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Report for the Stage 3 *ad-hoc* review of emission inventories submitted under the UNECE LRTAP Convention:

STAGE 3 REVIEW REPORT

SWEDEN

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INTRODUCTION

The mandate and overall objectives for the emission inventory review process under the LRTAP Convention is given by the UNECE document '*Updated methods and procedures for the technical reviews of air pollutant emission inventories reported under the Convention*'[1] – hereafter referred to as the 'Review guidelines 2018'.

1. Paragraph 7 (c) of the 'Review guidelines 2018' defines that stage 3 reviews may be annual centralized reviews or ad hoc reviews. Paragraph 18 of the 'Review guidelines 2018' further specifies that such ad hoc reviews could, for instance, focus on specific source sectors, specific pollutants such as heavy metals or persistent organic pollutants, gridded and projections data, or on other areas as requested by the Implementation Committee and that where appropriate, ad hoc reviews could be conducted in line with the present Methods and Procedures for the In-depth (Stage 3) review.

2. At its seventh joint session in September 2021 the Steering Body and the Working Group approved the plan to perform (in 2022) an in-depth review of $PM_{2.5}$ emissions from residential heating and road transport, with a special focus on the topic of '*condensable particulate matter*' and a follow-up review of the implementation of recommendations given as part of the review carried out in 2021. The Parties reviewed in 2021 are Kazakhstan, Liechtenstein, Monaco and Montenegro.

3. Particulate matter can exist as solid or liquid matter (the "filterable" portion) or as gases (the "condensable" portion). Condensable particulate matter is vapour phase at stack conditions, but condenses and/or reacts upon cooling and dilution upon discharge into ambient air to form solid or liquid PM. All condensable PM is assumed to be in the $PM_{2.5}$ size fraction[2]. The inclusion of the condensable component of $PM_{2.5}$ emissions can have a big impact on the emission estimate for certain sources[3].

4. This ad-hoc review has assessed $PM_{2.5}$ emission estimates with a special focus on the topic of '*condensables*' for the years 2000 to 2020.

5. This report covers the results of the stage 3 centralised review (ad hoc review) 2022 of the UNECE LRTAP Convention of Sweden coordinated by the EMEP emission centre CEIP acting as review secretariat. The review took place between April and June 2022 and was performed as desk review with an in person meeting between 30 of May 2022 and 3 June 2022. The following team of nominated experts from the roster of experts performed the review.

<u>Ad hoc review - condensables</u>

1A3b Road Transport: Gudrun Stranner, Katrina Young, Magdalena Zimakowska-Laskowska, Martina Toceva and Rebecca Rose

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[1] Decision 2018/1 adopted by EB: *Updated methods and procedures for the technical review of air pollutant emission Inventories reported under the Convention*. ECE/EB.AIR/142/Add.1 https://unece.org/fileadmin/DAM/env/documents/2018/Air/EB/ECE_EB.AIR_142_Add.1-1902937E.pdf

[2] Condensable Particulate Matter Definition | Law Insider

[3] For more technical details please refer to the EMEP/EEA Guidebook (https://www.eea.europa.eu/publications/emep-eea-guidebook-2019) or the report 'How should condensables be included in PM emission inventories reported to EMEP/CLRTAP?' https://emep.int/publ/reports/2020/emep_mscw_technical_report_4_2020.pdf

1A4bi Residential: stationary: Aleksandra Nestorovska-Krsteska, André Amaro, Benjamin Cuniasse, Canan Esin Köksal, Damian Zasina, Laureta Dibra, Marion Pinterits, Sam Gorji and Wolfgang Schieder

6. Kristina Saarinen and Jeroen Kuenen were the lead reviewers. The review was coordinated by Sabine Schindlbacher (EMEP Centre on Emission Inventories and Projections - CEIP).

7. The review was performed on the basis of CLRTAP emission data officially reported by Sweden due by 15 February 2022 for emission inventories. The Informative Inventory Reports (IIR), reported due 15 March 2022 under the CLRTAP, informed the review.

