoluble in water and in organic solvents, and (4) existence as an aggregate of small carbon spherules.
<u>Measurement methods:</u>	Measured BC mass concentrations can be different depending on instruments/techniques. For example, in the case of several light absorption measurements, the measured absorption coefficient is converted to BC mass concentration by assuming conversion factors, which can induce uncertainties. Some studies proposed the methods to reduce the uncertainties. However, due to small number of the BC and EC measurements, reliable and available data should be used for the inventory work.
<u>Reference/Source:</u>	Seinfeld, J. H., and S. N. Pandis (2016), Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition, Wiley  Ohata, S., Mori, T., Kondo, Y., Sharma, S., Hyvärinen, A., Andrews, E., Tunved, P., Asmi, E., Backman, J., Servomaa, H., Veber, D., Eleftheriadis, K., Vratolis, S., Krejci, R., Zieger, P., Koike, M., Kanaya, Y., Yoshida, A., Moteki, N., Zhao, Y., Tobo, Y., Matsushita, J., and Oshima, N.: Estimates of mass absorption cross sections of black carbon for filter-based absorption photometers in the Arctic, Atmos. Meas. Tech., 14, 6723–6748, <a href="https://doi.org/10.5194/amt-14-6723-2021">https://doi.org/10.5194/amt-14-6723-2021</a> , 2021.

<b>Black Carbon</b>	
<u>Definition:</u>	<ul style="list-style-type: none"> <li>- Defined as (pseudo) fraction of PM<sub>2.5</sub> – various activities have assigned part of PM<sub>2.5</sub> as BC [5]. Definition according to the EMEP/LRTAP methodology [5] applied in the Polish LRTAP/NEC Emission Inventory.</li> <li>- It is defined on the basis of characteristic aggregate morphology (graphitic sp<sup>2</sup>-bonded carbon) of primary combustion particles. BC aerosols have the characteristic property of being refractory at 4000 K, insoluble in water and common organic solvents, acids and bases, and light absorption with mass absorption coefficient (MAC) of *5–15 m<sup>2</sup> g<sup>-1</sup> at 550 nm [6, definition given in 4].</li> <li>- Equivalent Black Carbon (eBC): It is defined on the basis of absorption coefficient which is converted to mass concentration using a constant value of mass absorption coefficient (MAC). However, with the known contribution of brown carbon (absorption in visible wavelength: 300–600 nm), the bias in estimating the equivalent BC due to constant MAC value can be reduced. Although, there are different filter-based and in-situ particle absorption measurement methods to derive eBC, the filter-based methods suffer from different biases such as particle and multiple light scattering, filter loading, and RH effect. However, the in-situ particle absorption measurements include photoacoustic techniques (e.g., photoacoustic soot spectrometer: PASS), interferometric techniques, and remote sensing techniques, which are more reliable [4].</li> <li>- Refractory black carbon (rBC): It is the carbon mass which is stable at ~ 4300 K and measured by thermal emission of carbon component of the particle absorbing laser energy. It is measured by laser-induced incandescence (LII) [4].</li> </ul>
<u>Measurement methods:</u>	Light absorption, EC/OC ratio, eBC, refractory Black Carbon [14].
<u>Reference/Source:</u>	<p>[5] EEA (2019). DOI: 10.2800/293657.</p> <p>[6] Lack et al. (2014). DOI: 10.1007/s00216-013-7402-3.</p> <p>[14] Sharma et al. (2017). DOI: 10.5194/acp-17-15225-2017.</p>

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	First of all, for the specific emission inventory purpose, we should clearly state that “primary PM <sub>2.5</sub> ” is to be treated here, such that BC (always primary) and POA fractions as emitted are to be discussed. Of course SOA (and sulfate etc) are important but their precursors (i.e., NMVOCs and SO <sub>2</sub> etc) should be treated in the “emission inventory” methodology which we aim here.
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	ACSM, GC/MS <sup>n</sup> , HPLC/MS <sup>n</sup> , PIXE, ICP-MS, IC, IC-MS, TOT
<u>Measurement methods:</u>	Beta-attenuation, TEOM-FDMS
<u>Reference/Source:</u>	Nozière et al. Chem. Rev. 2015 (doi:10.1021/cr5003485) Grover et al. Aerosol. Sci. Technol. 2006 (doi:10.1080/02786820600615071)

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	Particulates of aerodynamic diameter size up to 2.5 µm (1 µm = 10 <sup>-6</sup> m). According to [16, section 2.7.4 Sizes of Atmospheric Particles]. According to EMEP/LRTAP methodology [5] BC is a semi-direct fraction of PM <sub>2.5</sub> .
<u>Measurement methods:</u>	Air quality measurements. The main instruments and methods of measuring concentration (gravimetric, optical, and microbalance) and size distribution Scanning Mobility Particle Sizer (SMPS), Electrical Low Pressure Impactor (ELPI), and others were described and compared. The aim of this work was to help researchers choose the most suitable equipment to measure particulate matter. When choosing a measuring instrument, a researcher must clearly define the purpose of the study and determine whether it meets the main specifications of the equipment. ELPI and SMPS are the suitable devices for measuring fine particles; the ELPI works in real time. In health-related studies, a Diffusion Charger is the instrument that best characterizes the surface of ultrafine particles. Several methods and different particle measuring instruments should be used to confirm the values obtained during sampling [17]. Low cost techniques are given in [18].
<u>Reference/Source:</u>	[15] Pfeiffer (2005). URL: <a href="https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2398&amp;context=usdaarsfacpub">https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2398&amp;context=usdaarsfacpub</a> . [16] Seinfeld, and Pandis (2006). ISBN: 978-0-471-72017-1. [17] Amaral et al. (2015). DOI: 10.3390/atmos6091327. [18] Alfano et al. (2020). DOI: 10.3390/s20236819.

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	From Lack et al. (2014): “This is the component of carbonaceous particles where the carbon molecules are chemically combined with hydrogen and other elements like oxygen, sulfur, etc.”
<u>Measurement methods:</u>	From WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations: “For mass measurements and chemical analyses, except organic carbon, filtration with a Teflon filter is recommended for aerosol collection.” “A list of core aerosol particle chemical analysis is strongly recommended: i) mass concentration with gravimetric analysis; continuous measurements with Tapered Element Oscillating Microbalance (TEOM). ii) major ionic species (sulfate, nitrate, chloride, sodium, ammonium, potassium, magnesium, and calcium) using ion chromatography; iii) mineral dust (at least four of the major crustal elements Al, Si, Fe, Ti, Sc and the related elements Na, Mg, K, Ca). No specific analytical technique is recommended as there is a good selection available including PIXE, INAA, XRF, AAS and ICP-MS; iv) carbonaceous components. Total particulate carbon mass (TC) can be divided into three fractions: inorganic carbonates, organic carbon (OC), and a third fraction referred to variously as elemental carbon, equivalent black carbon (EBC), soot, or refractory carbon. Some of these terms are related to the measurement method used.”
<u>Reference/Source:</u>	GAW Report No. 227, WMO/GAW Aerosol Measurement Procedures, Guidelines and Recommendations, 2nd Edition, 2016.

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	Particulate matter with a diameter less than 2.5 micrometer. Need of distinguishing the inclusion or not of condensable components when reporting emission factors.
<u>Measurement methods:</u>	Filters, gravimetric methods, etc. Alternatively, dilution methods of the exhausts with ambient air can be used and the filterable and condensable components are collected on a filter at lower temperatures. It is highly important to evaluate the presence of condensable material in the measured data.
<u>Reference/Source:</u>	EMEP/EEA Guidebook 2019 and scientific literature

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	PM <sub>2.5</sub> refers to atmospheric particulate matters that have equivalent diameters less than 2.5 micrometers.
<u>Measurement methods:</u>	a. The most accurate measurement uses a gravimetric method by drawing air onto a filter where particles can be collected. b. Particulate matter can also be measured by using optical instruments that measure different properties of light, including light scattering, light absorption, and light extinction, and how they react to the presence of particles.
<u>Reference/Source:</u>	<a href="https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter">https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter</a> <a href="https://www.intechopen.com/chapters/52206">https://www.intechopen.com/chapters/52206</a>

<b>PM<sub>2.5</sub></b>	
<u>Speciation methods:</u>	Ambient Online Methods

	<p>Continuous or semi-continuous measurements often used in research studies but not currently used in EPA's ambient monitoring network.</p> <p>Aerosol mass spectrometer (e.g., Aerodyne Aerosol Chemical Speciation Monitor) for organic aerosol, NO<sub>3</sub>, SO<sub>4</sub>, NH<sub>4</sub>, Cl.</p> <p>Carbon analyzer (e.g., Sunset Semi-continuous carbon analyzer) organic carbon, elemental carbon</p> <p>Ion chromatography (e.g., URG ambient ion monitor) nitrate, sulfate, nitrite, phosphate, chloride, sodium, calcium, potassium, magnesium</p> <p>Ambient Offline Methods</p> <p>Batch samples collected and analysed. An example of measurements can be found in EPA's chemical speciation network <a href="https://www.epa.gov/amtic/chemical-speciation-network-csn-general-information">https://www.epa.gov/amtic/chemical-speciation-network-csn-general-information</a> :</p> <p>Ion chromatography for NO<sub>3</sub>, SO<sub>4</sub>, NH<sub>4</sub>, Na, K</p> <p>X-Ray fluorescence for elemental composition (Na through Pb on the periodic table)</p> <p>Thermal optical analysis for elemental carbon, organic carbon using IMPROVE_A protocol (SOP#402)</p> <p>Source Methods</p> <p>There are no EPA methods for speciation of source particulate matter emissions so ambient methods are often adapted for obtaining speciation data from source emissions.</p>
<p><u>Measurement methods:</u></p>	<p>Ambient Online Methods</p> <p>EPA federal equivalent methods rely on different measurement technologies, some examples include beta attenuation, light scattering, and tapered oscillating microbalance</p> <p>Ambient Offline Methods</p> <p>EPA federal reference methods rely on PM<sub>2.5</sub> inlets (virtual impactor, cyclone) and filter samples</p> <p>Source Methods</p> <p>Most EPA methods for stationary sources do not size fractionate. EPA method 5 is a general method for filterable material with additional modifications to the method for specific sources (Method 5A – 5I). EPA method 5 extracts a sample from an exhaust source. EPA method 17 measures filterable material in the exhaust stack.</p> <p>EPA Method 201A is the PM<sub>2.5</sub> sampling method for stationary sources and collects only the filterable particulate matter at the filter temperature, which must be greater than 30 °C.</p> <p>EPA Method 202 is the sampling method for condensable material, which is assumed to be entirely in the PM<sub>2.5</sub> size fraction.</p>
<p><u>Reference/Source:</u></p>	<p>EPA PM speciation guidelines: <a href="https://www.epa.gov/sites/default/files/2017-01/documents/final_draft_pm2.5_speciation_guidance_1999.pdf">https://www.epa.gov/sites/default/files/2017-01/documents/final_draft_pm2.5_speciation_guidance_1999.pdf</a></p> <p>EPA designated reference instruments/samplers: <a href="https://www.epa.gov/system/files/documents/2021-12/designated-referene-and-equivalent-methods-12152021.pdf">https://www.epa.gov/system/files/documents/2021-12/designated-referene-and-equivalent-methods-12152021.pdf</a></p> <p>EPA stationary source methods: <a href="https://www.epa.gov/emc/emc-promulgated-test-methods">https://www.epa.gov/emc/emc-promulgated-test-methods</a></p>

