Joint 1st and 2nd IPCC Expert Meeting on Short-lived Climate Forcers

Report of IPCC Expert Meeting

11 – 22 October 2021, Virtual Meeting

Task Force on National Greenhouse Gas Inventories

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This Joint 1st and 2nd 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

We are pleased to present this report of the Joint 1st and 2nd Expert Meeting on Short-lived Climate Forcers held on 11-22 October 2021 as a virtual meeting.

At the 45th 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 46th 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:

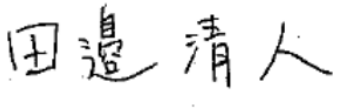
- *Improved emission inventories of SLCFs are necessary to enhance scientific understanding and assessment of their role in climate change as well as to inform climate policy at the national and international levels.*
- *Internationally-agreed, globally applicable methodologies and emission factors for 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 49th Session in Kyoto, Japan in May 2019, to develop a Methodology Report on SLCFs during the IPCC's 7th Assessment Cycle (Decision IPCC-XLIX-7).

This Joint 1st and 2nd Expert Meeting on SLCFs was an important step of the preparatory work for that Methodology Report. It brought together 115 participants comprising 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. They are 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 7th 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 ones of TFI Technical Support Unit, for their contribution, that enabled to make this meeting a success.

Eduardo Calvo Buendia
Co-Chair
Task Force on National Greenhouse Gas Inventories
Intergovernmental Panel on Climate Change



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List of Acronyms and Abbreviations

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_4	Methane
CO	Carbon Monoxide
CO_2	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_2O	Nitrous Oxide
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
NTCF	Near-term Climate Forcers
OA	Organic Aerosol
OC	Organic Carbon
OM	Organic Matter
PM_{10}	Particulate Matter with aerodynamic diameter ≤ 10 µm (micrometer)
$PM_{2.5}$	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_2	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 Environnent (United Nations Environnent 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

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 1st and 2nd IPCC Expert Meeting on SLCFs (Joint Meeting) on 11 – 22 October 2021 virtually via ZOOM and MS Teams platforms.

Scope of the meeting was mainly 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 secondarily to identify knowledge gaps in the available methodological guidance and datasets needed to estimate SLCFs emissions by all countries in the world.

The following SLCF species were considered:

- Aerosols
  - Black Carbon (BC)
  - Organic Carbon (OC)
- Precursors (ozone precursors and aerosol precursors)
  - Nitrogen Oxides (NO_x)
  - Carbon Monoxide (CO)
  - NMVOC (including Biogenic Volatile Organic Compounds (BVOC))
  - Sulphur Dioxide (SO_2)
  - Ammonia (NH_3)

Methane and halogenated compounds were not included, because inventory methodologies for them are already provided in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*) and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*).

Most of the SLCF species listed above are included in existing methodological guidance analysed. In addition, the current approach to derive BC and OC emissions as a fraction of $PM_{2.5}$ (e.g., in the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019 (EMEP/EEA Guidebook)) might need improvement or elaboration due to significant variability in observed (measured) BC/$PM_{2.5}$ ratios, which often change when an emission reduction technology is applied, and because although $PM_{2.5}$ concentration is the proxy for the radiative impact of all kinds of composing species, its relationship with emissions of SLCF species is limited since most $PM_{2.5}$ in the atmosphere, aside from dust and sea salt, is of secondary formation.

To facilitate and support the work at the virtual meeting the TSU and the participants went through a desk-work phase that resulted in the production of three documents for each sector:

- Table 1 - Summary Information - where for each source of emissions and SLCF species information on availability of methodological information and activity data (AD) is compiled to define its relevance and global applicability
- Table 2 - Category List - where all identified relevant sources, and associated SLCF species, categorized consistently with the *2006 IPCC Guidelines* classification scheme have been listed
- Issue paper, a list of main issues related with the categorization of SLCF sources.

Information collated and analysed was mainly sourced from the EMEP/EEA Guidebook, the UNEP Atmospheric Brown Clouds Emission Inventory Manual and the US EPA Compilation of Air Emissions Factors (AP-42), with additional information mainly sourced from national methodological frameworks as e.g. the US EPA National Emissions Inventory.

At the meeting, experts worked on Table 1 by adding:

- source categories and/or SLCF species, not yet identified

- for each source category and associated SLCF species, information on the availability of methods to estimate emissions (including AD and emission factors (EFs)), with the aim to judge whether the relevant methodology is globally applicable or there are limits/knowledge gaps to its application
- for each source categories and/or SLCF species for which no methods are currently available, information on the likelihood to be a significant source.

On the basis of the work done in Table 1, experts worked on Table 2 with the aim to, as far as practicable, provide a complete categorization of SLCF sources considered relevant for a national emission inventory. (Both tables are included for each sectoral break-out group (BOG) in Annex 1).

During the work at BOGs on the tables, and associated issue papers, experts identified most relevant gaps, which are thus listed in the BOG reports, as well as identified some cross-sectoral issues (see Section 2.5). Outcomes of the BOGs work were presented and discussed at the closing plenary (BOGs reports are published on the IPCC TFI website at: https://www.ipcc-nggip.iges.or.jp/public/mtdocs/2110_SLCF.html). Finally, at the closing plenary cross-cutting issues were discussed in a dedicated session where, without drawing any conclusion, their relevance for the preparation of the Methodology Report was noted and further consideration of those was observed to be desirable.

The expert meeting resulted in the collection and categorization of a large amount of information, in a format expected to be useful for the scoping of the Methodology Report.

Participants noted that levels and rates of SLCF emissions and associated climate impacts are largely more regionally dependent than GHGs, so to ensure the availability of regional/national datasets of EFs and AD is more challenging than for a National Greenhouse Gas Inventory.

In summary, this expert meeting concluded that:

- Methods to estimate emissions for most relevant SLCF sources are available, and for most of those IPCC methods can be either directly applicable or applicable with modifications.
- Global coverage of available data on EFs and any needed ancillary parameters remains a challenge for setting an IPCC default methodology for each of those sources.
- Methods that use same AD to estimate greenhouse gas (GHG) emissions from same sources of SLCFs allow to readily estimate also SLCF emissions, although the availability of data for EFs and any ancillary parameters may impair such statement.
- Applying the classification scheme of the *2006 IPCC Guidelines* to the categorization of SLCF sources is proven effective, facilitates methods design and minimizes data needs. However, the IPCC classification scheme needs to be expanded to cover additional sources.
- Emissions abatement technologies are a prominent variable when estimating SLCF emissions. In application of an EF, it needs to be clarified whether the EF is for unabated emissions or for abated emissions. When developing and presenting default EFs, underlying assumptions about abatement technology must be clarified.
- Small scale use of fuels has a larger relevance than for GHGs, e.g. cookers, fireplaces, small boilers and stoves used in households; appliances to supply heat, hot water and small-scale power (like, backup generators), kerosene wick lamps under residential, commercial/institutional and agriculture/forestry/fishing subsectors, and waste open burning-, which has major methodological and data needs implications.
- Apportioning of SLCF species between sectors, e.g. Energy vs IPPU can effectively be implemented by applying the same approaches used by *2006 IPCC Guidelines* to apportion among sectors GHGs emitted across a single process.
- Detailed lists of knowledge/data gaps are provided in each BOG report (Sections 2.1, 2.2, 2.3 and 2.4).

- The Tiered approach applied in the *2006 IPCC Guidelines* relies on the analysis of the significance of sources and associated species of emissions, i.e. the Key Category Analysis (KCA). The KCA is performed based on CO_2-equivalent emissions using 100-year global warming potentials (GWP) as common metrics. Emissions of SLCFs would be estimated in mass units and a common metrics has not been identified yet at this and previous IPCC meetings on SLCFs. Otherwise, an alternative approach to guide inventory-compilers in the choice of the most appropriate methodological Tier level to be applied for each source category and associated SLCF species could be designed.

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 Working Group I (WG I) (April 2021) and Working Group III (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 1st and 2nd 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.

- **Preliminary desk-work to serve the Joint Meeting on SLCFs**

Ahead of the desk-work, TSU made a technical analysis of the main methodological frameworks to estimate SLCF emissions. The technical analysis goals were to list all source categories and associated SLCF species for which methods to estimate emissions are available, and to provide a comparison between SLCF methods and IPCC methods for GHGs. The technical analysis consisted in a set of excel worksheets, one worksheet for each sector, where all information collected were organised.

The following guidelines were analysed by TSU:

- EMEP/EEA Guidebook (https://www.eea.europa.eu/publications/emep-eea-guidebook-2019)
- UNEP Atmospheric Brown Clouds Emission Inventory Manual (https://www.unep.org/resources/report/atmospheric-brown-clouds-emission-inventory-manual)
- US AP-42 (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors)

The following SLCF[1] species were considered:

- Aerosols
  - BC
  - OC
- Precursors (ozone precursors and aerosol precursors)
  - NO_x
  - CO
  - NMVOC (including BVOC)
  - SO_2
  - NH_3

Methane and halogenated compounds were not included, because inventory methodologies for them are already provided in the *2006 IPCC Guidelines* and the *2019 Refinement*.

On the basis of the technical analysis prepared by TSU, participants, at their desks, provided additional information from national methodological frameworks for SLCF emissions and also complemented the information compiled by TSU.

- **Material prepared to inform work at the Joint Meeting on SLCFs**

To serve the work at the expert meeting, all feedbacks received from participants were collected by TSU and elaborated in a set of four documents for each sector (see Annex 1):

i. An issue paper, with a list of main issues related with the categorization of SLCF sources
ii. An information table on SLCF source categories and associated SLCF species, where for each category and SLCF species information on availability of methodological information and of AD is compiled to define its relevance and global applicability (Table 1 Summary Information)
iii. A summary table (Table 2 Category List) where all identified source categories, and associated SLCF species, for which a method available was identified as:
   - either the corresponding IPCC method in the *2006 IPCC Guidelines*, or a modification of it,
   - or a method from one of the other methodological frameworks
iv. A compilation table where all information collected by TSU and compiled by participants is collated (collected in TFI electronic discussion group and not attached to this meeting report).

- **Organization of the Joint Meeting on SLCFs**

The Joint Meeting was held on 11 – 22 October 2021 virtually via ZOOM and MS Teams platforms. At the opening plenary, following the welcome address and explanation of background of the Joint Meeting by TFI Co-Chairs, a number of presentations were delivered to inform the discussion at this meeting. After the opening plenary, the meeting split into 4 sectoral break-out groups (BOGs) and held 4 sessions of each BOG. At the closing plenary, each of 4 BOG reported on its discussion and conclusions, which was followed by plenary discussion on cross-cutting issues. The Joint Meeting was closed by expression of appreciation by TFI Co-Chairs to all the participants and TSU. (See Agenda of the Joint Meeting in Annex 2 and List of Participants in Annex 3).

[1] These species were selected taking into account the report of the IPCC Expert Meeting on SLCFs held in Geneva in May 2018 (https://www.ipcc-nggip.iges.or.jp/public/mtdocs/1805_Geneva.html).

- **Outcome of the Joint Meeting on SLCFs**

Discussion and conclusions of the Joint Meeting are summarized in Chapter 2 of this meeting report. In addition, the following outcomes of BOGs work are published on the IPCC TFI website at https://www.ipcc-nggip.iges.or.jp/public/mtdocs/2110_SLCF.html.

A. Main: A list of source categories[1] and associated SLCFs, for further consideration at the Scoping Meeting for the IPCC Methodology Report on SLCFs emissions.

B. Secondary: A list of identified gaps in methods and EFs and other parameters needed to estimate SLCFs emissions within a climate change context.

Box: Definition of Short-lived Climate Forcers

In August 2021 (two months ahead of this Joint Meeting), "Climate Change 2021: The Physical Science Basis" (Working Group I contribution to the Sixth Assessment Report) was approved and accepted by the IPCC. In this report, the "short -lived climate forcers" is defined as follows.

Short-lived Climate Forcers (SLCFs) A set of chemically reactive compounds with short (relative to CO_2) atmospheric lifetimes (from hours to decades) but characterised by different physiochemical properties and environmental effects. Their emission or formation has a significant effect on radiative forcing over a period determined by their respective atmospheric lifetimes. Changes in their emissions can also induce long-term climate effects via, in particular, their interactions with some biogeochemical cycles. SLCFs are classified as direct or indirect, with direct SLCFs exerting climate effects through their radiative forcing and indirect SLCFs being the precursors of other direct climate forcers. Direct SLCFs include methane (CH_4), ozone (O_3), primary aerosols and some halogenated species. Indirect SLCFs are precursors of ozone or secondary aerosols. SLCFs can be cooling or warming through interactions with radiation and clouds. They are also referred to as near-term climate forcers (NTCFs). Many SLCFs are also air pollutants. A subset of exclusively warming SLCFs is also referred to as short-lived climate pollutants (SLCPs), including methane, ozone, and black carbon.

[IPCC, 2021: Annex VII: Glossary [Matthews, J. B. R., J. S. Fuglestvedt, V. Masson-Delmotte, V. Möller, C. Méndez, R. van Diemen, A. Reisinger, S. Semenov (ed.)]. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.]

[1] Source categories and associated SLCFs included in the list were those:
- ✓ *for which a globally applicable method is either already available or can be developed from available knowledge,*
- ✓ *that although there is a gap in the available methodological knowledge contribute significantly to SLCFs emissions*

2. Meeting discussion and conclusions

2.1 ENERGY BOG

The work of the Energy Breakout Group was facilitated by Dario Gomez and reported to the closing plenary session by Vincent Camobreco. Valentyna Slivinska (TSU) and Takeshi Enoki (consultant) provided technical support.

Discussion:

Consideration of SLCF source categories and associated species provided in Table 1 (see Annex 1)

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

- Some cross-cutting issues that would apply across all the categories in Table 1:
  - Tier 1 EFs for SLCF could be based on the approach for non-CO_2 GHG methodology but would need to include additional details on fuel characteristics (e.g., S content) and abatement technologies applied (e.g., reduction efficiency and implementation rate), Note some abatement options might have negative efficiencies. It should maintain as much as possible the Tier 1 structure for non-CO_2 GHGs (and for cases where SLCF EFs are already provided, e.g., NMVOC factors provided for oil and gas fugitive emissions). For GHGs, it is not always the case that the tier 1 approach provides only one default EF for a given fuel and emission source. There are cases, for which ranges or levels are used to express the variability of diverse emission conditions. A similar structure should be maintained for SLCF. When information on abatement technologies is not available, the estimates would correspond to unabated emissions.
  - Co-firing (complementary firing or co-combustion) is the combustion of two or more different fuels in the same combustion system. Methodologies for stationary combustion should allow the possibility of estimating emissions under co-firing practices and provide the corresponding guidance, including AD collection, emission factors and other parameters. For CO_2 it may be possible to estimate emissions from a mix of fuels based on each individual fuel's characteristics (i.e., C content). For SLCF a blended fuel may have different emissions characteristics compared to burning each fuel individually. Furthermore, some emission sources could have a variable and poorly defined fuel mix over time. Therefore, more research is needed on developing SLCF EFs for co-firing of fuels.
  - $PM_{2.5}$ is considered a SLCP highly heterogeneous spatially and temporally (varying from positive to negative RF depending on sources and meteorological characteristics). The $PM_{2.5}$ concentration is the proxy for the radiative impact of all kinds of particles. Given that most BC and OC EFs are expressed as fraction of $PM_{2.5}$, the participants of this BOG decided to include primary $PM_{2.5}$ in the list of emissions to be estimated not only because it is a SLCF but as an intermediate variable often needed to estimate BC and OC emissions.
  - The IPCC methods for SLCFs should include small emissions sources and nonconventional/informal fuels. Small-scale combustion often with use of informal fuels covers emissions from fuels burned in smaller installations and apparatus than those present in energy industries and industrial facilities. They include cookers, fireplaces, small boilers and stoves used in households; appliances to supply heat, hot water and small-scale power (like backup generators) and kerosene wick lamps under residential, commercial/institutional and agriculture/forestry/fishing sectors. These sources are especially relevant in developing countries where there could be large numbers of these sources using informal fuels without any emission controls that are a large contributor to SLCF (and air pollution in general). Combustion and abatement technologies guidance currently in IPCC categories for GHGs will therefore require additional analysis when developing SLCF guidance for these smaller sources and fuels. Critical aspects of developing SLCF methodologies for small emission sources include that EFs vary by several of orders of magnitude as a function of appliances and abatement technologies for a given fuel type. Furthermore, cooking exhaust (meat cooking etc., not from fuel itself) could be considered as small-scale combustion

sources for OC, BC, and $PM_{2.5}$. Emissions from informal combustion normally uses various types of fuels across the same year. This practice may be difficult to capture in an inventory. The AD of non-conventional fuels are often difficult to obtain and there are issues concerning the reconciliation of AD with the energy balance which may not contain nonconventional fuels. Quality, type, and moisture content of solid fuels may have a large effect on EFs. Many solid fuels are collected rather than marketed and estimates of AD would benefit from diverse inputs. Country-specific practices of one country are not always translatable to other countries therefore there is the need to develop country-specific EFs and parameters.

- Discussions around Category 1.A.1 Energy Industries
  - The cross-cutting issues mentioned above apply to this category but in particular the co-firing of fuels could be a major contributor in this category.
  - Generally, the methodology at upper level covers lower levels for these stationary combustion sources

- Discussions around Category 1.A.2 Manufacturing industries and construction
  - The cross-cutting issues mentioned above apply to this category but in particular small-scale combustion and use on nonconventional and variable fuels may occur under some facilities in particular for brickworks.
  - Emissions arising from off-road and other mobile machinery in industry should, if possible, be broken out under the corresponding subcategory, because emission factors for mobile sources can be very different from those for stationary sources.
  - The use of product produced as AD instead of fuel used deserves attention for developing T1 factors. In addition, potential omission or double counting with IPPU sector should be considered.

- Discussions around Category 1.A.3 Transport
  - For aviation sources the landing and take-off (LTO) is critical for SLCFs so need to highlight that if only fuel based T1 approach is used the EF needs to reflect the whole LTO and cruise. For more accurate calculations a T2 should be used based on LTO data
  - For on road sources there were a number of considerations including:
    - The time dependency of technologies is especially relevant for fleets that have vehicles of different age and technology class. The time dimension is important for older technologies and within the same technology because as it ages it emits differently.
    - The time dimension is also relevant to estimate emissions for future years. It is expected that the methodology report would allow estimating emissions according to the technologies in use at the time of issuing the report but since this is a category of rapid technological changes, the IPCC may wish to consider how EFs and other parameters may be updated to reflect the evolving nature of road transportation.
    - The engine start-up emissions of SLCF may be large for the high-mileage fleets, especially for the fleets in developing countries.
    - Also note that super emitters might be a large portion of fleet emissions so may need to consider those in technology or EF development
    - As for CH_4 and N_2O, it is expected that the distance travelled approach would be more appropriate to estimate SLCF emissions. However, it is convenient to have a fuel-based Tier 1 approach even if not used it provides a check.
    - Several new categories were added, see below.
  - For waterborne sources the following was discussed:
    - IPCC factors and technology description for GHGs might be too simple for SLCFs especially for NO_x (e.g., new hybrid types of ships) so the need to use updated information was flagged.
    - The need to add a new Tier 3 to the IPCC methodology for NO_x and particulates based on engine power (current GHG approaches does not have a Tier 3 for this category) was identified.
  - For off-road sources the following was discussed:

- Although the estimation methods for this subcategory are addressed in Chapter 3 Volume 2 of the *2006 IPCC Guidelines* (Mobile combustion), off-road mobile combustion encompasses a wide variety of off-road vehicles and other machinery used across the different combustion categories namely, mobile combustion under manufacturing industries and construction (1.A.2), mobile machinery under commercial and institutional (1.A.4.a.ii); mobile equipment used under residential (1.A.4.b.ii) e.g., household and gardening machinery; off-road vehicles and other machinery used in agriculture/forestry/fishing (1.A.4.c.ii); other mobile including military mobile machinery (1.A.5.b.iii). The methodology for SLCFs should contemplate and be consistent with the widespread distribution of off-road combustion across the mentioned categories.
- Except for SO_2, the emissions of SLCFs are highly dependent on the type of equipment and technology.
- Most alternative methodologies do not cover BC and OC emissions from these sources.
- Guidance on the collection and/or estimation of AD is required as this may constitute the main challenge in estimating these emissions.
- A fuel-based methodology may also be useful for these categories.

- Discussions around Category 1.A.4 Other Sectors
  - The cross-cutting issues mentioned above apply to this category but in particular small-scale combustion and use on nonconventional fuels and variable fuel pattern may occur. For this category especially there would be a diverse amount of combustion technologies and difficulties in collecting AD on fuels which may not be marketed and therefore not included in traditional energy use data.
  - This category is also more likely to have older equipment so age of technology and developing age dependent technology factors is especially important for this category as well

- Discussions around Category 1.B.1 Fugitive emissions from Solid fuels
  - The category 1.B.1.a was expanded to include subcategories for underground and surface mines and within each category emissions from mining, post-mining activities and flaring and conversion of gas were included (see below).
  - For coal mining and handling, EFs for underground and surface mines should contain, if possible, the three level values provided for CH_4 EFs (e.g., EFs for low, average and high values).
  - Regarding cross cutting comment on consistency of Tier definitions, the EMEP Tier 2 approach provides information for SLCFs at a more aggregated level that is considered for Tier 1 IPCC method for GHGs.
  - All SLCFs instead of just NMVOC were included. Mining and post-mining are not combustion sources so likely there aren't any NO_x or SO_2 emissions but were left to further scoping to define
  - For category 1.B.1.c Fuel transformation, there could be potential differences in emissions from commercial vs informal production so development of EFs would need to take that into consideration.

- Discussions around Category 1.B.2 Fugitive emissions from Oil and natural gas
  - All SLCFs instead of just NMVOC were included. Non combustion sources will not likely have any NO_x or SO_2 emissions but were left to further scoping to define
  - In terms of the cross-cutting issue above about developing Tier 1 factors, the *2019 Refinement* provides Tier 1 default EFs for NMVOC for a number of technologies used under the different oil and natural gas subcategories. In addition, Annex 4A.2 to Chapter 4 of the *2019 Refinement*, presents the percent of emissions that are leaked, vented, and flared in the data sets used for the Tier 1 EFs. This disaggregation should be kept and, if possible, enriched for NMVOCs and considered for the other SLCFs, when applicable. It is expected that the IPCC SLCF methodology development for estimating NMVOC emissions for oil and natural gas would take as a starting point the detailed information already available in the *2019 Refinement*.
  - If alternative methodologies are used for SLCF estimation, it is important to identify which types of emissions (leaks, venting or flaring) are estimated.
  - A new category was added for Liquified Petroleum Gas (LPG) leakage as shown below.

- For category 1.B.2.b.vi Gas post-meter, depending on the approach used to estimate emissions from road transportation especially evaporative emissions in category 1.A.3.b.v, checks for double counting of AD may be needed.

- Discussions around Category 1.B.3 Other emissions from energy production
  - Add SO_2 to potential SLCF emissions from geothermal activities. Some Parties (e.g., Iceland and Italy) already estimates and report SO_2 emissions from geothermal power to the UNFCCC.
  - Remove categories for civil power generation facilities and combustion due to agriculture/livestock/fishery facilities (see below)

Consideration of issues associated with the identification of SLCF source categories and associated species.

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

The following issues, which were presented as part of an issue paper on the energy sector, were discussed:

- Issue 1 from Issues Paper Discussion: For industrial sources, emissions of SO_2, PM, and NMVOCs are often due to a combination of fuel combustion, the materials that are processed, and emission control techniques. This poses a challenge for SLCF emission allocation between the Energy sector and the IPPU sector categories because in some cases the only data available are the sector fuel use or amount of industrial product created by the sector.
  - Conclusion was that this is the same as for GHG emissions from similar sources and there is already existing IPCC guidance on avoiding double counting across sectors (Energy and IPPU) so the existing IPCC guidance on this for GHGs so would also apply to SLCFs

- Issue 2 from Issues Paper Discussion: "Civil power generation facilities" and "Combustion due to agriculture/livestock/fishery facilities" have been proposed as new categories for SLCF emission inventories. The emissions for these categories are estimated like other fuel combustion activities, i.e. product of amount of fuel consumed and the EF of the fuel. Could these categories be included in 1.A.1.a and 1.A.4.c, respectively or should these categories be added to the IPCC category list?
  - There was some confusion of what civil power means but existing IPCC source categories cover all thermal power sources.

- Issue 3 from Issues Paper Discussion: Categories/subcategories have not been explicitly described to have a methodology to estimate SLCF emissions. Emissions from most categories/subcategories may be estimated using the method provided in the upper-level category (for example, 1.A.1.a.i. electricity generation is not explicitly mentioned in existing methodologies but can be estimated using the method for 1.A.1.a.). Other categories, such as 1.B.1.b. spontaneous combustion and burning coal dumps may not have an existing methodology. See the discussion below for discussion of inclusion of additional categories and species (also highlighted in above discussion by category)

The following issues were also discussed from the WASTE sector issue paper

- Waste incineration Method/AD/Cross-sectoral: 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.
  - During the discussions 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

- Other: Cooking exhaust (J-STREAM) - Method: Times of meals multiplied by emissions (See the Waste sector compilation table).

- During the discussions it was determined that the cooking category could be captured as part of the small-scale emission methodology development discussion above as part of Category 1.A.4 Other Sectors.

Conclusions:

During the BOG sessions the experts concluded on:

- The adoption of the list of source categories and associated SLCF species, as provided in the annexed Table 2 that was based on discussions around Table 1 above.

- The inclusion of additional SLCF source categories and/or species to Table 2, also based on discussions around Table 1 above:
  - Need to include $PM_{2.5}$ in addition to BC and OC.
  - Include category 1.A.3.b.v "Evaporative emissions from vehicles" in the table for SLCF and note any potential double counting with post meter estimates form fugitive emissions in Category 1.B.2
  - Include category 1.A.3.b.vi "Urea-based catalysts" there is current confusion on where urea use is included for GHG so would be good to include as category with clear guidance on where to report. There are some SLCF EFs for urea Selective Catalytic Reduction (SCR) vehicles available in the literature. Failure of urea SCR systems also has implications on the emissions and should be considered.
  - Include a new category of Non-exhaust emissions from brake and tire wear for OC, BC etc. (maybe as fugitive) also important for EVs so EFs not just based on fuel use. There are globally applicable methodologies
  - Include a new category or as new fuel use for existing categories for use of lubricants; the need for a discussion on avoiding double counting with category 2.D.1 "Lubricant Use" was also noted. The contribution of lube oil is important for SLCFs (more so than GHGs) and is burned in 2-stroke, but also other vehicles so need to consider lube oil for all vehicles
  - Exclude distinction of 3-way catalysts, also the types of control could vary going forward so need to be forward looking and not mention specific technology.
  - Include category 1.A.3.e.i Pipeline transport with all SLCF species for combustion related emissions from the operation of pump stations and maintenance of pipelines. Note: the EMEP methodology refers the estimation of these emissions to that of small-scale combustion under category 1.A.4.
  - The category 1.B.1.a was expanded to include the following categories and SLCF species:
    - 1.B.1.a.i Underground mines
    - 1.B.1.a.i.1 Mining NO_x, NH_3, SO_2, CO, NMVOC, BC, OC and $PM_{2.5}$
    - 1.B.1.a.i.2 Post-mining seam gas emissions NO_x, NH_3, SO_2, NMVOC, BC, OC and $PM_{2.5}$
    - 1.B.1.a.i.4 Flaring of drained CH_4 or conversion of CH_4 to CO_2 NO_x, NH_3, SO_2, NMVOC, BC, OC and $PM_{2.5}$
    - 1.B.1.a.ii Surface mines
    - 1.B.1.a.ii.1 Mining NO_x, NH_3, SO_2, CO, NMVOC, BC, OC and $PM_{2.5}$
    - 1.B.1.a.ii.2 Post-mining seam gas emissions NO_x, NH_3, SO_2, NMVOC, BC, OC and $PM_{2.5}$
  - The category 1.B.2.a.vi Other was added with NMVOC to include leakage from the use of LPG in appliances. A methodology similar to that to estimate post-meter emissions from natural gas appliance may be developed for LPG.
  - Categories for civil power generation facilities and combustion due to agriculture/livestock/fishery facilities were not needed.

- Forwarding the following issues to the Plenary discussion:
  - Consistency between Tiered-approaches: In certain occasions the Tiered approach from alternative methodologies to estimate emissions for SLCFs is not entirely consistent with the IPCC three-Tiered approach to estimate GHG emissions. (One example of this is the EMEP methodology for coal mining

and handling in which the Tier 2 approach provides information at a more aggregated level than the IPCC Tier 1 approach). When selecting methods from an alternative methodological framework the characterization for the Tiers in the report on SLCFs estimation methods should be consistent with those defined by IPCC, independently from the characterization given in the alternative methodological framework.

- Decision trees: The basic decision process in the IPCC guidance indicates the use of higher Tier methods (Tier 2 or Tier 3) when the detailed data needed are readily available or the category being estimated is key. Otherwise, if the category is non-key a Tier 1 approach may be applied. For GHG, KCA) is performed on the basis of CO_2-equivalent emissions using GWPs as metrics. Emissions of SLCFs would be estimated in mass units and therefore KCA as that for GHG would not be possible. Decision trees are at the core of the IPCC methodology, therefore a substitute/equivalent for the key category concept needs to be found/identified if the basic decision process for GHG would hold for SLCFs.

2.2 IPPU BOG

The work of the IPPU BOG was facilitated by Kristina Saarinen and reported to the closing plenary session by Vigdis Vestreng. Pavel Shermanau (TSU) and Eduard Karapoghosyan (TSU) provided technical support.

Delineation of work and cross-cutting issues:

- The task of the expert meeting is not to provide EFs for all regions of the world, but to focus on the availability and applicability of the methodology to estimate emissions and to identify possible gaps.
- Assessment of the source categories and associated SLCF species, as well as expert judgement on whether a source is insignificant or not should be focused on the climate effect of the SLCFs (not on air pollution)
- "IPCC methodology" in Table 1 means the *2006 IPCC Guidelines* and the *2019 Refinement* methodology (even though the latter is not yet adopted by the UNFCCC).
- The definition of "Insignificant sources" is provided in footnote 3 (iii) to the guidance document[1]. However, the IPPU experts felt that this cross-cutting issue should further be clarified between different BOGs.
- For the nomination of authors for the new methodology report on SLCFs, it is recommended that countries nominate experts with in-depth knowledge of SLCFs from different IPPU sectors and preferably with good knowledge about emission inventory work.

Discussion:

Consideration of SLCF source categories and associated species provided in Table 1.

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

- The allocation principle
  - The way emissions are to be distributed between Energy and IPPU is elaborated in the Issue paper (see Annex 1). In the IPPU sector, guidance on the allocation of emissions between industry, energy and waste sectors should be detailed especially for 2 C 1 Iron and steel, e.g. related to flaring of blast furnace gas, diffuse/fugitive emissions from storage of fuels at the industrial facilities, off-road machinery, paved/unpaved roads, etc. Also, care should be taken to ensure that emissions coming from the use of fuels or from the treatment of waste are allocated under the respective inventory sectors and not under IPPU. Waste containing fuels may be used in many activities and clear guidance should be given which is energy use and which is non-energy use
  - The IPPU sector emissions should be estimated keeping in mind that there is a possibility for double counting with the Energy and Waste sectors in cases where the method is not clearly defined only for those emissions arising from the industrial process itself or from the use of solvents/products.