8. The emission inventory of Sweden was received on 14 February 2022 and thus by the deadline of 15 February. The Informative Inventory Report was received on 12 March 2022 and thus by the deadline of 15 March.

RECOMMENDATIONS FOR IMPROVEMENTS TO THE PARTY

1.A.4.b.i Residential: stationary

9. Sweden use a Tier 2 methodology for calculating $PM_{2.5}$ emissions from '1A4bi – Residential: stationary', which is a key category for $PM_{2.5}$ emissions for Sweden.

10. Activity data is taken from official statistics (annual energy balances[4], which, *inter alia*, are based on three surveys regarding biomass combustion in households (one- and two-dwelling statistics)[5], holiday cottage statistics[6] and multi-dwelling statistics[7]. Biomass activity data and emission factors are separated into traditional and modern technologies for the whole time series. Stationary combustion of fuels has decreased mainly due to a continuous increase in district heating and due to the use of heat pumps in the recent years, the use of heating oils is still decreasing while combustion of wood has increased. Fuel consumption increase due to cold winters, especially in 2010.

11. The ERT notes that the activity data is not described transparently enough in the IIR. The Party informed the ERT, that the time series of the final energy consumption in category 1A4bi by energy carrier including non-fuels such as ambient heat, district heating and electricity as well as the references for all surveys contributing to the sector will be included. The ERT recommends Sweden to include this information in the next IIR submission.

12. The activity data for Sweden include collected wood, i.e. wood directly harvested from the forest outside formal market activity.

13. The total fuel consumption for each fuel type is stratified into different appliance types such as boilers and stoves, in a consistent and complete manner, and uses the statistics of the different dwelling types and complementary data sources to get more details on biomass combustion. The Party also gave further background information to sufficiently display the share of all appliances[8]. In addition, the emission factors were also developed to coincide with the activity data[9]. The ERT notes that information about this is not sufficiently documented in the IIR and recommends Sweden to include this documentation in the next IIR submission.

14. Sweden uses for biomass fuels a Nordic/country-specific methodology based on measurements.

15. The emission factors partially include the condensable component of $PM_{2.5}$ emissions (Table 1). For biomass the EFs are based on measurements in diluted flue gases including the condensable component of particulate matter[10]. The Party also informed that it remains unknown whether the condensable component of PM is included in the EFs for non-biomass fuels combustion[11] as these EFs are often the same as for commercial plants and are based on a number of larger research studies compiling measurements from the 80's and 90's, combined with knowledge about abatement technology and measured emissions from individual facilities. The ERT recommends Sweden to include in the next IIR submission

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[4] Swedish Energy Agency, http://www.energimyndigheten.se/
[5] No reference available
[6] Statistic Sweden.ES 2012:03. Energy statistics for dwellings with no registered permanent resident (holiday homes) 2011 http://www.energimyn-digheten.se/sv/Statistik/Slutlig-anvandning/Bostader-och-service/Fritidshus/
[7] No reference available
[8] File 'Energy consumption additional info 1a4b.xlsx', SMED Rapport Nr 19 2021
[9] SMED Rapport Nr 19 2021. Helbig, T. & Josefsson Ortiz, C. 2021. Uppdateringar av utsläppsberäkningar för småskalig bio-massaeldning inom övrigsektorn (CRF/NFR 1A4) 2017-2021.
[10] Emission factors for SLCP emissions from residential wood combustion in the Nordic countries Improved emission inventories of Short Lived Climate Pollutants (SLCP) Karin Kindbom, Ingrid Mawdsley, Ole-Kenneth Nielsen, Kristina Saarinen, Kári Jónsson and Kristin Aasestad TemaNord 2017:570
[11] SMED report 7:2004. Kindbom et al. 2004. Emissions of particles, metals, dioxins and PAH in Sweden

information on the measurement standards and/or equipment used for non-biomass fuels. The ERT also recommends checking on, whether emission factors from SMED report 7:2004 given for non-residential purpose are suitable for emission calculations for '1A4bi – Residential: stationary'.