	University of California Davis Chemical Speciation Network Standard Operating Procedure #402 Thermal/Optical Reflectance (TOR) Carbon Analysis Using a Sunset Carbon Analyzer <a href="https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf">https://www.epa.gov/sites/default/files/2019-11/documents/ucd_sop402_tor_carbon_analysis_final_srsedit.pdf</a>
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<b>PM<sub>10</sub></b>	
<u>Speciation methods:</u>	Particulate matter with a diameter less than 10 micrometer. Need of distinguishing the inclusion or not of condensable components when reporting emission factors.
<u>Measurement methods:</u>	Filters, gravimetric methods, etc. Alternatively, dilution methods of the exhausts with ambient air can be used and the filterable and condensable components are collected on a filter at lower temperatures. It is highly important to evaluate the presence of condensable material in the measured data.
<u>Reference/Source:</u>	EMEP/EEA Guidebook 2019 and scientific literature

<b>PM<sub>10</sub></b>	
<u>Speciation methods:</u>	PM <sub>10</sub> refers to atmospheric particulate matters that have equivalent diameters less than 10 micrometers.
<u>Measurement methods:</u>	<ol style="list-style-type: none"> <li>a. The most accurate measurement uses a gravimetric method by drawing air onto a filter where particles can be collected.</li> <li>b. Particulate matter can also be measured by using optical instruments that measure different properties of light, including light scattering, light absorption, and light extinction, and how they react to the presence of particles.</li> </ol>
<u>Reference/Source:</u>	<a href="https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter;">https://www.clarity.io/blog/air-quality-measurements-series-particulate-matter;</a> <a href="https://www.intechopen.com/chapters/52206">https://www.intechopen.com/chapters/52206</a>

<b>PM<sub>10</sub></b>	
<u>Speciation methods:</u>	Particulates of aerodynamic diameter size up to 10 µm. According to [16, section 2.7.4 <i>Sizes of Atmospheric Particles</i> ].
<u>Measurement methods:</u>	See info for PM <sub>2.5</sub> .
<u>Reference/Source:</u>	See info for PM <sub>2.5</sub> .

<b>PM<sub>10</sub></b>	
<u>Speciation methods:</u>	ACSM, GC/MS <sup>n</sup> , HPLC/MS <sup>n</sup> , PIXE, ICP-MS, IC, IC-MS, TOT
<u>Measurement methods:</u>	Beta-attenuation, TEOM-FDMS
<u>Reference/Source:</u>	Nozière et al. Chem. Rev. 2015 (doi:10.1021/cr5003485) Grover et al. Aerosol. Sci. Technol. 2006 (doi:10.1080/02786820600615071)



<b>PM<sub>10</sub></b>	
<u>Speciation methods:</u>	Same methods as listed for PM <sub>2.5</sub> above, although most online methods have been developed or adapted only to PM <sub>10</sub> and have not been thoroughly evaluated for larger size fractions.
<u>Measurement methods:</u>	Same methods as listed for PM <sub>2.5</sub> above
<u>Reference/Source:</u>	See references for PM <sub>2.5</sub> above

<b>NMVOCs</b>	
<u>Relevant species:</u>	Isoprene (relevant for both ozone and SOA production), C <sub>2</sub> -C <sub>10</sub> hydrocarbons (especially ozone precursors, with aromatic species also SOA-forming), C <sub>11</sub> -C <sub>20</sub> hydrocarbons (relevant for SOA formation)
<u>Speciation methods:</u>	GC/MS systems of varying complexity for an in-depth speciation.
<u>Measurement methods:</u>	GC/FID can be implemented as automatic systems suitable for monitoring of the simplest compounds (up to C <sub>10</sub> ).
<u>Reference/Source:</u>	Blas et al., STOTEN 2011 (doi:10.1016/j.scitotenv.2011.08.072) Jathar et al., PNAS 2014 (doi:10.1073/pnas.1323740111) Huo et al. J. Geophys. Res. (doi:10.1029/2021JD035835)

<b>NMVOCs</b>	
<u>Relevant species:</u>	Non-methane volatile organic compounds.
<u>Speciation methods:</u>	25 GEIA species through the application of speciation profiles. Specific profiles are available in the EMEP/EEA Guidebook 2019 (e.g. for gasoline evaporative emissions from road transport, see Table 3-16).
<u>Measurement methods:</u>	Proton transfer reaction mass spectrometer (PTRMS), Gas Chromatograph (GC)-Mass Spectrometry (MS)
<u>Reference/Source:</u>	Scientific literature

<b>NMVOCs</b>	
<u>Relevant species:</u>	<p>Relevant species will be dependent on the source and the atmospheric conditions and chemistry into which they are emitted, so there is no list of relevant species that is applicable to all conditions. A recent approach to address this complexity is to estimate total reactive organic carbon, which includes VOCs, semi-volatile organic compounds (SVOCs), and intermediate volatility organic compounds (IVOCs) (Heald and Kroll 2020).</p> <p>SVOCs and IVOCs are very important SOA precursors (Robinson et al. 2007). Some examples of important chemical classes for specific sources are aromatics, cyclic alkanes in mobile source emissions (Lu et al. 2020), oxygenated organic compounds and heterocyclic compounds in biomass burning (Ahkerati et al. 2020), non-oxygenated IVOCs in volatile chemical products (Pennington et al. 2021).</p>

	EPA does maintain a list of compounds that are not considered VOCs, because their rate of reaction with OH is sufficiently small that they are considered negligible for the formation of ozone on local and regional scales.
<u>Speciation methods:</u>	Chemical speciation is generally derived from mass spectrometry or chromatography approaches. See Nozière et al. (2015) for a review of EPA and research methods for organic speciation.
<u>Measurement methods:</u>	EPA has measurement methods for gaseous nonmethane organic emissions (Method 25 and variations A-E) from sources. EPA has methods for toxic organic compounds in ambient air (EPA TO-Methods). <a href="https://www.epa.gov/amtic/compendium-methods-determination-toxic-organic-compounds-ambient-air">https://www.epa.gov/amtic/compendium-methods-determination-toxic-organic-compounds-ambient-air</a>
<u>Reference/Source:</u>	Heald and Kroll 2020 <a href="https://www.science.org/doi/10.1126/sciadv.aay8967">https://www.science.org/doi/10.1126/sciadv.aay8967</a> Nozière et al. 2015 <a href="https://pubs.acs.org/doi/10.1021/cr5003485">https://pubs.acs.org/doi/10.1021/cr5003485</a> Ahkerati et al. 2020 <a href="https://pubs.acs.org/doi/10.1021/acs.est.0c01345">https://pubs.acs.org/doi/10.1021/acs.est.0c01345</a> Lu et al. 2020 <a href="https://acp.copernicus.org/articles/20/4313/2020/">https://acp.copernicus.org/articles/20/4313/2020/</a> Pennington et al. 2021 <a href="https://acp.copernicus.org/articles/21/18247/2021/acp-21-18247-2021.pdf">https://acp.copernicus.org/articles/21/18247/2021/acp-21-18247-2021.pdf</a> Robinson et al. 2007 <a href="https://www.science.org/doi/10.1126/science.1133061">https://www.science.org/doi/10.1126/science.1133061</a> Compounds exempted from VOC regulations: <a href="https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-51/subpart-F/section-51.100">https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-51/subpart-F/section-51.100</a>

<b>NMVOCs</b>	
<u>Relevant species:</u>	No speciation nor the measurement methods given in Polish emission inventory (LRTAP/NEC). Some applications of US EPA SPECIATE database for air quality modelling [19].
<u>Speciation methods:</u>	No data
<u>Measurement methods:</u>	No data
<u>Reference/Source:</u>	[19] <a href="https://www.epa.gov/air-emissions-modeling/speciate">https://www.epa.gov/air-emissions-modeling/speciate</a> .

<b>NMVOCs</b>	
<u>Relevant species:</u>	small oxygenated species, phenolics and furanics
<u>Speciation methods:</u>	Fully speciated emission factors are available from the references given in paper.
<u>Measurement methods:</u>	All emission factors applied in this study included measurement by PTR-ToF-MS, a technique well suited to species released in significant quantities from solid fuel combustion such as small oxygenated species, phenolics and furanics. These species are often missed by GC measurement alone.
<u>Reference/Source:</u>	Gareth J. Stewart, Beth S. Nelson, W. Joe F. Acton, Adam R. Vaughan, James R. Hopkins, Siti S.M. Yunus, C. Nicholas Hewitt, Oliver Wild, Eiko Nemitz, Ranu Gadi, Lokesh K. Sahu, Tuhin K. Mandal, Bhola R. Gurjar, Andrew R. Rickard, James D. Lee, Jacqueline F. Hamilton, Emission estimates and inventories of non-methane volatile organic compounds from anthropogenic burning sources in India, Atmospheric

