

# “Update of transport chapters of the EMEP/EEA air pollutant emission inventory Guidebook”

TFEIP meeting – Transport Expert Panel

Tuesday, 12<sup>th</sup> May 2026

# **Project identity**

# Objectives



- > **Update** the transport chapters of the Guidebook, based on the [prioritization list](#) adopted by TFEIP in its [2025 meeting](#) (“SR13 Guidebook review” EC DG ENV project)

## EMEP/EEA Guidebook 2023 Review - Appendix A - Compiled Improvements List

<b>Prepared by:</b>	Ricardo Plc, Aether Ltd, Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique (Citepa)
<b>Authors:</b>	Chris Dore, Annie Thornton, Melanie Hobson, Céline Gueguen, Bernard Hyde, Barbara Amon, Thamara Braish, Yvonne Pang, Rob Stewart, Gareth Horton, Dan Wakeling, John Norris, Joe Hague, Jekabs Jursins
<b>Version:</b>	v 4.0 - TFEIP Approved
<b>Date:</b>	30/05/2025
<b>Purpose</b>	This document is provided to support TFEIP Expert Panel Leaders with compiling their Guidebook improvement lists and has been approved by the TFEIP at the 2025 annual meeting
<b>Sheets</b>	<b>Description</b>
<b>Introduction</b>	Introductory sheet setting out purpose and version of document
<b>Individual Tables --&gt;</b>	Bookmark sheet (empty sheet)
<b>Part A</b>	Compiled improvements applicable to chapters under Part A of the EMEP/EEA Guidebook
<b>Part B --&gt;</b>	Compiled improvements applicable to chapters under Part B of the EMEP/EEA Guidebook (empty sheet)
<b>Transport</b>	Compiled improvements applicable to chapters relating to <b>transport</b> emission sources under Part B of the EMEP/EEA Guidebook

## > Provide:

- ∴ a systematic and comprehensive review of relevant data sources
- ∴ a thorough analysis of the improvements that can be made

- > **Draft** updated chapters to the TFEIP [Expert Panel on transport](#), in time for the 2027 update of the GB

# Client, partners, roles, and project duration



> **Client:** EC DG ENV

> **7 partners**

- ∴ [EMISIA](#): Overall project management and technical coordination, Road and Aviation lead
- ∴ [LAT/AUTH](#): Navigation lead
- ∴ [INFRAS](#): NRMM lead
- ∴ [TNO](#): Support in Road and NRMM
- ∴ [EAA](#) (Environment Agency Austria): Support in Aviation
- ∴ [FVT](#) (TU Graz): Support in NRMM
- ∴ [AQC/Logika](#): Support in Road, QA/QC activities, overall framework coordinator

> **Project duration:** From Nov. 2025 to Dec. 2026

> **Specific Contract no.** 090202/2025/4500134180/SER/ENV.C.3 implementing Framework Contract no. FRA/C.3/ENV/2021/OP/0017

# Summary of target issues/items to be updated and tasks



Transport mode	Number of issues High/Medium	Number of issues Low	Number of issues Total
Road	6	2	8
NRMM	2		2
Navigation (shipping)	7	1	8
Aviation	12	1	13
<b>Grand Total</b>	<b>27</b>	<b>4</b>	<b>31</b>

- › **Task 1:** Systematic and comprehensive review of relevant data sources
- › **Task 2:** Detailed list of improvements to be made to the relevant chapters and methodologies
- › **Task 3:** Drafting of updates to all relevant transport chapters

# List of items



No.	TFEIP ID	Priority	NFR	Chapter	Identified issues shortcomings	Proposed solution	Short issue name
1	18	High/medium	1.A.3.b	Road Transport	Introduce H <sub>2</sub> as a fuel.	Hydrogen (H <sub>2</sub> ) can be introduced as	H <sub>2</sub>
2	21	High/medium	1.A.3.b	Road Transport	Review/update brake emission	Brake emission factors should be	Brake EFs
3	22	High/medium	1.A.3.b	Road Transport	Review/update tyre emission	Tyre emission factors should be	Tyre EFs
4	24	High/medium	1.A.3.b	Road Transport	Introduce control options for	To review what emission control	Control options tyre brake
5	25	High/medium	1.A.3.b	Road Transport	Review/update chemical	Chemical speciation methods should	Chemical speciation
6	42	High/medium	1.A.4	NRMM	Emission factors for all	Emission factor update on the basis	EFs not updated since 2016
7	43	High/medium	1.A.4	NRMM	NRMM is a very diverse sector	Update and review guidance on	Activity data
8	30	High/medium	1.A.3.d	Navigation	More detailed/expanded ship	Ship categories should be expanded	Expanded ship categories
9	31	High/medium	1.A.3.d	Navigation	Emission factor update,	Emission factors should be updated	EFs update (alt. fuels, Tier III)
10	32	High/medium	1.A.3.d	Navigation	Addition of N <sub>2</sub> O, CH <sub>4</sub> –	Emission inventories should include	N <sub>2</sub> O, CH <sub>4</sub> for LNG vessels
11	33	High/medium	1.A.3.d	Navigation	Estimated % load of MCR for	Table 3-20 should include estimated	Load values
12	34	High/medium	1.A.3.d	Navigation	Improve guidance, examples,	Guidance, examples, and tables such	Improve guidance-activity data
13	38	High/medium	1.A.3.d	Navigation	Guidance on CCS and impact on	The Guidebook should include	Carbon Capture and Storage (CCS)
14	40	High/medium	1.A.3.d	Navigation	Inconsistent (or unclear)	Provide improved guidance on	Intern. cross boundary emissions
15	2	High/medium	1.A.3.a	Aviation	The section reports the	Information /emission factors on	Non-regulated pollutants
16	3	High/medium	1.A.3.a	Aviation	The section describes ICAO	Review Taxiing times and add	Taxi times
17	4	High/medium	1.A.3.a	Aviation	Particulate matter emissions	Update the description of PM	nvPM and vPM emissions
18	6	High/medium	1.A.3.a	Aviation	Table 2-1 provides information	Update Table 2-1 to 2024	2024 movements
19	7	High/medium	1.A.3.a	Aviation	Description of Tier 3B	Tier 3B - update to Eurocontrol	Tier 3B update to IMPACT tool
20	8	High/medium	1.A.3.a	Aviation	Alternative fuels, in particular	Add content on the impacts of SAF	Alternative fuels SAF
21	9	High/medium	1.A.3.a	Aviation	Note that SAF does not reduce	Include these aspects in the	WTW CO <sub>2</sub>
22	11	High/medium	1.A.3.a	Aviation	Summary and example tables	Add CO <sub>2</sub> and PM (mass and number)	CO <sub>2</sub> and PM EFs
23	12	High/medium	1.A.3.a	Aviation	The Excel tools provided as	For Tier 3 add description of choice	'Surrogate' aircraft excel tool
24	13	High/medium	1.A.3.a	Aviation	Section 4.8.3 says 'it is assumed	PM <sub>10</sub> vs. PM <sub>2.5</sub> - evidence suggests	PM <sub>10</sub> vs. PM <sub>2.5</sub>
25	14	High/medium	1.A.3.a	Aviation	The tools provided as Annex 5	Update tool to latest IMPACT	Update to IMPACT and EEDB
26	15	High/medium	1.A.3.a	Aviation	Annex 1 presents projections	Annex 1 - update to EAER 2025	Europ. Avi. Env. Report 2025
27	47	High/medium	All	All Chapters	Guidebook too relevant for EU	Include references with good	Non-EU countries road
28	16	Low	1.A.3.b	Road Transport	Review/enhance ageing	Review remote sensing data and	Ageing patterns
29	20	Low	1.A.3.b	Road Transport	Make Guidebook more useful to	The Guidebook should be updated	Count Emissions EU directive
30	37	Low	1.A.3.d	Navigation	Include anchoring phase.	The emissions inventory should	Anchoring phase
31	1	Low	1.A.3.a	Aviation	The section reports the use of	Review/compare/update ICAO	Update ICAO EFs