16. According to the response from Sweden the measurements used to derive the biomass emission factors cover the start phase (ignition) and the end (ember) phase of the combustion cycle. It is unresolved, whether this also applies for non-biomass fuels. The ERT recommends Sweden to include emissions during the start and end phases of the combustion cycle in the emission factors used for inventory compilation, to reflect the actual emission levels occurring during combustion of all fuel used (including non-biomass fuels). If this is already included, the ERT recommends to transparently describe it in the next IIR submission.

17. The inventory takes into account user-induced impacts that affect emission levels (so-called user impact). The ERT found the information in the IIR not to be transparent regarding which impacts are included and the applied ratio of EFs from negative user impacts were not provided. The Party informed that all technologies listed in IIR Annex Table A2-20, identical to table 1 in "SMED rapport no 13 2018", are included in emission calculations. For boilers, the ratios on EFs for moist/standard fuel and part load/nominal load were assigned a 5% impact each on the final EF. For stoves, 10% of the final EF are based on the ratio of EFs of part load to nominal load[12]. The 10% assumption is based on a survey of a number of Swedish chimneysweepers and is in line with Finland's estimate of 10.5%. The ERT recommends the Party to incorporate the above information in the IIR report for the next submission.

[12] SMED Rapport Nr 19 2021

Table 1: Inclusion of condensables per fuel type

Fuel Type	Includes the condensable component of $PM_{2.5}$ emissions
Domestic heating oil / Other consumption (1A4)	Unknown
Gas works gas / Other consumption (1A4)	Unknown
LPG / Other consumption (1A4)	Unknown
Natural gas / Other consumption (1A4)	Unknown
Other biomass / Other consumption (1A4)	Unknown
Other non-specified / All consumption	Unknown
Other petroleum fuels / All consumption	Unknown
Other solid fuels / All consumption	Unknown
Residual fuel oil / Other consumption (1A4)	Unknown
Wooden fuels / Other consumption: Boilers: pellets	Yes
Wooden fuels / Other consumption: Boilers: wood chips	Yes
Wooden fuels / Other consumption: Boilers: wood logs Modern	Yes
Wooden fuels / Other consumption: Boilers: wood logs Traditional	Yes
Wooden fuels / Other consumption: Stoves: pellets	Yes
Wooden fuels / Other consumption: Stoves: wood logs Modern	Yes
Wooden fuels / Other consumption: Stoves: wood logs Traditional	Yes
Wooden fuels / Other consumption: Open fireplaces	Yes
Boiler - pellets / NFR 1A4b1	Yes
Boiler - wood chips / NFR 1A4b1	Yes
Traditional boiler - wood / NFR 1A4b1	Yes
Modern boiler - wood / NFR 1A4b1	Yes
Stove - pellets / NFR 1A4b1	Yes
Stove - wood chips / NFR 1A4b1	Yes
Traditional stove - wood / NFR 1A4b1	Yes
Modern stove - wood / NFR 1A4b1	Yes
Open fireplace / NFR 1A4b1	Yes

18. The ERT notes that the time series is consistent.

19. $PM_{2.5}$ emissions from small combustion are spatially distributed using proxy data at municipal level based on several statistics and assumptions[13] (IIR, p.288f). The Party provided further details on the method and references used to compile the gridded emission data[14].

[13] Assumptions such as Statistics from The Swedish Civil Contingencies Agency (MSB) on the number of fireplases, the ENLOSS energy balance model on the energy needs of small houses, assumptions about heating habits and share of fuel

[14] Detailed information provided by the Party include:

Statistics from The Swedish Civil Contingencies Agency (MSB) on the number of fireplaces (wood boilers, local fireplaces, pellet boilers and oil boilers) per municipality /emergency services.