	<p>Environment: X, Volume 11, 2021, 100115, ISSN 2590-1621, <a href="https://doi.org/10.1016/j.aeaoa.2021.100115">https://doi.org/10.1016/j.aeaoa.2021.100115</a>.</p> <p>Stewart, G. J., Acton, W. J. F., Nelson, B. S., Vaughan, A. R., Hopkins, J. R., Arya, R., Mondal, A., Jangirh, R., Ahlawat, S., Yadav, L., Sharma, S. K., Dunmore, R. E., Yunus, S. S. M., Hewitt, C. N., Nemitz, E., Mullinger, N., Gadi, R., Sahu, L. K., Tripathi, N., Rickard, A. R., Lee, J. D., Mandal, T. K., and Hamilton, J. F.: Emissions of non-methane volatile organic compounds from combustion of domestic fuels in Delhi, India, <i>Atmos. Chem. Phys.</i>, 21, 2383–2406, <a href="https://doi.org/10.5194/acp-21-2383-2021">https://doi.org/10.5194/acp-21-2383-2021</a>, 2021.</p> <p>Time-Resolved Intermediate-Volatility and Semivolatile Organic Compound Emissions from Household Coal Combustion in Northern China; Siyi Cai, Liang Zhu, Shuxiao Wang, Armin Wisthaler, Qing Li, Jingkun Jiang, and Jiming Hao; <i>Environmental Science &amp; Technology</i> 2019 53 (15), 9269-9278 DOI: 10.1021/acs.est.9b00734</p> <p>Stewart et al., 2021' G.J. Stewart, B.S. Nelson, W.S. Drysdale, W.J.F. Acton, A.R. Vaughan, J.R. Hopkins, R.E. Dunmore, C.N. Hewitt, E.G. Nemitz, N. Mullinger, B. Langford, Shivani, E.R. Villegas, R. Gadi, A.R. Rickard, J.D. Lee, J.F. Hamilton; Sources of non-methane hydrocarbons in surface air in Delhi, India; <i>Faraday Discuss</i>, 226 (2021), pp. 409-431, 10.1039/D0FD00087F</p>
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<b>NMVOCs</b>	
<u>Relevant species:</u>	In CMIP6 anthropogenic emission inventory, there are 25 speciated-VOC type and total NMVOC files.
<u>Speciation methods:</u>	
<u>Measurement methods:</u>	
<u>Reference/Source:</u>	

<b>NMVOCs</b>	
<u>Relevant species:</u>	Non-methane volatile organic compounds (NMVOCs) are a set of organic compounds that are typically photochemically reactive in the atmosphere, which are marked by the exclusion of methane.
<u>Speciation methods:</u>	
<u>Measurement methods:</u>	Gas chromatography/mass spectrometry(GC/MS)
<u>Reference/Source:</u>	<a href="https://en.wikipedia.org/wiki/Non-methane_volatile_organic_compound">https://en.wikipedia.org/wiki/Non-methane_volatile_organic_compound</a> Nourian, A., Abba, M.K., Nasr, G G., 2021, Measurements and analysis of non-methane VOC (NMVOC) emissions from major domestic aerosol sprays at “source”. <i>Environ. Int.</i> 146,106152, <a href="https://doi.org/10.1016/j.envint.2020.106152">https://doi.org/10.1016/j.envint.2020.106152</a> .

<b>NMVOCs</b>	
<u>Relevant species:</u>	So many but could be categorized to 'lumped' species normally treated in atmospheric chemistry transport model simulations
<u>Speciation methods:</u>	Gas chromatography (GC), mass spectrometry (GC-MS, PTR-MS etc)

<u>Measurement methods:</u>	
<u>Reference/Source:</u>	

**Note for BOG2 <General Inventory Issues>  
(including experts' feedback to the questionnaire)**

Several general inventory issues were raised by participants for further discussion and consideration with the aim to inform the scoping meeting of a new Methodology report on Short-lived Climate Forcers (SLCFs). BOG2 participants are expected to consider how general guidance provided in the 2006 IPCC Guidelines and its 2019 Refinement can be applied to emission inventories that includes SLCF species. In particular:

1. *Approaches to data collection and time series consistency*

Development of spatially and temporally disaggregated estimates within an annual national emission inventory, by applying different resolutions: daily, monthly, annually; point sources, transport lines, urban areas, etc. in order to provide information needed to assess each SLCF climate impact.

- a. *How to address finer temporal and spatial distribution?*
- b. *What are the implications in terms of good practice for data collection?*
- c. *What are implications on time series consistency?*

2. *Key category analysis:*

- d. *How quantitative approaches be applied (see KCA note)?*
- e. *Should qualitative criteria be applied as provided in the KCA note or should be revised or new to be added?*

3. *Given SLCF emissions have large spatial and temporal variability:*

- f. *Should verification with atmospheric observation data be further promoted?*
- g. *Is there any regional/global independent monitoring system/dataset to be suggested for verification of SLCF emissions?*

## Compilation of experts' feedback to the questionnaire

Some specific issues and suggestions provided by participants in the questionnaire are summarised hereafter:

### Approach to Data Collection

- *Use of proxy (such as GDP, population, vehicle fleet, etc.) to be used to disaggregate national estimates. Downscale national totals by key category or sub-sector making use of several spatial proxies (e.g. point sources, linear sources, area sources).*
- *Gathering of national annual statistics or monthly data to be aggregated to annual activity data.*
- *Many inventories are top-down compiled on annual basis by national jurisdiction and by subnational jurisdictions (provinces or states). However, if the application is oriented towards air quality or global change models, a fine spatial distribution is required (for example,  $0.1^\circ \times 0.1^\circ$ ). However, achieving adequate spatial disaggregation of the activity data (AD) on national scales requires making certain assumptions about their distribution, which leads to significant levels of uncertainty. For smaller scale inventories (i.e., facilities, cities), a bottom-up procedure is recommended, by organizing an exhaustive list of sources with their respective AD, avoiding the use of proxy information.*
- *National inventories usually use population distribution as proxy data to spatially disaggregate the AD. Population is a well-known data in subnational districts for most of the countries. For example, residential emissions can be well represented using population density distribution.*
- *Transport emissions may need additionally an active fleet distribution and some additional information such as road density and road classification in the spatial grid resolution. This information will help to disaggregate fuel consumption.*
- *New satellite monitoring sensors may help to produce better large-scale spatial disaggregation's at finer resolutions.*
- *Many national statistic offices and international agencies, stores and archive annual activity data, especially for key energy production and consumption indices. Many countries have better organized data bases from 1990 and onwards. It is important to construct a consistent annual series for fuel production, (import-export), fuel transformation subproducts (i.e. gasoline, gas-oil, diesel oil, natural gas, on so on). Since a good energy balance is the base of many national inventories, maintaining a good annual AD series helps a good interpretation of the emissions data.*
- *Activity data that has spatial variability, such as location of facility, road locations, location of ships. For some sources a spatial surrogate is used, like population distribution. Current IPCC guidance on GHGs discusses differences in emissions across facilities, etc. but does not get into spatial disaggregation of emissions. For GHGs spatial disaggregation is not critical within a reporting country but for SLCFs it is important to accurately estimate emission impacts.*
- *The strategy is to find activity data with the highest available time resolution. If not available, a profile is applied with monthly and / or weekday variability. The current IPCC guidance on GHGs discusses adjusting time series of data, etc. For SLCFs the temporal aspect of emissions matters. Also, in terms of developing measurement approaches to data collection, fuel properties are not as critical to SLCFs but mitigation and control technologies are more important compared to GHGs. Also, some SLCF emissions and emission factors could change over time for a given source and technology as it ages (e.g., some vehicle emissions over time).*

### References:

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The EMEP/EEA Guidebook 2019: <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-a-general-guidance-chapters/3-data-collection/view>

The US EPA Inventory Document: <https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tds>

### **Key Category Analysis (KCA).**

*(also, see the separate note on KCA)*

- *As they are many new substances to be considered, and many might be insignificant, guidance on estimating only relevant emissions should be included. Also, as they cannot be summed up, if one source has many SLCF emissions, it should also be prioritised. And how to define which substance is the most damaging, should the country consider local circumstances? Is effects in health a criteria or other co-benefits? In this case spatial and temporal information should be taken into account.*
- *All IPCC categories for GHGs should be in general covered also by the SLCFs. As a starting point all key categories reported in the EMEP/EEA Guidebook 2019 should be taken into account together with the critical aspects discussed in the First/Second IPCC expert meetings. Follow existing guidelines. Most of SLCFs are co-emitted by the same sources.*
- *Categories whose cumulative percentage contribution is greater than 80% should be identified as key category.*
- *Facilities that have the potential to emit 100 tonnes per year are required to report emissions. Other sources are classified as “nonpoint” and are required to report on a county-level basis. Individual sectors that are regulated with performance standards have reporting requirements (akin to higher Tier IPCC GHG methods) based on attributes of the facility. Possibility to define key categories for SLCFs for each individual gas (based on sources that contribute to >95% of emissions) as opposed to combining all SLCFs based on GWP. Could still include different approaches to KCA (e.g., Level, Trend/Approach 1, Approach 2). It may also be appropriate to do a KCA at the sub-national level (as described in the 2019 Refinement) in addition to a national analysis, due to the spatial variability in emissions).*

- *Potential to emit 100 tonnes per year, size of facility or operation. For GHG KCA is used to help define what Tier is appropriate for measuring emissions. For SLCF selection of appropriate Tier might be based on emission source and type as opposed to KCA. Or could be based on KCA if conducted for each compound. For example, the US Clean Air Act specifies facility limits. Guidance documents for different sectors regulated with performance standards. This guidance is currently under revision.*

#### References:

The EMEP/EEA Guidebook 2019: <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-a-general-guidance-chapters/2-key-category-analysis-and/view>

The US EPA guidance: <https://www.epa.gov/air-emissions-inventories/air-emissions-inventory-improvement-program-eiip>

#### Time series consistency

- *Interpolation may be performed when data is available only for certain years. Different type of interpolation may be evaluated (e.g. linear, non-linear, etc.) or a proxy could be used to extrapolate missing data. Monthly or inter-annual data are needed to extract information on seasonal trends. For lack of data mostly linear interpolation. Extrapolations for projections. No data about seasonal trends in EMEP/LRTAP emission inventory. Seasonal trends may be obtained from the statistical analysis of many years with monthly data. If a particular year does not have monthly data or some are missing, then the prior trend may be used to fill the gap.*
- *Many international inventory comparisons show correlated time series data, i.e. emissions from power plant emissions, however some bias are always present. Although consulting the same statistical sources some bias and differences appear from discrepancies in the AD series. Sometimes energy-data gathering offices change the way data are stored, or historical data bases are re-organized producing significant differences (steps or jumps) in the time series. This may happen, for example since 2 or 3 items have been moved and merged to a new category, making it impossible to discriminate the proportion of each item afterwards. In this case a common item should be recalculated to produce a smooth series of that particular AD. National offices normally produce revised versions of the main data, where many inconsistencies are removed. In any case a fine quality control is required to produce a consistent time series.*
- *When annual data are missing for some years, or some backwards extrapolation may be needed, some proxy data could be used to fill the gap. For energy data, for example, economic (i.e. GDP) and population data may be used, since they are strongly correlated.*
- *If the variable only has annual data, then two things may be done: 1. Investigate the nature of the variable to detect the possible seasonal variability, i.e., feedstock, agricultural production, or heating/cooling demand. 2. Once the nature of the variability is understood, then look for a proxy variable. For example, temperature for heating/cooling consumption demands, fuel sales demand for the agriculture activity, electricity demand, and so on.*
- *Time series consistency depends on the available activity data. The goal is to get year-specific activity data, which are available for large point sources, vehicles, and non-road vehicles. If not available, possible scaling factors include industrial output for the sector, economy-wide statistics, or to simply leave constant in the absence of any better information. The GHG guidance is based on annual reporting where seasonal and other variations are important for SLCF inventories. The strategy is usually to use activity data with the highest available time resolution. If not available, a profile is applied with monthly and / or weekday variability.*
- *Since the SLCFs would be a new category it is unclear if they would be reported back to 1990. The guidance for GHG is generally applicable to SLCF however, some assumptions for GHGs like emission factors or other estimation parameters do not change over time might not hold for SLCFs.*