- SLCF species
  - SLCFs considered: BC, OC, SO_x, NO_x, CO, NMVOC and NH_3.
  - All Sulphur and nitrogen compounds[2] to be as NO_2 and SO_2.
  - Definition of NMVOC[3] compounds to be considered for climate purposes.

[1] Guidance to experts for the virtual joint 1st and 2nd expert meeting on SLCFs

[2] Sulphur oxides cover all sulphur compounds expressed as sulphur dioxide (SO_2) (including sulphur trioxide (SO_3), sulphuric acid (H_2SO_4), and reduced sulphur compounds, such as hydrogen sulphide (H_2S), mercaptans and dimethyl sulphides, etc.); NO_x cover nitric oxide and nitrogen dioxide, expressed as nitrogen dioxide (NO_2)

[3] Non-methane volatile organic compounds" (NMVOCs) cover all organic compounds of an anthropogenic nature, other than methane, that are capable of producing photochemical oxidants by reaction with nitrogen oxides in the presence of sunlight. Volatile organic compounds (VOC) have been defined as any organic compound having a vapour pressure of 0.01 kPa or more at 293.15 K or having the corresponding volatility under the conditions of use. To be considered if the definition above used in the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) is sufficient, or if there is need to be redefined for climate purposes. In addition, under

- A definition of BC and OC and possibly EC should be provided in SLCF guidelines.
- The EFs to be provided for BC (OC, EC) should include information of the measurement method used to develop them as well as information on whether the condensable particle fraction is or is not included.
- BC can be estimated with the use of shares of BC in $PM_{2.5}$, in case no direct emission factors are available. If using shares of PM emissions to estimate BC, information should be provided on if the condensable particle fraction is nor not included. Note that BC covers both the filterable and condensable particle fractions, however, the condensable fraction is not present in all sources. Note also that while TSP emissions may be measured and thus be rather accurate, uncertainty is added using default shares to calculate $PM_{2.5}$ from TSP and additional uncertainty by using default shares to calculate BC from this $PM_{2.5}$.

- General on Methodology, AD and default EFs
  - It is important to clearly spell out the differences between IPCC, EMEP/EEA and AP42 methodologies in terms of the different approaches (e.g., the Tier 1 approach in each methodology can be different).
  - The BOG recognized that AD collection is needed where the AD is not the same or is additional to that data collected for the GHG inventories. The guidance should be given on how to collect or estimate AD that can be used in the calculation of SLCF emissions.
  - Although the default Tier 1 methods presented in the EMEP/EEA Guidebook may be globally applicable, the default Tier 1 EFs may not if they have been developed in the context of a specific region because of the considerable variability in process and abatement techniques at plant level. Many of the EFs are representative to the EU 2015 abatement level (EMEP/EEA Guidebook), which may not be the global case. Therefore, higher Tier methods that include more components, such as AD, technology specific EFs, abatement efficiencies for specific abatement techniques etc. may be easier to convert to local conditions anywhere but would also include the need to collect this data regarding the region to which it is applied. The methods to be developed could thus provide default values for e.g. the penetration of a certain process and/or abatement techniques in the industrial activity for certain regions as well as default values for the abatement efficiencies taking into account the impact of maintenance.
  - The presentation of any SLCF EFs must include information on if the EF is for unabated emissions or for abated emissions and what has been the default efficiency considered in the preparation of this default EF. For instance, information of abatement technologies and their efficiencies (as ranges, e.g. 60-80%,) can be found in the EMEP/EEA Guidebook.

- SLCF category specific methodologies
  - Even though there are no PM process emissions from Lime productions, there might be other emissions from storage and handling and transport on site. On-site transport and mobile machinery should be allocated under Energy/Transport and the part of storage and handling relevant to IPPU should be reported in this sector, if not emissions will not be accounted for.
  - As waste fuels and scrap materials may include plastics, the possibility of BC emissions should be noted when developing methods. This may be the case e.g. for secondary production of non-ferrous metals, e.g. recycling of lead, zinc etc.
  - For non-ferrous industry (copper, lead, zinc, nickel), a mass balance approach to estimate SO_2 could provide more accurate results than EF approach.
  - The category of Solvent and Other Product Use includes various emission sources which are not covered in the current IPCC Guidance. In the future IPCC SLCF methodology report it would be useful to have sub-categories such as e.g. in the EMEP/EEA Guidebook: Domestic solvent use including fungicides, Road paving with asphalt, Asphalt roofing, Coating applications, Degreasing, Dry cleaning, Chemical products, Printing, Other solvent use (to be specified in the national inventory report), Other product use (to be specified in the national inventory report).
  - The activity in the source categories Ammonia production and Hydrogen production (Chemical Industry) are increasing and need to be monitored.

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the UNECE CLRTAP the reporting unit is kilotonnes, while the carbon content in VOCs is not considered. The Chapter 7 Volume 1 of the *2006 IPCC Guidelines* provides a conversion factor 44/12 and default mass of 0.6 to convert NMVOCs into CO_2

- Food and Beverage charbroiling, fat frying, grain handling, fermenting/ distilling, drying/ roasting, natural gas cooking – risk for double counting with Energy.

Conclusions:

During the BOG sessions the experts concluded on:

- The adoption of the updated list of source categories and associated SLCF species, as provided in the annexed Table 2

- The inclusion of the following additional comments, SLCF source categories and/or species to Table 2 were recommended:
  - CO from 2C7 Other metals - Rare Earth Production is insignificant.
  - 2C7 Other metals – Metal welding and cutting. Literature suggests emissions of PM (not BC, mainly metal oxides), but also CO, NO_x and SO_2 from metal welding and cutting might be insignificant, but this needs further evaluation.
  - 2F Product Uses as Substitutes for Ozone Depleting Substances. Ammonia is used in refrigeration. The source is added to Table 1, but the significance of the source must be looked into. Also, emissions of NMVOC are possible (use of propane, butane, pentane, etc.).
  - Hydrogen production – the *2019 Refinement* introduced this source category in IPPU with the methodology focused on stand-alone facilities using fossil fuels (please note, that hydrogen production at refineries is included in Energy sector). Allocation of fuel combustion and process related emissions is an issue

- The BOG decided not to include the following two sources in Table 2 as insignificant in addition to those mentioned in the Issue paper and in line with the comments provided in Table 1:
  - Explosives Manufacturing
  - Ordnance Detonation

- The following issues related to the identification of relevant source-categories and associated SLCF species:
  - Storage and Handling of materials (raw materials, feedstock, fuels, final products, etc.) may lead to SLCF emissions (particularly NMVOC). This source of emissions can be present in each source category. The information on possible SLCFs emissions from Storage and Handling should be analysed and should be provided in the future methodology report

- Forwarding the following issues to the Plenary discussion:
  - Definition of BC and VOC emissions
  - New SLCF methods to clearly indicate the division of emissions between Energy-IPPU-Waste sectors to avoid double-counting
  - Need to additional or new AD collection to enable calculation of SLCFs (e.g. process and abatement technologies)
  - Need to present SLCF default EFs with information of the process and abatement efficiencies used in the development of the EF
  - Better understanding of different approaches used in the Tier methods of the different international guidance (IPCC, EMEP/EEA, US EPA) is needed

- The IPPU Gaps list as follows:
  - 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

o 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_2 from desulfurization, PM and SO_2 from foundries, PM, OC, EC, CO and VOCs from scrap preparation. Rolling mills – SO_2 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_2 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_2 emissions in roofing materials
- 2F Product Uses as Substitutes for Ozone Depleting Substances – NH_3, NMVOC – Methods, AD, EFs
- 2H1 Pulp and Paper Industry – Updated EFs

2.3 AFOLU BOG

The work of the AFOLU BOG was facilitated by Dominique Blain and reported to the closing plenary session by Savitri Garivait. Sandro Federici and Eriko Nakamura (TSU) provided technical support.

Discussion:

Consideration of SLCF source categories and associated species provided in Table 1 (see Annex 1), as well as with the identification of SLCF source categories and associated species

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

- Manure management (IPCC 3.A.2)
  - IPCC methods for estimating N_2O and CH_4 emissions provide a good basis for globally applicable estimation methods for NO_x/NH_3 and NMVOCs respectively.
  - Although, where EMEP methods are used to source data, TAN (Total Ammonia Nitrogen) and Nex (Total Nitrogen Excreted) need to be reconciled. Further, fluxes of NO_x/NH_3 and of indirect emissions of N_2O need to be consistent with each other.
- Managed Soils (IPCC 3.C.4 and 3.C.5 – Direct and Indirect N_2O Emissions from Managed Soils)
  - IPCC methods for estimating direct and indirect N_2O emissions provide a good basis for estimating direct and indirect NO_x and NH_3.
  - NO_x and NH_3 emissions are part of the same process that determines N_2O emissions; although EFs provided in the *2019 Refinement* for the aggregate of NH_3+NO_x need to be revised.
  - However, the nomenclature of the category won't cover additional species as NO_x and NH_3, so either new categories are created, and this is the proposal, or the nomenclature of existing categories is revised.
  - Further, the need to maintain N-balance across source-categories within this sector (i.e., NH_3, NO_x, N_2O emissions from manure management, including anaerobic digestion) and across sectors (NH_3, NO_x, N_2O emissions from manure combustion and incineration)
  - Main gap identified is the availability of EF values to cover the global variability of agrosytems/agro-practices (e.g., fertilizer spreading vs fertilizer incorporation into the soil, irrigation, drainage, soil type).
  -
- Burning
  - The nature of fires was discussed as a trigger for the inclusion of emissions in an inventory that according with some should focus on the use of fire as a management tool/practice.
    - Burning in Forest Land
      - Underlying assumptions of parameters/calculations used in IPCC and alternative methods need likely to be reconciled.
      - Factors/parameters values used for emission estimation need to be updated with new literature.
    - Burning in Cropland
      - To reconcile the IPCC method with the need to estimate in the sector the open burning of agricultural waste in crop fields.
      - During COVID-19 pandemic, connections were observed between solid waste burning and crop residue burning in Southeast Asia, that can be cross-sectoral with the Waste sector
      - Need of specific emission factors (NO_x, SO_2, etc.) for sugarcane burning, particularly in South and Central America, Southeast Asia.
    - Burning in all other lands
      - For peat fires need to reconcile nomenclatures of soil types and land use categories.
      - Consistency between IPCC land use definitions and open burning categories should be assured.

- Others

A number of sources of SLCFs emissions for which no methods are available and/or no corresponding IPCC categories are available, although further consideration and investigation is seen needed to allow to draw conclusions, have been discussed.

- For NMVOC emissions from "Livestock manure applied to soils" as well as from "Urine and Dung deposited on pasture" the discussion pointed out the lack of knowledge on actual emissions produced per unit of activity and on the main variables determining the rate of emissions.
- For NMVOC emissions from Pesticide application, although a methodology is available from the US AP-42, the methodology is data intensive and therefore not likely to be replicated all across the World. Thus, although the source deserves further consideration and investigation no default methodology for its inclusion in Methodology Report on SLCF emissions has been identified.
- Biogenic VOCs from Cultivated crops; Managed deciduous/coniferous forests; Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub). The discussion pointed out differences in emissions attribution between man-made vegetation -i.e. cropland, pasture and plantation for which associated VOC fluxes are triggered by and depends on the human activity that set and manage the culture- and natural vegetation i.e. forests, rangeland and other natural systems- where VOCs emissions would anyhow occur, regardless of the human impact, and for which anyhow the difference in the rate of emissions associated with human impacts cannot be quantified to derive a robust default methodology given the current knowledge.
- Fugitive dust from tilling is recognized as a significant source of OC and EC from PM_{10}, although the only available methodology, from US National Emission Inventory, is seen complex and likely not applicable globally.

A sources category of SLCFs emissions for which no methods and no corresponding IPCC category are available and for which the available knowledge was not enough to have any consideration at this expert meeting:

- Fugitive dust from animals

Conclusions:

<u>During the BOG sessions the experts concluded on</u>:

- The addition of source-categories to cover emissions of NMVOCs, NH_3 and NO_x from Manure management as well as from Fertilizer uses
- The exclusion of "Fugitive dust from animals" from the list of potential source categories to be considered for the Methodology Report on SLCF emissions
- The inclusion in the list of those categories to be considered for a Methodology Report of all source-categories listed in table 1, including those for which no method globally applicable (i.e., under any national circumstances) was identified, since the further investigation of those categories was considered needed in order to conclude on their relevance.
- Gaps were identified mainly in:
  - Disaggregated default IPCC EF for NO_x and NH_3 from managed soils
  - Burning, specific values for fuel load, combustion factors, and EFs associated with most relevant crops as well as management systems, including for cropland open burning
  - Manure management, N balance, including digestate/manure transfer (including transfer to waste-treatment facilities) and co-digestion of manure and other organic matter (OM) (e.g., crop residues/slashes from pruning/trimming). Improve representation of grazing practices to properly count for the fraction of dung/urine left on pasture/yards
  - Globally applicable methods and EFs for fugitive dust from tilling/machinery-operations in farms, and from animals

2.4 WASTE BOG

The work of the Waste BOG was facilitated by Jongikhaya Witi and reported to the closing plenary session by Erin McDuffie. Baasansuren Jamsranjav (TSU) provided technical support.

Discussion:

Consideration of SLCF source categories and associated species provided in Table 1.

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

- 4.A.1 Solid Waste Disposal – recommendation to add sub-categories for landfill fires and flaring
  Proposed sub-categories (and compounds):
  - 4.A.1 – Managed Waste Disposal Sites:
    - 4.A.1.a – Landfill fires (PM (BC/OC), NO_x, CO, NMVOC, SO_2)
    - 4A.1.b – Flaring (PM (BC/OC), NO_x, CO, NMVOC, SO_2)
    - 4.A.1.c – Decomposition (CO, NMVOC, NH_3)
  - 4.A.2 – Unmanaged Waste Disposal Sites
    - 4.A.2.a – Landfill fires (PM (BC/OC), NO_x, CO, NMVOC, SO_2)
    - 4.A.2.b – Flaring (n/a)
    - 4.A.2.c – Decomposition (CO, NMVOC, NH_3)
  - 4.A.3 – Uncategorized Waste Disposal Sites
    - 4.A.3.a – Landfill fires (PM (BC/OC), NO_x, CO, NMVOC, SO_2)
    - 4.A.3.b – Flaring (PM (BC/OC), NO_x, CO, NMVOC, SO_2)
    - 4.A.3.c – Decomposition (CO, NMVOC, NH_3)

- 4.B. Biological Treatment of Solid Waste – suggest splitting anaerobic digestion and composting into two sub-categories
  Proposed sub-categories (and compounds):
  - 4.B.1 – Composting (NH_3, CO, NMVOC)
  - 4.B.2 – Anaerobic Digestion (NH_3)

Consideration of issues associated with the identification of SLCF source categories and associated species.

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

- **Key Categories**
  - Of the five Waste sector categories, 4.C. Incineration and Open Burning of Waste is a dominant source of air pollutant emissions. Efforts to develop robust estimates of AD and EFs for this category should be prioritized

- **Impact/Importance of Waste Emissions**
  - Waste emissions from many categories (e.g., landfill fires, landfill flares, open burning) have a greater impact at the local level (e.g., local air quality impacts next to landfills), than at the national or global level.

- **Uncertainties**
  - Limited activity and EF data result in large uncertainties in air pollutant emissions from Waste sector, BUT these uncertainties should not limit efforts to develop robust emission estimates for Waste

- **Key Issues (see Table 1 for complete list of issues)**

  - Methodological Approach
    - Available methods (e.g., IPCC, EMEP, USEPA NEI) for many categories may be applicable to Tier 1 approach (or as a starting point to develop Tier 1 approach)
    - Flexible reporting may be beneficial for categories where emissions can't be derived at the sub-category level (e.g., emissions from waste incineration with or without energy recovery)

  - AD
    - There is **limited AD** on the amount of waste burned (and burned per capita), composition of waste, smouldering or burning conditions, waste disposal approaches in rural areas, etc.,
    - For Open Burning:
      - The definition of the **fraction of waste burned (B_{frac})** needs to be clarified
      - The estimation of **the fraction of population burning waste (P_{frac})** should be revised
      - The classification of materials included in the **definition of agricultural waste burning or land clearing** needs to be clarified so that emissions can be apportioned to the correct sector (AFOLU/Waste) without double counting or missing emissions

  - EFs
    - **Tier 1 EFs** for many categories will need to be **regionally or technologically specific** (e.g., open waste burning, biological treatment, etc.,)
    - Some regional EF estimates are available (e.g., EMEP/EEA and US EPA), but others will need to be developed based on measurements of real conditions

Conclusions:

During the BOG sessions the experts concluded on:

- The adoption of the list of source categories and associated SLCF species, as provided in the annexed Table 2

- The inclusion of additional SLCF source categories and/or species to Table 2:
  - Landfill fires and flares (PM, CO, NO_x, SO_2, NMVOC) added to 4.A (see Tables 1 and 2)
  - NH_3 added to 4.A (see Tables 1 and 2)
  - 4.B split into sub-categories for composting and anaerobic digestion (see Tables 1 and 2)

- The following issues for further consideration, related to the identification of relevant source-categories and associated SLCF species:

  - Key Knowledge Gaps

    - **4.A Solid Waste Disposal**
      - AD
        + No known guidance available to help countries estimate the amount of waste burned at landfills
        + It may be difficult to find information about flaring efficiencies and volumes at landfills
      - EFs
        + There will be a need to develop regional EFs for landfill fires, flares, and decomposition (using available methodologies as a starting point)
      - Other
        + The significance of NH_3 from decomposition needs to be investigated further

+ 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 CH_4 GHG guidelines). This needs to be investigated further.

- **4.B Biological Treatment of Solid Waste**
  - AD
    + Limited data, especially on amount of green-waste (composting)
    + Need to know the amount of N in the feedstock (waste + manure), which might vary regionally (anaerobic digestion)
  - EFs
    + There will be a need to develop regional EFs for composting (using available methodologies as a starting point)
    + Lack or limited data about N in feedstocks constraints quality of EFs
  - Other
    + 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**
  - AD
    + The assumption of no urban open burning needs to be re-evaluated
    + The equation to estimate the amount of waste open burned needs to be reviewed and the definition of B_{frac} clarified
    + The estimation of the population fraction that is burning waste (P_{frac}) also needs to be re-evaluated.
  - EFs
    + Waste Incineration - Need to be technology dependent and account for abatement efficiencies
    + Available EFs for open burning are not likely globally applicable
    + Need to develop non-laboratory EFs for tire burning (for tire burning outside of landfills)
  - Other
    + Waste incineration - Emissions will depend on incineration conditions (e.g., waste moisture content, level of smoulder, etc.) and these impacts on EF will need to be considered further.
    + Open burning - Emissions will depend also on environmental conditions (e.g., soil moisture content, meteorology, etc.) and these impacts on EFs will need to be considered further.

- **4.D Wastewater Treatment and Discharge**
  - AD
    + 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
    + Available EFs (NMVOC, NH_3 (EPA-only)) are not specific to domestic or industrial wastewater treatment. Domestic wastewater EFs for NH_3 from EMEP are for latrines only.
  - Other
    + 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**
  - AD
  - EFs
    + Global Tier 1 EF may be able to be derived for car fires
    + Tier 1 EF for building fires is likely not globally applicable
  - Other

- Forwarding the following issues to the Plenary discussion:
  - During the BOG sessions the experts didn't achieve a common view on the definition of agricultural waste burning, which needs to be clarified. The definition needs to help clarify which types of agricultural or small-scale biomass burning activities to include in this category.

2.5 CROSS-CUTTING ISSUES

During the BOGs discussion following cross-cutting issues were identified by experts:

- Black carbon (BC) / Effective black carbon (EBC) / Elemental carbon (EC): BC is identifiable by its 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 "EBC" or "EC". This working group recognizes that these analytical differences and measurement technical differences create uncertainty in EFs and predicted light absorption. However, the working group also acknowledges the need to constrain highly variable emissions and the small number of input measurements. For practical purposes, emission measurements, where any standard method is used to quantify BC, EBC, or EC are to be considered equivalent for the development of BC EFs. During the development of the methodological report on SLCFs, the authors may revisit this consideration in light of the likely availability of more abundant and differentiated information on the carbon fraction of carbonaceous aerosols.

- Organic carbon (OC) / Organic material (OM): OC is the amount of carbon present in carbonaceous excluding EC (defined above) and mineral carbon (dust carbon occurring as calcite, dolomite or other C-bearing minerals). Thermal-optical analysis is used to quantitatively determine OC and EC. Organic aerosols (OA) and OM can be considered equivalent terms and refers to the mass concentration of organic particulate species present in the aerosols. This mass might be built by hundreds of organic compounds. The difference with OC is that OM and OA consider the mass of heteroatoms, such as O and H, having a relevant contribution. OM could be 20-100% more than OC, depending on the duration of ageing of OC in the atmosphere. Two options exist for EFs and for inventories: Using OC values may increase consistency of reporting, but OM mass will have in total to be assessed by modelling activities. OM is atmospherically more relevant, but it may be inconsistently reported, depending on sampling conditions at time of the measurement. At this stage and due to the fact that not many data exist for different sectors and classes at least transparency on whether OC or OM values are reported would be necessary. On the other hand, many models input seasonally and spatially dependent OM:OC ratios so that the model could convert inventory estimates of OC in OM for its simulations.

- $PM_{2.5}$ is highly heterogeneous spatially and temporally (varying from positive to negative RF depending on sources and meteorological characteristics). Measurements and modelling of particles concentration have been used to evaluate the radiative effect of absorption or scattering. One example is the effect of light-absorbing particles reducing surface albedo in the cryosphere not only due to BC but also other absorbing compounds (e.g. brown carbon, dust). Although the composition is not always known, the effect of $PM_{2.5}$ is evaluated based on average compositions determined by local/emissions characteristics (many countries have EFs for $PM_{2.5}$). Given that most BC and OC EFs are expressed as fraction of $PM_{2.5}$, the participants of the Energy BOG concluded that primary $PM_{2.5}$ should be included in the list of emissions to be estimated not only because it is as SLCF but as an intermediate variable often needed to estimate BC and OC emissions.
  Further, several BOGs highlighted the importance of characterizing the condensable portion[1] of PM and how that can impact BC and OC estimates since these are often calculated as the fraction of PM.

- Precursors of secondary organic aerosols (SOA). There is an asymmetry in the set of selected SLCFs regarding the role of aerosols precursors. While the precursors of inorganic aerosols have been clearly targeted, the precursors of organic SOA have not been considered. A large source of uncertainty stands in the actual SOA formation yields in real-world conditions. However, the precursors are better known:

[1] The condensable portion of PM is not always measured or may be measured by applied methods, given that some do not capture all the condensable PM. Since PM mass estimate is dependent on the method, applying a fraction to derive BC or OC from PM measured under different conditions or different methods can introduce errors.

aromatic NMVOC + intermediate volatility OCs (iVOCs). Semi-volatile compounds are also important, but they could be already partly accounted for in current primary OC inventories. It is important to note that in a first approximation, precursors of anthropogenic SOA can be represented therefore with a few classes of organic compounds, hence not requiring a molecular-level speciation (which for compounds with molecular carbon numbers of 10 to 25, it would be even impossible). At this stage, this may be flag as a scientific gap and a topic for future research.

- Ozone formation in the troposphere depends on direct sunlight concurrence with ozone-precursor emissions (e.g., NMVOC and NO_x). Similarly, secondary aerosol formation depends on concurrence with PM-precursor emissions (e.g., NH_3, SO_2, NO_x, NMVOC) and primary aerosol emissions (BC, OC). Thus, timing (i.e., hour to monthly frequency) and place (i.e., within 50-100 km spatial resolution) of emissions do matters for a climate-relevant inventory of emissions.

Cross-cutting issues were further discussed at the closing plenary. Although no conclusions were drawn, agreement was general on the need to further explore those issues.

Annex 1: Sectoral Tables

Through a desk-work phase implemented, by TSU and participants, ahead of the meeting, two tables have been prepared for each sector with information on source categories and associated SLCF species.

Table 1 provides Summary of Information including on methods and factors available to estimate SLCFs emissions from the relevant source category. Associated to Table 1, Issue paper provides for relevant sectoral issues to be addressed in formulating a complete list of sectoral source-categories and associated SLCF species.

Table 2 provides List of relevant sectoral source-categories and associated SLCFs.

Both Tables, and the associated Issue paper, were used to inform the work of BOGs at the expert meeting.

Table 1 Summary Information (Energy)

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.A	**Fuel combustion activities**							
								1. G: In certain occasions the tiered approach from alternative methodologies to estimate emissions for SLCFs is not entirely consistent with the IPCC three-tiered approach to estimate GHG emissions. When selecting methods from an alternative methodological framework the characterization for the tiers in the report on SLCFs estimation methods should be consistent with those defined by IPCC, independently from the characterization given in the alternative methodological framework. 2. C: Given that most BC and OC EFs are expressed as fractions of PM2.5, the methodology will need to include PM2.5 in the list of emissions to be estimated as intermediate variable to estimate BC and OC emissions. 3. F: Maintain the Tier 1 structure like for non-CO2 GHGs for the development of default emission factors but if necessary; add layers to include details on fuels, technologies (with and without abatement), etc. When information on abatement technologies is not available, the estimates would correspond to unabated emissions.
1.A.1	**Energy Industries**							D: The methodology at upper level covers lower levels for stationary combustion.
1.A.1.a	Main activity electricity and heat production	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method with modifications, see comment #3 to 1.A)	Availability of methods to estimate SLCF emissions from co-firing practices. (See comment #3 in column I).	1. E: US NEI method incorporates handling efficiencies of prevention facilities. 2. G: Emissions of SLCFs for subcategories under 1. A.1.a.i, 1.A.1.a.ii, 1.A.1.a.iii and 1.A.1.a.iv can be estimated using the method for category 1.A.1.a. 3. F: Co-firing (complementary firing or co-combustion) is the combustion of two or more different fuels in the same combustion system. Methodologies for stationary combustion should allow the possibility of estimating emissions under co-firing practices and provide the corresponding guidance, including activity data collection, emission factors and other parameters.
		PM2.5						See comment #2 to 1.A
1.A.1.b	Petroleum refining	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method with modifications, see comment #3 to 1.A)		E: US NEI method incorporates handling efficiencies of prevention facilities.
		PM2.5						See comment #2 to 1.A
1.A.1.c	Manufacture of solid fuels and other energy industries							
1.A.1.c.i	Manufacture of solid fuels	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method with modifications, see comment #3 to 1.A)		
1.A.1.c.ii	Other energy industries							E. AP-42 emission factor applied to fuel produced
		PM2.5						See comment #2 to 1.A

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.A.2	**Manufacturing industries and construction**							1. Please see the comments to 1.A and 1.A.1 2. E: Small-scale combustion may occur under some facilities. Comments ##1-7 to 1.A.4 apply also here. 3. E: Emissions arising from off-road and other mobile machinery in industry should, if possible, be broken out under the corresponding subcategory. Comments ##1-4 to 1.A.3-e-ii apply also here.
1.A.2.a.	Iron and steel	NO_X, NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method with modifications, see comment #3 to 1.A)		
1.A.2.b	Non-ferrous metals			-				
1.A.2.c	Chemicals			-				
1.A.2.d	Pulp, paper and print			-				E. AP42: emission factor applied to product produced
1.A.2.e	Food processing, beverages and tobacco			-				
1.A.2.f	Non-metallic minerals			-				E. AP42: emission factor applied to product produced 1. E. The use of product produced as activity data instead of fuel used deserves attention for developing T1 factors. In addition, potential omission or double counting with IPPU sector should be considered. 2. F, G: Brickworks 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.
1.A.2.g	Transport equipment			-				
1.A.2.h	Machinery			-				
1.A.2.i	Mining (excluding fuels) and quarrying			-				
1.A.2.j	Wood and wood products			-				
1.A.2.k	Construction			-				
1.A.2.l	Textile and leather			-				
1.A.2.m	Non-specified industry			-			Small-scale combustion may occur under some facilities. Comments ##1-7 to 1.A.4 apply also here.	
		PM2.5						See comment #2 to 1.A

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.A.3	**Transport**							
1.A.3.a	Civil aviation							1. E, F: LTO is critical for SLCFs so need to highlight that if only fuel based T1 approach is used the EF needs to reflect the whole LTO and cruse phase even without the LTO activity data 2. E: Indicate that for more accurate calculations use T2 based on LTO data
1.A.3.a.i	international aviation (international bunkers)	NO_X,SO_2, CO, NMVOC, BC, OC	Yes (fuel consumption based and LTO based)	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	Embedding emissions from landing and take-off in the Tier 1 EFs of a fuel-based approach. (See comment #1 to 1.A.3.a)	
1.A.3.a.ii	Domestic aviation							
		PM2.5						See comment #2 to 1.A
1.A.3.b	Road transportation							1. E: The time dependency of technologies is especially relevant for mobile source fleet that has vehicles of different age and technology class. The time dimension is important for older technologies and also that as technology ages it emits differently Super emitters might be a large portion of fleet emissions. In addition, the emission characteristics of the old vehicular fleet is relevant to estimate emissions across the time series of interest. 2.E: The time dimension is also relevant to estimate emissions for future years. It is expected that the methodology report would allow estimating emissions according to the technologies in use at the time of issuing the report but since this is a category of rapid technological changes, the IPCC may wish to consider how emission factors and other parameters may be updated to reflect the evolving nature of road transportation. 3. E: As for CH4 and N2O, it is expected that the distance travelled approach would be more appropriate to estimate SLCF emissions. However, it is convenient to have a fuel-based Tier 1 approach even if not used it provides a check. Regarding the development of Tier 1 default EFs, see comment #3 to 1.A. 4. E, F: The engine start-up emissions of SLCF may be large for the high-mileage fleets. We need to address this concern, especially for the fleets in developing countries
1.A.3.b.i	Cars	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC	Yes (fuel consumption and km travelled)	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	Time dependency of technologies (See comments ##1 and 2 to 1.A.3.b)	
1.A.3.b.ii	Light duty trucks	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC						
		PM2.5						See comment #2 to 1.A
1.A.3.b.iii	Heavy duty trucks and buses	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC						

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
		PM2.5						See comment #2 to 1.A
1.A.3.b.iv.	Motorcycles	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC						
		PM2.5						See comment #2 to 1.A
1.A.3.b.v	Evaporative emissions from vehicles	NMVOC				Yes (as per IPCC method)		
1.A.3.b.vi	Urea-based catalysts	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC				Yes (as per IPCC method with modifications)	Emissions of SLCFs from vehicles equipped with urea selective catalytic reduction systems	1. E: EFs of some SLCFs from vehicles equiped with urea SCR systems are becoming available (e.g., EMEP, Guo, J., Ge, Y., Hao, L., Tan, J., Li, J., & Feng, X. (2014). Atmospheric environment, 99, 1-9; Grigoratos, T., Fontaras, G., Giechaskiel, B., & Zacharof, N. (2019). Atmospheric environment, 201, 348-359; Ntziachristos, L., Papadimitriou, G., Ligterink, N., & Hausberger, S. (2016). Atmospheric environment, 141, 542-551). 2. E: Failure of urea SCR systems has implications on the emissions.
	Non-exhaust emissions	BC, OC				Yes	Emissions of BC and OC from automotive wear	E: Tire and brake wear for OC, BC etc. needs to be included as a category (maybe as fugitive). G: Emissions from automotive wear. There are globally applicable methodologies. However, a fuel-based approach may not be possible for this type of emissions.
		PM2.5						See comment #2 to 1.A
	Use of lubricants	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC					Emissions of SLCFs from the use of lubricants in all types of vehicles	E: The contribution of lube oil is important for SLCFs (more so than GHGs) and is burned in 2-stroke but also other vehicles so need to consider lube oil for all vehicles, with category 2.D.1
		PM2.5						See comment #2 to 1.A
1.A.3.c	Railways	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)		E: US EPA estimates by number of trains on link times fuel consumed by train class times emission factor for all except
		PM2.5						See comment #2 to 1.A
1.A.3.d	Waterborne navigation							E: EPA uses distance travelled times EF. OPRF estimate by engine power. E. IPCC factors and technology description for GHGs might be too simple for SLCFs especially for NOx (e.g., new hybrid types of ships) so flag need to use new information E. Flag the need to add a new Tier 3 to the IPCC methodology for NOx and particles based on engine power (current GHG approaches do not have a T3 for this category)
1.A.3.d.i	International waterborne navigation (international bunkers)	NO_X, NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	Emission estimation methods based on engine power	