# Support – engagement of stakeholders

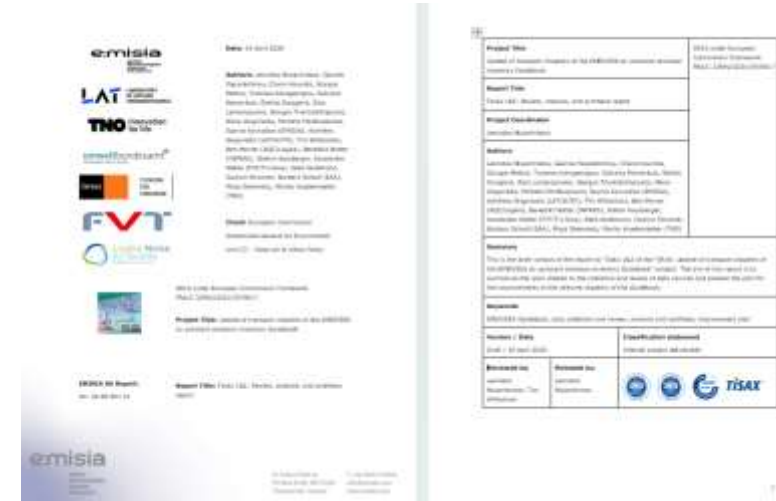


- We have ensured the engagement of various stakeholders for this project
  - ∴ They expressed their interest, willingness, commitment to support the project
  - ∴ Communication established, meetings organized
  - ∴ Data and email exchange is ongoing
  
- [Eurocontrol](#) for Aviation and [EMSA](#) (European Maritime Safety Agency) for Navigation
- [JRC](#) (Joint Research Centre) for Road and NRMM
- [ISPRA](#) (Italian Institute for Environmental Protection and Research) and [ARPAV](#) (Veneto Environmental Agency) for Navigation
- [Swedish Environmental Protection Agency](#) for Road and Navigation
- [VTT](#) (Technical Research Centre of Finland) for Road (studded tyres and non exhaust emissions)
- Expert Panel on Transport

# Feedback expected from TFEIP



- A draft version of the first project report has already been delivered to you
- Please review and provide your comments, suggestions, to the EP Leaders
  - ∴ Leonidas Ntziachristos, [leon@auth.gr](mailto:leon@auth.gr)
  - ∴ Georgios Fontaras, [georgios.fontaras@ec.europa.eu](mailto:georgios.fontaras@ec.europa.eu)



- ✓ Identify items that are missing from the update list
- ✓ Provide remarks related to the issues identified and/or the solution proposed
- ✓ Data, methods, reports, or other evidence that should be considered
- ✓ Specific information on emission factors
- ✓ Guidance from own national inventories, ranges of uncertainty, model activity data

**Road**

## **2 (21) Brake emission factors**

***“Review/update brake emission factors.”***

# Review of data sources



➤ Brake emissions in Guidebook are currently based on a review of studies until 2023 following GTR24, so the current review\* mainly targets post-2023 data:

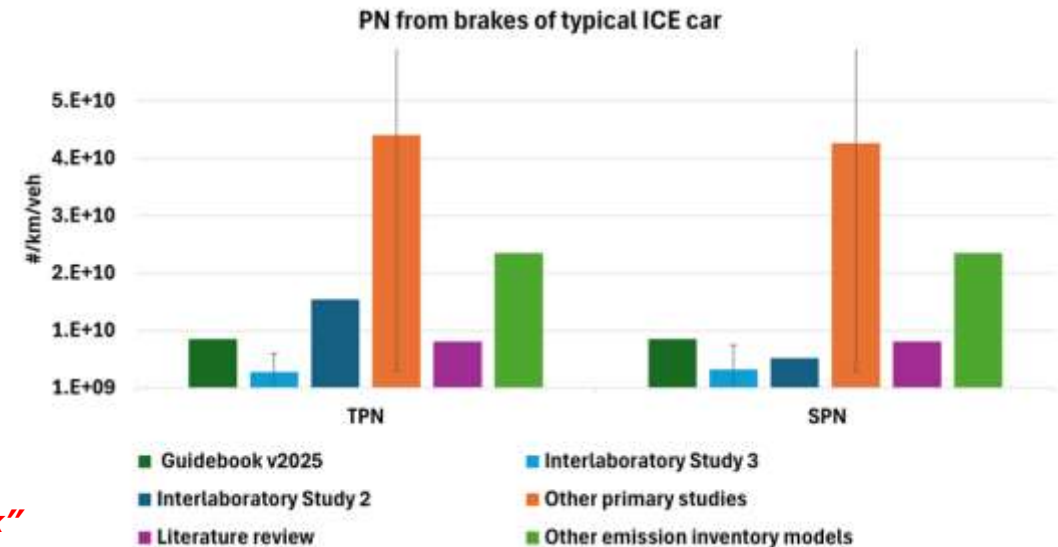
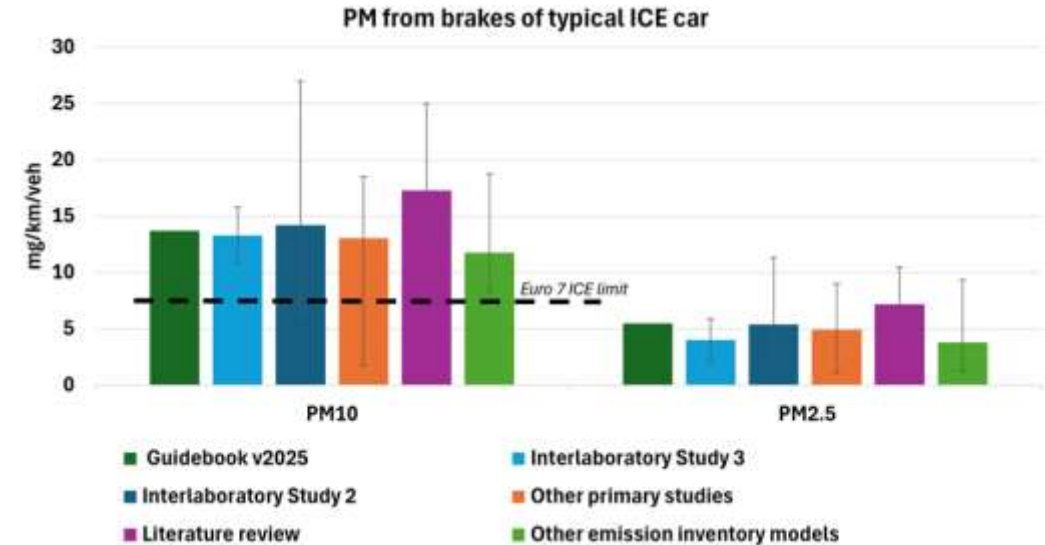
- ⋯ UNECE PMP Interlaboratory studies (ILS 1 & 2)
- ⋯ New GTR24-compliant primary studies
- ⋯ Comparison with other reviews & inventory models