- *Inventory recalculations are done as needed to support regulatory actions. Individual reporters (e.g., states) are not required to re-report historic emissions.*
- *Use of satellite-derived inventories based on the combination of IASI or CrIS NH<sub>3</sub> columns and regional chemical transport model (CTM). HEMCO model computes soil Nox emissions worldwide at horizontal resolutions of 0.5° lat. × 0.625° lon. for 1980–2017 and 0.25° lat. × 0.3125° lon. for 2014–2017*

#### References:

EMEP/EEA Guidebook 2019:

<https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-a-general-guidance-chapters/4-time-series-consistency/view>

The US EPA Technical support document for National Emission Inventory:

<https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd>

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Weng, H., Lin, J., Martin, R. et al. Global high-resolution emissions of soil NO<sub>x</sub>, sea salt aerosols, and biogenic volatile organic compounds. *Sci Data* 7, 148 (2020). <https://doi.org/10.1038/s41597-020-0488-5>

#### Verification

*Verification may be done in different ways.*

- *Checking of the completeness of the computed emissions against the mapped key categories. Comparison of the emission estimates with global and regional emission inventory data. Check ratios between pollutants co-emitted by the same sources. Check the PM balance when looking at its speciation.*
- *Verification of input data, partial verification of point data.*
- *If a bottom-up approach has been developed to organize the AD, for example, transport emissions at a national/subnational scale, then the calculated fuel/energy consumption, may be compared to the national energy balance (top-down). For example, total diesels sales from refinery production and export/import balances.*
- *If a subnational inventory is organized, then some economic index for that district or province may be calculated. The bottom-up calculated AD should be proportional to the national AD and the estimated subnational economic index.*
- *Satellite inversions data may be also possible for some sectors and pollutants.*
- *Add list of sources and SLCF that are likely monitored due to health concerns*
- *Outliers and missing data are compared with previous years and large changes are investigated further. Location of emissions are checked against reported addresses and aerial imagery. Alternative emission calculation approaches are compared with results from EPA methods. Emissions are used as input to chemical transport models and resulting concentrations are compared to ambient observations. Locations with large differences are examined for possible errors in the emission inventory. Comparisons to*

overall fuel statistics are not as relevant for SLCFs as for GHGs (e.g., reference approach for CO<sub>2</sub>). Location and temporal aspects of SLCF emissions are more important than for GHGs.

- Observation-based flux estimations (inversions from atmospheric concentrations, data assimilations, comparisons to emission sensitivity runs of forward atmospheric chemistry transport models). Satellite observations and in-situ high precision observations can be used, together with numerical model simulations where meteorology is well represented.
- Comparison with another source of information. Specific example, for emissions from manure application and N fertilization, compare calculated annual amount of field application of (i) manure from annual average populations, N and TAN excretion and (ii) synthetic N fertilisers from sales reports with national cultivation practices survey analysis if available, giving the amounts of each types of manure and synthetic fertilizers applied to soils. Verify EF calculation with satellite data of soil NO<sub>x</sub>.

#### References:

The US EPA Technical support document for National Emission Inventory:

<https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd>

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Tong Sha, et al. Impacts of Soil NO<sub>x</sub> Emission on O<sub>3</sub> Air Quality in Rural California Environmental Science & Technology 2021 55 (10), 7113-7122 DOI: 10.1021/acs.est.0c06834

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## Consideration for the Key Category Analysis of SLCF sources

The key category analysis (KCA) aims at prioritizing those sources/sinks that have a significance influence in the estimated national total emissions.

### Current guidance

Guidance on KCA for national GHG inventories is provided in the IPCC Guidelines (Chapter 4, Vol.1 of *2006 IPCC Guidelines*, Chapter 4, Vol.1 of *2019 Refinement*). In addition, guidance on KCA for air pollutant emission inventories is provided in the EMEP/EEA air pollutant emission inventory guidebook (Chapter 2, Part A of the EMEP/EEA Guidebook 2019).

- Guidance in the IPCC Guidelines

The *quantitative* determination of key categories considers GHG emissions and CO<sub>2</sub> removals by weighting the contribution -in absolute terms- of each GHG from each source/sink to the absolute level of national total GHG emissions as well as to the trend across time of total emissions. For such a quantitative analysis a common metric is required to aggregate emissions and removals of different GHGs. GWPs<sub>100</sub> from IPCC Assessment Reports are used as an example of such common metrics in the IPCC Guidelines. Under the Paris Agreement, the Parties are obliged to use GWPs<sub>100</sub> from IPCC Fifth Assessment Report (AR5).

The *qualitative* determination of key categories applies criteria, a category that qualify for any of those criteria is identified as key

- a. Mitigation techniques and technologies:  
emissions have decreased or removals have increased through the use of climate change mitigation techniques
- b. Expected growth:  
increase of emissions or decrease of removals in the future
- c. No quantitative assessment of Uncertainties performed  
when Approach 2 including uncertainties in the key category analysis is not applied, assumed to contribute most to the overall uncertainty
- d. Completeness  
when some potential key categories are not estimated yet, expected to be/likely to be key category (for instance in comparison with GHG inventories of other countries with similar national circumstances)

- Guidance in the EMEP/EEA Guidebook 2019

The methodology follows the IPCC approach and covers Approaches 1 and 2 for both level and trend assessments. However, there are some differences as compared to the IPCC Guidelines, for example:

- *KCA for each air pollutant is considered separately (produce pollutant- specific key categories)*
- *Key categories are those which, when summed together in descending order of magnitude, cumulatively add up to 80 % of the total level (as opposed to 95% used in the IPCC Guidelines)*

In addition, Annex A of the Chapter 2, Part A of the EMEP/EEA Guidebook 2019 provides procedures (optional) which can be used by countries if they wish to aggregate their pollutant-specific key categories to a single list of key categories. Once the trend and level key categories have been identified and ranked for each pollutant, they can be combined by scoring each key category according to its position in the ranked pollutant key category list.

For more details, please refer to Chapter 2 “2 Key category analysis and methodological choice 2019”, Part A of the EMEP/EEA Guidebook 2019 <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-a-general-guidance-chapters/2-key-category-analysis-and/view>

## SLCFs status

SLCFs have positive and negative radiative forcing -similarly to emissions and removals- however a GWP<sub>100</sub> value for each of SLCF species is not available.

## Considerations

At the 3<sup>rd</sup> expert meeting, the participants will be invited to consider possible approaches to KCA that can be applied to SLCF inventory, taking the above-mentioned background into account. For example, the following 3 approaches may be considered. The expert meeting is not to decide on the best approach but to come up with possible approaches and consider advantages and disadvantages of each approach to help authors of a Methodology Report on SLCFs to be produced in the IPCC AR7 cycle.

- Considering that no GWP<sub>100</sub> values are available for all SLCF species, identifying an alternative common metric

To determine a common metric for SLCF emissions, possibly fungible with that applied to GHGs, appears a challenge since SLCFs have direct and indirect effects through absorption/reflection of solar and/or earth radiations, chemical reactions in the atmosphere, alteration of clouds and surface reflectance as well as clouds lifetime. Nevertheless, IPCC Working Group I (WGI) provides in the AR6 the radiative forcing associated to main SLCF species -although the radiative contribution of SLCFs differs depending on the environmental conditions at emission- and papers have been published on methods to calculate the GWPs of SLCFs -e.g. through specific forcing pulse<sup>25</sup>. Following two appears to be the options to address the common metric need:

1. Request WGI to have during AR7 cycle a focused discussion with the aim to produce such common metric although associated uncertainties may be larger.

*Note that some Parties to the UNFCCC have black carbon (BC) emissions reduction as a mitigation policy within the Paris Agreement NDC accounting. It may therefore be the case that UNFCCC will interrogate/request IPCC to provide for such common metric.*

2. Providing good practice for qualitative analysis only (see next approach)

Note that these two options are not mutually exclusive, while for some SLCFs option 1 can be applied for others option 2 may be considered the most viable option.

- Focusing KCA on qualitative determinants only

For this approach:

- criteria a. and b. of the IPCC Guidelines on qualitative KCA can be readily applicable. *For instance, for those countries with mitigation actions on BC in their NDCs, sources of BC emissions will be a key category.*
- criterion c. may not be so relevant since associated with a KCA with a common metric.
- criterion d. may also be readily applicable. *For instance, sources that are key for GHG emissions may also be considered key when considering SLCF emissions.*

- Identifying significant source categories applying quantitative criteria within each SLCF species only

This means that no common metric is needed, although emissions of each single SLCF species from each source category are quantified and the significance of those assessed in comparison to the total emissions of that SLCF species only. For this approach good practice for quantitative KCA can be applied.

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<sup>25</sup> Bond T.C., Zarzycki C., Flanner M. G., Koch D. M. (2010). *Quantifying immediate radiative forcing by black carbon and organic matter with the Specific Forcing Pulse*. Atmos. Chem. Phys., 11, 1505–1525, 2011 - doi:10.5194/acp-11-1505-2011

**Note for BOG3 work <List of data gaps and List of SCLF categories>, including participants' feedback to the questionnaire**

As outcome of the Joint 1<sup>st</sup> and 2<sup>nd</sup> IPCC Expert Meeting, sectoral BOGs developed the list of data gaps and list of SCLF categories. The list of data gaps has been further complemented with those gaps identified at the IPCC meeting on SLCFs held in Geneva in 2018.

Although the list of data gaps not necessarily details each source gaps as it highlights the major areas, it aims at identifying the lack of data or methodological information that may prevent to develop for the relevant source category and associated SCLF species a robust Tier 1 methodological approach.

*BOG 3 participants are expected to refine the list of data gaps and, where needed, to refine the list of SCLF categories as well.*

*The gaps can be prioritized, for future research needed, according to the significance of the sources for which methods' gaps and/or data gaps are identified.*

*Also, the participants are requested to review the list of allocation issues (cross-sectoral/cross-category), where a further work or clarification is needed and to refine the list, if needed.*

Lists should be assessed with the view that those may be used for preparation to the scoping meeting of a new Methodology report on SLCFs.