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.A.3.d.ii	Domestic waterborne navigation	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC						
		PM2.5						See comment #2 to 1.A
1.A.3.e	Other transportation							
1.A.3.e.i	Pipeline transport	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC				Yes (e.g., EMEP)		1. E: Combustion related emissions from the operation of pump stations and maintenance of pipelines. 2. E: The EMEP methodology refers the estimation of these emissions to that of small-scale combustion under category 1.A.4.
1.A.3.e.ii	Off-road	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method with modifications see comment #3 to 1.A)	Most alternative methodologies do not cover BC and OC emissions	1. D, E: Although the estimation methods for this subcategory are addressed in Chapter 3 Volume 2 of the *2006 IPCC Guidelines* (Mobile combustion), off-road mobile combustion encompasses a wide variety of off-road vehicles and other machinery used across the different combustion categories namely, mobile combustion under manufacturing industries and construction (1.A.2), mobile machinery under commercial and institutional (1.A.4.a.ii); mobile equipment used under residential (1.A.4.b.ii) e.g., household and gardening machinery; off-road vehicles and other machinery used in agriculture/forestry/fishing (1.A.4.c.ii); other mobile including military mobile machinery (1.A.5.b.iii). The methodology for SLCFs should contemplate and be consistent with the widespread distribution of off-road combustion across the mentioned categories. 2. D, E: The emissions from the diverse types of equipment used across all categories arise from the combustion of small number of fuels (typically diesel oil, gasoline and LPG) to power the equipment. 3. E: Except for SO2, the emissions of SLCFs are highly dependent on the type of equipment and technology. 4. E: Guidance on the collection and/or estimation of AD is required as this may constitute the main challenge in estimating these emissions. 5. E: MOVES model estimates by product of an adjusted EF multiplied by rated power, load factor, engine population and activity
		PM2.5						See comment #2 to 1.A
1.A.4	**Other Sectors**							1. D, E: The IPCC methods for GHGs should generally cover SLCFs from this category including small emissions sources and nonconventional fuels. 2. H: However, need to point out that combustion and abatement technologies especially in small emission sources may go beyond what is currently in IPCC categories for GHGs so may require additional analysis when developing SLCF guidance. 3. G. Emissions from SLCFs are more diverse than GHGs for this category so it would need more focus when developing EFs and guidance for SLCFs 4. H. This category is also more likely to have older equipment, so the age of technology is especially important for this category as well. 5. F: EFs vary in several of orders and magnitude as a function of appliances and abatement technologies 6. G: Country-specific practices of one country are not always translatable to other countries. Need to develop country-specific EFs and parameters.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
								7. E, F: Emissions from informal combustion normally used of various types of fuels across the same year. This practice may be difficult to capture in an inventory.
1.A.4.a	Commercial/ institutional							
1.A.4.a.i	Stationary combustion	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	Guidance on the treatment and the collection of AD for informal combustion (see comment #7 to 1.A:4 and comment #1 to 1.A.4.a.i) Guidance to develop country-specific EFs and other parameters (see comments ##2-6 to 1.A.4)	1. G: 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. See comments ##1-7 to 1.A:4
1.A.4.a.ii	Off-road vehicles and other machinery	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC					Most alternative methodologies do not cover BC and OC emissions	See comments to 1.A.3.e.ii
		PM2.5						See comment #2 to 1.A
1.A.4.b	Residential							
1.A.4.b.i	Stationary combustion	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	See 1.A.4.a.i concerning emissions from small scale combustion and AD concerns with use of informal fuels	1.See comment #1 to 1.A.4.i 2. F: Quality, type, and moisture content of solid fuels may have a large effect on emission factors. 3. G: Special consideration should be given to identifying contributions of stationary diesel generators and kerosene wick lamps, as well as candle burning for BC. 4. E: US NEI Survey data are used to estimate number of appliances, types, appliance emission controls if any, burn rate, types of wood for NO_X, CO, BC. 5. cooking exhaust (meat cooking etc., not from fuel itself) could be considered as small-scale combustion sources for OC, BC, and PM2.5 See comments ##1-7 to 1.A.4
1.A.4.b.ii	Off-road vehicles and other machinery	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	Most alternative methodologies do not cover BC and OC emissions	
		PM2.5						See comment #2 to 1.A
1.A.4.c	Agriculture/forestry/fishing							

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.A.4.c.i	Stationary	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	See 1.A.4.a.i	Collected solid fuels used for drying or other processes may need special attention to provide accurate activity data.
1.A.4.c.ii	Off-road vehicles and other machinery	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC					Most alternative methodologies do not cover BC and OC emissions	See comments to 1.A.3.e.ii
1.A.4.c.iii	Fishing (mobile combustion)	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC						
		PM2.5						See comment #2 to 1.A
1.A.5	**Other (Not specified elsewhere)**							
1.A.5.b.ii	Mobile (waterborne component)	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)		
1.A.5.b.iii	Mobile (other)	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC		-			Most alternative methodologies for off-road do not cover BC and OC emissions	See comments to 1.A.3.e.ii
		PM2.5						See comment #2 to 1.A
1.B	**Fugitive emissions from fuels**							
								See comments ##1-3 to 1.A
1.B.1	**Solid fuel**							
1.B.1.a	Coal mining and handling							1. B: Category 1.B.1.a was expanded to include subcategories for underground and surface mines 2. B: Within each category emissions from mining, post-mining activities and flaring and conversion of gas were included. 3. C: All SLCFs instead of just NMVOC were included. Mining and post-mining are not combustion sources then likely there aren't any NOx or SO2 emissions but leave to authors to define 4. Regarding comment #1 to 1.A, note that the EMEP tier 2 approach provides information for SLCFs at a more aggregated level than the Tier 1 IPCC method for GHG.
1.B.1.a.i	Underground mines							
1.B.1.a.i.1	Mining	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC				Yes (as per IPCC method)		

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
		PM2.5						See comment #2 to 1.A
1.B.1.a.i.2	Post-mining seam gas emissions	NO_x,NH_3, SO_2, NMVOC, BC, OC				Yes (as per IPCC method)		
		PM2.5						See comment #2 to 1.A
1.B.1.a.i.4	Flaring of drained CH4 or conversion of CH4 to CO2	NO_x,NH_3, SO_2, NMVOC, BC, OC				Yes (as per IPCC method)		
		PM.25						See comment #2 to 1.A
1.B.1.a.ii	Surface mines							
1.B.1.a.ii.1	Mining	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC				Yes (as per IPCC method)		
		PM2.5						See comment #2 to 1.A
1.B.1.a.ii.2	Post-mining seam gas emissions	NO_x,NH_3, SO_2, NMVOC, BC, OC				Yes (as per IPCC method)		
		PM.25						See comment #2 to 1.A
1.B.1.c	Fuel transformation							A: 2019 Refinement category E: Differences in emissions from commercial vs informal production may be significant and the methodology should contemplate this situation.
1.B.1.c.i.	Charcoal and biochar production	NO_x, NH_3, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table)	Yes (as per IPCC method)	See comment in Category 1.B.1.c concerning developing EFs for commercial and informal production	A: 2019 Refinement category
1.B.1.c.ii	Coke production	NO_x,NH_3, SO_2, CO, NMVOC, BC, OC						A: 2019 Refinement category
		PM2.5						See comment #2 to 1.A
1.B.2	**Oil and natural gas**							
1.B.2.a.i	Exploration	NO_x, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table) including the	Yes (as per IPCC method)		1. E: Regarding comment #1 to.A, note that the 2019 Refinement to the 2006 IPCC Guidelines provides tier 1 default emission factors for NMVOC for a number of technologies used under the different oil and natural gas subcategories. In addition, Annex 4A.2 to Chapter 4 of the *2019 Refinement*, presents the percent of emissions that are leaked, vented, and flared in the data sets used for the Tier 1 emission factors. It is expected that the IPCC methodology for estimating
		PM2.5						

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.B.2.a.ii	Production and upgrading	NO_X, SO_2, CO, NMVOC, BC, OC		-	*2019 Refinement* for each category			NMVOC emissions for oil and natural would take as a starting point the detailed information already available in the2019 Refinement. This disaggregation should be kept and, if possible, enriched for NMVOCs and considered for the other SLCFs, when applicable. 2. E: If alternative methodologies are used, it is important to identify, which types of emissions (leaks, venting or flaring) are estimated. 3. H: A methodology similar to that to estimate post-meter emissions from natural gas appliance may be developed for LPG. 4. E: US NEI model to estimate emissions for each piece of equipment on a well pad in a county or basin, based on average equipment counts taken from surveys, literature searches, or the GHG reporting program, also accounting for control devices and gas composition
		PM2.5						
1.B.2.a.iii	Transport	NMVOC		-				
1.B.2.a.iv	Refining	NO_X, NH_3, SO_2, CO, NMVOC, BC, OC		-				
		PM2.5						
1.B.2.a.v.	Distribution of oil products	NMVOC		-				
1.B.2.a.vi	Other	NMVOC					Leakage from the use of LPG in appliances has not been considered.	
1.B.2.b	Natural gas							
1.B.2.b.i	Gas exploration	NO_X, SO_2, CO, NMVOC, BC, OC	Yes	-	Yes (see Energy compilation table) including the *2019 Refinement* for each category	Yes (as per IPCC method)		
		PM2.5						
1.B.2.b.ii	Production and gathering	NO_X, SO_2, CO, NMVOC, BC, OC		-				
		PM2.5						
1.B.2.b.iii	Processing	NO_X,NH_3, SO_2, CO, NMVOC, BC, OC		-				
		PM2.5						
1.B.2.b.iv	Transmission and storage	NMVOC		-				
1.B.2.b.v	Gas distribution	NMVOC						
1.B.2.b.vi	Gas post-meter	NMVOC						G: Depending on the approach used to estimate emissions from road transportation, checks for double counting of AD may be needed.
1.B.3	**Other emissions from energy production**							

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCFs[3]	IPCC method applicable[4]	Alternative Methodology [5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
1.B.3.a	Other							
	Geothermal energy extraction	NH_3, SO_2	No	EMEP	Yes (see energy compilation table)			A: additional category identified. E: electricity produced by emission factor C: Some Parties (e.g., Iceland and Italy) already estimates and report SO_2 emissions from geothermal power to the UNFCCC.

1. Apply here the *2006 IPCC Guidelines* categorization. If the *2019 Refinement* has a specific category while the *2006 IPCC Guidelines* have not, use it and notes that it is a *2019 Refinement* category
2. Use the IPCC category name or use "Others" for all those categories for which IPCC does not provide a specific categorization followed by the name of the new category taken from the relevant guidebook/sourcebook/guidelines. If the *2019 Refinement* has a specific category while the *2006 IPCC Guidelines* have not, use it and note that it is a *2019 Refinement* category
3. List here SLCFs for which the method, as noted in Columns D or E, applies. Where different methods apply to different SLCFs from the same source-category compile a row of information for each method
4. Is an applicable IPCC method available?

In the case the IPCC method needs modifications further than providing for the SLCF EF to be applicable, answer "yes with modifications" and possibly provide in the comment box indication on the modification needed. Examples of modifications are, additional parameters, e.g. technologies, and/or additional data to ensure full coverage of SLCFs emissions

5. In case the IPCC methodology is not applicable or there is not an IPCC methodology for the listed category (i.e. Column D has been compiled with "No"), provide the reference to any other methodological source from which the category is sourced
6. Provide reference to the source where default values for EFs and any other parameters are provided
7. Is the method globally applicable so far as can be judged? The answer should be based on the availability, or likelihood of availability in the next future without need of significant additional resources, of activity data as national datasets or regional datasets or global datasets. In Column I "comments" you may provide for information about datasets availability
8. In the case the experts identify any gaps that need to be closed in the next future to allow for a global methodology, such gaps should be noted here with, where possible, guidance on research and/or data collection work considered to be needed
9. In providing any additional information/comment on any information compiled in any of the previous columns, first provide the letter of the column to which the comment applies

Issue Paper (Energy sector)

Issues

I. For industrial sources, emissions of SO_2, PM, and NMVOCs are often due to a combination of fuel combustion, the materials that are processed, and emission control techniques. This poses a challenge for SLCF emission allocation between the Energy sector and the IPPU sector categories because in some cases the only data available are the sector fuel use or amount of industrial product created by the sector.

II. "Civil power generation facilities" and "Combustion due to agriculture/livestock/fishery facilities" have been proposed as new categories for SLCF emission inventories. The emissions for these categories are estimated like other fuel combustion activities, i.e. product of amount of fuel consumed and the emission factor of the fuel. Could these categories be included in 1.A.1.a and 1.A.4.c, respectively or should these categories be added to the IPCC category list?

III. The following categories/subcategories have not been explicitly described to have a methodology to estimate SLCF emissions. Emissions from most categories/subcategories may be estimated using the method provided in the upper-level category (for example, 1.A.1.a.i. electricity generation is not explicitly mentioned in existing methodologies, but can be estimated using the method for 1.A.1.a.). Other categories, such as 1.B.1.b. spontaneous combustion and burning coal dumps may not have an existing methodology. Could the group confirm the list to identify if any categories/subcategories are missing from tables1/2?

Category/subcategory	Method provided by group (✔: method provided)
1.A. Fuel combustion activities	-
1.A.1 Energy industries	-
1.A.1.a Main activity electricity and heat production	✔
1.A.1.a.i Electricity generation	No (but same as 1.A.1.a?)
1.A.1.a.ii Combined heat and power generation	No (but same as 1.A.1.a?)
1.A.1.a.iii Heat plants	No (but same as 1.A.1.a?)
1.A.1.a.iv Other	No (but same as 1.A.1.a?)
1.A.3 Transport	-
1.A.3.b Road transportation	-
1.A.3.b.i Cars	✔
1.A.3.b.i.1 with 3-way catalysts	No (but same as 1.A.3.b.i?)
1.A.3.b.i.2 without 3-way catalysts	No (but same as 1.A.3.b.i?)
1.A.3.b.ii Light duty trucks	✔
1.A.3.b..ii.1 with 3-way catalysts	No (but same as 1.A.3.b.ii?)
1.A.3.b.ii.2 without 3-way catalysts	No (but same as 1.A.3.b.ii?)
1.A.3.b.v Evaporative emissions from vehicles	No
1.A.3.b.vi Urea-based catalysts	No
1.A.3.e Other transportation	✔
1.A.3.e.i Pipeline transport	No
1.A.5 Other (Not specified elsewhere)	-
1.A.5.a Stationary	No
1.A.5.b Mobile	-
1.A.5.b.i Mobile (aviation component)	No
1.A.5.b.ii Mobile (waterborne component)	✔
1.A.5.b.iii Mobile (other)	✔
1.A.5.c Multilateral operations	No
1.B Fugitive emissions from fuels	-
1.B.1 Solid fuels	-
1.B.1.a Coal mining and handling	✔
1.B.1.a.i Underground mines	No (but same as 1.B.1.a?)
1.B.1.a.i.1 Mining activities	No (but same as 1.B.1.a?)
1.B.1.a.i.2 Post-mining seam gas emissions	No (but same as 1.B.1.a?)
1.B.1.a.i.3 Abandoned underground mines	No (but same as 1.B.1.a?)

1.B.1.a.i.4 Flaring of drained methane or conversion of methane to CO2	No (but same as 1.B.1.a?)
1.B.1.a.ii Surface mines	No (but same as 1.B.1.a?)
1.B.1.a.ii.1 Mining activities	No (but same as 1.B.1.a?)
1.B.1.a.ii.2 Post-mining seam gas emissions	No (but same as 1.B.1.a?)
1.B.1.a.ii.3 Abandoned surface mines	No (but same as 1.B.1.a?)
1.B.1.a.iii Coal exploration	No (but same as 1.B.1.a?)
1.B.1.b Uncontrolled combustion and burning coal dumps	No
1.B.1.c Fuel transformation	No
1.B.1.c.i Charcoal and biochar production	No
1.B.1.c.ii Coke production	No
1.B.1.c.iii Solid to solid fuel production	No
1.B.1.c.iv Gasification transformation	No
1.B.2 Oil and natural gas	-
1.B.2.a Oil	-
1.B.2.a.vii Abandoned oil wells	No
1.B.2.b Natural gas	-
1.B.2.b.viii Abandoned gas wells	No

From WASTE sector issue paper

1. Waste incineration: Method/Activity data/Cross-sectoral: 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.

2. Other: Cooking exhaust (J-STREAM) - Method: Times of meals multiplied by emissions (See the Waste sector compilation table).

Table 2 Category list (Energy)

A	B	C								I
IPCC categorization	Category	SLCFs							PM 2.5	Comments (Please see the corresponding comment in Table 1)
		NO_X	NH_3	SO_2	CO	NMVOC	BC	OC		
1.A	**Fuel combustion activities**									
1.A.1	**Energy Industries**									
1.A.1.a.	Main activity electricity and heat production	X	X	X	X	X	X	X	X	
1.A.1.b.	Petroleum refining	X	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	X	
1.A.1.c.ii.	Other energy industries	X	X	X	X	X	X	X	X	
1.A.2	**Manufacturing industries and construction**									
1.A.2.a.	Iron and steel	X	X	X	X	X	X	X	X	
1.A.2.b.	Non-ferrous metals	X	X	X	X	X	X	X	X	
1.A.2.c.	Chemicals	X	X	X	X	X	X	X	X	
1.A.2.d.	Pulp, paper and print	X	X	X	X	X	X	X	X	
1.A.2.e.	Food processing, beverages and tobacco	X	X	X	X	X	X	X	X	
1.A.2.f.	Non-metallic minerals	X	X	X	X	X	X	X	X	
1.A.2.g.	Transport equipment	X	X	X	X	X	X	X	X	
1.A.2.h.	Machinery	X	X	X	X	X	X	X	X	
1.A.2.i.	Mining (excluding fuels) and quarrying	X	X	X	X	X	X	X	X	
1.A.2.j.	Wood and wood products	X	X	X	X	X	X	X	X	
1.A.2.k.	Construction	X	X	X	X	X	X	X	X	
1.A.2.l.	Textile and leather	X	X	X	X	X	X	X	X	
1.A.2.m.	Non-specified industry	X	X	X	X	X	X	X	X	
1.A.3.	**Transport**									
1.A.3.a.	Civil aviation									
1.A.3.a.i.	international aviation (international bunkers)	X		X	X	X	X	X	X	
1.A.3.a.ii.	Domestic aviation	X		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	X	
1.A.3.b.ii.	Light duty trucks	X	X	X	X	X	X	X	X	
1.A.3.b.iii.	Heavy duty trucks and buses	X	X	X	X	X	X	X	X	
1.A.3.b.iv.	Motorcycles	X	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	X	
	Non-exhaust emissions						X	X	X	
	Use of lubricants	X	X	X	X	X	X	X	X	
1.A.3.c.	Railways	X	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	X	
1.A.3.d.ii.	Domestic waterborne navigation	X	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	X	
1.A.4.	**Other Sectors**									
1.A.4.a.	Commercial/institutional									
1.A.4.a.i.	Stationary combustion	X	X	X	X	X	X	X	X	

A	B	C								I
IPCC categorization	Category	SLCFs							PM 2.5	Comments (Please see the corresponding comment in Table 1)
1.A.4.a.ii.	Off-road vehicles and other machinery	X	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	X	
1.A.4.b.ii.	Off-road vehicles and other machinery	X	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	X	
1.A.4.c.ii.	Off-road vehicles and other machinery	X	X	X	X	X	X	X	X	
1.A.4.c.iii.	Fishing (mobile combustion)	X	X	X	X	X	X	X	X	
1.A.5	**Other (Not specified elsewhere)**									
1.A.5.b.ii.	Mobile (waterborne component)	X	X	X	X	X	X	X	X	
1.A.5.b.iii.	Mobile (other)	X	X	X	X	X	X	X	X	
1.B	**Fugitive emissions from fuels**									
1.B.1	**Solid fuel**									
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	X	
1.B.1.a.i.2	Post-mining seam gas emissions	X	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	X	
1.B.1.a.ii	Surface mines									
1.B.1.a.ii.1	Mining	X	X	X	X	X	X	X	X	
1.B.1.a.ii.2	Post-mining seam gas emissions	X	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	X	
1.B.1.c.ii.	Coke production	X	X	X	X	X	X	X	X	
1.B.2	**Oil and natural gas**									
1.B.2.a	Oil									
1.B.2.a.i.	Exploration	X		X	X	X	X	X	X	
1.B.2.a.ii.	Production and upgrading	X		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	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	X	
1.B.2.b.ii.	Production and gathering	X		X	X	X	X	X	X	
1.B.2.b.iii.	Processing	X	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				
1.B.3	**Other emissions from energy production**									
1.B.3.a.	Other									
	Geothermal energy extraction		X	X						

Table 1 Summary Information (IPPU)

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
2A Mineral Industry								
2A1	Cement production	SO2, NMVOC – process emissions See comments	Yes		EMEP/EEA, US AP-42, UNEP, REAS, US SPECIATE, MEP China	Yes		SO2 – non-combustion source (raw materials) NMVOC – non-combustion source (other processes) The basic Tier 1 method ADxEF can be modified to include abatement ADxEF (1-Abatement efficiency). BC (EC) and OC. For establishing BC EF, it is important to have data on PM2.5 EF, inventory of particles/profile, fraction of BC (EC) in PM2.5. BC (EC) and OC are combustion related. Data on abatement techniques, their efficiency, maintenance are very important. C,D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. It is assumed that these SLCFs emissions to be mainly due to the combustion of the solid and waste fuels and to be included in category 1.A.2.f. Manufacturing Industries – Non-Metallic Minerals (Energy Sector), also double counting should be avoided. OC emission factor is presented in the US SPECIATE, UNEP, REAS. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – SOx, BC, OC, PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, NMVOC, SOx, CO (incl. combustion emissions) REAS – BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – NMVOC, PM2.5, PM10 (incl. combustion emissions)
2A2	Lime production	No process emissions, all emissions	Yes		EMEP/EEA, US AP-42, US SPECIATE	Yes	Data collection by type of kiln, and	Significant emissions of PM during different sub processes (storage, crushing, calcining), however as the raw materials are mostly calcium carbonate and dolomite no OC or BC emissions occurs. BC emissions are related to combustion, but what happens with carbon fuel storage emissions? If the emissions of BC are considered in this sector it is important to take in to account that the magnitude of the differences

[1] Apply here the *2006 IPCC Guidelines* categorization. If the *2019 Refinement* has a specific category, while the *2006 IPCC Guidelines* have not, use it and note that it is the *2019 Refinement* category

[2] Use the IPCC category name and use "Others" for all those sources from which IPCC does not provide a specific categorization followed by the name of a new category taken from the relevant guidebook/sourcebook/guidelines. If the *2019 Refinement* has the specific category, while the *2006 IPCC Guidelines* have not, use it and note that it is the *2019 Refinement* category

[3] List here SLCFs for which the method, as noted in Column E, applies. Where different methods apply to different SLCFs from the same source category, compile a row of information for each method

[4] Is an applicable IPCC method available?
In the case when the IPCC method needs modifications, further than providing for the SLCF EF to be applicable, answer "yes with modifications" and possibly provide in the comment box indication on the modification needed. Examples of modifications are, additional parameters, e.g. technologies, and/or additional data to ensure full coverage of SLCF emissions

[5] In case the IPCC methodology is not applicable or there is not an IPCC methodology for the listed category (i.e. Column E has been compiled with "No"), provide the reference to any other methodological source from which the category is sourced

[6] Provide reference to the source, where default values for EFs and any other parameters are provided

[7] Is the method globally applicable so far as can be judged? The answer should be based on the availability, or likelihood of availability in the next future without need of significant additional resources, of activity data as national datasets or regional datasets or global datasets. In Column I "Comments" you may provide information about datasets availability

[8] In the case when the experts identify any gaps that need to be closed in the next future to allow for a global methodology, such gaps should be noted here with, where possible, guidance on research and/or data collection work considered to be needed

[9] In providing any additional information/comment on any information compiled in any of the previous columns, first provide the letter of the column to which the comment applies

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
		are combustion related See comments			UNEP, REAS, MEP China		abatement	for PM emissions factors (BC) between types of kilns (uncontrolled) is important (i.e. Shaft Kiln 3 kg/Mg lime and rotary long kiln 140 kg/Mg lime) this could be considered in the evaluation of whether a Tier 1 method is globally applicable or not. Also, traditional lime kilns (built using brick or stones) probably are not considered in the EMEP guidelines and are commonly used in countries with small production of lime and the aggregate could be important. As indicated below, others SLCF are accounted for in the energy sector as combustion is the significant source. C, D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. It is done because it is very difficult to separate process and combustion emissions and the majority of emissions for other SLCFs to be due to the combustion of fuels. OC emission factor is presented in the US SPECIATE, UNEP, REAS. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – BC, OC, PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, SOx, CO (incl. combustion emissions) REAS – BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – PM2.5, PM10 (incl. Industrial processes), give EFs to BC and OC
2A3	Glass production (incl. glass fibre/ mineral wool)	NMVOC – process related See comments	Yes, with modifications. Tier 1 of the 2006 IPCC Guidelines includes the cullet ratio	EMEP/EEA	EMEP/EEA, US AP-42, US SPECIATE, MEP China	Yes		NMVOC come from process BC and OC from combustion. Dust from material handling Small amount of dust and NMVOC emissions from non-melting activities (coating, cutting, and milling). It is glass type dependent. References - Best available techniques (BAT) reference document for the manufacture of glass, Joint Research Center, Scalet et al., 2013. https://op.europa.eu/en/publication-detail/-/publication/ff8a3955-d0d0-46f5-8a15-4b638896cb56 C,D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. OC emission factor is presented in the US SPECIATE. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) US AP-42 – NOx, NMVOC, SOx, CO (incl. combustion emissions) MEP China – PM2.5, PM10 (incl. Industrial Processes, give emission factors to OC and BC as 0)
2A4	Other Process Uses of Carbonates: - bricks - ceramics	SO2, NMVOC	No. The IPCC methods are based on carbonates	BC, OC - US SPECIATE, REAS SO2 – US	US SPECIATE, US AP-42, UNEP, REAS,			To check BC, OC, NMVOC as process emissions, because it can be combustion related. Sulphur is contained in fuels and raw materials (SO2 emissions) Clay/ceramic processing: The basic steps include raw material procurement, beneficiation, mixing, forming, green

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	- others (tiles, gypsum, refractory, frit)	See comments	consumed (limestone and dolomite) as AD, SLCF methodologies use output AD (bricks, tiles, etc.).	AP-42, UNEP	MEP China			machining, drying, presinter thermal processing, glazing, firing, final processing, and packaging. There are PM emissions from many stages, and combustion emissions from drying and other thermal processes. Mixing generally is a wet process. However, VOC emissions from this step may arise from the volatilization of binders, plasticizers, and lubricants. EPA-42 Ch 11.7 provides an emission factor for VOC emission Combustion processes may be considered in Energy sector. C,D: EMEP/EEA provides no guidance for this category. According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. US SPECIATE presents BC and OC. C,F: US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – SO2 (bricks), PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, SOx, NMVOC, CO (incl. combustion emissions) REAS - BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – NMVOC, PM2.5, PM10 (incl. combustion emissions)
2A5	Other - coal cleaning - clay processing - sand and gravel processing - lightweight aggregate manufacturing - taconite ore processing - phosphate rock processing		No IPCC guidance					C,D: No SLCF process emissions, Energy emissions should be estimated in Energy sector C,F: US AP-42 - NOx, CO, NMVOC, SOx (combustion emissions) This category excludes coal mining. EMEP follows AP-42. Fugitive emissions of TSP, PM10, PM2.5 from quarrying drilling, blasting, extraction, crushing, of stone, sand and clay Emissions of TSP, PM10, PM2.5 are calculated AD x EF. No specific impact on NMVOC, BC. All activity with mining such as material handling and processing, transport, that involves use and combustion of fuel in machinery, etc, should be considered elsewhere (Energy, transport). Similar can be said for construction, demolition. Use of fuel, solvents, etc are considered elsewhere Coal cleaning: The first stages include typical mining activities: coal load/unload, crushing, storage, where fugitive emissions of PM are expected. Process use water to separate coal sizes, but then it needs to be dried. Final stage consists of drying coal materials where most of the NMVOC, NOx, SO2, CO2 emissions occur. But this stage should be included in elsewhere. AP-42 (Ch 11.10) gives EF and description of the process Clay/ceramic processing: The basic steps include raw material procurement, beneficiation, mixing, forming, green machining, drying, presinter thermal processing, glazing, firing, final processing, and packaging There are Pm emissions from many stages, and combustion emissions from drying and other thermal processes. Mixing generally is a wet process. However, VOC emissions from this step may arise from the volatilization of binders, plasticizers, and lubricants. EPA-42 Ch 11.7 provides an emission factor for VOC emission Combustion processes may be considered in Energy sector.