➤ Key parameters are better evidenced:

- ⋯ PM/SPN, TPN/SPN, PM2.5/PM10, chemical composition, and effects of vehicle mass, braking technology & electrification.

➤ Remaining gaps:

- ⋯ Speed correction factors show inconsistencies
- ⋯ HDVs brake wear evidence remains limited (no ILS)



\* Results of the review in "Items 2 (21), 3 (22), 4 (24) - Brake and Tyre EFs.xlsx"

# Proposal for the improvement

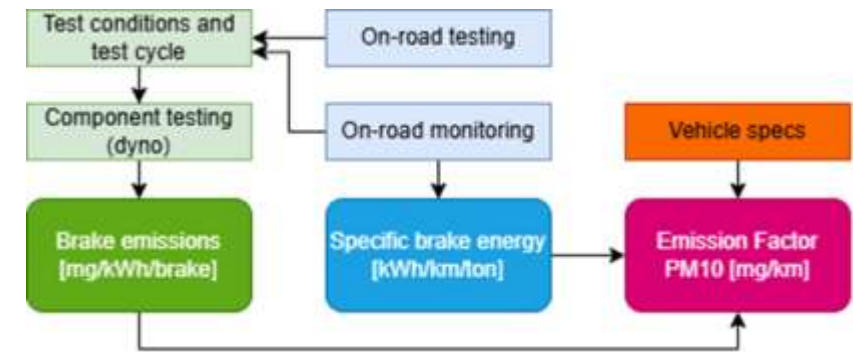


- Update core emission factor tables for PM10, PM2.5 and SPN, keeping alignment with PMP evidence:
  - ⋯ Recent measurements for LDVs show good agreement with existing EFs in Guidebook (differences within  $\pm 20\%$ ), suggesting limited EF adjustment.
- Strengthen documentation for impact of key parameters
  - ⋯ vehicle mass, brake system type, regenerative braking share) & chemical composition of PM.
- Improve treatment of HDVs
  - ⋯ introducing dedicated HDV EFs rather than deriving from LDV, while clearly flagging where assumptions is required.
- Explicitly state uncertainty/knowledge gaps where evidence is insufficient. For example:
  - ⋯ speed correction factors, secondary/volatile particle formation.

Parameters planned to be updated and their estimated level of uncertainty (high/medium/low).

Vehicle type	Wear factors	PM <sub>10</sub> & PM <sub>2.5</sub> factors	TPN & SPN factors	Regenerative braking	Speed correction	Vehicle mass	Chemical composition
LDVs	Low	Low	Low	Medium	High	Low	Medium
HDVs	High	High	Medium	High	High	High	High

Schematic approach towards determining emission factors for HDV brake wear.



## **3 (22) Tyre emission factors**

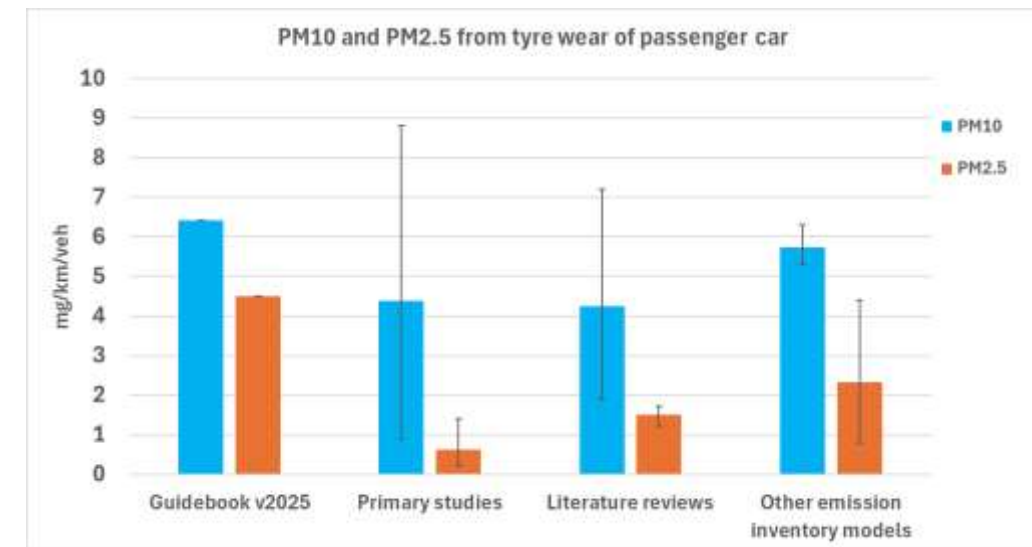
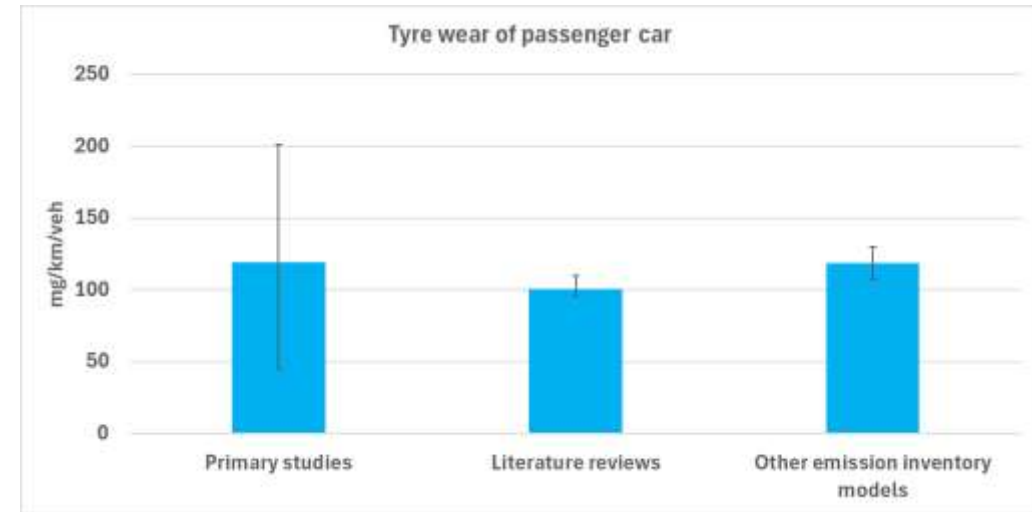
***“Review/update tyre emission factors.”***