Information provided by experts on knowledge and data gaps ahead of this meeting is aimed at helping the work of BOG3 on the lists' refinement. It is compiled hereafter.

## Compilation of participants' feedback to the questionnaire

### Sources and associated SLCF species for which there is no data for Tier 1 estimate

- *Expert meetings 1&2 developed Table 1 for each major source category (Energy, IPPU, Waste, AFOLU) which identified for each source if existing IPCC methodologies applied to SLCFs. The compilation tables were also generated prior to the meeting by source experts which have detailed information on each source by gas. However, from the two it is not clear where there are gaps in developing Tier 1 approaches across the different categories. Also, it is not clear where it might not be appropriate for some sources to develop a Tier 1 approach. The gaps list identified for the meeting highlights major areas but not necessarily details for each source*
- *No default emission factors are available for NMVOC emissions from the application of manure to soils in the EMEP/EEA Guidebook 2019. These values could be provided for the Tier 1 method for different world regions.*
- *Relevance of ultra-fine particles and particle number and the corresponding size distribution for climate related issues (cloud condensation nuclei, etc.). This topic may be relevant for future investigations.*
- *No EMEP/EEA methodology for OC. (Theoretically) possible for particular categories (NFR/IPCC) estimation of OC using BC emission data or using external data source (modelling?).*
- *Determination of high-molecular weight NMHCs emissions from various sources has been conducted so far mainly for scientific research purposes and not systematically by regulatory agencies.*
- *In the transport sector, emissions from shipping are not characterized in many geographical areas, not only in low- and middle-income countries.*

### Missing data or methods for those sources and associated SLCF species for which higher tier methods are likely needed (e.g., considering mitigation aspects)

- *Any SLCF emission from common combustion practices is relevant in respect to mitigation aspects (because of importance for air pollution mitigation purposes as well) and should be included in inventories with a higher tier, as emission factors are often very much dependent on burning conditions and fuel type. Emissions can vary much geographically depending on fuel availability, access to technologies (starting from electricity) and other socio-economical factors. Emissions from the most widespread and standardized practices (often linked to traditional burning for domestic and agricultural usages) should be targeted for better characterizing emission factors with dedicated projects. To this scope, several programmes have already been put in place in low- and middle-income countries (especially in Asia, and more recently in Africa), but more efforts are needed to cover all relevant areas and activities.*
- *Need of pragmatic solutions for constraining emission factors in low-income countries: for instance, monitoring with non-regulatory grade methodologies coupled to modelling techniques where appropriate. For some aerosol precursors (SO<sub>2</sub>, NH<sub>3</sub>, NO<sub>2</sub>), top-down techniques (satellite remote sensing) can provide valuable information about the geographical regions for which missing data issues are more problematic.*
- *Characterizing the emissions from large fires requires complex observational platforms (in situ, aircrafts, satellite) with a strong commitment of the scientific community.*
- *Table 1 developed at the expert meetings 1&2 highlighted sources where higher Tiers were needed (at least for Energy sector). However, it is not clear if data exist across regions to develop guidance for those sources.*

**Any other gaps (including issues on allocation of emissions among different sectors/categories where existing approaches in the 2006 IPCC Guidelines do not work well)**

*(see Note on allocation issues)*

- *During expert meetings 1&2 there was some discussion across different sectors on allocation issues, etc. and it was generally felt that the existing IPCC guidance for GHGs would apply to the SLCF methodologies as well. Most issues are covered by data gaps file (at least for Energy) however, there are some categories where the IPCC GHG guidance might not be fully applicable to SLCFs. For example, super emitters might be a large portion of some SLCF emissions (e.g., fleet emissions).  
Suggestions: i) It would be helpful to synthesize the gaps identified in the consolidated Desk Work tables, Expert Meeting summaries, and Gaps List, including linking gaps to the significance of each source category; ii) Focus the BOG discussion on differentiating methods gaps and data gaps; iii) Discuss uncertainty methods/approaches for SLCFs relative to current GHG guidelines.*
- *The observed PM2.5 and PM10 contain secondary particles, such as sulphate and nitrate, but the PM2.5 inventory does not contain secondary particles, so there is a large gap between them. Also PM2.5 and PM10 contain various chemical compositions, and their scattering/absorption properties for atmospheric radiation and properties of cloud condensation nuclei and ice nuclei are highly dependent on their chemical compositions. Therefore, when preparing the SLCFs Methodology, which is intended for climate change mitigation, it is essential to consider the composition-specific inventory of the PM2.5 and PM10 categories, including the precursor gases of the secondary particles. This issue should be further discussed.*
- *CMIP6 emission inventories include agricultural waste burning (AGRI) in open burning or biomass burning emission files (not anthropogenic emission files), but some emission inventories include AGRI in anthropogenic emission files.*

*References provided by experts:*

EMEP technical report MSC-W 4/2020 "How should condensables be included in PM emission inventories reported to EMEP/CLRTAP?"

Akagi et al. Emission factors for open and domestic biomass burning for use in atmospheric models. Atmos. Chem. Phys., 2011 (doi:10.5194/acp-11-4039-2011)

Jayarathne et al. Nepal Ambient Monitoring and Source Testing Experiment (NAMaSTE): emissions of particulate matter from wood- and dung-fueled cooking fires, garbage and crop residue burning, brick kilns, and other sources, 2018 (doi: 10.5194/acp-18-2259-2018)

Pokhrel et al. Determination of Emission Factors of Pollutants From Biomass Burning of African Fuels in Laboratory Measurements, 2021 (doi: 10.1029/2021JD034731)

## Gaps List

Hereafter gaps identified as relevant for achieving globally applicable methods to estimate significant sources of SLCFs

### ENERGY BOG

IPCC code	Category	Gaps
1.A.1.a.	Main activity electricity and heat production	Availability of methods to estimate SLCF emissions from co-firing practices
1.A.2.m.	Non-specified industry	Small-scale combustion may occur under some facilities
1.A.3.a.ii.	Domestic aviation	Embedding emissions from landing and take-off in the Tier 1 EFs of a fuel-based approach
1.A.3.b.i.	Cars	Time dependency of technologies
1.A.3.b.ii.	Light duty trucks	
1.A.3.b.iii.	Heavy duty trucks and buses	
1.A.3.b.iv.	Motorcycles	
1.A.3.b.vi.	Urea-based catalysts	Emissions of SLCFs from vehicles equipped with urea selective catalytic reduction systems
	Non-exhaust emissions	Emissions of BC and OC from automotive wear
	Use of lubricants	Emissions of SLCFs from the use of lubricants in all types of vehicles
1.A.3.d.i.	International waterborne navigation (international bunkers)	Emission estimation methods based on engine power
1.A.3.d.ii.	Domestic waterborne navigation	
1.A.3.e.ii.	Off-road	Most alternative methodologies do not cover BC and OC emissions
1.A.4.a.i.	Stationary combustion	Guidance on the treatment and the collection of AD for informal combustion Guidance to develop country-specific EFs and other parameters
1.A.4.a.ii.	Off-road vehicles and other machinery	Most alternative methodologies do not cover BC and OC emissions
1.A.4.b.i.	Stationary combustion	See 1.A.4.a.i concerning emissions from small scale combustion and AD concerns with use of informal fuels
1.A.4.b.ii.	Off-road vehicles and other machinery	Most alternative methodologies do not cover BC and OC emissions
1.A.4.c.i.	Stationary	Guidance on the treatment and the collection of AD for informal combustion Guidance to develop country-specific EFs and other parameters
1.A.4.c.ii.	Off-road vehicles and other machinery	Most alternative methodologies do not cover BC and OC emissions
1.A.5.b.iii.	Mobile (other)	Most alternative methodologies for off-road do not cover BC and OC emissions
1.B.1.c.ii.	Coke production	Developing EFs for commercial and informal production considering differences in emissions from commercial vs informal production
1.B.2.a.vi.	Other	Consideration of leakage from the use of LPG in appliances

### IPPU BOG

General gaps:

- Lack of AD, additional or different AD can be needed for SLCFs than to GHGs
- Abatement techniques and efficiencies



- Availability of regional or country specific EFs for all SLCFs
- Definition of BC and OC emissions, measurements standards, availability of EFs for BC and OC, and documentation of EFs with indication of measurement standards
- Definition of VOC (NMVOC), speciation
- Allocation of energy and process emissions, in terms of disaggregation between different processes
- No agreed climate metrics for SLCFs

#### Categories gaps:

- 2A2 Lime production – Data collection by type of kiln, and abatement
- 2B8f Carbon black – BC and OC from diffuse emissions, NMVOCs from storage tanks
- 2C1 Iron and Steel – Fugitive PM emissions, SO<sub>2</sub> from desulfurization, PM and SO<sub>2</sub> from foundries, PM, OC, EC, CO and VOCs from scrap preparation. Rolling mills – SO<sub>2</sub> from use of volatile halogenated organics (VHO)
- 2C5 Lead production and 2C6 Zinc production – Data collection of domestic industries (processes, abatement, raw material)
- 2C7 Other (Copper) – SO<sub>2</sub> from acid mist
- 2D3 Solvent use (Domestic solvent use) – Guidance on how to collect AD and on how to estimate AD if there are no statistics (e.g. modelling from a similar country etc.)
- 2D3 Solvent use (Coating application and Degreasing) – AD
- 2D3 Solvent use (Printing) – Collection of AD (use of ink and/or applied abatement techniques, default efficiencies for abatement are provided in EMEP/EEA)
- 2D3 Solvent use (Other Solvent use) – AD capita or product/solvent use
- 2D4 Other (Asphalt Roofing) – SO<sub>2</sub> emissions in roofing materials
- 2F Product Uses as Substitutes for Ozone Depleting Substances – NH<sub>3</sub>, NMVOC – Methods, AD, EFs
- 2H1 Pulp and Paper Industry – Updated EFs

## AFOLU BOG

### 3.A.2 Manure Management

#### Activity Data

1. Reconcile N sources in manure (Total N excreted (N<sub>ex</sub>) vs. Total Ammonia N (TAN))
2. Find AD on manure and digestate transfer between farms and waste treatment facilities.
3. Improve representation of grazing practices (Urine and dung deposited by grazing livestock)

#### EFs

1. Crop-specific EF for regionally important crops (e.g. sugar cane in Central and South America and some countries in Southeast Asia).

#### Method

1. Integrate methods to estimate emissions across categories to maintain integrity of N balance.
2. Methods to estimate SLCFs emissions from the treatment, storage and spreading of digestate
3. Methods to estimate “On-farm co-digestion”.