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								Taconite ore processing: only PM emissions from extraction, crushing and grinding. Pellet formation is a combustion process AP-42 Ch 11.23 Phosphate rock processing. The major emission sources for phosphate rock processing are dryers, calciners, and grinders. These sources emit particulate matter (PM) in the form of fine rock dust and sulphur dioxide (SO2). Emissions are due to Combustion process. AP-42 Ch 11.21
2B Chemical Industry								
2B1	Ammonia production	NOx, NH3, CO, NMVOC, SOx	Yes, with modification, the method is slightly different: fuel and carbon content (IPCC-CO2) per output of ammonia vs. EF of SLCF per output of ammonia	EMEP/EEA	EMEP/EEA, UNEP, US AP-42, REAS, MEP China	Yes		Expected to be a growing source C,D: In the 2006 IPCC Guidelines, in the case of ammonia production no distinction is made between fuel and feedstock emissions with all emissions accounted for in the IPPU Sector. The method for CO2 and SLCFs is slightly different: input of fuel and its carbon content (IPCC-CO2) by output of ammonia vs. EF of SLCF by output of ammonia (SLCF). C,F: EMEP/EEA – NOx, CO, NH3. NMVOC - Tier2, Tier 2 - technology specific. EMEP/EEA distinguishes fuel combustion emissions from process emissions. UNEP – NOx, CO, NH3, SOx, NMVOC US AP-42 – NH3, SO2, CO, NMVOC, also NOx and PM for fuel combustion. US AP-42 and WebFIRE emissions databases distinguish emissions from fuel combustion used to generate heat for the reformer (NOx, VOC, CO, PM) and emissions from removing impurities in the natural gas feedstock (NH3, SO2, CO, NMVOC). Check availability of method and EFs for NH3 REAS – NH3 MEP China – NMVOC
2B2	Nitric Acid production	NOx, NH3	Yes		EMEP/EEA, UNEP, US AP-42	Yes		C,F: IPCC and those listed here only include process emissions, not fuel combustion. EMEP/EEA – NOx. UNEP – NOx and NH3 US AP-42 – NOx
2B3	Adipic Acid production	NOx, CO, NMVOC	Yes		EMEP/EEA, UNEP, US AP-42	Yes		C,F: EMEP/EEA – NOx, CO UNEP and US AP-42 – NOx, CO, NMVOC
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production							C,D,F: No SLCF process emissions in this category EMEP/EEA - 2.B.10.a Other (Glyoxylic Acid) – Not Estimated (NE)
2B5	Carbide Production							C,D,F: No SLCF process emissions in this category. Energy Emissions should be estimated in Energy Sector EMEP/EEA – TSP only US AP-42 – SOx US EPA NEI / EPA SPECIATE – BC, OC
2B6	Titanium Dioxide Production	NOx, CO, SOx	Yes, with modification. See comments	EMEP/EEA	EMEP/EEA, UNEP	Yes		To check. BC - NFR 2B6 Titanium dioxide: no methods in the EMEP GB, e.g. Finland uses domestic EFs for particles and for BC 1.8% of PM2.5 (a calculated average of chemical industry BC fractions). The chloride process does not emit SO2, while the sulphate process does C,D: The 2006 IPCC Guidelines do not include the sulphate route (only chloride route), so AD and EF for both routes are

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								needed. C,F: EMEP/EEA – NOx, CO, SOx UNEP ABC EIM – SOx
2B7	Soda ash production	CO, NH3	Yes		EMEP/EEA	Yes		C, F: EMEP/EEA – CO and NH3 (OK)
2B8	Petrochemical and Carbon Black Production							
	Extraction of petroleum and natural gas							Energy sector (MEP China – NMVOC)
2B8a	Methanol							No SLCF process emissions in this category, CO is used and NMVOC is utilised
2B8b	Ethylene	NMVOC	Yes		EMEP/EEA, REAS, MEP China	Yes		D: The 2006 IPCC Guidelines include Geographical adjustment factor. C,F: EMEP/EEA, REAS, MEP China - NMVOC
	- Propylene	NMVOC	*(No IPCC guidance – same as ethylene)*		REAS, MEP China			D: EMEP/EEA: The default emission factor for Ethylene production emissions only takes into account the amount of emitted NMVOC directly related to the ethylene production. In fact, actual emissions can relate not only to ethylene production but also to the production of other olefins as propylene. Propylene is produced by thermal cracking of naphtha fractions, in the same process as the production of ethylene.
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer	NMVOC	Yes		EMEP/EEA, MEP China	Yes		C,F: EMEP/EEA - 2.B.10.a Other (Dichloroethane + vinyl chloride) – NMVOC MEP China - Chloroethylene production - NMVOC
2B8d	Ethylene Oxide	NMVOC	Yes		EMEP/EEA	Yes		C,F: EMEP/EEA - 2.B.10.a Other (Ethylene Oxide) - NMVOC
2B8e	Acrylonitrile	NMVOC	Yes		EMEP/EEA, MEP China	Yes		C,F: EMEP/EEA - 2.B.10.a Other (Acrylonitrile) – NMVOC MEP China - NMVOC
2B8f	Carbon Black - *Secondary Carbon black (recovery of carbon black)*	[NOx], CO, NMVOC, SOx, BC, OC	Yes		EMEP/EEA, US AP-42, US EPA NEI/EPA SPECIATE, UNEP, REAS	Yes	BC OC from diffuse emissions NMVOCs for storage tanks	No IPCC methodology for NMVOCs from oil storage tanks – EFs from EMEP and AP42 No IPCC methodology for PM diffuse emissions C,F: EMEP/EEA – NOx, CO, NMVOC, SOx, BC UNEP – NOx, CO, NMVOC, SOx, BC US AP-42 – NOx, SOx, NMVOC US EPA NEI / EPA SPECIATE – BC, OC REAS – NMVOC, BC, OC. Also PM2.5 and PM10
2B9	Fluorochemical Production							No process emissions in this category, it is the source of F-gases emissions
2B10	Other (please specify)							
	- Hydrogen production	[CO, other SLCFs?]						Similar to Ammonia production Allocation of emissions Production from Ammonia Different feedstock – different EFs
	- Sulfuric acid	SOx	No IPCC guidance	EMEP/EEA	EMEP/EEA, UNEP, REAS, US AP-42			D, E: EMEP/EEA, REAS, UNEP, US AP-42 - SOx Combustion emissions should be estimated in Energy sector (MEP China – NMVOC in Sulphuric acid)

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	- Sulphur recovery	CO, SOx, NMVOC		US AP-42	US AP-42			D: Sulphur recovery refers to the conversion of hydrogen sulphide (H2S) to elemental sulphur. Hydrogen sulphide is a by-product of processing natural gas and refining high-sulphur crude oils. It should be estimated in Energy sector.
	- Ammonium nitrate	NH3		EMEP/EEA	EMEP/EEA, REAS, UNEP, US AP-42			C,F: EMEP/EEA, REAS, UNEP, US AP-42 – NH3
	- Ammonium phosphate	NH3 [SO2]		UNEP, US AP-42	UNEP, US AP-42			C: EMEP/EEA presents only TSP and PM, no SOx and NH3. UNEP references the US EPA. The US AP-42 – totals for one plant - NH3, [SOx (Energy - combustion emissions)]
	- Urea	NH3, BC, [NMVOC]		EMEP/EEA	EMEP/EEA, UNEP, REAS, US AP-42, MEP China			C,F: EMEP/EEA – NH3 and BC UNEP, US AP-42, REAS – NH3, MEP China – NMVOC (Energy?)
	- Polyethylene	NMVOC		EMEP/EEA	EMEP/EEA, REAS, MEP China			
	- Polyvinylchloride	NMVOC		EMEP/EEA	EMEP/EEA, REAS			
	- Styrene	NMVOC		EMEP/EEA	EMEP/EEA, REAS, MEP China			
	- Polystyrene	NMVOC		EMEP/EEA	EMEP/EEA, REAS, MEP China, US AP-42			
	- Styrene butadiene, Styrene-butadiene latex, Styrene-butadiene rubber (SBR)	NMVOC		EMEP/EEA	EMEP/EEA, REAS, MEP China, US AP-42			B: EMEP/EEA - Styrene butadiene, Styrene-butadiene latex, Styrene-butadiene rubber (SBR) - NMVOC US AP-42 – Synthetic rubber, synthetic fibres - NMVOC REAS – Synthetic rubber – NMVOC MEP China – Butadiene – NMVOC
	- Acrylonitrile Butadiene Styrene (ABS) resins	NMVOC		EMEP/EEA	EMEP/EEA			
	- Formaldehyde	NMVOC		EMEP/EEA	EMEP/EEA			
	- Ethylbenzene	NMVOC		EMEP/EEA	EMEP/EEA, MEP China			
	- Phthalic anhydride	NMVOC [CO, SO2]	No IPCC guidance	EMEP/EEA	EMEP/EEA, US AP-42			C,F: EMEP/EEA – NMVOC US AP-42 – NMVOC [CO, SO2 (Energy)]
	- Benzene	NMVOC		MEP China	MEP China			
	- Methylbenzene / Toluene	NMVOC		MEP China	MEP China			

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	- Xylene	NMVOC		MEP China	MEP China			
	- Glycol	NMVOC		MEP China	MEP China			
	- Terephthalic acid	NMVOC, CO		MEP China, US AP-42	MEP China, US AP-42			C,F: MEP China – NMVOC, US AP-42 – CO, NMVOC
	- Polyethylene terephthalate	NMVOC		US AP-42	US AP-42			
	- Maleic anhydride	NMVOC, CO		US AP-42	US AP-42			
	- Explosives Manufacturing *-- manufacture of explosives* *-- open burning of explosives wastes*	NOx, SOx, CO, NMVOC		US AP-42	US AP-42			For manufacture of explosives, these emissions methods and factors are detailed and described in AP-42. But the emission factors are considered low reliability, because of variability in the processes used in this sector. Also, total emissions are quite small for the U.S. I suggest we consider putting this sector in the "not significant" category. B: EMEP/EEA presents Explosives manufacturing in 2B10 Other Chemical Industry – with no guidance. US AP-42 presents Explosives manufacturing in Chapter 6 Organic Chemicals (sub-chapter 6.3): Oxides of nitrogen (NOx) and sulphur (SOx) are the major emissions from the processes involving the manufacture, concentration, and recovery of acids in the nitration process of explosives manufacturing. Emissions from the manufacture of nitric and sulfuric acid are discussed in other sections. Volatile organic compound (VOC) emissions result primarily from fugitive vapours from various solvent recovery operations. Explosive wastes and contaminated packaging material are regularly disposed of by open burning, and such results in uncontrolled emissions, mainly of NOx and particulate matter.
2C Metal Industry								
2C1	Iron and Steel Production - Sintering - Pellets - Pig Iron - Blast furnace - Open hearth furnace - Electric arc furnace (scrap emissions) - fugitive/diffuse emissions from raw materials	NOx, CO, NMVOC, SOx, BC, OC	Yes. Issues with coking and rolling mills (Energy and IPPU sectors, see below)		EMEP/EEA, US AP-42, US EPA NEI/EPA SPECIATE, UNEP, REAS, MEP China	Yes	Fugitive PM emissions SO2 from desulfurization PM and SO2 from foundries PM, OC, EC, CO and VOCs from scrap preparation	No IPCC method for fugitive PM (BC, OC) emissions from: (1) receiving, uploading and conveying of raw materials, (2) storage piles (3) paved and unpaved roads within facilities PM size distribution has to be considered in fugitive emissions Desulfurization process is not included in IPCC method (SOx and PM) PM and SO2 foundry emissions, from the use of Cupola furnaces – No IPCC methodology No IPCC methodology for Scrap preparation (PM, EC, OC, CO, NMVOCs), previous metal melting in electric arc furnaces, only data in AP42 from solvent degreasing. With methodology 2.D.3) Flaring BFG in IPPU C,F: EMEP/EEA: Tier 1 EF for Iron & Steel (NMVOC and BC), Tier 2 EFs for technologies (NOx, CO, NMVOC, BC). US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species REAS - CO, BC, OC, PM2.5, PM10 - Crude steel and Pig iron EFs UNEP - NOx, CO, NMVOC, SOx, BC,OC - only Pig iron (no steel) MEP China – Iron and Steel – NMVOC. US EP-42 – Gray iron foundries (NMVOC, CO, SOx, NOx) and Iron&Steel (NOx, CO), Coking (NOx, CO, NMVOC, SOx

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								and NH3). Despite robust test methods, the emission factors listed here can not be reliably applied across the industry because there is considerable variability in the process at different facilities.
	- Rolling mills	NMVOC, SO2	No IPCC guidance		EMEP/EEA		SO2 from the use of VHO	When volatile halogenated organic (VHO) gas is used some sulphur dioxide will also be emitted. (EMEP), but no EFs is reported D: EMEP/EEA – NMVOC (hot rolling mills, Tier 3) In general, it can be said that emissions from rolling mills are small compared to the other emissions from the (integrated) steel plant. Therefore, rolling mills will not be considered as a separate source in the Tier 1 and Tier 2 emission factors.
	- Coking	NOx, CO, SOx, NMVOC, NH3						D: Coking emissions should be reported in Energy sector, to check reporting NH3 (US AP-42).
2C2	Ferroalloys production	BC	Yes		EMEP/EEA	Yes		[Possibly other SLCF species] C.F: EMEP/EEA - BC. T1 EF for BC (10% of PM2.5) based on USEPA 2011
2C3	Aluminium Production - primary (Prebake and Soderberg) - secondary	NOx, CO, NMVOC, SOx, BC, OC	Yes, with modifications. IPCC Guidelines in Tier 1 differentiate Prebake and Soderberg (EMEP/ EEA – Tier 2), no secondary emissions	EMEP/EEA	EMEP/EEA, US EPA NEI/EPA SPECIATE, UNEP, REAS, MEP China	Yes		Aluminium production is very energy intensive. SO2 is the main process emission gas, also from anode BC from anode baking and fuels, also BC is from secondary aluminium. C,F: EMEP/EEA: primary – NOx, CO, SOx, BC, secondary – BC US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species UNEP: NOx, CO, NMVOC, SOx, BC, OC REAS – SOx, BC, OC, PM2.5, PM10 Norway: BC, OC - BC and OC from aluminium: https://www.ssb.no/en/natur-og-miljo/artikler-og-publikasjoner/_attachment/107884?_ts=13dfd568678 See table 5.3. It seems that Norway estimates some emissions from secondary aluminium. SO2 from electrolysis and consumption of anode, anode baking furnace. NOx from the same sources plus from use of natural gas in foundries. Norway EFs for NOx from electrolysis is 0.15 kg NOx/tonne of Al CO from electrolysis BC, OC possible from electrolysis, anode baking, use of fuels NMVOC – foundries, anode baking, storage and handling, paste plant Secondary Aluminium – all species from fuels
	[- alumina/ aluminium oxide]							B,C,D: 2019 Refinement sub-category. MEP China presents only PM2.5 and PM10 in Aluminium oxide (Energy)
2C4	Magnesium production							B,C: No SLCF process emissions in this category, it is the source of CO2 and F-gases emissions For Magnesium production, MEP China –SO2,PM2.5, PM10 (incl. Industrial Processes, give emission factors to SO2,OC and BC as 0)
2C5	Lead Production - primary - secondary - electrolytic	[SOx], [NOx][CO] [BC, OC]	Yes		EMEP/EEA, UNEP, US AP-42, US EPA NEI/EPA SPECIATE, REAS, MEP China	Yes Need to check the processes and feedstocks used in the domestic	Data collection of domestic industries (processes, abatement, raw material)	Plant-specific emissions Primary lead SOx – can occur or not depending on the plant structure, processes and abatement (EMEP T1 and T2 EFs for EU countries for 2015 abatement level) - emissions are diffuse emissions from the oxidation stages, direct emissions from the sulphuric acid plant and the emissions of residual sulphur in the furnace charge. Good extraction and sealing of the furnaces prevents diffuse emissions, with the collected gases from the oxidation stages passed to a gas-cleaning plant and then to the sulphuric acid plant or gypsum plant.

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						plants and their corresponde nces to the default methods. Also if any abatement techniques are used and maintained. Default efficiencies of different abatement techniques are widely available, however, the domestic maintenance situation to be checked.		NOx - can occur or not depending on the plant structure, processes and abatement (EMEP no EFs) - may be formed in the melting stages or from nitrogen components that are present in the concentrates or as thermal NOx. The sulphuric acid produced can absorb a large part of the NOx, and this can affect the sulphuric acid quality. Other furnaces that use oxy-fuel burners can also exhibit a reduction in NOX. The range for all the processes is 20 mg/Nm3 to 300 mg/Nm3 BC, OC, CO -yes, especially if plastics are present (EMEP T1 PM EFs for EU countries for 2015 abatement level and T2 unabated EFs for European countries 2014 – both for filterable PMs while BC needs both filterable and condensable PMs) (EMEP/USEPA T2 unabated EF for filterable PMs while BC needs both filterable and condensable PMs) Organic carbon compounds and CO can be emitted from the drying stage depending on the raw materials and the fuel used for drying. The most significant source of organic carbon compounds and CO is the reduction step of the smelting process, especially when plastic/plastic residues are present in the furnace charge. An afterburner is the most common technique used to abate this pollutant. Secondary lead – SOx and NOx at low levels (EMEP EF for SOx for European 2015 abatement level) Most important SOx and NOx emission ia smelting furnaces. The amount of SOx formed depends on the amount of sulphur contained in the raw materials and in the fuel used. A major part of the sulphur remains in the slag formed during the smelting process, some can be converted to SOx. SOx in the off-gas has been measured at about 0.1% v/v. At a blast furnace using coke as fuel an even smaller off-gas concentration in the range of about 0.03% v/v has been measured BC –no EMEP T1 and T2 EFs for filterable PMs, no BC fraction, which would require both filterable and condensable PMs Mass-balance for SO2 can be more accurate than the EF approach C,F: EMEP/EEA, US AP-42 and UNEP – SOx. EMEP/EEA – PM2.5, PM10, TSP. US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species. SPECIATE Profiles - 91139 sintering furnace, 91168 lead processing. REAS – SOx, BC, OC, PM2.5, PM10 MEP China – Lead production and Electrolytic lead production - PM2.5 and PM10
2C6	Zinc production - primary - secondary - electrolytic - zinc oxide - zinc calcine	SOx [BC, OC]	Yes		EMEP/EEA, REAS, MEP China	Yes Need to check the processes and feedstocks used in the domestic plants and their corresponde nces to the default	Data collection of domestic industries (processes, abatement, raw material)	Primary zinc SO2 – depending on processes and abatement/construction (EMEP T1 and T2 unabated and EU 2015 abatement level) mainly from roasting (sulphur in the feed), lower levels from electrolysis and H2SO4 plant from tanks, sinter plant (depending on S content of the feedstock) ovens and separation (coverings to reduce emissions) NOx – maybe depending on the process from roasting and smelting if N components present in the concentrates or as thermal NOx BC – no information (EMEP EFs for filterable unabated PMs only) Secondary zinc SO2 – depending on processes and abatement/construction (EMEP T1 and T2 unabated and EU 2015 abatement level)

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						methods. Also if any abatement techniques are used and maintained. Default efficiencies of different abatement techniques are widely available, however, the domestic maintenance situation to be checked.		BC and NOx – no information (EMEP EFs for filterable unabated PMs only) Mass-balance for SO2 can be more accurate than the EF approach C,D,F: EMEP/EEA and UNEP – SOx, PM2.5, PM10, TSP. NOx and CO are reported in Energy sector. REAS – SOx, BC, OC, PM2.5, PM10 MEP China – Zinc, Electrolytic zinc, zinc oxide, zinc calcine production - PM2.5 and PM10
2C7	Other (please specify)							
	- Copper	SOx, BC, OC [NMVOC]	No IPCC guidance	EMEP/EEA	EMEP/EEA, UNEP, US AP-42, REAS	Yes, EMEP/EEA	SO2 from acid mist	SO2: Copper smelting important source. Also The basic Tier 1 method ADxEF can be modified to include abatement ADxEF (1-Abatement efficiency). SO2, SO3: from acid mist from acid plants within smelting process and acid mist from other metallurgical processes such as flotation, lixiviation and mills BC: from Pyro-refining, final step in smelting, with fuels (oil or natural gas) to extract remaining oxygen. NMVOC: solvent use in solvent extraction/electrowinning Recycling – Secondary – BC Recover of wires - fires Mass-balance for SO2 can be more accurate than the EF approach C,D,F: EMEP/EEA – SOx, BC US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species UNEP –SOx, PM2.5, PM10. [NMVOC EF taken form 1996 IPCC for rolling mills] US AP-42 – SOx REAS – SOx, BC, OC, PM2.5, PM10 MEP China – PM2.5 and PM10
	- Nickel	SOx		EMEP/EEA	EMEP/EEA	Yes, EMEP/EEA		Mass-balance for SO2 can be more accurate than the EF approach Abatement is important C,D,F: EMEP/EEA – SOx NOx, CO are assumed to be mainly due to combustion activities and addressed in Energy sector. SOx emissions are to a large extent from the ore – IPPU sector. TSP or PM factors represent filterable PM emissions only (excluding any

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
								condensable fraction). MEP China –SO2, PM2.5, PM10 (incl. Industrial Processes, give emission factors to SO2, OC and BC as 0)
	- Other metals (Silicium production, Magnesium production, Alloyed metal manufacturing, Galvanizing, Electroplating, Manufacture of basic precious and non-ferrous metals, Other)	SOx		EMEP/EEA	EMEP/EEA			B,C,D: EMEP/EEA – SOx. The emission factors are adapted from the revised BREF document for the non-ferrous metal industry (European Commission, 2014) and applicable for precious metal production facilities controlled by a fabric filter, hot electrostatic precipitators and cyclone.
	- Rare Earths							B,C,D: 2019 Refinement category. Possible source of SLCF emissions
	- Metal welding and cutting							B,C,D: No methodological guidance - Insignificant source - Possible source of SLCF emissions. Further data collection is needed.
2D Non-Energy Products from Fuels and Solvent Use								
2D1	Lubricant Use							No emissions in this category
2D2	Paraffin Wax Use							No emissions in this category
2D3	Solvent Use		Only very general guidance is given in the 2006 IPCC Guidelines and the Revised 1996 IPCC Guidelines - no methods and EFs					
	- Domestic solvents use	NMVOC		EMEP/EEA	EMEP/EEA, REAS, MEP China, US AP-42	Yes – EMEP/EEA The EFs need to be checked for global use but there are also EFs per capita Data	Guidance on how to collect AD and on how to estimate AD if there are no statistics (e.g., modelling from a	(EMEP T1 EFs per capita is universal and provided for both Western/Other countries) (EMEP T1 EFs for different product categories for European countries 2015) EMEP: T2 EFs for different product categories using USEPA 1005 /EU 2012 methods) – global per capita (EMEP : solvent contents by different product groups in Europe 2015) NMVOC – yes – a growing source (1990 ~4%, 2019 ~8%) Per capita EF can over or underestimate emissions from country to country, intra-city EFs

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
						collection by different product groups (T2) may be challenging	similar country etc.)	
	- Coating application (Paint application, Manufacture of automobiles, Car repairing, Construction and buildings, Domestic use, Coil coating, Boat building, Wood, Other industrial paint application, Other non-industrial paint application)	NMVOC		EMEP/EEA	EMEP/EEA, REAS, US AP-42, US SPECIATE	Yes – EMEP/EEA	AD	Share In 1990 12%, in 2019 9% of NMVOCs Per capita EFs can over or under estimate emissions, type of paints and solvent content is important, economic indicators (other proxies) can be used, if the types of paints or solvent content is not known The inventorying of NMVOCs' emissions from the categories coating, degreasing, dry cleaning is problematic, and done by application of the 'Tier 1'-like methodology described in the EMEP/EEA Guidebook (methodology given, however emission factors should be discussed), however for the local air quality assessment, the modellers sometimes including commissioned analysis about that. Unfortunately, we have still very limited knowledge about the real composition of paints and coatings which is crucial information for the emission estimation. The problem is also in the market analysis (paints and coatings sold = paints and coatings used). If we know the volume of coatings used in industry (e.g., painting of vessels), we can somehow estimate NMVOCs emissions. The paints and coatings used for both: industrial and non-industrial purposes should be in compliance with current EU Directives (and Decisions, such as : https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2020.414.01.0019.01.ENG&toc=OJ%3AL%3A2020%3A414%3ATOC&utm_campaign=ESIG%20Newsflash%20October%202021&utm_medium=email&utm_source=Mailjet and concentration of solvents in paints and coatings (probably?) decreasing from year to year. The estimation of the volume of solvents can be (theoretically) carried out, it might be worth to ask ESIG for some help (Europe, https://www.esig.org/). Poland: 2D3d, Coating applications, methodology: Tier 1, country specific EF [NMVOCs, Waterborne paints 0.03 Mg/Mg paints (assumption: non-industrial purposes), Conventional solvent paints, 0.5 Mg/Mg paints (assumption: industrial purposes)], Uncertainty 28% (possibly bigger).All of EFs are derived from the former analysis of Institute of Ecology of Industrial Areas (Katowice, Poland). B: US AP-42 presents NMVOC for the following sub-categories (Non-industrial surface coating, Industrial surface, Can coating, Magnet wire, Other metal coating, Flat wood interior panel, Paper, Polymeric, Automobile, Metal coil surface coating, Large appliances, Metal furniture, Magnetic tape, Plastic parts surface coating, Paints and Varnish). C: US EPA NEI / EPA SPECIATE presents for Surface coating - BC, OC, PM2.5, SO4, NO3, remaining PM species
	- Degreasing (Metal degreasing, Electronic components manufacturing, Other industrial cleaning)	NMVOC		EMEP/EEA	EMEP/EEA, REAS, US AP-42	Yes – EMEP/EEA	AD	4% of NMVOC in 1990, <2% in 2019 Degreasing is rather industrial category, and the type of solvents used are specific for the particular type of industry. The amount (volume) of industrial solvents used for degreasing is not can be possible from some kind of bottom-up inventory compared with data about sold chemicals. Poland: 2D3e, Degreasing (of metal), methodology: Tier 1, country specific EF (NMVOCs, 1 Mg/Mg solvent - 100% evaporating), Uncertainty 30% (possibly bigger).
	- Dry cleaning	NMVOC		EMEP/EEA	EMEP/EEA, REAS	Yes – EMEP/EEA		An insignificant source 0.1-0.3% "Tier 1 method has been used for calculation of fugitive emissions from this category. Activity data (population) used for calculation of fugitive emissions of NMVOC was taken from statistical yearbook [GUS] and emission factors have been developed by the Institute for Ecology of Industrial Areas (IETU)."

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
								Poland: 2D3f, Dry cleaning, methodology: Tier 1, country specific EF (NMVOCs, 0.15 Mg/1000 people (inhabitants)), Uncertainty 30% (possibly bigger).
	- Chemical products (Polyester, Polyvinylchloride, Polyurethane foam, Polystyrene foam, Rubber, Pharmaceutical products, Paints manufacturing, Inks, Glues, Asphalt blowing, Adhesive, Magnetic tapes, Films and photographs manufacturing, Textile finishing, Leather tanning, Other)	NMVOC		EMEP/EEA		Yes – EMEP/EEA global		Use of solvents in the subcategories under "Chemical Products" is mainly considered insignificant (3-4% of NMVOC) but can in some countries be source of a considerable part of NMVOC emissions, These processes are complicated, variable and unique so that no general guidance can be provided. Guidance in EMEP/EEA Guidebook can be applied in most countries where production volumes are known. B: MEP China presents NMVOC for the following products (Ink, Dye, Tire, Textile, Artificial leather/ synthetic leather, Acrylic production, Nylon, Vinylon, Artificial board Manufacturing, Architectural coating production, Cementing compound, Foamed plastic, Gelatinous fibre, Woolen yarn, Silk production, Cloth production) and PM2.5 for Carbon production, Fertilizer production
	- Printing	NMVOC	Only very general guidance is given in the 2006 IPCC Guidelines and the Revised 1996 IPCC Guidelines - no methods and EFs	EMEP/EEA	EMEP/EEA, REAS, US AP-42	Yes – EMEP/EEA global	Collection of AD (use of ink and/or applied abatement techniques, default efficiencies for abatement are provided in EMEP/EEA)	A minor source today, 2-3% of NMVOC. includes several subprocesses. If no abatement is used 50-80% of solvents used are emitted. EMEP/EEA-NMVOC The Tier 1 approach for emissions from other product use uses the general equation: E *pollutant* = AR *production* x EF *pollutant* (1) This equation is applied at the national level. It involves either the use of solvent consumption data or combining ink consumption with emission factors for the industry. Unless the solvent consumption data is used, no account is taken of the use of water-based or low solvent inks, and no account is taken of the extent of controls such as incineration. In cases where specific abatement options are to be taken into account a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different printing processes that may occur in the country
	- Other solvent and product use (Other use of solvents and related activities, Glass wool enduction, Mineral wool enduction, Fat,	NMVOC		EMEP/EEA	EMEP/EEA, MEP China, REAS	Yes – EMEP/EEA global	AD: capita or product/solvent use	A minor source ~4% of NMVOC emissions. EMEP/EEA methods represent EU countries and are based on detailed mass balances on national production, import and export statistics on the use of products/chemicals and information from industries and trade organisations. Methods are product and pollutants specific because the NMVOC concentrations vary by pollutant or the use pattern of the product. Preservation of wood with organic solvent-born preservatives and use of solvent containing vehicle treatments are small activities but almost all NMVOCs included in the AD are emitted. B: MEP China (Nonedible vegetable oil production)

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
	Edible and non-edible oil extraction, Application of glues and adhesives, Preservation of wood, Underseal treatment and conservation of vehicles, Vehicles dewaxing, Aircraft deicing, Use of fireworks, Use of tobacco, Use of shoes, Other)							REAS (Preservation of wood, Vehicles treatment, Adhesive application)
2D4	Other (please specify)							
	- Road paving with asphalt	NOx, CO, NMVOC, BC	Yes. The update is needed. General guidance is in the 2006 IPCC Guidelines without methods and EFs, some guidance in the Revised 1996 IPCC Guidelines with default EFs	EMEP/EEA	EMEP/EEA, UNEP, US AP-42, REAS, MEP China	Yes		An insignificant source, ~0.1% of NMVOC C,F: EMEP/EEA – NMVOC, BC UNEP – NOx, CO, NMVOC US AP-42 – NOx, CO, SOx, NMVOC REAS, MEP China – NMVOC EPA calcs
	- Asphalt roofing	NOx, CO, NMVOC, BC		EMEP/EEA	EMEP/EEA, UNEP, US AP-42	Yes	Yes – SO2 emissions in roofing materials	An insignificant source for NMVOC SO2 emissions – but this is for asphalt blowing (listed under 2D3), which is listed above? Clarify what process included here? https://doi.org/10.1002/ep.10071 Another paper, including recycled content, not sure what stages (e.g., transport) are included in emissions: https://www.sciencedirect.com/science/article/pii/S0921344913000554 New work showing there are numerous missing emissions of SVOCs. Major SOA precursors (Both roofing and paving), even after application: https://www.science.org/doi/10.1126/sciadv.abb9785 C,F: EMEP/EEA – CO, NMVOC, BC UNEP – CO, NMVOC US AP-42 – CO, NMVOC (VOCs from both the process and fuel combustion)
2E	**Electronics Industry**							No SLCF process emissions, it is the source of F-gases and N2O emissions. Energy emissions should be estimated in Energy sector (US EPA NEI / EPA SPECIATE – BC, OC. Also, PM2.5, SO4, NO3, remaining PM species)
2F	**Product Uses as Substitutes for Ozone Depleting**	NH3, NMVOC					Method, AD, EFs	It is the source of F-gases emissions. NH3 and NMVOC emissions are also possible