# Review of data sources



- Tyre emissions in Guidebook are currently based on old data. Tyre data\* less harmonized & high variability across sources:
  - ∴ Primary sources: Mix of on-road (convoy) & lab tests
  - ∴ Comparison with other reviews & inventory models
- Total tyre wear of cars is relatively consistent:
  - ∴ Tyre wear is 100–120 mg/km/veh
  - ∴ PM vary a lot across sources (0.3-10% of tyre wear)
- Key parameters:
  - ∴ Differentiation by tyre type & vehicle mass
  - ∴ Limited studies provide urban/rural/motorway splits
- Key gaps remain:
  - ∴ Road abrasion & studded tyres have limited quantified evidence
  - ∴ chemical speciation is available but limited/not harmonized
  - ∴ Sparse data for HDVs.

\* Results of the review in "Items 2 (21), 3 (22), 4 (24) - Brake and Tyre EFs.xlsx"



# Proposal for the improvement



- Update tyre wear, PM and PN emission factors across different tyre types & powertrain/vehicle mass:
  - ⋯ Currently overestimation of PM from tyre wear
- Strengthen documentation for impact of key parameters:
  - ⋯ vehicle mass, tyre type, ambient temperature, driving behavior, mileage, etc.
- Update chemical speciation of tyre wear emissions:
  - ⋯ including organic compounds and secondary particles, acknowledging limited evidence.
- Address low-evidence topics:
  - ⋯ keep road wear and studded tyres as “high uncertainty / provisional” unless additional measurements can be added
  - ⋯ document gaps for future updates (e.g. HDVs).

**Information availability for parameters related to tyre wear.**

	LDVs (C1/C2)	HDVs (C3)
<b>Tyre wear factors</b>	High	Low
<b>PM<sub>10</sub> &amp; PM<sub>2.5</sub> factors</b>	High	Low
<b>TPN &amp; SPN factors</b>	Medium	Low
<b>Road wear factors</b>	Low	Low
<b>Powertrain type</b>	Medium	Low
<b>Speed correction factor</b>	Medium	Low
<b>Ambient temperature</b>	Low	Low
<b>Mileage</b>	Low	Low
<b>Studded tyres</b>	Low	Low
<b>Chemical composition</b>	Medium	Low

## **4 (24) Brake and tyre control options**

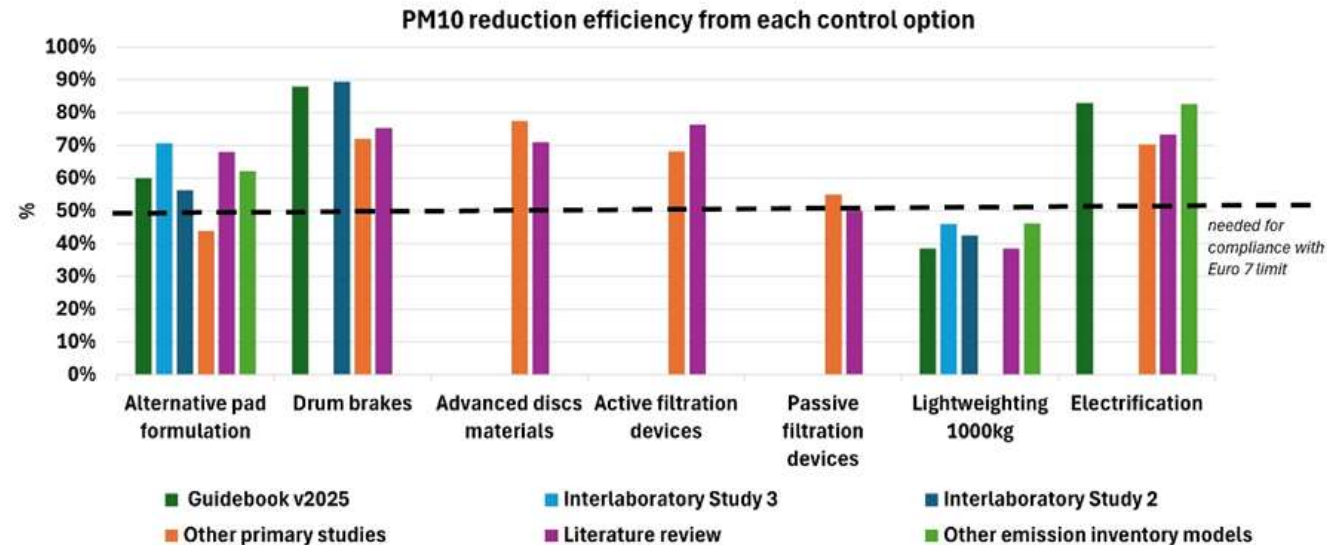
***“Introduce control options for road tyre and brake wear.”***