### 3.C.1 Burning

#### EFs

1. Crop-specific EF for regionally important crops (e.g. sugar cane in Central and South America and some countries in Southeast Asia).

### 3.C.4/5 Managed soils

#### EFs

1. *Disaggregate default IPCC EF for NOX and NH3 (in 2019 Refinement).*

### 3.D.X Fugitive Dust from Tilling

#### Method

1. *Tilling is recognized as a significant source of OC and EC from PM10, based on an assessment of available data and monitoring tools.*
2. *Existing method may not be applicable globally due to its complexity.*
3. *Parameters involved in the existing method may not reflect crops, technologies or practices in all countries.*

### 3.D.X Fugitive Dust from Animals

#### Method

1. *Insufficient knowledge to be considered.*

## WASTE BOG

### 4.A Solid Waste Disposal

#### Activity Data

1. *No known guidance available to help countries estimate the amount of waste burned at landfills*
2. *It may be difficult to find information about flaring efficiencies and volumes at landfills*

#### EFs

1. *There will be a need to develop regional EFs for landfill fires, flares, and decomposition (using available methodologies as a starting point)*

#### Other

1. *The significance of NH3 from decomposition needs to be investigated further*
2. *Landfill fires and flaring - It is unclear how activity and EF data change for different landfill types (e.g., managed vs. unmanaged), but weighted correction factors for different site types may be appropriate to use (analogous to CH4 GHG GLs). This needs to be investigated further.*
3. *The definition of landfill type may also impact whether there is flaring at unmanaged landfill sites*

### 4.B Biological Treatment

#### Activity Data

1. *Limited data, especially on amount of greenwaste (composting)*
2. *Need to know the amount of N in the feedstock (waste + manure), which might vary regionally (anaerobic digestion)*

#### EFs

1. *There will be a need to develop regional EFs for composting (using available methodologies as a starting point)*
2. *Lack or limited data about N in feedstocks constraints quality of EFs*

#### Other

1. *Feedstock storage emissions (length of storage period, if stored at all at the AD site) – consistency with AFOLU to avoid potential double counting*

#### **4.C Incineration and Open Burning of Waste**

##### Activity Data

1. *The assumption of no urban burning need to be re-evaluated*
2. *The equation to estimate the amount of waste open burned needs to be reviewed and the definition of Bfrac clarified*

##### EFs

1. *Waste Incineration - Need to be technology dependent and account for abatement efficiencies*
2. *Available EFs for open burning are not likely globally applicable*
3. *Need to develop non-laboratory EFs for tire burning (for tire burning outside of landfills)*

##### Other

1. *Waste incineration - Emissions will depend on incineration conditions (e.g., waste moisture content, level of smolder, etc.) and these impacts on EF will need to be considered further*
2. *Open burning - Emissions will depend also on environmental conditions (e.g., soil moisture content, meteorology, etc.) and these impacts on EF will need to be considered further*

#### **4.D Wastewater Treatment and Discharge**

##### Activity Data

1. *It is unclear whether the total amount of wastewater treated at facilities (EMEP method) or the wastewater flow rate (USEPA NEI method) is more readily available nationally or globally*

##### EFs

1. *Available EFs (NMVOC, NH<sub>3</sub> (EPA-only)) are not specific to domestic or industrial treatment. Domestic EFs for NH<sub>3</sub> from EMEP are for latrines only.*

##### Other

1. *If Landfill leachate is treated onsite at the landfill include under 4.D.2, [if treated wastewater is directed to another treatment facility include under 4.D.1.]*

#### **4.E Other Waste**

##### Activity Data

##### EFs

1. *Global Tier 1 EF may be able to be derived for car fires*
2. *A Tier 1 EF for building fires is likely not globally applicable*

##### Other

**Annex**  
**The most significant knowledge gaps and uncertainties**  
*(Excerpt from the Geneva meeting report)*

**Theme 1: Assessment of existing methodological framework, observation of atmospheric concentrations and methods to estimate emissions of SLCF**

1. From break-out group 1a

- Sources: Residential cooking, open burning;
- OC: methods and emission factors are not covering all sources and needs further development and improvement
- Activity data mostly missing in developing countries (sources of data and additional studies – guidance on local work to develop activity data)
- Other sources: gas flaring, brick kilns, burning of agricultural residues, charcoal making
- AP 42 – possible source of data
- BC estimation methodologies for the transport sector exists and are generally applicable but we are missing representative emissions factors
- Challenges with methodologies for Off-road and super-emitters (malfunction)

2. From break-out group 1b

*Sources/categories - SLCF: AD and EFs*

- Liquid biofuels for transportation
- Traditional coal-coke production
- Biofuel cooking
- Biofuel heating
- Coal heating
- Open waste burning
- Brick kilns
- Kerosene lamps
- Flaring
- Agricultural silage – BVOC
- Non-combustion process emissions (e.g. refineries SO<sub>2</sub>)
- Agricultural waste burning on fields (AD)

*Uncertainties*

- Lack of AD can lead to high uncertainties
- Technology shares
- Behaviour/practices
- Testing versus in practice

**Theme 2: Assessment of climate impacts of SLCF emissions**

3. From break-out group 2a

- Models all have to scale up perturbations from a region, there are problems in scaling and linearities. Its limited to the computing capacities
- Regional forcing to regional response is more uncertain, but may be refined thanks to AerChemMIP
- Tremendous regional heterogeneity in inventories

- Spatial (e.g. vertical) & temporal distribution of absorbing species, speciation
- Model process level uncertainty is also high (concentrations -> radiative effects)
- Downscaling global simulations to regional and urban scales
- S/N issue for attribution is tough – variability is amplified locally
- Some success for D&A of SLCFs using observations, but quite limited
- Oxidative capacity (observations needed!!!) is central source of uncertainty

#### 4. From break-out group 2b

- Uncertainties in calculating forcing from emissions (chemistry and aerosol-cloud interactions); response to precursors not well known, just to O<sub>3</sub>, CH<sub>4</sub>, aerosols
- Rapid adjustments vs. slow response to warming/cooling
- Role of SLCFs on precipitation and extreme events; we cannot separate signature of global warming from specific contributions from SLCFs
- Feedbacks from changes in climate (temperature and water vapour) on chemistry and aerosols, e.g. NO<sub>x</sub>, BVOCs/SOA
- Impacts of regional SLCF emissions (compared to global emissions) on regional climate
- Impacts of SLCFs on carbon cycle, ecosystems, and snow

## List of SLCF Categories and Species

### 1. ENERGY

IPCC categorization	Category	SLCFs						
		NO <sub>x</sub>	NH <sub>3</sub>	SO <sub>2</sub>	CO	NM VOC	BC	OC
<b>1</b>	<b>ENERGY</b>							
<b>1.A</b>	<b>Fuel combustion activities</b>							
<b>1.A.1</b>	<b>Energy Industries</b>							
1.A.1.a.	Main activity electricity and heat production	X	X	X	X	X	X	X
1.A.1.b.	Petroleum refining	X	X	X	X	X	X	X
1.A.1.c.	Manufacture of solid fuels and other energy industries							
1.A.1.c.i.	Manufacture of solid fuels	X	X	X	X	X	X	X
1.A.1.c.ii.	Other energy industries	X	X	X	X	X	X	X
<b>1.A.2</b>	<b>Manufacturing industries and construction</b>							
1.A.2.a.	Iron and steel	X	X	X	X	X	X	X
1.A.2.b.	Non-ferrous metals	X	X	X	X	X	X	X
1.A.2.c.	Chemicals	X	X	X	X	X	X	X
1.A.2.d.	Pulp, paper and print	X	X	X	X	X	X	X
1.A.2.e.	Food processing, beverages and tobacco	X	X	X	X	X	X	X
1.A.2.f.	Non-metallic minerals	X	X	X	X	X	X	X
1.A.2.g.	Transport equipment	X	X	X	X	X	X	X
1.A.2.h.	Machinery	X	X	X	X	X	X	X
1.A.2.i.	Mining (excluding fuels) and quarrying	X	X	X	X	X	X	X
1.A.2.j.	Wood and wood products	X	X	X	X	X	X	X
1.A.2.k.	Construction	X	X	X	X	X	X	X
1.A.2.l.	Textile and leather	X	X	X	X	X	X	X
1.A.2.m.	Non-specified industry	X	X	X	X	X	X	X
<b>1.A.3.</b>	<b>Transport</b>							
1.A.3.a.	Civil aviation							
1.A.3.a.i.	international aviation (international bunkers)	X		X	X	X	X	X
1.A.3.a.ii.	Domestic aviation	X		X	X	X	X	X
1.A.3.b.	Road transportation							
1.A.3.b.i.	Cars	X	X	X	X	X	X	X
1.A.3.b.ii.	Light duty trucks	X	X	X	X	X	X	X
1.A.3.b.iii.	Heavy duty trucks and buses	X	X	X	X	X	X	X
1.A.3.b.iv.	Motorcycles	X	X	X	X	X	X	X
1.A.3.b.v.	Evaporative emissions from vehicles					X		

1.A.3.b.vi	Urea-based catalysts	X	X	X	X	X	X	X
	Non-exhaust emissions						X	X
	Use of lubricants	X	X	X	X	X	X	X
1.A.3.c.	Railways	X	X	X	X	X	X	X
1.A.3.d.	Waterborne navigation							
1.A.3.d.i.	international waterborne navigation (international bunkers)	X	X	X	X	X	X	X
1.A.3.d.ii.	Domestic waterborne navigation	X	X	X	X	X	X	X
1.A.3.e.	Other transportation							
1.A.3.e.i	Pipeline transport	X	X	X	X	X	X	X
1.A.3.e.ii.	Off-road	X	X	X	X	X	X	X
<b>1.A.4.</b>	<b>Other Sectors</b>							
1.A.4.a.	Commercial/institutional							
1.A.4.a.i.	Stationary combustion	X	X	X	X	X	X	X
1.A.4.a.ii.	Off-road vehicles and other machinery	X	X	X	X	X	X	X
1.A.4.b.	Residential							
1.A.4.b.i.	Stationary combustion	X	X	X	X	X	X	X
1.A.4.b.ii.	Off-road vehicles and other machinery	X	X	X	X	X	X	X
1.A.4.c.	Agriculture/forestry/fishing							
1.A.4.c.i.	Stationary	X	X	X	X	X	X	X
1.A.4.c.ii.	Off-road vehicles and other machinery	X	X	X	X	X	X	X
1.A.4.c.iii.	Fishing (mobile combustion)	X	X	X	X	X	X	X
<b>1.A.5</b>	<b>Other (Not specified elsewhere)</b>							
1.A.5.b.ii.	Mobile (waterborne component)	X	X	X	X	X	X	X
1.A.5.b.iii.	Mobile (other)	X	X	X	X	X	X	X
<b>1.B</b>	<b>Fugitive emissions from fuels</b>							
<b>1.B.1</b>	<b>Solid fuel</b>							
1.B.1.a.	Coal mining and handling							
1.B.1.a.i	Underground mines							
1.B.1.a.i.1	Mining	X	X	X	X	X	X	X
1.B.1.a.i.2	Post-mining seam gas emissions	X	X	X		X	X	X
1.B.1.a.i.4	Flaring of drained CH4 or conversion of CH4 to CO2	X	X	X		X	X	X
1.B.1.a.ii	Surface mines							
1.B.1.a.ii.1	Mining	X	X	X	X	X	X	X
1.B.1.a.ii.2	Post-mining seam gas emissions	X	X	X		X	X	X
1.B.1.c.	Fuel transformation							
1.B.1.c.i.	Charcoal and biochar production	X	X		X	X	X	X
1.B.1.c.ii.	Coke production	X	X	X	X	X	X	X
<b>1.B.2</b>	<b>Oil and natural gas</b>							