Every year, the Swedish Civil Contingencies Agency (MSB) conducts, together with the county administrative boards, a follow-up of the municipalities' work according to the Act on Protection against Accidents (LSO) in the municipality. Statistics on the number of fireplaces are produced and are available from MSB's database IDA (http://ida.msb.se/). The mix of combustion appliances for recent inventory year are also collected from this database. This data was used to verify data from the Swedish Energy Agency. However, there is no information on the age or technological level of the registered appliances which makes these statistics from MSB less reliable. Data from MSB is not used in the inventory or Sweden's emissions calculations.

ENLOSS energy balance model

The energy needs of small houses have been calculated by county for meteorological conditions for the year 2012, since the emission calculations are made for this year. Furthermore, energy needs are also calculated for a normal year. By normal year is meant the single-family houses' average energy needs for the meteorological reference years 1960-1990. In this way, a sensitivity analysis of the emission calculations can be done later. In the calculations with ENLOSS, the energy requirement for the total heating requirement is calculated by living space for detached houses by county.

When calculating emissions from fireplaces, however, the energy requirement is needed expressed per detached house unit, which is why a living space on an average house (152 m2) has been assumed in these calculations (Energimyndigheten, 2015: Det svenska genomsnittshuset 2013. https://www.energimyndigheten.se/Hushall/Din-uppvarmning/).

Assumptions about heating habits and share of fuel (outside experience from other studies and surveys as well as knowledge on the number of detached houses connected to district heating networks per municipality)

To appreciate the heating habits and share of fuel experiences, result from a previous small-scale wood burning study have

20. The Party provided following information planned improvements:

- EF revision for other fuels than biomass in the sector.
- Revise the fraction of city gas from natural gas. The split used is from 2010 to be updated.
- Revision of fuel technologies by fuel type revised where needed.

The ERT commends Sweden for their improvement plans and recommends implementing them as soon as possible.

21. In addition, the ERT recommends Sweden to implement the following:

- Inclusion of the time series of final energy consumption of '1A4bi – Residential: stationary' by energy carrier (including non-fuels such as ambient heat, district heating and electricity) in the IIR
- Inclusion of the fuel share of all technologies by energy carrier used in the inventory compilation in the IIR
- Inclusion of references for all surveys contributing to the sector in the IIR
- Inclusion of information on the measurement standards and/or equipment used for non-biomass fuels in the IIR
- Correction of incorrect emission factor in Table A2-16 (see Q/A 12) in the IIR
- Full description of all the references (data sources) used in the IIR chapter 'References Section 10'

And the ERT encourages to implement the following:

- Calculation of PM emissions from charcoal use (e.g. for barbecue and other purpose) in '1A4bi – Residential: stationary' (or in another inventory sector)

1.A.3.b.i-iv Road transport - exhaust emissions

22. Sweden's transport sector emissions are calculated using country specific emission factors taken from HBEFA version 4.1. All emission factors in HBEFA are based on the Tier 3 methodology in the 2019 EMEP/EEA Guidebook. The IIR provides details of the main features of the model. The IIR describes the calculation of transport emissions transparently.

23. The activity data is taken from various official statistics: total fuel sales by national fuel statistics, fuel specifications and fuel blends by the Swedish fuel quality act, Swedish national

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been used where a questionnaire was sent out to 176 households in Västerbotten County [Omstedt m fl, 2014, "Vedrök i Västerbotten - mätingar, beräkningar och hälsokonsekvenser". SMHI Meteorologi nr 156, http://www.smhi.se/polopoly_fs/1.80218!/Meteorologi_156.pdf]. Based on the survey, it is estimated that approximately 14.9 m³ wood consumption per year for areas that lack district heating, which corresponds to approximately 63% of the house's total energy needs. For areas with district heating, the detached houses are heated by an average of 21% wood. Based on this difference district heating factors have been developed from 0.2 (a lot of district heating) to 1 (district heating is missing).
For the distribution keys, separation has been made of wood boilers with ceramic fireplace, where these emissions are calculated with emission factors for environmentally approved boilers. While those without a ceramic fireplace have been calculated with emission factors for non-environmentally approved wood boilers. Within each municipality, the emissions are then distributed by living area per square kilometers for each house type. Any other factors than living area per square kilometres are not taken into account in the distribution of the emissions because of the absence of other necessary data. The living areas are taken from the property register. The district heating supply in each urban area has been calculated from statistics from the Swedish Energy Markets Inspectorate's (Ei) register of district heating networks. In this way, emissions within each urban area are reduced by a factor that depends on number of detached houses connected to district heating networks according to this register. As the Party is primarily looking for wood burning and therefore made an assumption that it is a negligible small number of district heating in other buildings than detached houses, which is why these are not included in the statistics. Thus emissions increase in urban areas that are less connected to district heating.