# Review of data sources & proposal for the improvement



- Brake control options have more mature evidence\* (incl. work aligned with Euro 7 context), while evidence\* for tyre-control options is less quantified.
- Brake options show high reduction potential:
  - ∴ pads/discs materials/design, particle collection devices, electrification, etc.
- Tyre options exist but needs to be quantified:
  - ∴ mainly linked to removal of high-abrasion tyres, reduce vehicle mass, and optimize driver behaviour.
- Brake/tyre control options not in current guidebook:
  - ∴ add a table of main tyre & brake control options with indicative PM10 reduction ranges and technology maturity/uncertainty

**Efficiency of various control options against brake wear.**



\* Results of the review in "Items 2 (21), 3 (22), 4 (24) - Brake and Tyre EFs.xlsx"

## 5 (25) Chemical speciation

*“Review/update chemical speciation.”*

# Review of data sources



- › Focus on composition of **NMVOOC** (current Guidebook focus).
- › A significant gap is identified: the Guidebook does not include **OVOCs & I/SVOCs**.
- › They play a major role in air pollution, particularly in ozone formation and Secondary Organic Aerosols (SOA).
- › **Measurement techniques:** for quantification hundreds of thousands chemical species
  - ∴ **PTR-ToF-MS**
    - ∴ Real-time VOC measurement (~1 s resolution)
    - ∴ Strong for **OVOCs & transient emissions**
    - ∴ No sample preparation
  - ∴ **GCxGC-MS**
    - ∴ Offline, high-resolution & sensitivity analysis
    - ∴ Identifies **I/SVOCs, UCMs, PAHs**
    - ∴ requires prior sampling, complex processing
- › Estimated emission composition based on the study [Wu et al. \(2025\)](#):
  - ∴ VOCs: **67.2%**
  - ∴ IVOCs: **24.3%**
  - ∴ SVOCs: **8.5%**

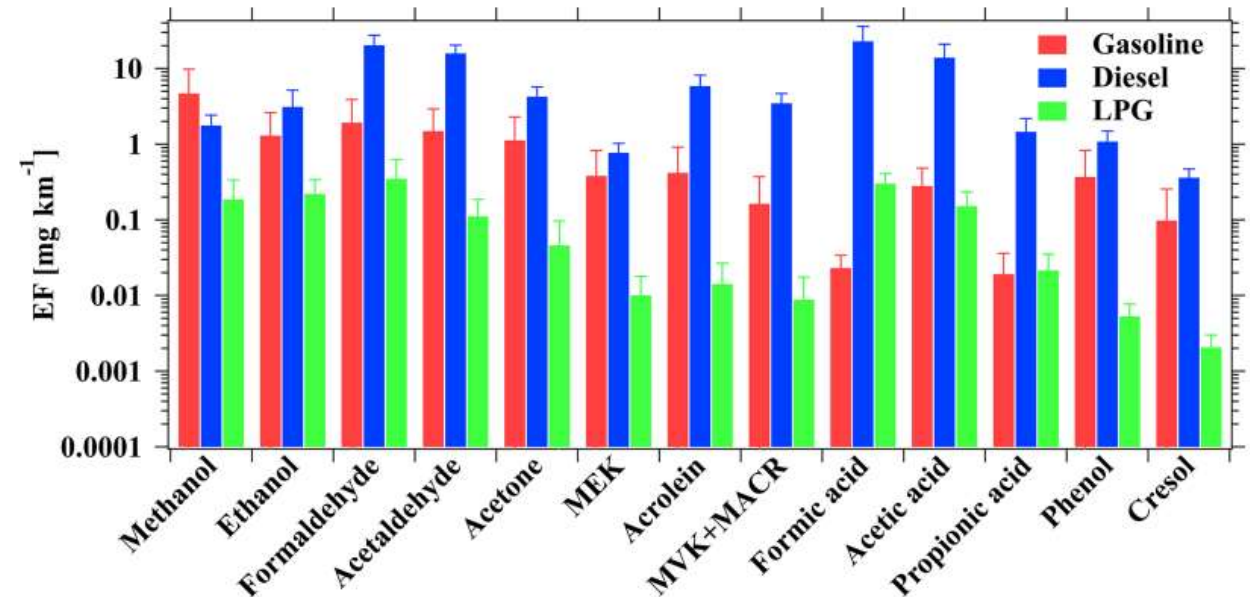
# Proposal for the improvement



- Include **PTR-ToF-MS & GC×GC-MS** in methodology section (chapter VOC speciation).
- Expand the speciation framework to explicitly include definitions and chemical composition of emerging pollutants:
  - ∴ OVOCs are dominated by **aldehydes** and **ketones** ([Wang et al. \(2022\)](#))
  - ∴ I/SVOCs define the **physical state** (how easily they evaporate), alkanes constitute the major fraction (~40%) ([Wu et al. \(2025\)](#), [Ling et al. \(2022\)](#))

## ➤ Tables 3.90a-e about composition of NMVOC:

- ∴ Literature review & update where is necessary ([Hakkim et al. \(2021\)](#))
- ∴ Incorporate recent studies about emissions in EURO 6 vehicles ([Ferrarese et al. \(2024\)](#))



**Figure:** The determined emission factors of representative OVOC species from different types of vehicles

## **27 (47) Guidance for non-EU countries**

***“Guidebook too relevant for EU member states, does not provide satisfactory guidance for non-EU countries.”***

# Review and assessment of data sources



- We were asked to focus on the **9 EU candidate countries (CLRTAP)**:
  - ∴ Albania, Bosnia and Herzegovina, Georgia, Montenegro, North Macedonia, Republic of Moldova, Serbia, Türkiye, Ukraine
- **Key information/data needed**:
  - ∴ Statistical activity data, i.e., number of vehicles per category/fuel/segment, mileage, energy consumption, etc.
  - ∴ Emissions standards and timeline of their introduction into the fleet
- We collected **country-specific** data from sources with policy measures and other relevant information
- All EU candidate countries use **Euro standards**, implemented with a **time delay** relative to the EU, through vehicle import and first-registration requirements
- There is strong reliance of these countries on **used-vehicle imports**, hence, the in-use vehicle fleets typically span multiple Euro emission classes

# Proposal for the improvement



- The EU candidate countries can base their emission calculations on the Euro standards **already existing** in the Guidebook
- The main difficulty remains on how to **allocate** the vehicle fleet into the various emission classes; this is a **known problem** not only for non-EU countries but also for many EU Member States
- We consider this as a good opportunity to provide a **general guidance** on how to obtain activity data and calculate emissions
  - ∴ With references, examples, tables with statistical data sources, etc.
  - ∴ Focus on EU candidate countries but, perhaps, we can make this guidance more general for all countries
  - ∴ Example on how to split the vehicle fleet per Euro standard can be given for a specific country
- Aim at **Tier 2/3**, since with the experience gained over the previous years in the road transport sector, countries should be discouraged from applying a method lower than Tier 2