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
	Substances							https://www.epa.gov/sites/default/files/2015-08/documents/eiip_areasourcesnh3.pdf Information of Ammonia emissions from refrigeration in food industry in Chile. 57 tonne NH3/year -. http://www.chilealimentos.com/wordpress/wp-content/uploads/2018/01/Informe-Final_3-29112017_Sin-anexos.compressed-1-1.pdf
2G	**Other Product Manufacture and Use**							No SLCF process emissions. Source of F-gases and N2O emissions.
2H Other								
2H1	Pulp and Paper Industry (Chipboard, Paper pulp (Kraft process), Paper pulp (acid sulphite process), Paper pulp (neutral sulphite semi-chemical process))	NOx, CO, NMVOC, SOx, NH3, BC, OC	Yes. The update is needed. The 2006 IPCC Guidelines have no guidance for Pulp and Paper Industry, but there is guidance in the Revised 1996 IPCC Guidelines - AD x default EF	EMEP/EEA	EMEP/EEA, UNEP, US AP-42, US SPECIATE, REAS, MEP China	Yes	Updated EFs	Tier 1 default emission factors are those for Kraft pulping, since this is by far the most important process in the manufacturing of pulp and paper. Values are taken from the BREF document for pulp and paper industries (European Commission, 2001); the emission factor for CO is from US EPA (1985) and the emission factor for BC1 is obtained from US EPA, SPECIATE database version 4.3 (US EPA, 2011), The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. The emission factors from all pollutants needs to be updated. Data on abatement techniques and equipment, their efficiency, maintenance are very important. Some examples of emission control: Particulates emissions :can be controlled by electrostatic precipitators, scrubbers, cyclone collectors and wire mesh demister pads. Electrostatic precipitators are the main type of collectors used to control recovery furnace particulate emissions C,E,F: EMEP/EEA – NOx, CO, SO2, NMVOC, BC. NH3 emissions occur from the pulping process and need to be determined plant by plant UNEP – NOx, CO, SO2, NMVOC, BC, OC. US AP-42 – SOx - Chemical Wood Pulping REAS and MEP China – NMVOC US EPA NEI / EPA SPECIATE – BC, OC. Also, PM2.5, SO4, NO3, remaining PM species Norwegian inventory: 2% of BC of TSP and 25% of OC of the TSP
2H2	Food and Beverages Industry (Bread, Wine, Beer Spirits, Sugar production Flour production, Meat, fish etc. frying / curing)	NMVOC, CO, NH3, SOx	Yes, update is needed. The 2006 IPCC Guidelines have no guidance for Food and Beverage	EMEP/EEA	EMEP/EEA, UNEP, US AP-42, REAS, MEP China	Yes		The Tier 1 approach needs emission factors for all relevant pollutants. These emission factors integrate all sub-processes within the industry from the feed of raw material to the final shipment of the products off site. The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. In the case of food and beverages production, these techniques are the various kinds of food and beverages produced (e.g., bread, sugar, wine, beer). B, C, F: US AP-42 – NMVOC, CO – malt beverages

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
			Industry, but there is guidance in the Revised 1996 IPCC Guidelines - AD x default EF, for some products					EMEP/EEA – animal rendering and animal feed - NMVOC US AP-42 - Sugar beet processing - NMVOC, CO, SOx (Energy emissions). US AP-42 - Meat Smokehouses - NMVOC, Meat Rendering Plants - NH3 US AP-42 – Coffee roasting - NMVOC, CO MEP China – NMVOC for various products UNEP and REAS – NMVOC
	- Food and Beverage charbroiling, fat frying, grain handling, fermenting/ distilling, drying/ roasting, natural gas cooking	BC, OC		US SPECIATE	US SPECIATE			BC emissions result from incomplete combustion during charbroiling activities. Commercial charbroiling operations are a significant source of PM10 and PM2.5 emissions within the overall nonpoint source emission inventories. The magnitude of PM emissions largely depends on the type of cooking equipment and the type of meat cooked. Under-fired charbroiling cooking operations are a major source of PM emissions compared to other charbroiling equipment operations. The Tier 1 method for estimating emissions from charbroiling is based on the type of equipment used for charbroiling. This method relies on per capita emission factors and the population of the inventory area. The per capita emission factors are dependent on the type of equipment used for charbroiling/commercial cooking activities (i.e., conveyorized, under-fired, flat-griddle, clamshell griddle, and deep-fat frying). Activity data for the Tier 1 method can be at the national, state, regional, or other required inventory area–level. Double counting with Energy NFR 2L Meat frying and barbeques: Emission factors for TSP, PM10 and PM3.5 (no EF for BC) can be found www.air.sk/tno/cepmeip B,C,F: US EPA NEI / EPA SPECIATE – BC, OC. Also PM2.5, SO4, NO3, remaining PM species
2H3	Other (please specify)							
	- Ordnance detonation	NOx, CO, NMVOC, SOx	No IPCC Guidance	US AP-42	US AP-42			For detonation of explosives (2H3), this guidance are marked as “draft” in AP-42 and I don’t think they were ever officially adopted. The total emissions from this sector are also quite small. Recommend we mark this sector in the “not significant” category.
	- Wood industry (Plywood manufacturing, Waferboard/oriented strandboard, Particleboard, Medium density fiberboard, Hardboard and fiberboard, Wood Preserving, Engineered wood products)	NOx, CO, NMVOC, SOx	No IPCC Guidance	US AP-42	US AP-42			Dust, TOC, TVOC and formaldehyde emissions from drying process. Two stages of TVOC and dust emissions: a) during drying and b) pressing. From (urea/phenol) formaldehyde-based resin use. NH3, NOX or SOX in the press exhaust are also possible Formaldehyde-free resins reduces TVOC. Is technology and end-product dependent. TVOC emissions also from painting / paper-impregnation and surfaces treatments of boards Emissions from mechanical wood industry (pressing) - to check. For particle board, fiberboard, and engineered wood products, this pressing stage can be an important source of VOCs. Gluing and coating are covered in Solvents AD is to be checked References Best Available Techniques (BAT) Reference Document for the Production of Wood-based Panels. Industrial Emissions

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative methodology[5]	Available EFs/ Parameters[6]	Globally applicable[7]	Gaps[8] (if any)	Comments[9]
								Directive 2010/75/EU (Integrated Pollution Prevention and Control); Kristine Raunkjær Stubdrup, Panagiotis Karlis, Serge Roudier, Luis Delgado Sancho; 2016. https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/WBPbref2016_0.pdf B, C, D: Combustion emissions should be reported in Energy sector, solvents use in IPPU – 2D3. Solvents. US AP-42 – NOx, CO, NMVOC, SO2 Engineered wood products – NMVOC. The drying process leads to VOC emissions, but emission factors may also include fuel combustion VOC. EMEP/EEA – 2I Wood Industry – only TSP (US EPA 1995 EF)
	- Charcoal							Energy sector US AP-42 – Charcoal – NOx, CO, NMVOC
	- Waste water collection, treatment and storage							Waste sector US AP-42 – NMVOC
	- Solid waste incineration							Waste sector MEP China – BC

Issue Paper (IPPU sector)

Issues

1. Allocation of emissions between Energy sector and IPPU sector

According to the *2006 IPCC Guidelines* emissions from fuel combustion should be estimated in Energy sector. Also, all emissions from coke production should be reported in Energy. All fugitive emissions from oil and gas industry should be estimated in Energy sector as well.

In some cases, fuels are used as feedstock and reductant and serve two-fold purposes to produce energy (heat) and to participate in a chemical reaction to produce final products (for example, use of coke in iron and steel, natural gas in ammonia production).

In Mineral Industry (cement, lime, glass, bricks, etc.) all combustion emissions from natural gas or coal are reported in Energy sector and CO2 emissions from chemical decomposition of carbonates reported in IPPU.

Several chemical elements are present in both - raw materials and fuels, for example sulphur, which is the source of SO2 emissions.

As it is difficult to estimate separate contribution of fuels or raw materials to final emissions, allocation to some sectors is used with indication of potential double counting. So, in the particular cases of use of coke in iron and steel and natural gas in ammonia – all emissions are allocated to IPPU.

The 2019 EMEP/EEA air pollutant emission inventory guidebook is generally consistent with the *2006 IPCC Guidelines* with focus on air pollutants, not greenhouse gases.

In Mineral industry the EMEP/EEA methodology suggests to allocate all emissions to Energy sector, except particulate matters (PM), which include black carbon (BC) and organic carbon (OC).

Only BC emission factors (EFs) are provided in Mineral industry. There is no OC EFs in EMEP/EEA methodology. Other methodological sources provide with some estimates of OC, for example US SPECIATE.

The participants are welcomed to discuss the issue of estimation and allocation of SLCF emissions in Mineral industry.

It is suggested to follow the EMEP/EEA approach.

2. Categories with no process (IPPU) emissions

The IPPU categories in the *2006 IPCC Guidelines* focus on process GHG emissions (CO2, CH4, N2O, HFCs, PFCs, SF6, NF3). CH4 and F-gases are SLCFs, but out of the scope of consideration, as methodology is already provided in the *2006 IPCC Guidelines*.

So, there are several IPPU categories which should be excluded from the SLCF IPPU sources mainly for two reasons:

i) a category is a solely source of F-gases (or N2O, CO2, CH4)
ii) a category is a source of combustion emissions (combustion emissions are estimated in Energy) and process emissions, but process emissions give rise only to GHGs which out of the scope (CH4, etc.).

The examples of these cases are listed below:

- 2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production
- 2B5 Carbide production
- 2B8a Methanol
- 2B9 Fluorochemical Production
- 2C4 Magnesium production
- 2D1 Lubricant Use
- 2D2 Paraffin Wax Use
- 2E Electronics Industry
- 2F Product Uses as Substitutes for Ozone Depleting Substances
- 2G Other Product Manufacture and Use

- 2H3 Other. Wood Industry (In Wood industry the use of solvents is estimated in category 2D3 Solvent use).

3. Other cases of allocation

There are several categories, which can be considered as industrial sources depending on classification, but in order to follow methodological approaches of complete and accurate emissions estimation, they should be treated in other sectors (e.g., Energy, Waste):

- 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, SOx, NMVOC.
  It should be reported in Energy sector.
- Alumina/aluminium oxide
  The *2019 Refinement* sub-category provides methodology for CO2 process emissions. MEP China presents PM2.5 and PM10 in Aluminium oxide. It is combustion emissions – Energy sector.
- Cocking
  According to the *2006 IPCC Guidelines*, the cocking emissions should be reported in Energy sector.
- Charcoal
  All charcoal related emissions (combustion and fugitives) should be reported in Energy sector.
- 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*.

4. Insignificant sources

There are several IPPU sources in the *2006 IPCC Guidelines* and the *2019 Refinement* or there are some literature publications that indicate possible emissions of SLCFs. These sources are not in the guidance of EMEP/EEA or other methodological guidance on SLCFs, which suggest that these sources are of insignificant nature:

- 2C7 Other metals - Rare Earths Production.

The 2019 Refinement category for CO2 and F-gases. This source is limited only to some countries. Literature suggests CO emissions which can be insignificant.

-- https://doi.org/10.1016/j.resconrec.2019.02.019

- 2C7 Other metals – Metal welding and cutting.

Literature suggests emissions of PM (not BC, mainly metal oxides), but also CO, NOx and SO2 from metal welding and cutting. This can be considered as insignificant source.

-- https://dx.doi.org/10.5812/jhealthscope.58267

-- http://dx.doi.org/10.1016/j.rser.2014.05.076

- 2F Product Uses as Substitutes for Ozone Depleting Substances

Ammonia is used in refrigeration. There is no guidance in EMEP/EEA. Some publications:

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https://www.ashrae.org/File%20Library/About/Position%20Documents/Ammonia-as-a-Refrigerant-PD-2017.pdf
-- https://www3.epa.gov/ttnchie1/conference/ei13/ammonia/sullivan.pdf

Table 2 Category list (IPPU)

A	B	C	I
IPCC code	Category	SLCF	Comments
2A1	Cement production	SO2, NMVOC – process emissions	SO2 – non-combustion source (raw materials) NMVOC – non-combustion source (other processes) The basic Tier 1 method ADxEF can be modified to include abatement ADxEF (1-Abatement efficiency). BC (EC) and OC. For establishing BC EF, it is important to have data on PM2.5 EF, inventory of particles/profile, fraction of BC (EC) in PM2.5. BC (EC) and OC are combustion related. Data on abatement techniques, their efficiency, maintenance are very important. C,D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. It is assumed that these SLCFs emissions to be mainly due to the combustion of the solid and waste fuels and to be included in category 1.A.2.f. Manufacturing Industries – Non-Metallic Minerals (Energy Sector), also double counting should be avoided. OC emission factor is presented in the US SPECIATE, UNEP, REAS. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – SOx, BC, OC, PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, NMVOC, SOx, CO (incl. combustion emissions) REAS – BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – NMVOC, PM2.5, PM10 (incl. combustion emissions)
2A2	Lime production	No process emissions, all emissions are combustion related	Significant emissions of PM during different sub processes (storage, crushing, calcining), however as the raw materials are mostly calcium carbonate and dolomite no OC or BC emissions occurs. BC emissions are related to combustion, but what happens with carbon fuel storage emissions? If the emissions of BC are considered in this sector it is important to take in to account that the magnitude of the differences for PM emissions factors (BC) between types of kilns (uncontrolled) is important (i.e., Shaft Kiln 3 kg/Mg lime and rotary long kiln 140 kg/Mg lime) this could be considered in the evaluation of whether a Tier 1 method is globally applicable or not. Also, traditional lime kilns (built using brick or stones) probably are not considered in the EMEP guidelines and are commonly used in countries with small production of lime and the aggregate could be important. As indicated below, others SLCF are accounted for in the energy sector as combustion is the significant source. C, D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. It is done because it is very difficult to separate process and combustion emissions and the majority of emissions for other SLCFs to be due to the combustion of fuels. OC emission factor is presented in the US SPECIATE, UNEP, REAS. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – BC, OC, PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, SOx, CO (incl. combustion emissions) REAS – BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – PM2.5, PM10 (incl. Industrial processes), give EFs to BC and OC
2A3	Glass production (incl. glass fibre/ mineral wool)	NMVOC – process	NMVOC come from process BC and OC from combustion.

A	B	C	I
IPCC code	Category	SLCF	Comments
		related	Dust from material handling Small amount of dust and NMVOC emissions from non-melting activities (coating, cutting, and milling). It is glass type dependent. References - Best available techniques (BAT) reference document for the manufacture of glass, Joint Research Center, Scalet et al., 2013. https://op.europa.eu/en/publication-detail/-/publication/ff8a3955-d0d0-46f5-8a15-4b638896cb56 C,D: According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. EMEP/EEA presents only BC (PM) in IPPU and estimates other gases (NOx, CO, NMVOC, SO2) in Energy, although sulphur is contained in fuels and raw materials. OC emission factor is presented in the US SPECIATE. C,F: EMEP/EEA – BC (incl. combustion emissions) US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) US AP-42 – NOx, NMVOC, SOx, CO (incl. combustion emissions) MEP China – PM2.5, PM10 (incl. Industrial Processes, give emission factors to OC and BC as 0)
2A4	Other Process Uses of Carbonates: - bricks - ceramics - others (tiles, gypsum, refractory, frit)	SO2, NMVOC	To check BC, OC, NMVOC as process emissions, because it can be combustion related. Sulphur is contained in fuels and raw materials (SO2 emissions) Clay/ceramic processing: The basic steps include raw material procurement, beneficiation, mixing, forming, green machining, drying, presinter thermal processing, glazing, firing, final processing, and packaging. There are PM emissions from many stages, and combustion emissions from drying and other thermal processes. Mixing generally is a wet process. However, VOC emissions from this step may arise from the volatilization of binders, plasticizers, and lubricants. EPA-42 Ch 11.7 provides an emission factor for VOC emission Combustion processes may be considered in Energy sector. C,D: EMEP/EEA provides no guidance for this category. According to the 2006 IPCC Guidelines combustion emissions should be estimated in Energy sector. US SPECIATE presents BC and OC. C,F: US SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species (incl. combustion emissions) UNEP – SO2 (bricks), PM2.5, PM10 (incl. combustion emissions) US AP-42 – NOx, SOx, NMVOC, CO (incl. combustion emissions) REAS - BC, OC, PM2.5, PM10 (incl. combustion emissions) MEP China – NMVOC, PM2.5, PM10 (incl. combustion emissions)
2B1	Ammonia production	NOx, NH3, CO, NMVOC, SOx	Expected to be a growing source C,D: In the 2006 IPCC Guidelines, in the case of ammonia production no distinction is made between fuel and feedstock emissions with all emissions accounted for in the IPPU Sector. The method for CO2 and SLCFs is slightly different: input of fuel and its carbon content (IPCC-CO2) by output of ammonia vs. EF of SLCF by output of ammonia (SLCF). C,F: EMEP/EEA – NOx, CO, NH3. NMVOC - Tier2, Tier 2 - technology specific. EMEP/EEA distinguishes fuel combustion emissions from process emissions. UNEP – NOx, CO, NH3, SOx, NMVOC US AP-42 – NH3, SO2, CO, NMVOC, also NOx and PM for fuel combustion. US AP-42 and WebFIRE emissions databases distinguish emissions from fuel combustion used to generate heat for the reformer (NOx, VOC, CO, PM) and emissions from removing impurities in the natural gas feedstock (NH3, SO2, CO, NMVOC). Check availability of method and EFs for NH3 REAS – NH3 MEP China – NMVOC

A	B	C	I
IPCC code	Category	SLCF	Comments
2B2	Nitric Acid production	NOx, NH3	C,F: IPCC and those listed here only include process emissions, not fuel combustion. EMEP/EEA – NOx. UNEP – NOx and NH3 US AP-42 – NOx
2B3	Adipic Acid production	NOx, CO, NMVOC	C,F: EMEP/EEA – NOx, CO UNEP and US AP-42 – NOx, CO, NMVOC
2B6	Titanium Dioxide Production	NOx, CO, SOx	To check. BC - NFR 2B6 Titanium dioxide: no methods in the EMEP GB, e.g. Finland uses domestic EFs for particles and for BC 1.8% of PM2.5 (a calculated average of chemical industry BC fractions) The chloride process does not emit SO2, while the sulphate process does C,D: The 2006 IPCC Guidelines do not include the sulphate route (only chloride route), so AD and EF for both routes are needed. C,F: EMEP/EEA – NOx, CO, SOx UNEP ABC EIM – SOx
2B7	Soda ash production	CO, NH3	C, F: EMEP/EEA – CO and NH3 (OK)
2B8	Petrochemical Industry		
2B8b	Ethylene	NMVOC	D: The 2006 IPCC Guidelines include Geographical adjustment factor. C,F: EMEP/EEA, REAS, MEP China - NMVOC
	- Propylene	NMVOC	D: EMEP/EEA: The default emission factor for Ethylene production emissions only takes into account the amount of emitted NMVOC directly related to the ethylene production. In fact, actual emissions can relate not only to ethylene production but also to the production of other olefins as propylene. Propylene is produced by thermal cracking of naphtha fractions, in the same process as the production of ethylene.
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer	NMVOC	C,F: EMEP/EEA - 2.B.10.a Other (Dichloroethane + vinyl chloride) – NMVOC MEP China - Chloroethylene production - NMVOC
2B8d	Ethylene Oxide	NMVOC	C,F: EMEP/EEA - 2.B.10.a Other (Ethylene Oxide) - NMVOC
2B8e	Acrylonitrile	NMVOC	C,F: EMEP/EEA - 2.B.10.a Other (Acrylonitrile) – NMVOC MEP China - NMVOC
2B8f	Carbon Black - *Secondary Carbon black (recovery of carbon black)*	[NOx], CO, NMVOC, SOx, BC, OC	No IPCC methodology for NMVOCs from oil storage tanks – EFs from EMEP and AP42 No IPCC methodology for PM diffuse emissions C,F: EMEP/EEA – NOx, CO, NMVOC, SOx, BC UNEP – NOx, CO, NMVOC, SOx, BC US AP-42 – NOx, SOx, NMVOC US EPA NEI / EPA SPECIATE – BC, OC REAS – NMVOC, BC, OC. Also, PM2.5 and PM10
2B10			
	- Hydrogen production	[CO, other SLCFs?]	Similar to Ammonia production Allocation of emissions Production from Ammonia Different feedstock – different EFs
	- Sulfuric acid	SOx	D, E: EMEP/EEA, REAS, UNEP, US AP-42 - SOx

A	B	C	I
IPCC code	Category	SLCF	Comments
			Combustion emissions should be estimated in Energy sector (MEP China – NMVOC in Sulphuric acid)
	- Ammonium nitrate	NH3	C,F: EMEP/EEA, REAS, UNEP, US AP-42 – NH3
	- Ammonium phosphate	NH3 [SO2]	C: EMEP/EEA presents only TSP and PM, no SOx and NH3. UNEP references the US EPA. The US AP-42 – totals for one plant - NH3, [SOx (Energy - combustion emissions)]
	- Urea	NH3, BC, [NMVOC]	C,F: EMEP/EEA – NH3 and BC UNEP, US AP-42, REAS – NH3, MEP China – NMVOC (Energy?)
	- Polyethylene	NMVOC	
	- Polyvinylchloride	NMVOC	
	- Styrene	NMVOC	
	- Polystyrene	NMVOC	
	- Styrene butadiene, Styrene-butadiene latex, Styrene-butadiene rubber (SBR)	NMVOC	B: EMEP/EEA - Styrene butadiene, Styrene-butadiene latex, Styrene-butadiene rubber (SBR) - NMVOC US AP-42 – Synthetic rubber, synthetic fibres - NMVOC REAS – Synthetic rubber – NMVOC MEP China – Butadiene – NMVOC
	- Acrylonitrile Butadiene Styrene (ABS) resins	NMVOC	
	- Formaldehyde	NMVOC	
	- Ethylbenzene	NMVOC	
	- Phthalic anhydride	NMVOC [CO, SO2]	C,F: EMEP/EEA – NMVOC US AP-42 – NMVOC [CO, SO2 (Energy)]
	- Benzene	NMVOC	
	- Methylbenzene / Toluene	NMVOC	
	- Xylene	NMVOC	
	- Glycol	NMVOC	
	- Terephthalic acid	NMVOC, CO	C,F: MEP China – NMVOC, US AP-42 – CO, NMVOC
	- Polyethylene terephthalate	NMVOC	
	- Maleic anhydride	NMVOC, CO	
2C1	Iron and Steel Production - Sintering - Pellets - Pig Iron - Blast furnace - Open hearth furnace - Electric arc furnace (scrap emissions) - fugitive/diffuse emissions from raw materials	NOx, CO, NMVOC, SOx, BC, OC	No IPCC method for fugitive PM (BC, OC) emissions from: (1) receiving, uploading and conveying of raw materials, (2) storage piles (3) paved and unpaved roads within facilities PM size distribution has to be considered in fugitive emissions Desulfurization process is not included in IPCC method (SOx and PM) PM and SO2 foundry emissions, from the use of Cupola furnaces – No IPCC methodology No IPCC methodology for Scrap preparation (PM, EC, OC, CO, NMVOCs), previous metal melting in electric arc furnaces, only data in AP42 from solvent degreasing. With methodology 2.D.3)

A	B	C	I
IPCC code	Category	SLCF	Comments
			Flaring BFG in IPPU C,F: EMEP/EEA: Tier 1 EF for Iron & Steel (NMVOC and BC), Tier 2 EFs for technologies (NOx, CO, NMVOC, BC). US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species REAS - CO, BC, OC, PM2.5, PM10 - Crude steel and Pig iron EFs UNEP - NOx, CO, NMVOC, SOx, BC,OC - only Pig iron (no steel) MEP China – Iron and Steel – NMVOC. US EP-42 – Gray iron foundries (NMVOC, CO, SOx, NOx) and Iron&Steel (NOx, CO), Coking (NOx, CO, NMVOC, SOx and NH3). Despite robust test methods, the emission factors listed here cannot be reliably applied across the industry because there is considerable variability in the process at different facilities.
	- Rolling mills	NMVOC, SO2	When volatile halogenated organic (VHO) gas is used some sulphur dioxide will also be emitted. (EMEP), but no EFs is reported D: EMEP/EEA – NMVOC (hot rolling mills, Tier 3) In general, it can be said that emissions from rolling mills are small compared to the other emissions from the (integrated) steel plant. Therefore, rolling mills will not be considered as a separate source in the Tier 1 and Tier 2 emission factors.
2C2	Ferroalloys production	BC	[Possibly other SLCF species] C.F: EMEP/EEA – BC. T1 EF for BC (10% of PM2.5) based on USEPA 2011
2C3	Aluminium Production - primary (Prebake and Soderberg) - secondary	NOx, CO, NMVOC, SOx, BC, OC	Aluminium production is very energy intensive. SO2 is the main process emission gas, also from anode. BC from anode baking and from fuels, also BC is from secondary aluminium. C,F: EMEP/EEA: primary – NOx, CO, SOx, BC, secondary – BC US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species UNEP: NOx, CO, NMVOC, SOx, BC, OC REAS – SOx, BC, OC, PM2.5, PM10 Norway: BC, OC - BC and OC from aluminium: https://www.ssb.no/en/natur-og-miljo/artikler-og-publikasjoner/_attachment/107884?_ts=13dfd568678. See table 5.3. It seems that Norway estimate some emissions from secondary aluminium. SO2 from electrolysis and consumption of anode, anode baking furnace. NOx from the same sources plus from use of natural gas in foundries. Norway EFs for NOx from electrolysis is 0.15 kg NOx/tonne of Al CO from electrolysis BC, OC possible from electrolysis, anode baking, use of fuels NMVOC – foundries, anode baking, storage and handling, paste plant Secondary Aluminium – all species from fuels
2C5	Lead Production - primary - secondary - electrolytic	[SOx], [NOx][CO] [BC, OC]	Plant-specific emissions Primary lead SOx – can occur or not depending on the plant structure, processes and abatement (EMEP T1 and T2 EFs for EU countries for 2015 abatement level) - emissions are diffuse emissions from the oxidation stages, direct emissions from the sulphuric acid plant and the emissions of residual sulphur in the furnace charge. Good extraction and sealing of the furnaces prevents diffuse emissions, with the collected gases from the oxidation stages passed to a gas-cleaning plant and then to the sulphuric acid plant or gypsum plant. NOx - can occur or not depending on the plant structure, processes and abatement (EMEP no EFs) - may be formed in the melting stages or from nitrogen components that are present in the concentrates or as thermal NOx. The sulphuric acid produced can absorb a large part of the NOx, and this can affect the sulphuric acid quality. Other furnaces that use oxy-fuel burners can also exhibit a reduction in NOX. The range for all the processes is 20 mg/Nm3

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IPCC code	Category	SLCF	Comments
			to 300 mg/Nm3 BC, OC, CO -yes, especially if plastics are present (EMEP T1 PM EFs for EU countries for 2015 abatement level and T2 unabated EFs for European countries 2014 – both for filterable PMs while BC needs both filterable and condensable PMs) (EMEP/USEPA T2 unabated EF for filterable PMs while BC needs both filterable and condensable PMs) Organic carbon compounds and CO can be emitted from the drying stage depending on the raw materials and the fuel used for drying. The most significant source of organic carbon compounds and CO is the reduction step of the smelting process, especially when plastic/plastic residues are present in the furnace charge. An afterburner is the most common technique used to abate this pollutant. Secondary lead – SOx and NOx at low levels (EMEP EF for SOx for European 2015 abatement level) Most important SOx and NOx emission ia smelting furnaces. The amount of SOx formed depends on the amount of sulphur contained in the raw materials and in the fuel used. A major part of the sulphur remains in the slag formed during the smelting process, some can be converted to SOx. SOx in the off-gas has been measured at about 0.1% v/v. At a blast furnace using coke as fuel an even smaller off-gas concentration in the range of about 0.03% v/v has been measured BC –no EMEP T1 and T2 EFs for filterable PMs, no BC fraction, which would require both filterable and condensable PMs Mass-balance for SO2 can be more accurate than the EF approach C,F: EMEP/EEA, US AP-42 and UNEP – SOx. EMEP/EEA – PM2.5, PM10, TSP. US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species. SPECIATE Profiles - 91139 sintering furnace, 91168 lead processing. REAS – SOx, BC, OC, PM2.5, PM10 MEP China – Lead production and Electrolytic lead production - PM2.5 and PM10
2C6	Zinc production - primary - secondary - electrolytic - zinc oxide - zinc calcine	SOx [BC, OC]	Primary zinc SO2 – depending on processes and abatement/construction (EMEP T1 and T2 unabated and EU 2015 abatement level) mainly from roasting (sulphur in the feed), lower levels from electrolysis and H2SO4 plant from tanks, sinter plant (depending on S content of the feedstock) ovens and separation (coverings to reduce emissions) NOx – maybe depending on the process from roasting and smelting if N components present in the concentrates or as thermal NOx BC – no information (EMEP EFs for filterable unabated PMs only) Secondary zinc SO2 – depending on processes and abatement/construction (EMEP T1 and T2 unabated and EU 2015 abatement level) BC and NOx – no information (EMEP EFs for filterable unabated PMs only) Mass-balance for SO2 can be more accurate than the EF approach C,D,F: EMEP/EEA and UNEP – SOx, PM2.5, PM10, TSP. NOx and CO are reported in Energy sector. REAS – SOx, BC, OC, PM2.5, PM10 MEP China – Zinc, Electrolytic zinc, zinc oxide, zinc calcine production - PM2.5 and PM10
2C7	Other		

A	B	C	I
IPCC code	Category	SLCF	Comments
	- Copper	SOx, BC, OC [NMVOC]	SO2: Copper smelting important source. Also The basic Tier 1 method ADxEF can be modified to include abatement ADxEF (1-Abatement efficiency). SO2, SO3: from acid mist from acid plants within smelting process and acid mist from other metallurgical processes such as flotation, lixiviation and mills BC: from Pyro-refining, final step in smelting, with fuels (oil or natural gas) to extract remaining oxygen. NMVOC: solvent use in solvent extraction/ electrowinning Recycling – Secondary – BC Recover of wires - fires Mass-balance for SO2 can be more accurate than the EF approach C,D,F: EMEP/EEA – SOx, BC US EPA NEI / EPA SPECIATE – BC, OC, PM2.5, SO4, NO3, remaining PM species UNEP –SOx, PM2.5, PM10. [NMVOC EF taken form 1996 IPCC for rolling mills] US AP-42 – SOx REAS – SOx, BC, OC, PM2.5, PM10 MEP China – PM2.5 and PM10
	- Nickel	SOx	Mass-balance for SO2 can be more accurate than the EF approach Abatement is important C,D,F: EMEP/EEA – SOx NOx, CO are assumed to be mainly due to combustion activities and addressed in Energy sector. SOx emissions are to a large extent from the ore – IPPU sector. TSP or PM factors represent filterable PM emissions only (excluding any condensable fraction). MEP China –SO2, PM2.5, PM10 (incl. Industrial Processes, give emission factors to SO2, OC and BC as 0)
	- Other metals (Silicium production, Magnesium production, Alloyed metal manufacturing, Galvanizing, Electroplating, Manufacture of basic precious and non-ferrous metals, Other)	SOx	B,C,D: EMEP/EEA – SOx. The emission factors are adapted from the revised BREF document for the non-ferrous metal industry (European Commission, 2014) and applicable for precious metal production facilities controlled by a fabric filter, hot electrostatic precipitators and cyclone.
	- Metal welding and cutting		B,C,D: No methodological guidance - Insignificant source - Possible source of SLCF emissions. Further data collection is needed
2D3	Solvent Use		
	- Domestic solvents use	NMVOC	(EMEP T1 EFs per capita is universal and provided for both Western/Other countries) (EMEP T1 EFs for different product categories for European countries 2015) EMEP: T2 EFs for different product categories using USEPA 1005 /EU 2012 methods) – global per capita (EMEP: solvent contents by different product groups in Europe 2015) NMVOC – yes – a growing source (1990 ~4%, 2019 ~8%) Per capita EF can over or underestimate emissions from country to country, intra-city EFs
	- Coating application	NMVOC	Share In 1990 12%, in 2019 9% of NMVOCs Per capita EFs can over or under estimate emissions, type of paints and solvent content is important, economic indicators (other proxies) can be used, if the types of paints or solvent content is not