vehicle register, national road mileage model (Edwards et al. 1999). All data sources are documented transparently in the IIR.

24. Sweden's transport emission inventory includes the condensable component of $PM_{2.5}$ emissions. Considering the measuring protocol within the HBEFA group (measuring procedure and the max. temperature of 52°C), it can be assumed that the country specific emission factors taken from HBEFA include the condensable component of $PM_{2.5}$ emissions.

25. The ERT commends the good level of detail in the methodology descriptions for the whole transport sector in annex 2.3 and 2.4. The inclusion of the condensable component of $PM_{2.5}$ is documented on p.93 and in the table A2-22 of the annex of the IIR. The ERT recommends Sweden to add this information also in the general road transport chapter and add the technical information, why it can be assumed that HBEFA emission factors are including the condensable component of $PM_{2.5}$.

26. The time series is consistent.

27. For planned improvements for their submission in 2023 Sweden refers to a separate document called "national QA/QC plan" which is in progress.

28. The ERT encourages to implement the following:

- In the course of the in-depth review Sweden was asked to clarify which version of the HBEFA is really in place. On p.290 HBEFA version 3.3 is mentioned; HBEFA version 3.1 on p.94 and on p.176 in the annex it says that HBEFA version 4.1 was implemented in submission 2021. Sweden answered that HBEFA version 4.1 is in place and that this information will be corrected in the next submission.

REVISED ESTIMATES AND TECHNICAL CORRECTIONS CONSIDERED AND/OR CALCULATED BY ERT

29. In the Appendix of the 'EMEP/UNECE Review Guidelines 2018[15]' it is stated that if the ERT considers that when emissions are significantly under- or overestimated, then during the review, the Party is invited to submit "Revised Estimates" that address the issue raised. Should the Party decline to do this, or should it not be possible to agree on the quantification of the Revised Estimates, then the ERT may calculate a "Technical Correction" in the absence of an updated emission estimate being provided by the Party itself. The threshold for significance for a technical correction for the in-depth review in 2022 was set at 2% of the national total, i.e. findings identified which result in an over- or under-estimate of emissions of more than 2% of the national total can result in a Technical Correction. The methods for calculating the Technical Corrections are set up in the "Review Guidelines 2018" and use the EMEP/EEA Emission "Inventory Guidebook" as a reference for methods and emission factors.

30. Sweden did not provide any revised estimates and the ERT did not calculate any technical corrections.

[15] https://www.ceip.at/fileadmin/inhalte/ceip/3_review/advance_version_ece_eb.air_142_add.1.pdf

LIST OF MATERIAL PROVIDED TO ERT

1. Sweden's Stage 2 S&A report
2. Sweden's Stage 1 report 2022
3. Sweden's IIR 2022
4. NFR tables submitted in 2022 by Sweden

LIST OF ADDITIONAL MATERIAL PROVIDED BY THE COUNTRY DURING THE REVIEW

5. Responses to preliminary question raised prior to the review
6. Responses to questions raised during the review
7. Energy consumption additional info 1a4b.xls
8. Energy consumption additional info 1a4b_v2.xls
9. ERT – Questions and answers regarding Residential Stationary combustion (1A4bi).doc
10. Kindbom et al., 2004. Emissions of particles, metals, dioxins and PAH in Sweden
11. Kopia av EF-bilaga luft (2022-02-22).xls
12. SMED Rapport Nr 19, 2021
13. Sweden Stage 3 review.xls
14. Sweden Stage 3 review.xlxs_2juni20200