1 (18) H<sub>2</sub>

*“Introduce H<sub>2</sub> as a fuel.”*

# Review of data sources



## Current status of EEA Guidebook

- › 1.A Annex Hydrogen Combustion covers chapters on “Internal Combustion Engines” and “Heavy Goods Vehicles” → provides only limited information on emissions
- › Due to insufficient data, emission factors for hydrogen combustion are currently considered similar to those for compressed natural gas

## Literature review

- › Target to identify the principal technologies (mainly market available), powertrain configurations, and vehicle categories in which H<sub>2</sub> is utilised as a fuel
- › Literature focused on engine testing and aftertreatment systems → up to now limited literature on complete vehicle w/ H<sub>2</sub>-ICE found
- › Significant amount of literature on retrofitting (and modifications) of existing ICEs to use H<sub>2</sub>
- › Fuel cell technology applied to both LDV and HDV → low market penetration

# Proposal for the improvement



- Define vehicle categories that represent the current market state-of-the-art
  - ⋮ LDVs and HDVs
  - ⋮ For vehicles with H<sub>2</sub>-ICE based powertrains → separation based on the EAT system if necessary
  - ⋮ For vehicles with fuel cell-based powertrains
  
- As this is the first inclusion of H<sub>2</sub> as a fuel in the EEA Guidebook, the update should clearly outline the defined vehicle categories
  - ⋮ Include a brief description of the H<sub>2</sub>-fueled technologies
  
- Introduction of emission factors for pollutant emissions and fuel/energy consumption → Tier 1 and Tier 2 methodologies may be applied at this initial stage
  - ⋮ few sources address full vehicles → introduction of speed-dependent emission factors may not be possible yet

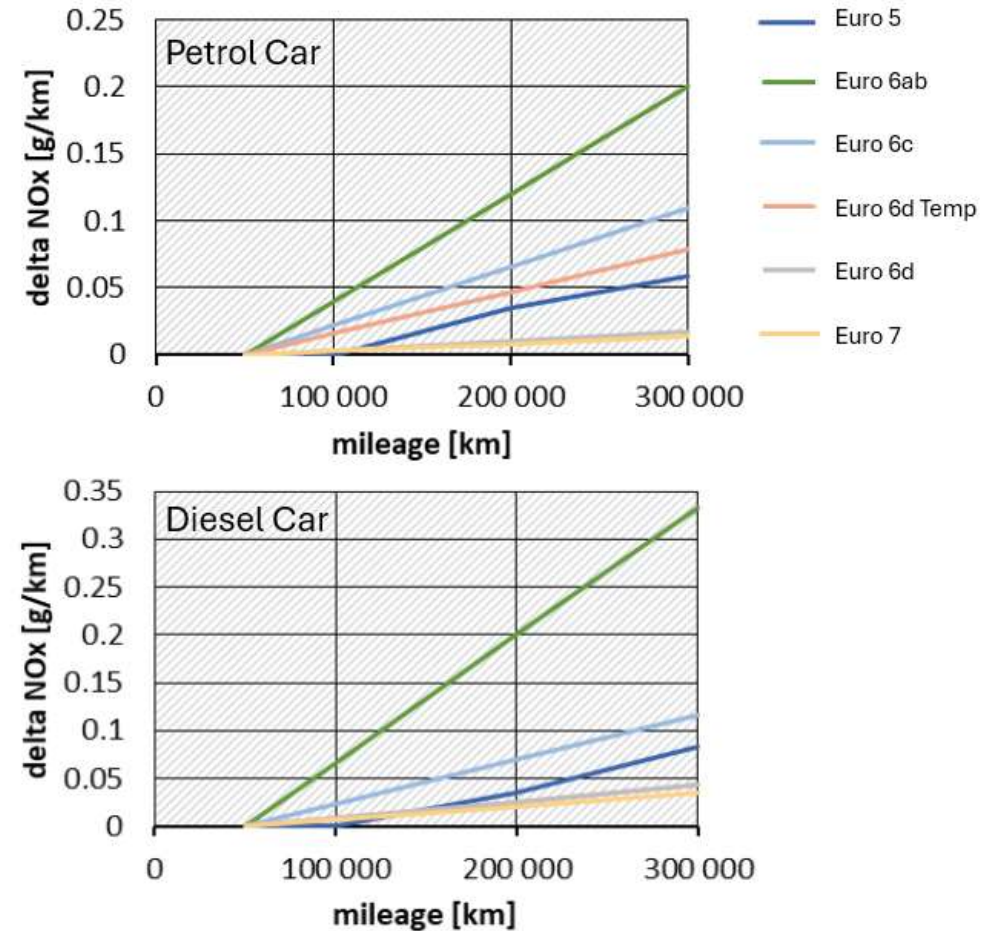
## **28 (16) Ageing patterns**

***“Review/enhance ageing patterns with remote sensing data.”***

# Review of data sources & proposal for the improvement



- The current Guidebook is based on remote sensing measurements collected between 2011 and 2017, and targeted measurements from 35 Euro 6 cars.
- Multiple subsequent remote sensing campaigns include:
  - ⋯ Euro 6ab cars and LCVs up to 160,000 km
  - ⋯ Euro 6d cars up to ca. 80,000 km.
  - ⋯ Euro VI HGVs up to 1,000,000 km.
- Some remote sensing data is collated and some is in unpublished databases.
- Few published studies have looked specifically at ageing.
- HBEFA update in 2025 to include ageing,
  - ⋯ Included detailed analysis of more recent remote sensing.
  - ⋯ Ageing factors in HBEFA 5.1 are by mass, not %.
  - ⋯ Work done to update HBEFA could inform the Guidebook update.