A	B	C	I
IPCC code	Category	SLCF	Comments
	(Paint application, Manufacture of automobiles, Car repairing, Construction and buildings, Domestic use, Coil coating, Boat building, Wood, Other industrial paint application, Other non-industrial paint application)		known The inventorying of NMVOCs' emissions from the categories coating, degreasing, dry cleaning is problematic, and done by application of the 'Tier 1'-like methodology described in the EMEP/EEA Guidebook (methodology given, however emission factors should be discussed), however for the local air quality assessment, the modellers sometimes including commissioned analysis about that. Unfortunately, we have still very limited knowledge about the real composition of paints and coatings which is crucial information for the emission estimation. The problem is also in the market analysis (paints and coatings sold = paints and coatings used). If we know the volume of coatings used in industry (e.g. painting of vessels), we can somehow estimate NMVOCs emissions. The paints and coatings used for both: industrial and non-industrial purposes should be in compliance with current EU Directives (and Decisions, such as: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2020.414.01.0019.01.ENG&toc=OJ%3AL%3A2020%3A414%3ATOC&utm_campaign=ESIG%20Newsflash%20October%202021&utm_medium=email&utm_source=Mailjet and concentration of solvents in paints and coatings (probably?) decreasing from year to year. The estimation of the volume of solvents can be (theoretically) carried out, it might be worth to ask ESIG for some help (Europe, https://www.esig.org/). Poland: 2D3d, Coating applications, methodology: Tier 1, country specific EF [NMVOCs, Waterborne paints 0.03 Mg/Mg paints (assumption: non-industrial purposes), Conventional solvent paints, 0.5 Mg/Mg paints (assumption: industrial purposes)], Uncertainty 28% (possibly bigger). All of EFs are derived from the former analysis of Institute of Ecology of Industrial Areas (Katowice, Poland). B: US AP-42 presents NMVOC for the following sub-categories (Non-industrial surface coating, Industrial surface, Can coating, Magnet wire, Other metal coating, Flat wood interior panel, Paper, Polymeric, Automobile, Metal coil surface coating, Large appliances, Metal furniture, Magnetic tape, Plastic parts surface coating, Paints and Varnish). C: US EPA NEI / EPA SPECIATE presents for Surface coating - BC, OC, PM2.5, SO4, NO3, remaining PM species
	- Degreasing (Metal degreasing, Electronic components manufacturing, Other industrial cleaning)	NMVOC	4% of NMVOC in 1990, <2% in 2019 Degreasing is rather industrial category, and the type of solvents used are specific for the particular type of industry. The amount (volume) of industrial solvents used for degreasing is not can be possible from some kind of bottom-up inventory compared with data about sold chemicals. Poland: 2D3e, Degreasing (of metal), methodology: Tier 1, country specific EF (NMVOCs, 1 Mg/Mg solvent - 100% evaporating), Uncertainty 30% (possibly bigger).
	- Dry cleaning	NMVOC	An insignificant source 0.1-0.3% "Tier 1 method has been used for calculation of fugitive emissions from this category. Activity data (population) used for calculation of fugitive emissions of NMVOC was taken from statistical yearbook [GUS] and emission factors have been developed by the Institute for Ecology of Industrial Areas (IETU)." Poland: 2D3f, Dry cleaning, methodology: Tier 1, country specific EF (NMVOCs, 0.15 Mg/1000 people (inhabitants)), Uncertainty 30% (possibly bigger).
	- Chemical products (Polyester, Polyvinylchloride, Polyurethane foam, Polystyrene foam, Rubber, Pharmaceutical products, Paints manufacturing, Inks, Glues, Asphalt blowing, Adhesive, Magnetic tapes, Films and photographs manufacturing, Textile finishing, Leather tanning, Other)	NMVOC	Use of solvents in the subcategories under “Chemical Products” is mainly considered insignificant (3-4% of NMVOC) but can in some countries be source of a considerable part of NMVOC emissions, These processes are complicated, variable and unique so that no general guidance can be provided. Guidance in EMEP/EEA Guidebook can be applied in most countries where production volumes are known. B: MEP China presents NMVOC for the following products (Ink, Dye, Tire, Textile, Artificial leather/ synthetic leather, Acrylic production, Nylon, Vinylon, Artificial board Manufacturing, Architectural coating production, Cementing compound, Foamed plastic, Gelatinous fibre, Woolen yarn, Silk production, Cloth production) and PM2.5 for Carbon production, Fertilizer production
	- Printing	NMVOC	A minor source today, 2-3% of NMVOC. includes several subprocesses. If no abatement is used 50-80% of solvents used are emitted. EMEP/EEA-NMVOC The Tier 1 approach for emissions from other product use uses the general equation: E*pollutant* = AR*production* X EF*pollutant*

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IPCC code	Category	SLCF	Comments
			(1) This equation is applied at the national level. It involves either the use of solvent consumption data or combining ink consumption with emission factors for the industry. Unless the solvent consumption data is used, no account is taken of the use of water-based or low solvent inks, and no account is taken of the extent of controls such as incineration. In cases where specific abatement options are to be taken into account a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different printing processes that may occur in the country
	- Other solvent and product use (Other use of solvents and related activities, Glass wool enduction, Mineral wool enduction, Fat, Edible and non-edible oil extraction, Application of glues and adhesives, Preservation of wood, Underseal treatment and conservation of vehicles, Vehicles dewaxing, Aircraft deicing, Use of fireworks, Use of tobacco, Use of shoes, Other)	NMVOC	A minor source ~4% of NMVOC emissions. EMEP/EEA methods represent EU countries and are based on detailed mass balances on national production, import and export statistics on the use of products/chemicals and information from industries and trade organisations. Methods are product and pollutants specific because the NMVOC concentrations vary by pollutant or the use pattern of the product. Preservation of wood with organic solvent-born preservatives and use of solvent containing vehicle treatments are small activities but almost all NMVOCs included in the AD are emitted. B: MEP China (Nonedible vegetable oil production) REAS (Preservation of wood, Vehicles treatment, Adhesive application)
2D4			
	- Road paving with asphalt	NOx, CO, NMVOC, BC	An insignificant source, ~0.1% of NMVOC C,F: EMEP/EEA – NMVOC, BC UNEP – NOx, CO, NMVOC US AP-42 – NOx, CO, SOx, NMVOC REAS, MEP China – NMVOC EPA calcs
	- Asphalt roofing	NOx, CO, NMVOC, BC	An insignificant source for NMVOC SO2 emissions – but this is for asphalt blowing (listed under 2D3), which is listed above? Clarify what process included here? https://doi.org/10.1002/ep.10071 Another paper, including recycled content, not sure what stages (E.g. transport) are included in emissions: https://www.sciencedirect.com/science/article/pii/S0921344913000554 New work showing there are numerous missing emissions of SVOCs. Major SOA precursors (Both roofing and paving), even after application: https://www.science.org/doi/10.1126/sciadv.abb9785 C,F: EMEP/EEA – CO, NMVOC, BC UNEP – CO, NMVOC US AP-42 – CO, NMVOC (VOCs from both the process and fuel combustion)
2F	Product Uses as Substitutes for Ozone	NH3, NMVOC	It is the source of F-gases emissions. NH3 and NMVOC emissions are also possible

A	B	C	I
IPCC code	Category	SLCF	Comments
	Depleting Substances		https://www.epa.gov/sites/default/files/2015-08/documents/eiip_areasourcesnh3.pdf Information of Ammonia emissions from refrigeration in food industry in Chile. 57 ton NH3/year -. http://www.chilealimentos.com/wordpress/wp-content/uploads/2018/01/Informe-Final_3-29112017_Sin-anexos.compressed-1-1.pdf
2H1	Pulp and Paper Industry (Chipboard, Paper pulp (Kraft process), Paper pulp (acid sulphite process), Paper pulp (neutral sulphite semi-chemical process))	NOx, CO, NMVOC, SOx, NH3, BC, OC	Tier 1 default emission factors are those for Kraft pulping, since this is by far the most important process in the manufacturing of pulp and paper. Values are taken from the BREF document for pulp and paper industries (European Commission, 2001); the emission factor for CO is from US EPA (1985) and the emission factor for BC1 is obtained from US EPA, SPECIATE database version 4.3 (US EPA, 2011), The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country., The emission factors from all pollutants needs to be updated. Data on abatement techniques and equipment, their efficiency, maintenance are very important. Some examples of emission control: Particulates emissions :can be controlled by electrostatic precipitators, scrubbers, cyclone collectors and wire mesh demister pads. Electrostatic precipitators are the main type of collectors used to control recovery furnace particulate emissions C,E,F: EMEP/EEA – NOx, CO, SO2, NMVOC, BC. NH3 emissions occur from the pulping process and need to be determined plant by plant UNEP – NOx, CO, SO2, NMVOC, BC, OC. US AP-42 – SOx - Chemical Wood Pulping REAS and MEP China – NMVOC US EPA NEI / EPA SPECIATE – BC, OC. Also PM2.5, SO4, NO3, remaining PM species Norwegian inventory: 2% of BC of TSP and 25% of OC of the TSP
2H2	Food and Beverages Industry (Bread, Wine, Beer Spirits, Sugar production Flour production, Meat, fish etc. frying / curing)	NMVOC, CO, NH3, SOx	The Tier 1 approach needs emission factors for all relevant pollutants. These emission factors integrate all sub-processes within the industry from the feed of raw material to the final shipment of the products off site. The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. In the case of food and beverages production, these techniques are the various kinds of food and beverages produced (e.g., bread, sugar, wine, beer). B, C, F: US AP-42 – NMVOC, CO – malt beverages EMEP/EEA – animal rendering and animal feed - NMVOC US AP-42 - Sugar beet processing - NMVOC, CO, SOx (Energy emissions). US AP-42 - Meat Smokehouses - NMVOC, Meat Rendering Plants - NH3 US AP-42 – Coffee roasting - NMVOC, CO MEP China – NMVOC for various products UNEP and REAS – NMVOC
	- Food and Beverage charbroiling, fat frying, grain handling, fermenting/ distilling, drying/ roasting, natural gas cooking	BC, OC	BC emissions result from incomplete combustion during charbroiling activities. Commercial charbroiling operations are a significant source of PM10 and PM2.5 emissions within the overall nonpoint source emission inventories. The magnitude of PM emissions largely depends on the type of cooking equipment and the type of meat cooked. Under-fired charbroiling cooking operations are a major source of PM emissions compared to other charbroiling equipment operations. The Tier 1 method for estimating emissions from charbroiling is based on the type of equipment used for charbroiling. This method relies on per capita emission factors and the population of the inventory area. The per capita emission factors are dependent on the type of equipment used for charbroiling/commercial cooking activities (i.e., conveyorized, under-fired, flat-griddle, clamshell griddle, and deep-fat frying). Activity data for the Tier 1 method can be at the national, state, regional, or other required inventory area–level. Double-counting with Energy NFR 2L Meat frying and barbeques: Emission factors for TSP, PM10 and PM3.5 (no EF for BC) can be found www.air.sk/tno/cepmeip B,C,F: US EPA NEI / EPA SPECIATE – BC, OC. Also, PM2.5, SO4, NO3, remaining PM species
2H3			
	- Wood industry (Plywood manufacturing, Waferboard/oriented strandboard, Particleboard, Medium density fiberboard, Hardboard and fiberboard,	NOx, CO, NMVOC, SOx	Dust, TOC, TVOC and formaldehyde emissions from drying process. Two stages of TVOC and dust emissions: a) during drying and b) pressing. From (urea/phenol) formaldehyde-based resin use. NH3, NOX or SOX in the press exhaust are also possible Formaldehyde-free resins reduces TVOC. Is technology and end-product dependent. TVOC emissions also from painting / paper-impregnation and surfaces treatments of boards Emissions from mechanical wood industry (pressing) - to check.

A	B	C	I
IPCC code	Category	SLCF	Comments
	Wood Preserving, Engineered wood products)		For particle board, fiberboard, and engineered wood products, this pressing stage can be an important source of VOCs gluing and coating are covered in Solvents AD is to be checked References: Best Available Techniques (BAT) Reference Document for the Production of Wood-based Panels. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control); Kristine Raunkjær Stubdrup, Panagiotis Karlis, Serge Roudier, Luis Delgado Sancho; 2016. https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-11/WBPbref2016_0.pdf B, C, D: Combustion emissions should be reported in Energy sector, solvents use in IPPU – 2D3. Solvents. US AP-42 – NOx, CO, NMVOC, SO2 Engineered wood products – NMVOC. The drying process leads to VOC emissions, but emission factors may also include fuel combustion VOC. EMEP/EEA – 2I Wood Industry – only TSP (US EPA 1995 EF)

Table 1 Summary Information (AFOLU)

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative Methodology[5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
3.A.2	Manure Management						Main GAP, emission factors available from EMEP/AP-42/EMEP may not/likely not cover the entire variability of agro-systems/practices in the World	**E.** source: EMEP. For NO_x – NH_3 The methodology uses TAN (Total Ammoniacal Nitrogen) instead of Nex (Total Nitrogen) *(AP-42 and UNEP provides methods for NH_3 only)* For NMVOC. An emission rate is applied to the animal population
3.A.2.a.i.	Dairy Cows	NO_x – NH_3	Yes (IPCC method for N_2O emissions)	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)	Need to reconcile TAN and Nex in the methods to estimate NOx and NH_3 vs N_2O	
3.A.2.a.ii.	Other Cattle							
3.A.2.b	Buffalo							
3.A.2.c	Sheep							
3.A.2.d	Goats							
3.A.2.e	Camels							
3.A.2.f	Horses							
3.A.2.g	Mules & Asses							
3.A.2.h	Swine							
3.A.2.i	Poultry							**B.** EMEP provides subdivisions for: Laying hens. Broilers, Turkey
3.A.2.j	Other							
3.A.2.a.i.	Dairy Cows	NMVOC	Yes (IPPC method for CH_4 emissions)	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)		
3.A.2.a.ii.	Other Cattle							
3.A.2.b	Buffalo							
3.A.2.c	Sheep							
3.A.2.d	Goats							
3.A.2.e	Camels							
3.A.2.f	Horses							
3.A.2.g	Mules & Asses							
3.A.2.h	Swine							
3.A.2.i	Poultry							**B.** EMEP provides subdivisions for: Laying hens. Broilers, Turkey
3.A.2.j	Other							
3.D.2	Other							**E.** Estimated at Tier 2 only and as a fraction of emission from housing - if a default method is needed EMEP and IPCC have to be considered for reconciliation See Issue II
3.D.2.x	"Livestock manure applied to soils"	NMVOC	No	EMEP (3.D.a.2.a) Tier 2 only	No (see AFOLU compilation table)	Common practice but poor understanding of emission-process	The literature investigation evidenced a lack in measurements on both amplitude and duration of emissions (7 papers from 3 teams). Only a small part of NMVOC is characterized.	This may be part of 3.C.4 (organic fertilizer) or 3.A.2. (MMS "daily spread") EMEP provides a Tier 2 method only, and as a fraction of emission from housing: the ratio is the same as the one obtained for ammonia, indicating that it may contribute significantly. It is not completely consistent with Tier 1 methodology, for which livestock manure applied to soil is not accounted for NMVOC emissions This category is not listed in table2 BOG concludes that the knowledge is insufficient to consider this source of VOCs in the upcoming methodology report.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative Methodology[5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
3.D.2.x	"Urine and dung deposited by grazing livestock"	NMVOC	No	EMEP (3.D.a.3.a) Tier 2 only	No (see AFOLU compilation table)	Common practice, but poor understanding of emission process	Under investigation for literature to assess significance (TSU)	This may be part of 3.C.4 (urine and dung deposited) or 3.A.2. (MMS "urine and dung") EMEP provides a Tier 2 method only This category is not listed in table2
New to check with Waste/Energy	Manure incineration	NOx, CO, BC	No				Cross-sectoral Need to reconcile Nex and NOx in the methods to estimate NOx **Notes from Oct 18 cross-sectoral discussion Energy, Waste, AFOLU)** Methodological gaps: Energy and Waste sectors have available emission factors for incineration of manure; methodological challenges: 1. integrated collection of activity data on manure management 2. Energy sector: developing data and emission factors for small-scale combustion such as on-farm burning of manure, manure burned for cooking 3. AFOLU sector: maintaining integrity of N balance in cross-sectoral guidance	**Notes from Oct 18 cross-sectoral discussion Energy, Waste, AFOLU)** Allocation: - 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; the latter may or not be significant, but if significant could be included in solid fuel transformation. - all other manure incineration and open burning should be reported in the Waste sector N emitted as NOx from manure incineration, kg N-NOxanimal-1year- https://static-content.springer.com/esm/art%3A10.1038%2Fs43016-020-0113-y/MediaObjects/43016_2020_113_MOESM1_ESM.pdf
	Anaerobic digestion of animal manure	NH3, NOx	Yes	EMEP (Waste sector)	Yes	Yes (IPCC)	Gaps: 1. Activity data on manure and digestate transfer between farms and waste treatment facilities 2. SLCF emissions from the treatment, storage and spreading of digestate (Agricultural soils, other?). 3. On-farm co-digestion Challenges: maintain N balance integrity	IPCC guidance (2019 Refinements) provides N2O EFs for anaerobic digesters in the Agriculture sector, although it describes this technology as one for "waste stabilization", whose output is "captured and flared or used as a fuel" (Table 10.21, 19R V4 ch10). Non-CO_2 emissions from the combustion of output gases are allocated to the Energy sector; emissions from storage or other uses of digestate should be reported at the point of use or disposal. Any fugitive emissions from the anaerobic digestion process itself are allocated to the Agriculture sector. EMEP considers anaerobic digestion in the context of facilities, not in an agricultural context. Accordingly, it does not consider on-farm anaerobic digestion and reports all emissions from anaerobic digestion in the Waste sector. NH3 emissions from the digestion process itself are considered negligible. Methods are provided for estimating emissions from storage of manure and of digestate on a facility site (as opposed to farm infrastructure). In both IPCC and EMEP frameworks, on-farm manure storage is considered as part of manure management, and the application of digestate to agricultural lands part of soil management.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative Methodology[5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
							when estimation methods for the pre-digestion storage and treatment, the anaerobic digestion itself and the use of digestate (combustion, storage, spreading onto fields) are reported in multiple sectors. (See also challenges in manure incineration)	AFOLU BOG recommendation for SLCFs: 1.same allocation as IPCC for reporting emissions from on-farm digesters (AFOLU) - with clarification regarding the allocation of emissions when manure is transferred between facilities and farms 2. maintain on-farm manure storage, application of digestate in AFOLU sector. 3. ensure methodological integrity in all manure-related emission sources (N mass balance)
3.C.1	Burning[iii]							**E.** source: EMEP, UNEP, US-NEI for 3.C.1.a and 3.C.1.b; US-NEI for 3.C.1.c and 3.C.1.d Global Fire Database[iv] also provides potentially useful parameters for significant fire events
3.C.1.a	Burning in Forest Land	NO_x – NH_3 – SO_2 – CO – NMVOC – BC & OC	Yes	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)	Underlying assumptions of parameters/calculations need likely to be reconciled	Factors/parameters values need likely to be updated with new literature
3.C.1.b	Burning in Cropland					Yes (as per IPCC method)	Tables 2.4, 2.5 and 2.6 of the IPCC GLs could be expanded to include open burning on cropland, which is not adequately represented in "prescribed burning" or "slash and burn"	IPCC lists four crop types (maize, wheat, rice, sugarcane) and other approaches more detailed. Need more specific emission factors (NOx, SO2, etc.) for sugarcane burning, particularly in South and Central America, Southeast Asia. During COVID-19 pandemic, observed connection between solid waste burning and crop residue burning in Southeast Asia – potential cross-sectoral issue. biochar production: ensure that all emissions are property accounted for in the Energy[v] or IP sectors (x-sectoral issue) - if not, consult whether some emissions should be reported in the land sector. Significance of emissions from open-pit burning for biochar production needs to be assessed.
3.C.1.c	Burning in Grassland					Yes (as per IPCC method)		
3.C.1.d	Burning in all other lands					Yes (as per IPCC method)	there is supplemental guidance for peatland burning by soil types in the 2013 Suppl. On Wetlands. Need to reconcile nomenclatures of soil types and land use categories	Consistency in the land use definitions/categories; Ignition types in NEI (wildfire, prescribed fire, croplands) may not map to land use categories (NEI methods is not a T1 method)
3.C.4	Direct N_2O emissions from managed soils (This is the name of the IPCC category which was not meant to include other species than GHGs. emissions of NOx and NH3 are included under this category to reflect the need to reconcile methods)							**B.** See Issue I Nomenclature issue. IPCC and EMEP guidance give different meaning to "indirect emissions" Cannot change existing IPCC category; could be augmented with new categories for NOx and NH3 emissions, both direct and indirect.
3.C.4	Sources of N: - Inorganic N fertilisers (includes urea); - Sewage sludge applied to soils; - Other organic fertilisers applied to soils (including compost) - Crop residues applied to soils	NO_x – NH_3	Yes	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)	2019 Refinement provides a combined EF for NOx and NH_3; should be separated. Verify with issue paper: EFs should be different when fertilizers are incorporated in the soils - for both NOx and NH_3.	**E.** source: EMEP, AP-42, UNEP

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative Methodology[5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
3.C.4	Sources of N: - Livestock manure applied to soils; - Urine and dung deposited by grazing livestock;	NO_x – NH_3	Yes	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)	Need to reconcile TAN and Nex in the methods to estimate NOx and NH3 vs N2O Default EFs do not represent grazing practices in South America.	**E.** source: EMEP, AP-42 for NH_3 only **F.** EFs based on AAP instead of on of N_{ex}
3.C.5	Indirect NOx emissions from managed soils	NO_x	Yes	---	Yes (see AFOLU compilation table)	Yes (as per IPCC method)		**B** See Issue I This row should be clarified: the processes causing indirect NOx emissions may also cause direct emissions of NOx. Indirect NOx emissions from managed soils can cause NOx and emissions to managed and natural soils. The Tier 1 EF should be used. Verify with Issue Paper
3.D.2	Other							See Issues IV and V
3.D.2.x	Other: "Pesticide application"	NMVOC	No	US AP-42 (9.2.2)	see AFOLU compilation table	Method may not be applicable globally due to its complexity and due to the lack of data on global pesticide use.	The applicability of methods for global development is uncertain.	See Issue III Pesticide application for agricultural purposes is 3-4% of the total VOC emissions in US excluding biogenic and wildfire emissions. This category is in the top 10 of anthropogenic VOC sources. NEI method is not a tier 1 method, but there may be a tier 1 approach in the Emission Inventory Improvement Program (EIIP) Ch9. Pesticide use may be increasing globally, but is approximately constant in the US. BOG concludes that source deserves further consideration.
3.D.2.x	"Cultivated crops"	NMVOC	No	EMEP (3.D.e)	see AFOLU compilation table			
3.D.2.x	"Managed deciduous/coniferous forests"			EMEP (11.C.1111, 11.C.1112)		Method is simple, uncertainty is very large.	Current knowledge may be insufficient to support the development of globally applicable methods - except perhaps for simple situations such as some crop type replacement.	Should naturally occurring emissions (not influenced by human management) from ecosystems be reported in inventories of anthropogenic emissions. There is some evidence that intensive ecosystem management may impact NMVOC emissions, e.g. coppice trees (ref). Accuracy of the present methodologies could be questioned. Main drivers: crop types, leaf area and env'al conditions.
3.D.2.x	"Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub)"			EMEP (11.C.110401, 11.C.110402, 11.C.110403, 11.C.110404)		Method is simple, uncertainty is very large.		
3.D.2	Other							See Issue VI BOG recommends to consider tillage as a significant source of OC and EC from PM10, based on an assessment of available data and monitoring tools. Future consideration might be given to a potential C imbalance resulting from significant lateral C transportation from fugitive dust.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC Method applicable[4]	Alternative Methodology[5]	Available EFs/ parameters[6]	Globally applicable[7]	Gaps *(if any)*[8]	Comments[9]
3.D.2.x	Other: "Fugitive dust from tilling"	BC – OC	No	US EPA NEI (4.3 Agriculture – Crops and Livestock dust)	(see AFOLU compilation table)	Method may not be applicable globally due to its complexity	Some parameters may not reflect crops, technologies or practices in all countries[vi].	**E.** 2017 National Emissions Inventory: January 2021 Updated Release, Technical Support Document U.S. Environmental Protection Agency See Issue VI Significance (in US): 10-14% of PM2.5 (tbc)[vii] Possible significance elsewhere unknown; SLCF fraction in dust appears to be small Are other agricultural practices - e.g. harvest or post-harvest operations – also causing these emissions?
3.D.2.x	Other: "Fugitive dust from animals"	OC	No	US EPA NEI (4.3 Agriculture – Crops and Livestock dust)	(see AFOLU compilation table)	O		**E.** 2017 National Emissions Inventory: January 2021 Updated Release, Technical Support Document U.S. Environmental Protection Agency See Issue VII Significance (in US): to be confirmed[viii]. Possible significance elsewhere unknown

1. Apply here the *2006 IPCC Guidelines* categorization. If the *2019 Refinement* has a specific category while the *2006 IPCC Guidelines* have not, use it and notes that it is a *2019 Refinement* category

2. Use the IPCC category name or use "Others" for all those categories for which IPCC does not provide a specific categorization followed by the name of the new category taken from the relevant guidebook/sourcebook/guidelines. If the 2019 Refinement has a specific category while the *2006 IPCC Guidelines* have not, use it and note that it is a *2019 Refinement* category

3. List here SLCFs for which the method, as noted in Columns D or E, applies. Where different methods apply to different SLCFs from the same source-category compile a row of information for each method

4. Is an applicable IPCC method available?

In the case the IPCC method needs modifications further than providing for the SLCF EF to be applicable, answer "yes with modifications" and possibly provide in the comment box indication on the modification needed. Examples of modifications are, additional parameters, e.g. technologies, and/or additional data to ensure full coverage of SLCFs emissions

5. In case the IPCC methodology is not applicable or there is not an IPCC methodology for the listed category (i.e. Column D has been compiled with "No"), provide the reference to any other methodological source from which the category is sourced

6. Provide reference to the source where default values for EFs and any other parameters are provided

7. Is the method globally applicable so far as can be judged? The answer should be based on the availability, or likelihood of availability in the next future without need of significant additional resources, of activity data as national datasets or regional datasets or global datasets. In Column I "comments" you may provide for information about datasets availability

8. In the case the experts identify any gaps that need to be closed in the next future to allow for a global methodology, such gaps should be noted here with, where possible, guidance on research and/or data collection work considered to be needed

9. In providing any additional information/comment on any information compiled in any of the previous columns, first provide the letter of the column to which the comment applies

i) For each category a single row is compiled
ii) All SLCFs associated with the source-category listed
iii) Classification of biomass type for Forest Lands such as -Conifer forest, deciduous forest, mixed forest, grassland, shrubland, as well as in case of agro-residue burning (rice, wheat, sugarcane, oil seeds) and relevant emissions factors are major challenges faced by those working on development of emission inventory of SLCFs. Need to provide these sub-sectors. What about fuel use? What about biochar?
iv) It might be helpful to briefly look at how GFED, GFAS, FINN, other global fire databases do or do not improve our understanding of fire management and emissions from managed fires. Is there a grouping of fires into "wildfires"? Are "prescribed" fires evident or statistically modelled? Are there improved emission factors, combustion completeness, fuels, burning/management types from these fire models? How can they be compared with the IPCC approaches or not? Do they help with identifying peat or wetlands? Do they miss agricultural or grassland?
v) CO_2, CH_4, NO_X, CO from biochar production is in Table 4.3.3 in Volume 2 (Energy), in *2019 Refinement*
vi) Depends on silt % and best estimate of number of tilling passes. US estimates by crop type and tilling type. See NEI2017_tsd_AgDust in Teams folder for details
vii) 8% of US OC emissions and 5% of EC emissions not including wildfires. See NEI-AgDust.xlsx in Teams folder for all data.
viii) Not a significant source of OC or EC in US

Issue Paper (AFOLU sector)

Issues

I. *2006 IPCC Categories* 3.C.4 (Direct N_2O emissions from managed soils) and 3.C.5 (Indirect N_2O emissions from managed soils) well fit methods applied to estimate direct emissions of NOx and NH3 and indirect emissions of NOx respectively.
However, the category name should be then revised to be expanded to e.g. N-based GHGs (although N is also a component of other GHGs as Nitrogen trifluoride and other fluorinated, and Allyl cyanide).

II. Tier 1 methodology for NMVOCs emissions from manure over land (as applied fertilizer or as urine and dung deposited) is missing.

III. A new category non-present in the *2006 IPCC Guidelines* is reported as 3.D.2.x "Pesticide application" for NMVOCs emissions.
Methodological information is available in AP-42_9.2.2. The algorithm to calculate NMVOC from pesticide application requires to:

1. Determine both the application method and the quantity of pesticide product applied;
2. Determine the type of formulation used;
3. Determine the specific AI(s) in the formulation and its vapor pressure(s);
4. Determine the percentage of the AI (or each AI) present;
5. Determine the VOC content of the formulation.

IV. Three new categories for NMVOCs non-present in the *2006 IPCC Guidelines*, reported as:
   a. 3.D.2.x "Cultivated crops",
   b. 3.D.2.x "Managed deciduous/coniferous forests",
   c. 3.D.2.x "Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub)".

Methodological information is available in EMEP.

The methodology for cultivated crop requires as activity data the area cultivated for the specific crop, as parameters the dry matter of standing crop, the time length of the cultivation period, and the EF – EMEP guidance provides default values for all parameters and the EF.

The methodology for all other vegetation requires as activity data the area covered and as parameters the average potential emissions, the foliar biomass density, the environmental correction factor representing the effects of short-term (e.g. hourly) temperature and solar radiation changes on emissions integrated across the growing season, and the EF - EMEP guidance provides default values for all parameters and the EF; although the environmental correction factor is geographically-based and therefore need to be calculated for all non-EU geographical areas.

V. With reference to two new categories for NMVOCs listed at IV. i.e.:
   a. 3.D.2.x "Managed deciduous/coniferous forests",
   b. 3.D.2.x "Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub)".

These emissions would occur also in absence of any human actions and could therefore be considered just natural and therefore excluded from a national inventory. Although a component, e.g. from forest plantations, could be considered as a consequence of human actions and therefore included in the national inventory.

VI. A new category non-present in the *2006 IPCC Guidelines* is reported as 3.D.2.x "Fugitive dust from tilling" for BC, OC, NOx emissions as PMs associated with land tilling.
Methodological information is available in the US EPA NEI. The methodology requires as activity data the area tilled, and the EF needs to be measured or calculated starting from an emissions rate for which default values are not provided.

VII. PM is emitted by livestock, not only in manure management operations. PM emissions are therefore allocated in a new category non-present in the 2006 IPCC Guidelines as: 3.D.2.x “Fugitive dust from animals”. Speciation of PM in BC and OC is not explored by EMEP, while US EPA NEI provides for speciation of PM in OC, NOx. NH_3.
Methodological information is available in the US EPA NEI. The methodology requires as activity data the animal population and the EF is calculated by applying a particle size multiplier (defaults provided), a percent silt content (area specific), the number of passes/tillings over the area (defaults provided).

From the WASTE sector Issue paper

1. 5.B.2 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).

2. Open burning:
    a. 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. The method requires a prior knowledge of the weight of agricultural waste produced per hectare of forestry, orchard and farm so national area of forestry and orchard is required. In the *2006 IPCC Guidelines*, agriculture residue burning is considered in AFOLU sector.
    b. EPA NEI covers residential yard waste open burning, land clearing and residential household waste. The emissions from land clearing debris are estimated based on the number of acres disturbed from non-residential, residential, and road construction. The number of acres disturbed is multiplied by a fuel loading factor to determine the amount of land clearing debris burned in each county. This number is multiplied by emissions factors from AP42. In the *2006 IPCC Guidelines*, emissions from land clearing burning are considered in AFOLU sector.