1.B.2.a	Oil							
1.B.2.a.i.	Exploration	X		X	X	X	X	X
1.B.2.a.ii.	Production and upgrading	X		X	X	X	X	X
1.B.2.a.iii.	Transport					X		
1.B.2.a.iv.	Refining	X	X	X	X	X	X	X
1.B.2.a.v.	Distribution of oil products					X		
1.B.2.a.vi	Other					X		
1.B.2.b	Natural gas							
1.B.2.b.i.	Gas exploration	X		X	X	X	X	X
1.B.2.b.ii.	Production and gathering	X		X	X	X	X	X
1.B.2.b.iii.	Processing	X	X	X	X	X	X	X
1.B.2.b.iv.	Transmission and storage					X		
1.B.2.b.v.	Gas distribution					X		
1.B.2.b.vi.	Gas post-meter					X		
<b>1.B.3</b>	<b>Other emissions from energy production</b>							
1.B.3.a.	Other							
	Geothermal energy extraction		X	X				



## 2. IPPU\*

IPCC categorization	Category	SLCFs						
		NOx	NH <sub>3</sub>	SO <sub>2</sub>	CO	NMVOC	BC	OC
<b>2</b>	<b>IPPU</b>							
<b>2.A</b>	<b>Mineral Industry</b>							
2.A.1	Cement Production			X		X		
2.A.3	Glass production					X		
2.A.4	Other Process Uses of Carbonates			X		X		
<b>2.B</b>	<b>Chemical Production</b>							
2.B.1	Ammonia production	X	X	X	X	X		
2.B.2	Nitric Acid production	X	X					
2.B.3	Adipic Acid production	X			X	X		
2.B.6	Titanium Dioxide Production	X		X	X			
2.B.7	Soda ash production		X		X			
2.B.8	Petrochemical Industry							
2.B.8.b	Ethylene					X		
	- Propylene					X		
2.B.8.c	Ethylene Dichloride and Vinyl Chloride Monomer					X		
2.B.8.d	Ethylene Oxide					X		
2.B.8.e	Acrylonitrile					X		
2.B.8.f	Carbon Black	?		X	X	X	X	X
2.B.10	Other							
	- Hydrogen production				?			
	- Sulfuric acid			X				
	- Ammonium nitrate		X	?				
	- Ammonium phosphate		X					
	- Urea		X			?	X	
	- Polyethylene					X		
	- Polyvinylchloride					X		
	- Styrene					X		
	- Polystyrene					X		
	- Styrene butadiene, Styrene-butadiene latex, Styrene-butadiene rubber (SBR)					X		
	- Acrylonitrile Butadiene Styrene (ABS) resins					X		
	- Formaldehyde					X		
	- Ethylbenzene					X		

\* Note that according to the 2006 IPCC Guidelines emissions from fuel combustion are reported in Energy Sector, not in IPPU. There are different methodological approaches regarding allocation of emissions in various methodological frameworks, e.g. EMEP/EEA reports BC/OC from Cement and other industries in IPPU and other pollutants (CO, NO<sub>x</sub>, NMVOCs, SO<sub>2</sub>) in Energy sector, although SO<sub>2</sub> may be present in raw materials.

	- Phthalic anhydride			?	?	X		
	- Benzene					X		
	- Methylbenzene / Toluene					X		
	- Xylene					X		
	- Glycol					X		
	- Terephthalic acid				X	X		
	- Polyethylene terephthalate					X		
	- Maleic anhydride				X	X		
<b>2.C</b>	<b>Metal Industry</b>							
2.C.1	Iron and Steel Production	X		X	X	X	X	X
2.C.2	Ferroalloys production						X	
2.C.3	Aluminium Production	X		X	X	X	X	X
2.C.5	Lead Production	?		?	?		?	?
2.C.6	Zinc production			X			?	?
2.C.7	Other							
	- Copper			X		?	X	X
	- Nickel			X				
	- Other metals			X				
	- Metal welding and cutting	?		?	?			
<b>2.D</b>	<b>Non-Energy Products from Fuels and Solvent Use</b>							
2.D.3	Solvent Use							
	- Domestic solvents use					X		
	- Coating application					X		
	- Degreasing					X		
	- Dry cleaning					X		
	- Chemical products					X		
	- Printing					X		
	- Other solvent and product use					X		
2.D.4	Other							
	- Road paving with asphalt	X			X	X	X	
	- Asphalt roofing	X			X	X	X	
<b>2.F</b>	<b>Product Uses as Substitutes for Ozone Depleting Substances</b>		X			X		
<b>2.H</b>	<b>Other</b>							
2.H.1	Pulp and Paper Industry	X	X	X	X	X	X	X
2.H.2	Food and Beverages Industry		X	X	X	X	X	X
2.H.3	Wood industry	X		X	X	X		

### 3. AFOLU

IPCC categorization	Category	SLCFs						
		NOx	NH <sub>3</sub>	SO <sub>2</sub>	CO	NMVOC	BC	OC
<b>3</b>	<b>AFOLU</b>							
<b>3.A.2</b>	<b>Manure Management</b>							
3.A.2.a.i.	Dairy Cows	X	X			X		
3.A.2.a.ii.	Other Cattle	X	X			X		
3.A.2.b	Buffalo	X	X			X		
3.A.2.c	Sheep	X	X			X		
3.A.2.d	Goats	X	X			X		
3.A.2.e	Camels	X	X			X		
3.A.2.f	Horses	X	X			X		
3.A.2.g	Mules and Asses	X	X			X		
3.A.2.h	Swine	X	X			X		
3.A.2.i	Poultry	X	X			X		
3.A.2.j	Other	X	X			X		
<b>3.C.1</b>	<b>Burning</b>							
3.C.1.a	Burning in Forest Land	X	X	X	X	X	X	X
3.C.1.b	Burning in Cropland	X	X	X	X	X	X	X
3.C.1.c	Burning in Grassland	X	X	X	X	X	X	X
3.C.1.d	Burning in all other lands	X	X	X	X	X	X	X
<b>3.C.4</b>	<b>Direct N<sub>2</sub>O emissions from managed soils</b>	X	X					
<b>3.C.5</b>	<b>Indirect N<sub>2</sub>O emissions from managed soils</b>	X						
<b>3.D.2</b>	<b>Other</b>							
3.D.2.x	Other: "Livestock manure applied to soils"					X		
3.D.2.x	Other: "Urine and dung deposited by grazing livestock"					X		
3.D.2.x	Other: "Manure incineration"	X	X	X	X	X	X	X
3.D.2.x	Other: "Anaerobic digestion of animal manure"	X	X					
3.D.2.x	Other: "Pesticide application"					X		
3.D.2.x	Other: "Cultivated crops"					X		
3.D.2.x	Other: "Managed deciduous/coniferous forests"					X		
3.D.2.x	Other: "Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub)"					X		
3.D.2.x	Other: "Fugitive dust from tilling"	X					X	X
3.D.2.x	Other: "Fugitive dust from animals"	X	X					X

#### 4. WASTE

IPCC categorization	Category	SLCFs						
		NO <sub>x</sub>	NH <sub>3</sub>	SO <sub>2</sub>	CO	NMVOC	BC	OC
<b>4</b>	<b>WASTE</b>							
<b>4.A</b>	<b>Solid Waste Disposal</b>							
<b>4.A.1</b>	<b>Managed Waste Disposal Sites</b>							
	- Landfill fires	X		X	X	X	X	X
	- Flaring	X		X	X	X	X	X
	- Other (decomposition)		X		X	X		
<b>4.A.2</b>	<b>Unmanaged Waste Disposal Sites</b>							
	- Landfill fires	X		X	X	X	X	X
	- Flaring	X		X	X	X	X	X
	- Other (decomposition)		X		X	X		
<b>4.A.3</b>	<b>Uncategorised Waste Disposal Sites</b>							
	- Landfill fires	X		X	X	X	X	X
	- Flaring	X		X	X	X	X	X
	- Other (decomposition)		X		X	X		
<b>4.B</b>	<b>Biological Treatment of Solid Waste</b>							
4.B.1	Composting		X		X	X		
4.B.2	Anaerobic Digestion	?	X					
<b>4.C</b>	<b>Incineration and Open Burning of Waste</b>							
4.C.1	Waste Incineration	X	X	X	X	X	X	X
4.C.2	Open Burning of Waste	X	X	X	X	X	X	X
<b>4.D</b>	<b>Wastewater Treatment and Discharge</b>							
4.D.1	Domestic Wastewater Treatment and Discharge		X			X		
4.D.2	Industrial Wastewater Treatment and Discharge		X			X		
<b>4.E</b>	<b>Other</b>							
	Other waste		X					

## Note on allocation issues of SLCF emissions between different sectors

There are several cases when SLCF emissions may be allocated to one sector or another. For example, fuel combustion emissions in industries are allocated to the Energy sector.

This note is a compiled list of allocation issues taken from the preparatory work and the outcomes of the Joint 1<sup>st</sup> and 2<sup>nd</sup> IPCC Expert Meeting on SLCFs.

It has been compiled by TSU to serve the work of BOG3 at the 3<sup>rd</sup> Expert Meeting on SLCFs.