Example of Ageing Factors from HBEFA 5.1

## **29 (20) Count Emissions EU directive**

***“Make Guidebook more useful to  
upcoming Count Emissions EU  
directive.”***

# Core methodological differences Guidebook vs. CountEmissions EU



	Guidebook 2023	CountEmissions EU
<b>System boundary</b>	Tank-to-Wheel (vehicle exhaust only)	Well-to-Wheel (full energy lifecycle)
<b>Primary objectives</b>	Air pollutant inventories (NO <sub>x</sub> , PM, NMVOC, SO <sub>x</sub> , NH <sub>3</sub> , etc.)	GHG accounting (CO <sub>2</sub> equivalent)
<b>Reporting metric</b>	g pollutant / kg fuel, totals per year	g CO <sub>2e</sub> / tonne-kilometer or passenger-kilometer
<b>Accounting logic</b>	Inventory-based reporting ensuring national completeness and consistency	Service-based GHG accounting supporting comparability and decision-making

➤ Main source: [CLEVER](#) project

# Consequences for vehicles and technologies



## > Electric and hydrogen vehicles:

- ∴ Guidebook: zero exhaust emissions in transport sector
- ∴ CountEmissions EU: upstream electricity / hydrogen emissions mandatory

## > Vehicle classification:

- ∴ Guidebook uses NFR codes and Euro standards
- ∴ CountEmissions EU follows ISO 14083 logistics-oriented categories

## > Transport intensity:

- ∴ CountEmissions EU requires load factors and activity-based assumptions

# Proposed approach – targeted Guidebook update



- › **Consistency** is needed between the two frameworks
- › **Distinct** objectives and scopes
- › **Recommended action:** add a short explanatory annex clarifying the relationship between
  - ∴ national inventories (Guidebook), and
  - ∴ corporate/service-level reporting (CountEmissions EU, ISO 14083)

**NRMM**

# Summary of NRMM chapter updates



## > **Emission factors**: not updated for many years, many references are prior to 2016

- ∴ Consider cold start and idling (which can make up about half of emissions) for newer diesel machinery Stages IV/V
- ∴ Update of gasoline evaporation
- ∴ Guidance for non-exhaust emissions

## > **Activity data**: better guidance considering the diversity of the NRMM sector

- ∴ Operation patterns
  - : Idling vs. working time
  - : Load factors
- ∴ Differentiation of working hours by operating phase (new approach for diesel Stages IV/V)
  - : Light/medium/heavy work
  - : Longer/shorter idling

## 6 (42) Emission factors

***“Emission factors for all pollutants have not been updated for many years. Many references for EFs in the GB are prior to 2016.”***

# Review of data sources



EF type	Current shortcoming(s)	Data sources for improvement
Hot exhaust	<ul style="list-style-type: none"> <li>• Mostly derived from emission limit values and outdated. Especially for machines with SCR, cold start and idling leads to higher emissions, which are not captured by available EF.</li> <li>• Degradation factors are not differentiated by emission stages so far.</li> </ul>	<ul style="list-style-type: none"> <li>• Most available data sources are from before 2016</li> <li>• Latest German and Dutch inventories feature updated EF for Stages IIIB or IV</li> <li>• Consideration of cold start and long idling in newest EF from PHEM, used in German study and current Swiss inventory update</li> </ul>
Gasoline evaporation	<ul style="list-style-type: none"> <li>• No guidance for machinery not explicitly covered</li> <li>• Unclear reference to hours (operation or lifetime)</li> </ul>	We propose to use simple methodology based on US EPA (implemented in the German inventory)
Non-exhaust	Not available/mentioned so far	Estimation of EF possible based on older sources from Switzerland
Electric/alternative propulsion systems	Not available/mentioned so far	Available NRMM emission inventories that include electric/alternative machinery

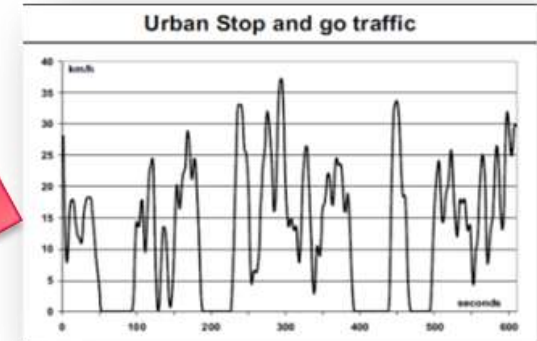
# NRMM emission modelling approach



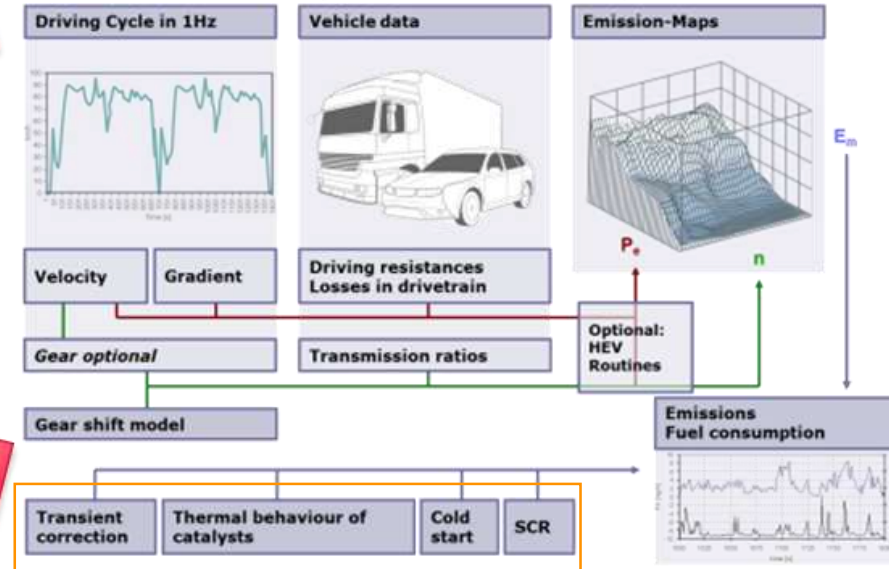
PEMS test data



Mission profiles



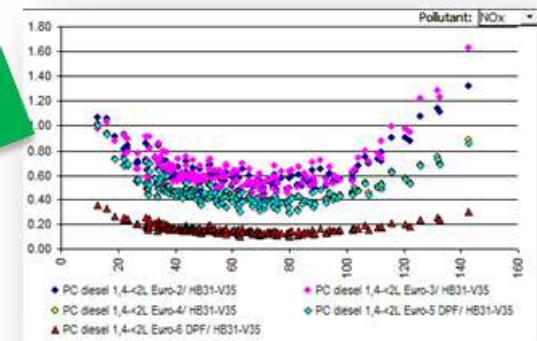
## PHEM Passenger car and Heavy duty Emission Model