3. Other waste EMEP: 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

Table 2 Category list (AFOLU)

A	B	D	J
IPCC code	Category[1]	SLCFs[2]	Comments
3.A.2	Manure Management		
3.A.2.a.i.	Dairy Cows	NO_x – NH_3 – NMVOCs	• *Main gap: the emission factors available from EMEP/AP-42/UNEP may likely not cover the entire variability of global agro-systems and practices.* • *There is a need to reconcile TAN and Nex in the EMEP and IPCC methods to estimate NOx and NH3 vs N2O.*
3.A.2.a.ii.	Other Cattle		
3.A.2.b	Buffalo		
3.A.2.c	Sheep		
3.A.2.d	Goats		
3.A.2.e	Camels		
3.A.2.f	Horses		
3.A.2.g	Mules & Asses		
3.A.2.h	Swine		
3.A.2.i	Poultry		
3.A.2.j	Other		
3.C.1	Burning		
3.C.1.a	Burning in Forest Land	NO_x – NH_3 – SO_2 – CO – NMVOC – BC & OC	• *Underlying assumptions of parameters/calculations need likely to be reconciled.* • *Factors/parameters values need to be updated with new literature*

3.C.1.b	Burning in Cropland		• *Tables 2.4, 2.5 and 2.6 of the IPCC 2006 GLs could be expanded to include open burning on cropland, which is not adequately represented in "prescribed burning" or "slash and burn".*
			• *IPCC 2006 GLs list four crop types (maize, wheat, rice, sugarcane) while other approaches are more detailed.*
			• *There is a need of more specific emission factors (NOx, SO2, etc.) for sugarcane burning, particularly in South and Central America, Southeast Asia.*
			• *During COVID-19 pandemic, connections were observed between solid waste burning and crop residue burning in Southeast Asia, and noted as a potential cross-sectoral issue.*
			• *For biochar production, BOG agreed on the followings:*
			  ○ *To ensure that all emissions are properly accounted for in the Energy or IP sectors (cross-sectoral issue);*
			  ○ *To assess the emissions from open-pit burning for biochar production.*

3.C.1.c	Burning in Grassland		
3.C.1.d	Burning in all other lands		• *There is supplemental guidance for peatland burning by soil types in the 2013 Supplement GLs on Wetlands.* • *There is a need to reconcile nomenclatures of soil types and land use categories.* • *Consistency in the land use definitions/categories should be assured.* • *Ignition/Burning types accounted in the US NEI (wildfire, prescribed fire, croplands) may not map to land use categories, since the US NEI method is not a Tier 1 method.*
3.C.4	Direct N2O emission from managed soil		• *This is a nomenclature issue* • *Emissions of NOx and NH3 are included under this category to reflect the need to reconcile methods.* • *Existing IPCC category cannot be changed, but new categories for NOx and NH3 emissions could be added for both direct and indirect emissions.*
3.C.4	Direct N_2O emissions from managed soils	NO_x – NH_3	For sources of N including Inorganic N fertilisers (includes urea); Sewage sludge applied to soils; Other organic fertilisers applied to soils (including compost); Crop residues applied to soils: • *To separate EF for NOx from EF for NH3 to avoid possible confusion.* • *To verify if EFs should be different when fertilizers are incorporated in the soils - for both NOx and NH3.*
3.C.4	Direct N_2O emissions from managed soils		For source of N including Livestock manure applied to soils; Urine and dung deposited by grazing livestock: • *Need to reconcile TAN (Total Ammonia Nitrogen) and Nex (Total Nitrogen Excreted) in the methods to estimate NOx and NH3 vs N2O.* • *It was noted that the default EFs do not represent grazing practices in South America.*
3.C.5	Indirect N2O emissions from managed soils		• *This is a nomenclature issue.* • *Emissions of NOx and NH3 are included under this category to reflect the need to reconcile methods.* • *Existing IPCC category cannot be changed, but new categories for NOx and NH3 emissions could be added for both direct and indirect emissions.* • *IPCC and EMEP GLs give different meaning to "indirect emissions".*
3.C.5	Indirect N_2O emissions from managed soils	NO_x	• *It was noted that indirect NOx emissions from managed soils can cause NOx emissions to managed and natural soils.*

A	B	D	J
IPCC code	Category[1]	SLCFs[2]	Comments
			• *Tier 1 EF should be used.*
3.D.2	Other		• *There is none IPCC method available.* • *Alternative methods estimated at Tier 2 only.* • *If a default method is needed, alternative methods have to be reconciled.*
3.D.2.x	Other: "Livestock manure applied to soils"	NMVOCs	• *BOG agreed that the current knowledge of this source category is insufficient to be considered in the upcoming methodology report.*
3.D.2.x	Other: "Urine and dung deposited by grazing livestock"	NMVOCs	• *Literature review by TSU to assess the significance of this source category is still on-going.* • *BOG agreed that this source deserves further consideration and investigation.*

3.D.2.x	Other: "Manure incineration"	NOx – NH3 – SO2 – CO – NMVOC – BC & OC	• *This is cross-sectoral between Energy, AFOLU and Waste sectors.*
			• *There is a need to reconcile TAN and Nex in the methods to estimate NOx.*
			• *BOG agreed on the followings:*
			  ○ *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.*
			  ○ *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 should be reported in the Waste sector.*

3.D.2.x	Other: "Anaerobic digestion of animal manure"	NH3, NOx	• *This is cross-sectoral between AFOLU and Waste sectors*
			• *BOG agreed on the followings:*
			  1. *To use the same allocation as IPCC for reporting emissions from on-farm digesters (AFOLU), with clarification regarding the allocation of emissions during the transfer of manure between facilities and farms.*
			  2. *To maintain on-farm manure storage, application of digestate in AFOLU sector.*
			  3. *To ensure methodological integrity in all manure-related emission sources (N mass balance)*

3.D.2.x	Other: "Pesticide application"	NMVOCs	• *US NEI method may not be applicable globally due to its complexity and due to the lack of data on global pesticide use.* • *Current knowledge may be insufficient to support the development of globally applicable methods.* • *BOG agreed that this source deserves further consideration and investigation.*
3.D.2.x	Other: "Cultivated crops"	NMVOCs	• *Estimation method is simple, but uncertainty is very large.* • *Current knowledge may be insufficient to support the development of globally applicable methods.* • *BOG agreed that this source deserves further consideration and investigation, especially on the main drivers including crop types, leaf area and environmental conditions.*
3.D.2.x	Other: "Managed deciduous/coniferous forests"		• *Estimation method is simple, but uncertainty is very large.* • *Current knowledge may be insufficient to support the development of globally applicable methods.* • *BOG agreed that this source deserves further consideration and investigation, especially on the main drivers including crop types, leaf area and environmental conditions.*
3.D.2.x	Other: "Grassland; Tundra; Other Low Vegetation; Other Vegetation (Mediterranean shrub)"		• *Estimation method is simple, but uncertainty is very large.* • *Current knowledge may be insufficient to support the development of globally applicable methods.* • *BOG agreed that this source deserves further consideration and investigation, especially on the main drivers including crop types, leaf area and environmental conditions.*
3.D.2.x	Other: "Fugitive dust from tilling"	BC – OC – NO_x	• *BOG agreed to consider tilling as a significant source of OC and EC from PM10, based on an assessment of available data and monitoring tools.* • *US NEI method may not be applicable globally due to its complexity.* • *Parameters involved in the US NEI method may not reflect crops, technologies or practices in other countries.*
3.D.2.x	Other: "Fugitive dust from animals"	OC – NO_x – NH_3	• *BOG agreed that the knowledge is insufficient to consider this source of SLCFs in the upcoming methodology report.*

1. For each category a single row is compiled
2. All SLCFs associated with the source-category listed

Table 1 Summary Information (Waste)

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
4.A	**Solid Waste Disposal**							**Comments from Experts:** B) It is the view of the experts that burning from landfill fires and flaring should be reported under 4A, not 4C (but this source should use methodology and guidance for Open Burning 4C2). B) The experts recommend that emissions from flaring, landfill fires, and decomposition processes be estimated separately for each managed, unmanaged, and uncategorised landfill types. E) For landfill fires – compilers will need to cross check the activity data between the proposed methods and the first order decay (FOD) method to avoid double counting of emissions (because waste burning will reduce the amount of organic material available for decomposition). E) Experts suspect that there may be more burning at unmanaged sites. Might also need to distinguish between shallow and deep sites in future guidelines. E) Experts discussed that 2006 IPCC Guidelines distinguish managed/unmanaged sites based on cover material and compactness of waste at each site (need to know aeration conditions at landfills for GHGs). We may need to apply a similar approach and use weighted correction factors (like methane correction factor). CROSS-SECTORAL (with Energy sector) - biogas collected from landfills is used for energy and emissions should be in that sector. CROSS-SECTORAL (with Energy sector) - energy used to manage the landfill sites should be considered in the energy sector.
4.A.1	Managed Waste Disposal Sites							
4.A.1.a	Managed Waste Disposal Sites	PM (BC/OC), NOx, CO,	No, but methods for Open	-	Information on estimating activity data	Yes	Limited activity data available (amount of	**Comments from Experts:** C) Burning emissions will be important at the local level, may be less important at the national level, and may not be significant at the global level.

[1] Apply here the *2006 IPCC Guidelines* categorization. If the *2019 Refinement* has a specific category while the *2006 IPCC Guidelines* have not, use it and note that it is a *2019 Refinement* category.
[2] Use the IPCC category name or use "Others" for all those categories for which IPCC does not provide a specific categorization followed by the name of the new category taken from relevant guidebook/sourcebook/guidelines. If the *2019 Refinement* has a specific category while the *2006 IPCC Guidelines* have not, use it and note that it is a *2019 Refinement* category.
[3] List here SLCFs for which the method, as noted in Column E, applies. Where different methods apply to different SLCFs from the same source-category, compile a row of information for each method.
[4] Is an applicable IPCC method available?
In the case the IPCC method needs modifications further than providing for the SLCF EF to be applicable, answer "yes with modifications" and possibly provide in the comment box indication on the modification needed. Examples of modifications are, additional parameters, e.g., technologies, and/or additional data to ensure full coverage of SLCF emissions.
[5] In the case the IPCC methodology is not applicable or there is not an IPCC methodology for the listed category (i.e., Column D has been compiled with "No"), provide the reference to any other methodological source from which the category is sourced.
[6] Provide reference to the source where default values for EFs and any other parameters are provided.
[7] Is the method globally applicable so far as can be judged? The answer should be based on the availability, or likelihood of availability in the next future without need of significant additional resources, of activity data as national datasets or regional datasets or global datasets. In Column I "Comments" you may provide for information about datasets availability.
[8] In the case the experts identify any gaps that need to be closed in the next future to allow for a global methodology, such gaps should be noted here with, where possible, guidance on research and/or data collection work considered to be needed.
[9] In providing any additional information/comment on any information compiled in any of the previous columns, first provide the letter of the column to which the comment applies.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
	– Landfill fires	NMVOC, SO_2	Burning (4C2) may be an applicable starting point		and EFs for open burning is available in IPCC 4C2 (may not be landfill specific)		waste burned). Activity data is particularly uncertain for this category and will remain uncertain, but is an important category to include Limited EF data available (though there may be a few measurements available)	H) There is no methodology or guidance that the experts are aware of to help countries estimate the amount of waste burned at landfills specifically. This activity data will likely need to be based on measurements. C) Future authors should consider the significance of SO_2 emissions from this source SO_2 emissions would depend on the S content of the waste. E) This category should include emissions from intentional and unintentional fires. E) The authors may have to review the applicability of the Open Burning methods (municipal solid waste – Equation 5.7, Chapter 5, Volume 5 of the 2006 IPCC Guidelines) to emissions from landfill fires. MSW in the 2006 IPCC Guidelines may not include waste landfilled. E) It is the practice in some areas to empty small local landfills by burning them. C/E) Default speciation for NMVOC could be considered as the same as for open burning of municipal waste (there may not be landfill fire-specific studies). The experts have identified this as a gap.
4.A.1.b	Managed Waste Disposal Sites – Flaring	PM (BC/OC), NOx, CO, NMVOC, SO_2	No	SO_2 – mass balance; see Comments for other possible methodological references	May be available parameters in AP-42, EMEP	Methods yes, but there may be differences in flare efficiencies	Refine existing methods so that they are applicable to derivation of a Tier 1 method	**Comments from Experts:** D) Note that flaring emissions (for GHGs) from landfills in the 2006 IPCC Guidelines are not treated at a Tier 1 level. E) These emissions will depend on the efficiency of the flare. C) SO_2 emissions would depend on the S content of the flared gas. Mass balance could be used to covert H_2S to SO_2. These emissions will be small relative to other categories of SO_2 emissions. E) Methods may be available from EMEP Chap. 1B2C (https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-b-fugitives/1-b-2-c-venting/view). E) There may be information in AP-42 Section 2.4 MSW landfills (Table 2.4.4 – flares treated as a control device from landfills, includes emission rates, https://www3.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf). Key update would be the estimation of fraction burned. E) New research in Estonia highlighted emissions can be site specific (https://www.klab.ee/wp-content/uploads/2017/01/KHG-inventuuri-j%25C3%25A4%25C3%25A4tmesektori-arendust%25C3%25B6%25C3%25B6.pdf) E) The landfill biogas flares will be a lower temperature than other (e.g., industrial) flares, which will impact the EFs. C) for all compounds, this source is likely significant at the local level, less significant at the national and global levels. E) EF could be expressed as compound per volume biogas flared. C) NOx emissions may be a significant source at the local, but not national level. C/E/H) There is limited information on PM or NMVOC speciation. It might be difficult to find a proxy based on industrial or fugitive flaring.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
4.A.1.c	Managed Waste Disposal Sites – Other (decomposition)	CO	No	NEI (uses AP42 EF)	CO	No to EFs but methodology yes (requires derivation of EFs)	No globally applicable Tier 1 information on EFs	**D:** Method requires concentration of pollutant in landfill gas. See the Waste sector compilation table. **Comments from Experts:** E/F) Methodology may be globally applicable but the EF (which relies on default CO concentrations at landfills, described in Section 3.5 of the 2017 NEI Technical Support Document) is not globally applicable. E/F) Activity data could be based on co-emitted methane emissions from managed landfills.
		NMVOC	No	EMEP/EEA	NMVOC	No to EFs but methodology yes (requires derivation of EFs)	No globally applicable Tier 1 information on EFs	**C:** Method/Emission factor (EF) for PM2.5 is provided but not for BC. **D:** National total waste deposited to landfills multiplied by EF. See the Issue Paper. **F:** For NMVOC, see the Waste sector compilation table (feedback in cell R9). **Comments from Experts:** E) EMEP method would need to be updated before incorporation by the IPCC (updated to use similar approach to NEI method, which uses a ratio of CO to CH_4 emissions for landfills) F) Activity data could be based on co-emitted methane emissions from managed landfills
		NH_3	No	Yes (?)	?	?	?	**Comments from Experts:** C) New research shows that NH_3 may be emitted from landfills.
4.A.2	Unmanaged Waste Disposal Sites							
4.A.2.a	Unmanaged Waste Disposal Sites – Landfill fires	PM (BC/OC), NOx, CO, NMVOC, SO_2	No, but methods for Open Burning (4C2) may be an applicable starting point	-	Information on estimating activity data and EFs for open burning is available in IPCC 4C2 (may not be landfill specific)	Yes	Limited activity data available (amount of waste burned) Limited EF data available (though there may be a few measurements available)	**Comments from Experts:** E/H) The methods will be the same as for managed landfills (4.A.1.a). There will be the same challenges for deriving activity data and EFs for unmanaged landfills. E) It is the practice in some areas to empty small local landfills by burning them. May have more fires than managed sites. H) It is not clear how EFs (or gas concentrations) are different between managed and unmanaged landfills.
4.A.2.b	Unmanaged Waste Disposal Sites – Flaring	n/a	n/a	n/a	n/a	n/a	n/a	**Comment from Experts:** C) It is the consensus of the experts that there is likely little or no flaring at unmanaged landfills.
4.A.2.c	Unmanaged Waste Disposal Sites – Other (decomposition)	CO, NMVOC, NH_3 (?)	No	Yes, NEI, EMEP (same as 4.A.1.c)	It is unclear how parameters might differ between managed and unmanaged landfills	Methods may be globally applicable, but not EFs	No globally applicable Tier 1 information on EFs	**Comments from Experts:** E/F) The method for this sub-category will be the same as for managed landfills (4.A.1.c), but the EFs and activity data may be different. F/H) It is unclear how EFs (or gas concentrations) are different between managed and unmanaged landfills. E/H) It is unclear if NH_3 is produced from uncategorized sites (recent research is only for managed sites, no information on unmanaged sites).

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
4.A.3	Uncategorised Waste Disposal Sites							
4.A.3.a	Uncategorised Waste Disposal Sites – Landfill fires	PM (BC/OC), NOx, CO, NMVOC, SO_2	No, but methods for Open Burning (4C2) may be an applicable starting point	-	-	-	-	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
4.A.3.b	Uncategorised Waste Disposal Sites – Flaring	PM (BC/OC), NOx, CO, NMVOC, SO_2	No	-	-	-	-	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
4.A.3.c	Uncategorised Waste Disposal Sites – Other (decomposition)	CO, NMVOC, NH_3 (?)	No	-	-	-	-	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
4.B	**Biological Treatment of Solid Waste**							**Comments from the Experts:** B) The experts recommend that emissions from anaerobic digestion be distinguished in a separate sub-category from composting. C) The experts have concluded that flaring emissions at anaerobic digestion treatment plants (NOx) are possible but negligible (could be included in future GL for completeness). CROSS-SECTORAL – note Issue 2
4.B.1	**Biological Treatment of Solid Waste – Composting**	NH_3 CO	NH_3 (Composting) : Yes CO (Composting) : Yes	EMEP/EEA	NH_3 (Composting) CO (Composting)	Yes (as per IPCC method), no to EFs	Methods are globally applicable, but the EFs are not	**F:** No Tier 1 (T1) EFs for NH_3 and CO emissions from composting. See the Issue Paper. **Comments from Experts:** E) Per EMEP guidance, sludge composting should be included in 4.B.1
		NH_3 NMVOC	NH_3 (Composting) : Yes (T2) NMVOC (Composting) : Yes (T2)	EPA NEI	NH_3 NMVOC (VOC)	Yes (as per IPCC method). EFs not globally applicable.	Limited information on activity data (amount of green waste) and no globally applicable EFs	**B:** Reported under 4.A.1 Managed Solid Waste Disposal Sites. See the Waste sector compilation table. Requires amount of yard trimmings and food waste recovered for compositing and population, then EFs applied from the California Air Resources Board (see compilation table). **Comments from Experts:** E) This method is only applicable to composting of residential yard scraps and food (e.g., 'green waste', not biosolids from wastewater treatment plants or manure management facilities).
4.B.2	**Biological Treatment of Solid Waste – Anaerobic**	NH_3	NH_3 (Anaerobic digestion): No	EMEP/EEA	NH_3 (Anaerobic digestion)	Yes (to be confirmed). There is a Tier 1	Tier 1 EF could be improved. Emission of N in NH_3 per N in	**D:** The method considers the potential for NH_3 emissions from the following sources: during storage of feedstock on the premises of the biogas facility and during storage of the digestate. T1 approach estimates the total emissions, and total annual amount of N in the feedstock is used for estimation of NH_3 emissions.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
	Digestion					method without considering differences pre- and post-treatment. Tier 2 accounts for the type of waste digested	feedstock (so need to know the N content of the feedstock, default values provided in EMEP/EEA, but the list may not be complete)	Anaerobic digestion at biogas facilities 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. See the Issue Paper. **Comments from Experts:** CROSS-SECTORAL - The experts note that it will be important to cross check with the AFOLU sector (manure management) on the correct accounting of emissions within the Waste sector of the storage (of stock piling) of pre- (feedstock) and post-treatment product (digestate), as well as treatment stage (to make sure that there is no double counting, and that Nitrogen flow models account for changes in N correctly). The emissions from storage of feedstock may not be large due to short storage times. (AFOLU) 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. E/F) The farmer will need to know how much organic waste (or type of waste) that was added to the manure in the digestor. There may be defaults for added waste types E/H) Emissions should be treated under the waste sector if routed to off-site (off-farm) biological treatment facilities. F) N content may be regionally dependent for municipal waste and from farms
4.C	**Incineration and Open Burning of Waste**							**Comments from Experts** CROSS-SECTORAL (AFOLU) – experts recommend that emissions from agricultural waste burning on fields should be considered in AFOLU. The classification of fire types included in this category needs to be clarified (e.g., **waste burning on farms/orchard, etc. of crop residues (e.g., cereal crops, peas, beans, soya, sugar beet, oil seed rape, etc.), wood, pruning, slash, leaves, plastics, and other general wastes)** CROSS-SECTORAL (Energy) – agricultural waste burning for energy should be considered in the Energy sector
4.C.1	Waste Incineration	NOx NH_3 SO_2 CO NMVOC BC OC	Yes	AP42 EMEP/EEA EPA NEI UNEP	**NOx:** AP42, EMEP/EEA, UNEP **NH_3:** EMEP/EEA **SO_2:** AP42, EMEP/EEA, UNEP C**O:** AP42, EMEP/EEA, UNEP **NMVOC**: EMEP/EEA, UNEP **BC:** EMEP/EEA, EPA/NEI, UNEP **OC:** EPA/NEI, UNEP	Yes (as per IPCC method)	Conditions are variable (e.g., different moisture content, level of smolder, etc.) and will need to be considered further.	**B** (EMEP/EEA): Categories by type of waste: municipal waste incineration, industrial waste incineration, hazardous waste incineration, clinical waste incineration, sewage sludge incineration, cremation. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** B/E/F) Emissions from waste incineration will vary based on waste type, combustion technology used, the use of emission controls, and operational conditions. It is the consensus of the experts that the methods across all waste and technology types will likely be that same, therefore the experts recommend keeping 4.C.1 as a single category. However, Tier 1 EFs will need to be technology dependent, waste type. Guidance on ensure timeseries consistency can be informed by guidance in the 2019 Refinement. F) Future guidelines will also need to include a table on different abatement efficiencies CROSS-SECTORAL – Emissions from waste incineration (to avoid double counting) … - *with energy recovery should be included in Energy, not Waste* - *without energy recovery should be included in Waste, not Energy* Note: if it is difficult to split emissions between (1) and (2), it will be important that all waste incineration emissions are reported either under Energy OR Waste and record where emissions are reported E) Cremation (human and animal) – there will be large regional differences that will likely need regional default factors. This is an important source of PM at the local level, but further investigation is needed as to whether or not this is a significant source on the national or global scale. Both the US NEI (AP-42) and EMEP have some guidance on activity data and EFs.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
								C) Per convention, do not need to consider whether CO is fossil or not (assume CO_2 emissions include all oxidation products). E) Per EMEP guidance, sludge incineration should be included in 4.C.1. E) Old report from US EPA "AIR EMISSIONS FROM SCRAP TIRE COMBUSTION", year 1997 https://www3.epa.gov/ttncatc1/dir1/tire_eng.pdf particulate matter, metals, PAHs (laboratory measurements).
		NOx SOx CO NMVOC BC OC	No	J-STREAM	NOx SOx CO NMVOC BC OC	Cannot be determined at this time	Cannot be determined at this time	**F:** EFs are for T2. **D:** Fuel consumption times emission factor. In the 2006 IPCC Guidelines, amount of waste incinerated is used as AD. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** No additional comments (no J-STREAM experts in the BOG meetings)
4.C.2	Open Burning of Waste	NOx NH_3 SO_2 CO NMVOC BC OC	Yes	AP42 EPA NEI UNEP	**NOx:** AP42, EPA NEI (AP42), UNEP **NH_3:** UNEP **SO_2:** AP42, EPA NEI (AP42), UNEP **CO:** AP42, EPA NEI, UNEP **NMVOC:** EPA NEI (VOC), UNEP **BC:** EPA NEI (AP42), UNEP **OC:** EPA NEI (AP42), UNEP	Yes (as per IPCC method). EFs from the NEI are dependent on land cover type and EFs are likely not globally applicable.	Equation to estimate amount of waste burned needs to be reviewed.	**B** (EPA NEI): Residential yard waste and residential household waste. **B** (UNEP): Municipal solid waste open burning. There are two kinds of burning activities: burning at source (i.e., community that generates the solid waste) and burning at disposal sites. **D** (EPA NEI)**:** Yes (T2) See the Waste sector compilation table. **Comments from Experts:** E) Experts recommend that three parameters required for estimation: a) Fraction of household waste, b) fraction of household waste burned, c) fraction that (ultimately) oxidizes to CO_2. D/E/F) Note on the B_{frac} parameter in the current GHG guidelines, the definition of B_{frac} needs to be clarified in future guidelines. The GHG guidelines were developed for CO_2 and need to be refined for SLCFs (however, the current approach may also need to be updated for GHGs). This was discussed in the process of the 2019 Refinement, but was not updated at that time for GHGs. - The current default for B_{frac} - 60% of waste burned is too high. There is not a lot of literature on this, but this needs to be reviewed. D/E/F) The current assumption in the 2006 IPCC Guidelines is also that waste is only burned in rural areas (not burned in urban areas). This assumption needs to be reviewed further as there is evidence that waste is burned in urban areas (at least in Mexico, Africa, and Brazil). Based on survey data in Brazil, urban waste was burned due to infrequent urban trash collection. Also consider: African Waste Management Outlook. https://www.sciencedirect.com/science/article/abs/pii/S0048969720362653?via%253Dihub E/F) A general methodology approach could also be Emission = A *EF, where A = waste generated per capita * amount of waste burned. But this approach will likely need regional parameters and should be investigated by future authors. Note that waste generated per capita could be investigated based on socioeconomic class. E) There are other nuances in waste composition and the possibility of multiple disposal methods in locations without municipal collection. F) Organics and plastics are a large fraction of waste in developing countries and the waste composition would impact emission. factors F) Reference – A reference (currently under review) that provides a summary of ~100 studies of EFs and fractions of waste being open burned around the world.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
								F) Cook and Velis (2021) open burning of plastics – provides estimates for the mass of solid waste open burned in LIMIC and HIC countries based on a detailed review.
		NOx SO_2 CO NMVOC BC	No	EMEP/EEA	NOx SO_2 CO NMVOC BC	No. Tier 1 EF based on vegetation type. May not be globally applicable. Waste composition will vary globally	EF only deals with agriculture, mixed MSW is missing in the EMEP guidance	**B:** 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. The method requires a prior knowledge of the weight of agricultural waste produced per hectare forestry, orchard and farmland. In the 2006 IPCC Guidelines, agriculture residue burning is considered in AFOLU sector. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** F) EMEP EFs do not include a mixed municipal solid waste, some of these may be available in energy chapters. B/E) EMEP guidance does include car and building fires. These should be considered under category 4.E. B/E) It is the consensus of the authors that emissions from Tire burning should be included in this category (4.C.2). In the EMEP guidance, tires are treated as a type of waste, but there is no EF. Since category 4.C does not consider whether fires are intentional or unintentional, all tire burning can be under 4.C.2. If the tires are being burned in the landfill, those emissions would be in the landfill category.
		NOx SO_2 CO NMVOC (VOC) BC OC	No	EPA NEI	NOx SO_2 CO NMVOC (VOC) BC OC	-	-	**B:** Land clearing. In the 2006 IPCC Guidelines, emissions from land clearing burning are considered in AFOLU sector. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** CROSS-SECTORAL – Emissions from 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.
4.D	**Wastewater Treatment and Discharge**							**General Comments from Experts:** E/H) Emissions from **leachate** – **leachate** could be directed back to landfill or directed to treatment plants. In some cases, this might be treated onsite. One suggestion from experts is to include these emissions in 4.D.2, unless the treatment is occurring at the landfill site, then this should be included in landfill emissions. C) There could be PM emissions from aeration, but these are likely small. There needs to be further investigation on whether or not this is a significant source. B/E) Emissions from anaerobic digestion at treatment facilities should be included in 4.D. (likely are included already). Emissions from flaring (where there is no energy recovery) from anaerobic wastewater treatment with methane capture – should be considered. C/E) It is worth considering whether the NH_3 emission methodology should be based on existing N_2O methods vs. CH_4 (emissions will depend on the amount of N). CROSS-SECTORAL - (Energy) – Emissions from the combustion of biogas collected for energy recovery purposes should be included in Energy, not Waste. Note: If flared (without energy recovery), included in Waste.

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
4.D	**Wastewater Treatment and Discharge**	NMVOC	No	EMEP/EEA	NMVOC	Method (yes) EF (no – based on 1 localised study)	EF for NMVOC needs an update	**B:** Activities considered within the 5.D Wastewater Handling sector are biological treatment plants and latrines (storage tanks of human excreta, located under naturally ventilated wooden shelters). Includes 5.D.1 Domestic wastewater handling, 5.D.2 Industrial Wastewater handling and 5.D.3 Other wastewater handling. **F:** According to the EMEP/EEA Guidebook, EF (T1) for NMVOC emissions for 5.D Wastewater Handling has been derived from one study, and it may not be applicable to all wastewater treatment plants. **D:** AD (T1) is total amount of wastewater handled by all wastewater treatment plants in the country. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** F) The EMEP/EEA NMVOC EF is highly uncertain and likely not globally applicable. This EF is applied to both industrial and domestic treatment facilities.
		NH_3 NMVOC	No	EPA NEI	NH_3 NMVOC (VOC)	Method may be globally applicable, but it may be difficult to collect national information on wastewater flow rates. EFs may also not be globally applicable	Potentially limited data on wastewater flow rate	**B:** Does not split into domestic and industrial. **D:** Method is based on the wastewater flow rate. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** F/H) In the current NEI method, the EF is not technology dependent. However, these emissions are likely also sensitive to technology and operating conditions. This should be reviewed.
4.D.1	Domestic Wastewater Treatment and Discharge	NH_3	No	EMEP/EEA	NH_3	Method yes, EF is not country specific and therefore is applicable to Tier 1	EFs are only for latrines	**F:** NH_3 EF is for T2 (latrines). **Comments from Experts:** B) Commercial wastewater treatment emissions should be included in 4.D.1. The wastewater composition could vary for industrial and commercial sources. B) Untreated wastewater emissions would fall under 4.D.1.
		NH_3	No	National Institute of Environmental Research	NH_3	EF= NH_3 per ton waste water handled. It cannot be determined if this EF is globally applicable at this time. But the method could be applied globally	EFs are only for latrines	**D:** AD is mass of wastewater handled. See the Waste sector compilation table. **Comments from Experts:** No further comments (no NIER experts in the Waste BOG discussions).