1. **IPPU-Energy:** In Mineral Industry (cement, lime, glass, bricks, etc.) all combustion emissions from natural gas or coal are reported in **Energy** sector and CO<sub>2</sub> emissions from chemical decomposition of carbonates reported in **IPPU**. NMVOC emissions can happen from other process than calcination and can be allocated to **IPPU** source categories.
2. **IPPU-Energy:** Sulphur recovery in refineries. US AP-42 provides methodology for sulphur recovery in refineries, where hydrogen sulphide is a by-product of processing natural gas and refining high-sulphur crude oils with missions of CO, SO<sub>x</sub>, NMVOC. It should be reported in **Energy** sector.
3. **IPPU-Energy:** Alumina/aluminium oxide. The 2019 Refinement sub-category provides methodology for CO<sub>2</sub> process emissions. The other emissions are of combustion origin – **Energy** sector.
4. **IPPU-Energy:** Coking. According to the 2006 IPCC Guidelines, the coking emissions should be reported in **Energy** sector.
5. **IPPU-Energy:** Charcoal. All charcoal related emissions (combustion and fugitives) should be reported in **Energy** sector.
6. **Waste-Energy:** Emissions from waste burnt for energy are reported under the **Energy** sector. Emissions from biogas collected and used for energy should be in **Energy**, not Waste. Emissions from energy used to manage landfill sites should be in **Energy**, not Waste. Note: If flared (without energy recovery), included in Waste.
7. **Waste-Energy:** Waste incineration. Fuel consumption is used as AD in J-STREAM method. In the 2006 IPCC Guidelines, amount of waste incinerated is used as AD. According to the 2006 IPCC Guidelines, emissions from waste burnt for energy are reported under the **Energy** Sector. It was determined that the J-STREAM method should be consistent with the IPCC guidance and therefore nothing more was needed in terms of SLCF methodology consideration.
8. **Waste-Energy:** Cooking exhaust (J-STREAM) - Method: Times of meals multiplied by emissions. During the discussions it was determined that the cooking category could be captured as part of the small scale emission methodology development as part of Category 1.A.4 Other Sectors in **Energy** sector.
9. **IPPU-Waste:** Waste treatment. Evaporative emissions in industry Waste Water Collection, Treatment and Storage (AP-42) and Solid waste incineration (MEP China) - it is **Waste** sector emissions according to the 2006 IPCC Guidelines.
10. **Waste – AFOLU/Energy:** Biological treatment of waste – Anaerobic digestion at biogas facilities (EMEP/EEA Guidebook) covers co-digestion of different feedstocks (e.g., waste material, energy crops, manures). In the 2006 IPCC Guidelines, anaerobic digestion of manure is considered/included in **AFOLU** sector (not in Waste sector).

**Waste sector BOG:** Emissions from anaerobic digestion of manure on farms (storage, digestion, post-storage) should be included in **AFOLU**, not Waste. Emissions from anaerobic digestion of manure in treatment plants (co-digestion with municipal waste or transported to an offsite treatment facility) should be included in **Waste**, not AFOLU. Emissions from combustion of biogas collected for energy use (energy or transport) should be in **Energy**, not Waste.

11. **Waste – AFOLU/Energy:** Open burning.
  - 11.1 EMEP/EEA Guidebook covers small-scale (agricultural) waste e.g., crop residues (e.g., cereal crops, peas, beans, soya, sugar beet, oil seed rape, etc.), wood, pruning, slash, leaves, plastics, and other general wastes. In the 2006 IPCC Guidelines, agriculture residue burning is considered in **AFOLU** sector.

**Waste sector BOG:** Emissions from agricultural waste burning should be included in AFOLU, not Waste. Emissions from agricultural waste burning for energy should be considered in **Energy**, not Waste. Note: The definition of agricultural waste burning needs to be discussed further.

- 11.2 EPA NEI covers residential yard waste open burning, land clearing and residential household waste. In the 2006 IPCC Guidelines, emissions from land clearing burning are considered in **AFOLU** sector.

**Waste sector BOG:** Emissions from small-scale biomass burning (e.g., land clearing not at farms) at the site of production, should be included in **AFOLU**, not Waste. Note: issues of allocation/categorization that may need to be further discussed

12. **Waste-AFOLU:** Other waste (EMEP/EEA): The category covers sludge spreading, car fires and house fires. In the 2006 IPCC Guidelines, sludge spread on agricultural land are considered in **AFOLU** sector.

**Waste sector BOG:** Emissions from sludge spreading should be included in the AFOLU sector, not Waste.

13. **AFOLU-Energy/Waste:** Manure incineration. All manure incineration for the purpose of generating energy should be reported in the **Energy** sector (IPCC). This includes combustion emissions and pre-treatment emissions. Note: Pre-treatment emissions from manure are actually reported under AFOLU, burning manure is a manure management system and it covers the emissions from manure before being actually incinerated/burned (IPCC 2006 Guidelines). If the pre-treatment emission is significant, it could be reported in the solid fuel transformation source category. All other manure incineration and open burning (without Energy recovery) should be reported in the **Waste** sector.

## Annex 2: Agenda

### The Third IPCC Expert Meeting on Short-Lived Climate Forcers (SLCFs)

In relation to the outcomes of the IPCC Working Groups I and III contributions to the Sixth Assessment Report (AR6) and follow-up issues from the Joint 1<sup>st</sup> and 2<sup>nd</sup> IPCC Expert Meeting on SLCFs

**11 – 15 April 2022**

Virtual Meeting

### Agenda

Day 1 – Monday, 11 April 2022

Day 1		Part I – Opening Plenary
11.00-14.00 (GMT, UTC+0)	11.00 - 11.20	➤ Welcome and adoption of Agenda (IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe) – 5 min
		➤ Background and Scope (IPCC TFI TSU) – 15 min
Geneva Time (UTC+2) 13.00-16.00	11.20 - 12.05	➤ Presentations – WGI and WGIII AR6 reports and general issues <ul style="list-style-type: none"> <li>• Relevant SLCF species for climate and their definitions (Jan S. Fuglestedt – WGI) – 20 min</li> <li>• SLCF in the IPCC WGIII AR6: Input to the TFI 3<sup>rd</sup> Expert meeting (Alaa Al Khourdajie– WGIII) – 15 min</li> <li>• Coordinated Development of Emission Inventories for Climate Forcers and Air Pollutants (Steven J. Smith and Erin E. McDuffie) – 15 min</li> </ul>
		12.05 -12.20 ➤ Q & A session
Tokyo time (UTC+9) 20.00-23.00	12.20 - 12.25	5 min break
Lima time (UTC-5) 06.00-09.00	12.25 - 13.35	➤ Presentations - National or international emissions inventories experiences on general methodological issues, including on data collection/measurements <ul style="list-style-type: none"> <li>• National Inventory of Norway (Julien Jabot) – 10 min</li> <li>• National Inventory of China (Bofeng Cai) – 10 min</li> <li>• National Inventory of Indonesia (Didin Agustian Permadi) – 10 min</li> <li>• National Inventory of Chile (Camila Labarca) – 10 min</li> <li>• National Inventory of South Africa (Patience Gwaze) – 10 min</li> </ul>
		13.35-14.00 ➤ Q & A session

**Day 2 – Tuesday, 12 April 2022**

<b>Day 2</b>				
<b>Part II – Break-out groups (BOG) discussion</b>				
<b>11.00-14.00</b> <b>(GMT, UTC+0)</b>  <i>Geneva Time</i> <i>(UTC+2)</i>  13.00-16.00  <i>Tokyo time (UTC+9)</i>  20.00-23.00	11.00 - 12.30	<b>BOG 1 – SLCF species (definitions &amp; relevance)</b>  <u>Facilitator</u> Laura Dawidowski <u>Rapporteur</u> Steven J. Smith  <u>TSU</u> Eduard Karapoghosyan Sandro Federici	<b>BOG 2 – General Inventory issues</b>  <u>Facilitator</u> Ole-Kenneth Nielsen <u>Rapporteur</u> Chia Ha  <u>TSU</u> Baasansuren Jamsranjav Valentyna Slivinska	<b>BOG 3 – List of data gaps and List of SLCF categories</b>  <u>Facilitator</u> Amit Garg <u>Rapporteur</u> Julia Drewer, Savitri Garivait  <u>TSU</u> Pavel Shermanau Takeshi Enoki
	12.30 - 12.35	5 min break		
<i>Lima time (UTC-5)</i>  06.00-09.00	12.35 – 14.00	<b>BOG 1</b> (continuation)	<b>BOG 2</b> (continuation)	<b>BOG 3</b> (continuation)

**Day 3 – Wednesday, 13 April 2022**

<b>Day 3</b>				
<b>Part II (continuation)</b>				
<b>11.00-14.00</b> <b>(GMT, UTC+0)</b>  <i>Geneva Time</i> <i>(UTC+2)</i>  13.00-16.00  <i>Tokyo time (UTC+9)</i>  20.00-23.00	11.00 - 12.30	<b>BOG 1 – SLCF species (definitions &amp; relevance)</b>	<b>BOG 2 – General Inventory issues</b>	<b>BOG 3 – List of data gaps and List of SLCF categories</b>
	12.30 - 12.35	5 min break		
<i>Lima time (UTC-5)</i>  06.00-09.00	12.35 – 14.00	<b>BOG 1</b> (continuation)	<b>BOG 2</b> (continuation)	<b>BOG 3</b> (continuation)



Day 4 – Friday, 15 April 2022

Part III – Closing Plenary	
<p><b>Day 4</b></p> <p><b>11.00-14.00</b></p> <p><b>(GMT, UTC+0)</b></p> <p><i>Geneva Time</i> <i>(UTC+2)</i> <i>13.00-16.00</i></p> <p><i>Tokyo time</i> <i>(UTC+9)</i> <i>20.00-23.00</i></p> <p><i>Lima time (UTC-5)</i> <i>06.00-09.00</i></p>	<p>11.00 – 12.00</p> <p>➤ <i>BOGs' Presentations</i></p> <ul style="list-style-type: none"> <li>• <i>BOG 1 – 20 min</i></li> <li>• <i>BOG 2 – 20 min</i></li> <li>• <i>BOG 3 – 20 min</i></li> </ul>
	<p>12.00 -12.30</p> <p>➤ <i>Q &amp; A session and Discussion</i></p>
	<p>12.30 - 12.35</p> <p><i>5 min break</i></p>
	<p>12.35 - 13.45</p> <p>➤ <i>Discussion of any other issues related to the SLCF inventory and development of a new Methodology report on SLCFs – 70 min</i></p>
	<p>13.45-14.00</p> <p>➤ <i>Way forward and closing the meeting</i> <i>(IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe) – 15 min</i></p>

## Annex 3: List of Participants

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### 3<sup>rd</sup> IPCC Expert Meeting on Short-Lived Climate Forcers 11 – 15 April 2022

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