A	B	C	D	E	F	G	H	I
IPCC code[1]	Category[2]	SLCF[3]	IPCC method applicable[4]	Alternative methodology[5]	Available EFs/ parameters[6]	Globally applicable?[7]	Gaps (if any)[8]	Comments[9]
4.D.2	Industrial Wastewater Treatment and Discharge	NMVOC	No	The IPCC methodology could be a starting point	NMVOC	Method (yes). No available EFs	EF data are needed for different industries	**D:** AD is amount of wastewater handled. **F:** According to the EMEP/EEA Guidebook, T2 EF is based on one study, and it may not be applicable to all wastewater treatment plants. **Comments from Experts:** E) EFs would depend on the type of industry
4E	**Other**							No guidance in the IPCC Guidelines
	Others: 5.E Other waste	NH_3	No guidance in the IPCC Guidelines	EMEP/EEA	NH_3	No	For cars (need to develop EFs as a function of car weight). Buildings method is not globally applicable	**B:** Activities covered under this category are sludge spreading, car fires and house fires. However, according to the 2006 IPCC Guidelines, sludge spreading is considered in AFOLU sector. **D:** For sludge spreading, the relevant activity statistics are the standard statistics on sludge production and the fraction that is dried by spreading. For accidental fires, activity data can be obtained from national statistics or national emergency management agencies. **F:** No T1 EFs. NH_3 EF (T2) for sludge spreading. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** CROSS-SECTORAL - (Energy/Waste) – There are emissions from different uses/treatment of sludge (e.g., co-firing with coal in cement industry (Energy), landfilling (Waste), biological treatment (Waste) CROSS-SECTORAL – sludge spreading in EMEP (NH_3) – In the EMEP guidance, N_2O emissions from this source are included in AFOLU and NH_3 emissions are included under 4E. For consistency, the experts recommend that NH_3 emissions from sludge spreading be included in AFOLU rather than waste. B/F/G/H) EMEP guidance for cars and building fires should be included here. However, methods and EFs are likely not globally applicable. Cooking exhaust: **D:** Times of meals multiplied by emissions. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** No further comments (not J-STREAM experts in the Waste BOG discussions). CROSS-SECTORAL – this source should be considered in the energy sector, not waste.
	Others: Cooking exhaust	BC OC	No guidance in the IPCC Guidelines	J-STREAM	BC OC	No additional information is available at this time	No additional information is available at this time	**D:** Times of meals multiplied by emissions. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** No further comments (not J-STREAM experts in the Waste BOG discussions). CROSS-SECTORAL – this source should be considered in the energy sector, not waste.

Note 1 : In this document "EMP/EEA" refers to the EMEP/EEA 2019 Guidebook
Note 2 : Each time a method is required for BC/OC, a method must also be defined for PM2.5 (indeed BC/OC is often estimated as a fraction of PM2.5)

Issue Paper (Waste sector)

Issues:

4.A Solid Waste Disposal

1. Method/Activity data: The methods in AP42 and EMEP/EEA 2019 Guidebook don't overlap with IPCC method (AP42 method requires concentration of pollutant in landfill gas). However, annual amount of waste deposited in solid waste disposal sites are used in both IPCC First-order Decay (FOD) method and EMEP/EEA 2019 Guidebook method – the same activity data (AD) can be shared for estimation of emissions.

For both EPA NEI and EMEP/EEA guidance, the methods for decomposition at solid waste disposal sites are likely globally applicable, however the EFs are likely not globally applicable.

There was no discussion of activity data

4.B Biological Treatment of Solid Waste

1. Category: In the EMEP/EEA 2019 Guidebook, composting and anaerobic digestion are separate categories. The method in the *2006 IPCC Guidelines* covers both composting and anaerobic digestion as types of biological treatment of solid waste.

The experts recommend that anaerobic digestion be covered under 4.B.1 and composting be covered under category 4.B.2

2. Cross-sectoral: 5.B.2 Biological treatment of waste – Anaerobic digestion at biogas facilities (EMEP/EEA 2019 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). The issue is shared with AFOLU sector (Issue paper).

   The experts should confirm with AFOLU BOG that manure digestion emissions are covered in AFOLU and not Waste.

3. Method/Activity data: 5.B.2 Biological treatment of waste – Anaerobic digestion at biogas facilities (EMEP/EEA 2019 Guidebook) considers the potential for NH_3 emissions from the following sources of biogas facilities: during storage of feedstock on the premises of the biogas facility and during storage of the digestate. Tier 1 approach estimates the total emissions and requires total annual amount of N in the feedstock entering the biogas plants. However, amount of waste anaerobically treated is used as AD in Waste sector method of the *2006 IPCC Guidelines*.

The experts suggest that the compilers need to be aware of this to make sure there is no double counting in any nitrogen flow models applied.

4. Emission factor: No Tier 1 EFs for NH_3 and CO emissions from composting in the EMEP/EEA 2019 Guidebook.
   Correct, there are no Tier 1 EFs for composting from EMEP/EEA or EPA NEI guidance

4.C Incineration and Open Burning of Waste

4.C.1 Waste Incineration

1. Category: The EMEP/EEA 2019 Guidebook divides into sub-categories by type of waste: municipal waste incineration, industrial waste incineration, hazardous waste incineration, clinical waste incineration, sewage

sludge incineration and cremation. The method in the *2006 IPCC Guidelines* covers these sub-categories (no guidance on cremation) as types of waste.
It was the consensus of the experts that the methods for 4.C.1 are likely the same for all types of waste and should be kept as a single category. However, the EFs will need to be technology dependent, there will need to be information on abatement efficiencies, and some types of waste may require different methods, based on the details of the technology.

2. Method/Activity data/Cross-sectoral: 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. The issue is shared with Energy sector (Issue paper).

   There were no JSTREAM experts in the Waste BOG to provide further comments

4.C.2 Open Burning of Waste

1. Cross-sectoral:

   I. EMEP/EEA 2019 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. The method requires a prior knowledge of the weight of agricultural waste produced per hectare of forestry, orchard and farm so national area of forestry and orchard is required. In the *2006 IPCC Guidelines*, agriculture residue burning is considered in AFOLU sector. The issue is shared with AFOLU sector (Issue paper).

   Waste BOG should confirm with AFOLU BOG that crop residue burning is included in AFOLU and not waste.

   II. EPA NEI covers residential yard waste open burning, land clearing and residential household waste. The emissions from land clearing debris are estimated based on the number of acres disturbed from non-residential, residential, and road construction. The number of acres disturbed is multiplied by a fuel loading factor to determine the amount of land clearing debris burned in each county. This number is multiplied by emissions factors from AP42. In the *2006 IPCC Guidelines*, emissions from land clearing burning are considered in AFOLU sector. The issue is shared with AFOLU sector (Issue paper).

   Waste BOG should confirm with AFOLU BOG that land clearing emissions are included in AFOLU and not Waste.

<u>4.D Wastewater Treatment and Discharge</u>

1. Category: EPA NEI does not split into domestic and industrial.
   The EPA NEI methods and activity data consider wastewater treatment at commercial, industrial, and domestic publicly owned treatment works. Therefore, this EF is likely not globally applicable and cannot be used for the individual sub-categories.

2. Method/Activity data:

   I. Tier 1 approach for 5.D Wastewater Handling (EMEP/EEA 2019 Guidebook) applies the total amount of wastewater handled by all wastewater treatment plants in the country as AD. Activities considered within the 5.D Wastewater Handling category (EMEP/EEA 2019 Guidebook) are biological treatment plants and latrines. In the *2006 IPCC Guidelines*, amount of organically degradable material (and other parameters) and amount of N in wastewater/effluent are used for estimation of CH_4 and N_2O emissions from wastewater treatment and discharge, respectively.
   II. EPA NEI method is based on the wastewater flow rate.

There is likely limited availability of wastewater flow rates at facilities, and a more globally applicable approach may be to account for the amount of waste handled at a treatment facility, following EMEP/EEA guidance.

2. Emission factor: According to the EMEP/EEA 2019 Guidebook, Tier 1 EF for NMVOC emissions for 5.D Wastewater Handling category has been derived from one study and it may not be applicable to all wastewater treatment plants.

   Correct, the EF for NMVOC is highly uncertain and not globally applicable.

4.E Other

2006 IPCC Guidelines: Emissions from other waste handling activities than listed in categories 4A to 4D categories. No guidance.

Other: 5.E Other waste (EMEP/EEA 2019 Guidebook)

1. Cross-sectoral: 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. The issue is shared with AFOLU sector (Issue paper).

   It is the consensus of the experts that car and building fires be included in category 5E. The Waste BOG should confirm with the AFOLU BOG that sludge spread on agricultural land should be included in AFOLU and not Waste.

2. Method/Activity data: For sludge spreading, the relevant activity statistics are the standard statistics on sludge production and the fraction that is dried by spreading. For accidental fires, activity data can be obtained from national statistics or national emergency management agencies.

   For cars, it may be possible to develop a globally applicable EF, but there will be no globally applicable EF for buildings. The Waste BOG did not discuss sources of activity data.

Other: Cooking exhaust (J-STREAM)

1. Method: Times of meals multiplied by emissions (See the Waste sector compilation table). The issue is shared with Energy sector (Issue paper).

   Waste BOG did not provide further comments

Table 2 Category list (Waste)

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
4.A Solid Waste Disposal			**Comments from Experts:** B) It is the view of the experts that burning from landfill fires and flaring should be reported under 4A, not 4C (but this source should use methodology and guidance from Open Burning 4C2). B) The experts recommend that emissions from flaring, landfill fires, and decomposition processes be estimated separately for each managed, unmanaged, and uncategorised landfill types. E) For landfill fires – compilers will need to cross check the activity data between the proposed methods and the first order decay (FOD) method to avoid double counting of emissions (because waste burning will reduce the amount of organic material available for decomposition). E) Experts suspect that there may be more burning at unmanaged sites. Might also need to distinguish between shallow and deep sites in future guidelines. E) Experts discussed that the 2006 IPCC Guidelines distinguish managed/unmanaged sites based on cover material and compactness of waste at each site (need to know aeration conditions at landfills for GHGs). We may need to apply a similar approach and use weighted correction factors (like methane correction factor). CROSS-SECTORAL (with Energy sector): biogas collected from landfills is used for energy and emissions should be in that sector. CROSS-SECTORAL (with Energy): energy used to manage the landfill sites should be considered in the energy sector.
4.A.1	Managed Waste Disposal Sites		
	Landfill fires	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comments from Experts:** C) Burning emissions will be important at the local level, may be less important at the national level, and may not be significant at the global level H) There is no methodology or guidance that the experts are aware of to help countries estimate the amount of waste burned at landfills specifically. This activity data will likely need to be based on measurements. C) Future authors should consider the significance of SO_2 emissions from this source SO_2 emissions would depend on the S content of the waste. E) This category should include emissions from intentional and unintentional fires. E) The authors may have to review the applicability of the Open Burning methods (municipal solid waste – 2006 IPCC Guidelines Eq. 5.7) to emissions from landfill fires. MSW in the 2006 IPCC Guidelines may not include waste landfilled. E) It is the practice in some areas to empty small local landfills by burning them. C/E) Default speciation for NMVOC could be considered as the same as for open burning of municipal waste (there may not be landfill fire-specific studies). The experts have identified this as a gap.

[1] For each category a single row is compiled
[2] All SLCFs associated with the source-category listed

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
	Flaring	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comments from Experts:** D) Note that flaring emissions (for GHGs) from landfills in the 2006 IPCC Guidelines are not treated at a Tier 1 level. E) These emissions will depend on the efficiency of the flare. C) SO_2 emissions would depend on the S content of the flared gas. Mass balance could be used to covert H_2S to SO_2. These emissions will be small relative to other categories of SO_2 emissions. E) Methods may be available from EMEP Chap. 1B2C (https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-b-fugitives/1-b-2-c-venting/view). E) There may be information in AP-42 Section 2.4 MSW landfills (Table 2.4.4 – flares treated as a control device from landfills, includes emission rates, https://www3.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf). Key update would be the estimation of fraction burned. E) New research in Estonia highlighted emissions can be site specific (https://www.klab.ee/wp-content/uploads/2017/01/KHG-inventuuri-j%25C3%25A4%25C3%25A4tmesektori-arendust%25C3%25B6%25C3%25B6.pdf) E) The landfill biogas flares will be a lower temperature than other (e.g., industrial) flares, which will impact the EFs. C) For all compounds, this source is likely significant at the local level, less significant at the national and global levels. E) EF could be expressed as compound per volume biogas flared. C) NOx emissions may be a significant source at the local, but not national level. C/E) There is limited information on PM or NMVOC speciation. It might be difficult to find a proxy based on industrial or fugitive flaring.
	Other (decomposition)	NMVOC, CO, NH_3	**CO:** **D:** Method requires concentration of pollutant in landfill gas. See the Waste sector compilation table. **Comments from Experts:** E/F) Methodology may be globally applicable but the EF (which relies on default CO concentrations at landfills, described in Section 3.5 of the 2017 NEI Technical Support Document) is not globally applicable. E/F) Activity data could be based on co-emitted methane emissions from managed landfills. ***NMVOCs:*** **C:** Method/Emission factor (EF) for PM2.5 is provided but not for BC. **D:** National total waste deposited to landfills multiplied by EF. See the Issue Paper. **F:** For NMVOC, see the Waste sector compilation table (feedback in cell R9). **Comments from Experts:** E) EMEP method would need to be updated before incorporation by the IPCC (updated to use similar approach to NEI method, which uses a ratio of CO to CH_4 emissions for landfills) F) Activity data could be based on co-emitted methane emissions from managed landfills

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
			NH_3: **Comments from Experts:** C) New research shows that NH3 may be emitted from landfills.
4.A.2	Unmanaged Waste Disposal Sites		
	Landfill fires	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comments from Experts:** E/H) The methods will be the same as for managed landfills (4.A.1.a). There will be the same challenges for deriving activity data and EFs for unmanaged landfills. E) It is the practice in some areas to empty small local landfills by burning them. May have more fires than managed sites. H) It is not clear how EFs (or gas concentrations) are different between managed and unmanaged landfills.
	Flaring	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comment from Experts:** C) It is the consensus of the experts that there is likely little or no flaring at unmanaged landfills.
	Other (decomposition)	NMVOC, CO, NH_3	**Comments from Experts:** E/F) The method for this sub-category will be the same as for managed landfills (4.A.1.c), but the EFs and activity data may be different. F/H) It is unclear how EFs (or gas concentrations) are different between managed and unmanaged landfills. E/H) It is unclear if NH_3 is produced from uncategorized sites (recent research is only for managed sites, no information on unmanaged sites).
4.A.3	Uncategorised Waste Disposal Sites		
	Landfill fires	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
	Flaring	PM (BC/OC), NOx, CO, NMVOC, SO_2	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
	Other (decomposition)	NMVOC, CO, NH_3	**Comments from Experts:** E/H) It is unclear how the parameters and methods for uncategorized sites (4.A.3) should differ from those applied to managed (4.A.1) or unmanaged (4.A.2) landfills.
4.B Biological Treatment of Solid Waste		NH_3, CO, NMVOC	**Comments from the Experts:** B) The experts recommend that emissions from anaerobic digestion be distinguished in a separate sub-category from composting. C) The experts have concluded that flaring emissions at anaerobic digestion treatment plants (NOx) are possible but negligible (could be included in future guidelines for completeness). CROSS-SECTORAL – note Issue 2.

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
4.B.1	Composting	NH_3, CO, NMVOC	**F:** No Tier 1 (T1) EFs for NH_3 and CO emissions from composting. See the Issue Paper. **Comments from Experts:** E) Per EMEP guidance, sludge composting should be included in 4.B.1. **B:** Reported under 4.A.1 Managed Solid Waste Disposal Sites. See the Waste sector compilation table. Requires amount of yard trimmings and food waste recovered for compositing and population, then EFs applied from the California Air Resources Board (see compilation table) **Comments from Experts:** E) This method is only applicable to composting of residential yard scraps and food (e.g., 'green waste', not biosolids from wastewater treatment plants or manure management facilities).
4.B.2	Anaerobic Digestion	NH_3 (NOx?)	**D:** The method considers the potential for NH_3 emissions from the following sources: during storage of feedstock on the premises of the biogas facility and during storage of the digestate. T1 approach estimates the total emissions, and total annual amount of N in the feedstock is used for estimation of NH_3 emissions. Anaerobic digestion at biogas facilities 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. See the Issue Paper. **Comments from Experts:** CROSS-SECTORAL - The experts note that it will be important to cross check with the AFOLU sector (manure management) on the correct accounting of emissions within the Waste sector of the storage (of stock piling) of pre- (feedstock) and post-treatment product (digestate), as well as treatment stage (to make sure that there is no double counting, and that Nitrogen flow models account for changes in N correctly). The emissions from storage of feedstock may not be large due to short storage times. (AFOLU) 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. E/F) The farmer will need to know how much organic waste (or type of waste) that was added to the manure in the digestor. There may be defaults for added waste types E/H) Emissions should be treated under the waste sector if routed to off-site (off-farm) biological treatment facilities. F) N content may be regionally dependent for municipal waste and from farms.
4.C Incineration and Open Burning of Waste			**Comments from Experts** CROSS-SECTORAL (AFOLU): experts recommend that emissions from agricultural waste burning on fields should be considered in AFOLU. The classification of fire types included in this category needs to be clarified (e.g., waste burning on farms/orchard, etc. of crop residues (e.g., cereal crops, peas, beans, soya, sugar beet, oil seed rape, etc.), wood, pruning, slash, leaves, plastics, and other general wastes). CROSS-SECTORAL (Energy): agricultural waste burning for energy should be considered in Energy sector.
4.C.1	Waste Incineration	NOx, NH_3, SO_2, CO, NMVOC, BC, OC	**B** (EMEP/EEA): Categories by type of waste: municipal waste incineration, industrial waste incineration, hazardous waste incineration, clinical waste incineration, sewage sludge incineration, cremation. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** B/E/F) Emissions from waste incineration will vary based on waste type, combustion technology used, the use of emission controls, and operational conditions. It is the consensus of the experts that the methods across all waste and technology types will likely be that same, therefore the experts recommend keeping 4.C.1 as a single category.

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
			However, Tier 1 EFs will need to be technology dependent, waste type. Guidance on ensure timeseries consistency can be informed by guidance in the 2019 Refinement. F) Future guidelines will also need to include a table on different abatement efficiencies. CROSS-SECTORAL – Emissions from waste incineration (to avoid double counting): - *with energy recovery should be included in Energy, not Waste* - *without energy recovery should be included in Waste, not Energy* Note: if it is difficult to split emissions between (1) and (2), it will be important that all waste incineration emissions are reported either under Energy OR Waste and record where emissions are reported E) Cremation (human and animal) – there will be large regional differences that will likely need regional default factors. This is an important source of PM at the local level, but further investigation is needed as to whether or not this is a significant source on the national or global scale. Both the US NEI (AP-42) and EMEP have some guidance on activity data and EFs. C) Per convention, do not need to consider whether CO is fossil or not (assume CO_2 emissions include all oxidation products). E) Per EMEP guidance, sludge incineration should be included in 4.C.1. E) Old report from US EPA "AIR EMISSIONS FROM SCRAP TIRE COMBUSTION", year 1997 (https://www3.epa.gov/ttncatc1/dir1/tire_eng.pdf) particulate matter, metals, PAHs (laboratory measurements). J-STREAM: **F:** EFs are for T2. **D:** Fuel consumption times emission factor. In the 2006 IPCC Guidelines, amount of waste incinerated is used as AD. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** No additional comments (no J-STREAM experts in the BOG meetings).
4.C.2	Open Burning of Waste	NOx, NH_3, SO_2, CO, NMVOC, BC, OC	**Comments from Experts:** E) Experts recommend that three parameters required for estimation: a) Fraction of household waste, b) fraction of household waste burned, c) fraction that (ultimately) oxidizes to CO_2. D/E/F) Note on the B_{frac} parameter in the current GHG guidelines, the definition of B_{frac} needs to be clarified in future guidelines. The GHG guidelines were developed for CO_2 and need to be refined for SLCFs (however, the current approach may also need to be updated for GHGs). This was discussed in the process of the 2019 Refinement but was not updated at that time for GHGs. - The current default for B_{frac} - 60% of waste burned is too high. There is not a lot of literature on this, but this needs to be reviewed. D/E/F) The current assumption in the 2006 IPCC Guidelines is also that waste is only burned in rural areas (not burned in urban areas). This assumption needs to be reviewed further as there is evidence that waste is burned in urban areas (at least in Mexico, Africa, and Brazil). Based on survey data in Brazil, urban waste was burned due to infrequent urban trash collection. Also consider: African Waste Management Outlook. https://www.sciencedirect.com/science/article/abs/pii/S0048969720362653?via%253Dihub E/F) A general methodology approach could also be Emission = A * EF, where A = waste generated per capita * amount of waste burned. But this approach will likely need regional parameters and should be investigated by future authors. Note that waste generated per capita could be investigated based on socioeconomic class. E) There are other nuances in waste composition and the possibility of multiple disposal methods in locations without municipal collects. F) Organics and plastics are a large fraction of waste in developing countries and the waste composition would impact EFs.

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
			F) Reference – A reference (currently under review) that provides a summary of ~100 studies of EFs and fractions of waste being open burned around the world. F) Cook and Velis (2021) open burning of plastics – provides estimates for the mass of solid waste open burned in LIMIC and HIC countries based on a detailed review. *EMEP:* **B:** 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. The method requires a prior knowledge of the weight of agricultural waste produced per hectare forestry, orchard and farmland. In the 2006 IPCC Guidelines, agriculture residue burning is considered in AFOLU sector. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** F) EMEP EFs do not include a mixed municipal solid waste, some of these may be available in Energy chapters. B/E) EMEP guidance does include car and building fires. These should be considered under category 4.E. B/E) It is the consensus of the authors that emissions from Tire burning should be included in this category (4.C.2). In the EMEP guidance, tires are treated as a type of waste, but there is no EF. Since category 4.C does not consider whether fires are intentional or unintentional, all tire burning can be under 4.C.2. If the tires are being burned in the landfill, those emissions would be in the landfill category. *EPA:* **B:** Land clearing. In the 2006 IPCC Guidelines, emissions from land clearing burning are considered in AFOLU sector. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** CROSS-SECTORAL – Emissions from 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.
4.D Wastewater Treatment and Discharge			**General Comments from Experts:** E/H) Emissions from **leachate** – **leachate** could be directed back to landfill or directed to treatment plants. In some cases, this might be treated onsite. One suggestion from experts is to include these emissions in 4.D.2, unless the treatment is occurring at the landfill site, then this should be included in landfill emissions. A summary of practices in China was provided. Authors should investigate this further. C) There could be PM emissions from aeration, but these are likely small. There needs to be further investigation on whether or not this is a significant source. B/E) Emissions from anaerobic digestion at treatment facilities should be included in 4.D. (likely are included already). Emissions from flaring (where there is no energy recovery) from anaerobic wastewater treatment with methane capture – should be considered. C/E) It is worth considering whether the NH_3 emission methodology should be based on existing N_2O methods vs. CH_4 (emissions will depend on the amount of N). CROSS-SECTORAL (Energy) – Emissions from the combustion of biogas collected for energy recovery purposes should be included in Energy, not Waste. Note: If flared (without energy recovery), included in Waste.
4.D Wastewater Treatment and Discharge		NH_3, NMVOC	*EMEP:* **B:** Activities considered within the 5.D Wastewater Handling sector are biological treatment plants and latrines (storage tanks of human excreta, located under naturally ventilated wooden shelters). Includes 5.D.1 Domestic wastewater handling, 5.D.2 Industrial Wastewater handling and 5.D.3 Other wastewater handling. **F:** According to the EMEP/EEA Guidebook, EF (T1) for NMVOC emissions for 5.D Wastewater Handling has been derived from one study, and it may not be applicable to all wastewater treatment plants. **D:** AD (T1) is total amount of wastewater handled by all wastewater treatment plants in the country. See the Issue Paper and Waste sector compilation table.

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
			Comments from Experts: F) The EMEP/EEA NMVOC EF is highly uncertain and likely not globally applicable. This EF is applied to both industrial and domestic treatment facilities. *EPA:* **B:** Does not split into domestic and industrial. **D:** Method is based on the wastewater flow rate. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** F/H) In the current NEI method, the EF is not technology dependent. However, these emissions are likely also sensitive to technology and operating conditions. This should be reviewed.
4.D.1	Domestic Wastewater Treatment and Discharge	NH_3, NMVOC	*EMEP:* **F:** NH_3 EF is for T2 (latrines). **Comments from Experts:** B) Commercial wastewater treatment emissions should be included in 4.D.1. The wastewater composition could vary for industrial and commercial sources. B) Untreated wastewater emissions would fall under 4.D.1. *NIER:* **D:** AD is mass of wastewater handled. See the Waste sector compilation table. **Comments from Experts:** No further comments (no NIER experts in the Waste BOG discussions).
4.D.2	Industrial Wastewater Treatment and Discharge	NH_3, NMVOC	**D:** AD is amount of wastewater handled. **F:** According to the EMEP/EEA Guidebook, T2 EF is based on one study, and it may not be applicable to all wastewater treatment plants. **Comments from Experts:** E) EFs would depend on the type of industry.
4.E Other			
	Other waste	NH_3	**B:** Activities covered under this category are sludge spreading, car fires and house fires. However, according to the 2006 IPCC Guidelines, sludge spreading is considered in AFOLU sector. **D:** For sludge spreading, the relevant activity statistics are the standard statistics on sludge production and the fraction that is dried by spreading. For accidental fires, activity data can be obtained from national statistics or national emergency management agencies. **F:** No T1 EFs. NH_3 EF (T2) for sludge spreading. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** CROSS-SECTORAL - (Energy/Waste) – There are emissions from different uses/treatment of sludge (e.g., co-firing with coal in cement industry (Energy), landfilling (Waste), biological treatment (Waste). CROSS-SECTORAL – sludge spreading in EMEP (NH_3) – In the EMEP guidance, N_2O emissions from this source are included in AFOLU and NH_3 emissions are included

A	B	C	I
IPCC code	Category[1]	SLCFs[2]	Comment
			under 4E. For consistency, the experts recommend that NH_3 emissions from sludge spreading be included in AFOLU rather than Waste. B/F/G/H) EMEP guidance for cars and building fires should be included here. However, methods and EFs are likely not globally applicable. Cooking exhaust: **D:** Times of meals multiplied by emissions. See the Issue Paper and Waste sector compilation table. **Comments from Experts:** No further comments (not J-STREAM experts in the Waste BOG discussions) CROSS-SECTORAL – this source should be considered in the Energy sector, not Waste.

Note 1: In this document "EMP/EEA" refers to the EMEP/EEA 2019 Guidebook

Note 2: Each time a method is required for BC/OC, a method must also be defined for PM2.5 (indeed BC/OC is often estimated as a fraction of PM2.5)

Annex 2: Agenda

Joint 1st and 2nd IPCC Expert Meeting on Short-Lived Climate Forcers

In relation to Methodologies for Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste Sectors

11 – 22 October 2021

Virtual Meeting

Agenda

Day 1 – Opening Plenary

Monday, 11 October 2021

Opening Plenary		
Day 1 Monday, **11 October 2021** **11.00-14.00 (GMT, UTC+0)** *Geneva Time (UTC+2) 13.00-16.00* *Tokyo time (UTC+9) 20.00-23.00* *Lima time (UTC-5) 06.00-09.00*	11.00 - 11.15	➢ Background and Scope (IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe) – *10 min* ➢ Adoption of agenda (IPCC TFI TSU Head – Sandro Federici) – *5 min*
	11.15 - 12.40	➢ Presentations • WGI presentation in relation to SLCFs (Jan Sigurd Fuglestvedt) – *20 min* • EMEP/EEA methodology on SLCFs (Kristina Saarinen) – *20 min* • US EPA inventory of SLCFs (Rob Pinder) – *15 min* • UNEP Atmospheric Brown Clouds Emission Inventory Manual (Maheswar Rupakheti) -*15 min* • SLCF inventory in China (Bofeng Cai) – *15 min*
	12.40 - 12.45	*5 min break*
	12.45 - 13.15	➢ Presentations • Emissions Database for Global Atmospheric Research (EDGAR) (Monica Crippa) – *10 min* • Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) (Zbigniew Klimont) – *10 min* • Community Emissions Data System (CEDS) (Steven Smith) – *10 min*
	13.15 - 14.00	➢ TSU guidance and Q & A session • Guidance on work in BOGs (Energy, IPPU, AFOLU and Waste) (IPCC TFI TSU Pavel Shermanau) – *10 min* • Q & A Session – *35 min*

Day 2, 3, 4 and 5 – Parallel Break-out Groups Sessions (Energy, IPPU, AFOLU and Waste)

Facilitators and Rapporteurs are TBC

<table>
<tr><th colspan="6">BOGs Sessions (Energy, IPPU, AFOLU, Waste)</th></tr>
<tr><td colspan="6">• Working in BOGs, supported by materials prepared by TSU – sectoral categories' tables and issue papers
• Preparation of BOGs' outcomes – sectoral categories' list, issues and gaps, BOGs' reports for the Closing plenary</td></tr>
<tr><td>Day 2

Wednesday,
13 October 2021</td><td>11.00-14.00
(GMT, UTC+0)

Geneva time (UTC+2)
13.00-16.00

Tokyo time (UTC+9)
20.00-23.00

Lima time (UTC-5)
06.00-09.00</td><td rowspan="4">Energy BOG

Facilitator:
Dario Gomez

Rapporteur:
Vincent Camobreco

TSU:
Takeshi Enoki
Valentyna Slivinska</td><td rowspan="4">IPPU BOG

Facilitator:
Kristina Saarinen

Rapporteur:
Vigdis Vestreng

TSU:
Pavel Shermanau
Eduard Karapoghosyan</td><td rowspan="4">AFOLU BOG

Facilitator:
Dominique Blain

Rapporteur:
Savitri Garivait

TSU:
Sandro Federici</td><td rowspan="4">Waste BOG

Facilitator:
Jongikhaya Witi

Rapporteur:
Erin E. McDuffie

TSU:
Baasansuren Jamsranjav</td></tr>
<tr><td>Day 3

Thursday,
14 October 2021</td><td>20.30-23.30
(GMT, UTC+0)

Geneva time (UTC+2)
22.30-01.30

Tokyo time (UTC+9)
05.30-08.30 (Friday, Oct 15)

Lima time (UTC-5)
15.30-18.30</td></tr>
<tr><td>Day 4

Monday,
18 October 2021</td><td>11.00-14.00
(GMT, UTC+0)

Geneva time (UTC+2)
13.00-16.00

Tokyo time (UTC+9)
20.00-23.00

Lima time (UTC-5)
06.00-09.00</td></tr>
<tr><td>Day 5

Tuesday,
19 October 2021</td><td>20.30-23.30
(GMT, UTC+0)

Geneva time (UTC+2)
22.30-01.30

Tokyo time (UTC+9)
05.30-08.30 (Wednesday, Oct 20)

Lima time (UTC-5)
15.30-18.30</td></tr>
</table>

Day 6 – Closing Plenary
Friday, 22 October 2021

Closing Plenary Session		
Day 6 Friday, **22 October 2021** **11.00-14.00** **(GMT, UTC+0)** *Geneva Time (UTC+2)* *13.00-16.00* *Tokyo time (UTC+9)* *20.00-23.00* *Lima time (UTC-5)* *06.00-09.00*	11.00 - 13.05	➢ Reports from BOGs, including Q & A • Each BOG *30 min* plus 5 *min* break
	13.05 - 13.50	➢ Discussion on Cross-Sectoral issues • TSU Presentation – 5 min • Discussion – 40 min
	13.50 - 14.00	➢ Way forward and Closing Remarks (IPCC TFI Co-Chairs Eduardo Calvo Buendia and Kiyoto Tanabe) – 10 min

Annex 3: List of Participants

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Amara Holder
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Toru Matsumoto

Eriko Nakamura

Takeshi Enoki (consultant)