Engine test data



Emission factors



Physical model of the exhaust aftertreatment system

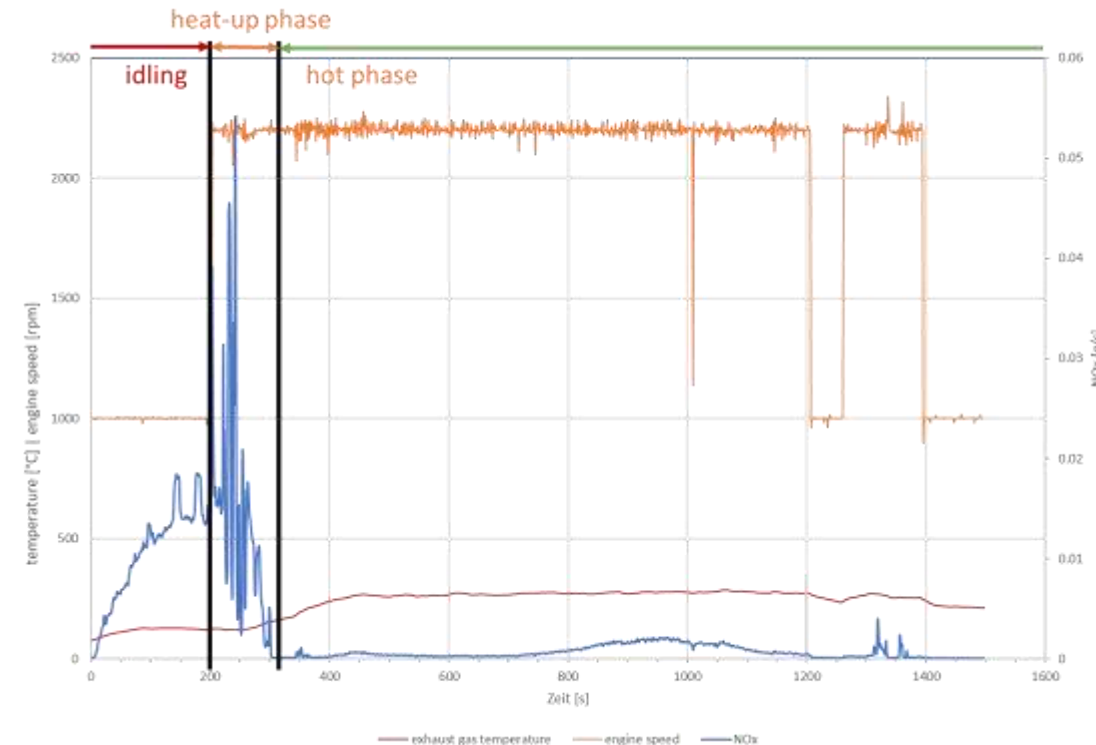
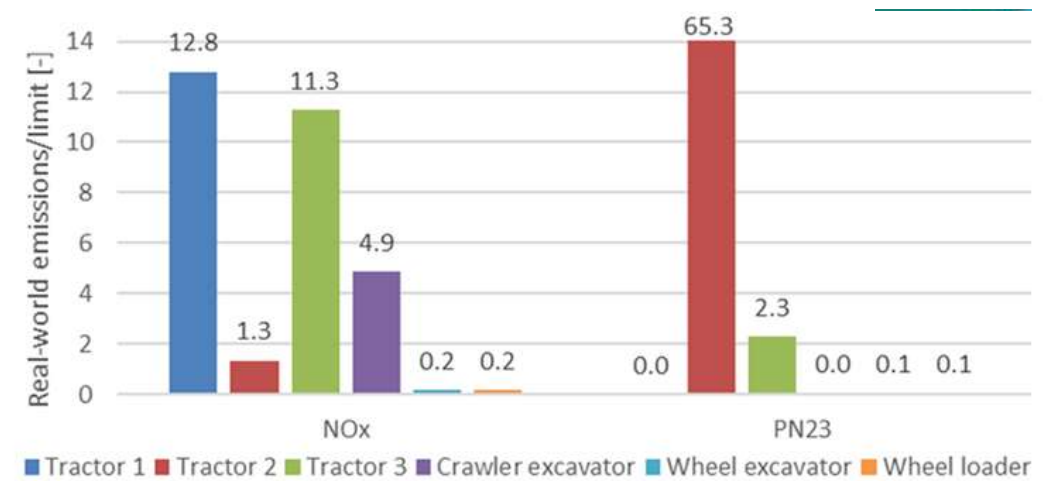
# Overview on available NRMM test data

## Test data from different sources

- Detailed emission test data from TUG (>10 machines) + ongoing test campaign until summer 2027 (+ 10 machines)
- Test data from TNO, TFZ Bayern, FH Biel, AVL MTC (ca. 10 machines)
- Discussion about possible use of ISM test data with JRC ongoing
- Ongoing research for other test data sources

## Measurement results

- Significant spread in emission performance of single machines
- High impact of cold start and longer idling periods on emissions
- Significant impact of higher operation hours on emission behaviour due to ageing
- Share of high emitting machines (tampered or defect) not clear so far



# Proposal for improvement



- Emission factors will be updated based on latest inventories – mainly Swiss inventory currently being updated.
  - ⋆ For the more generalized Tiers 1 and 2, EFs will be aggregated based on activity data from Switzerland (so far: based on activity data from Denmark).
- Ageing correction factors for Tier 3 will be updated as well
- SCR and Diesel Particulate Filter (DPF) tampering: Will be mentioned (likely relevant share of machinery is affected). However, number values for shares of tampered machinery cannot be proposed since no data is available so far and they are difficult to assess.
  - ⋆ Standard methods known for roadside inspections are not possible, e.g., plume-chasing is not possible in the work environments of NRMM, at least not without operators being aware.
- Energy and fuel consumption factors will be updated/added (mainly, electric machinery and other alternative propulsion systems)
- The evaporative NMVOC emissions chapter under Tier 3 will be re-written.
- A new chapter on non-exhaust particle emissions will be added under Tier 3.

## 7 (43) Activity data

***“NRMM is a very diverse sector and many countries find it challenging to obtain activity data such as information regarding operation patterns (e.g. idling vs. working time, load factor) which are one of the key parameters determining the level of emissions.”***

# Review of data sources



- Calculation approach for **modern diesel machinery** requires **differentiation of operating phases** (work at different load levels, idling and subsequent heat-up, number of cold or cool start)
  - ∴ TNO will analyze 1 Hz **telemetry data** from up to 150 construction machines measured over the course of several months to improve the load profiles for new diesel machinery. A publicly available report of this dataset is expected later this year
- **Older diesel machinery** and all other drivetrain technologies: **Total annual operating hours and average load factors** are required
  - ∴ Typical values for load factors have been compared across European NRMM emission inventories by the European Research group for Mobile Emission Sources (ERMES) NRMM working group in 2017
  - ∴ Typical operating hours will be taken from existing inventories at Tier 3 level
- Recommendations regarding **system boundaries towards road transport and towards stationary engines** need update
- Description of **current trends** needs update (e.g., there are observations that the earlier trend towards larger machinery has been halted or even reversed)

# Proposal for improvement



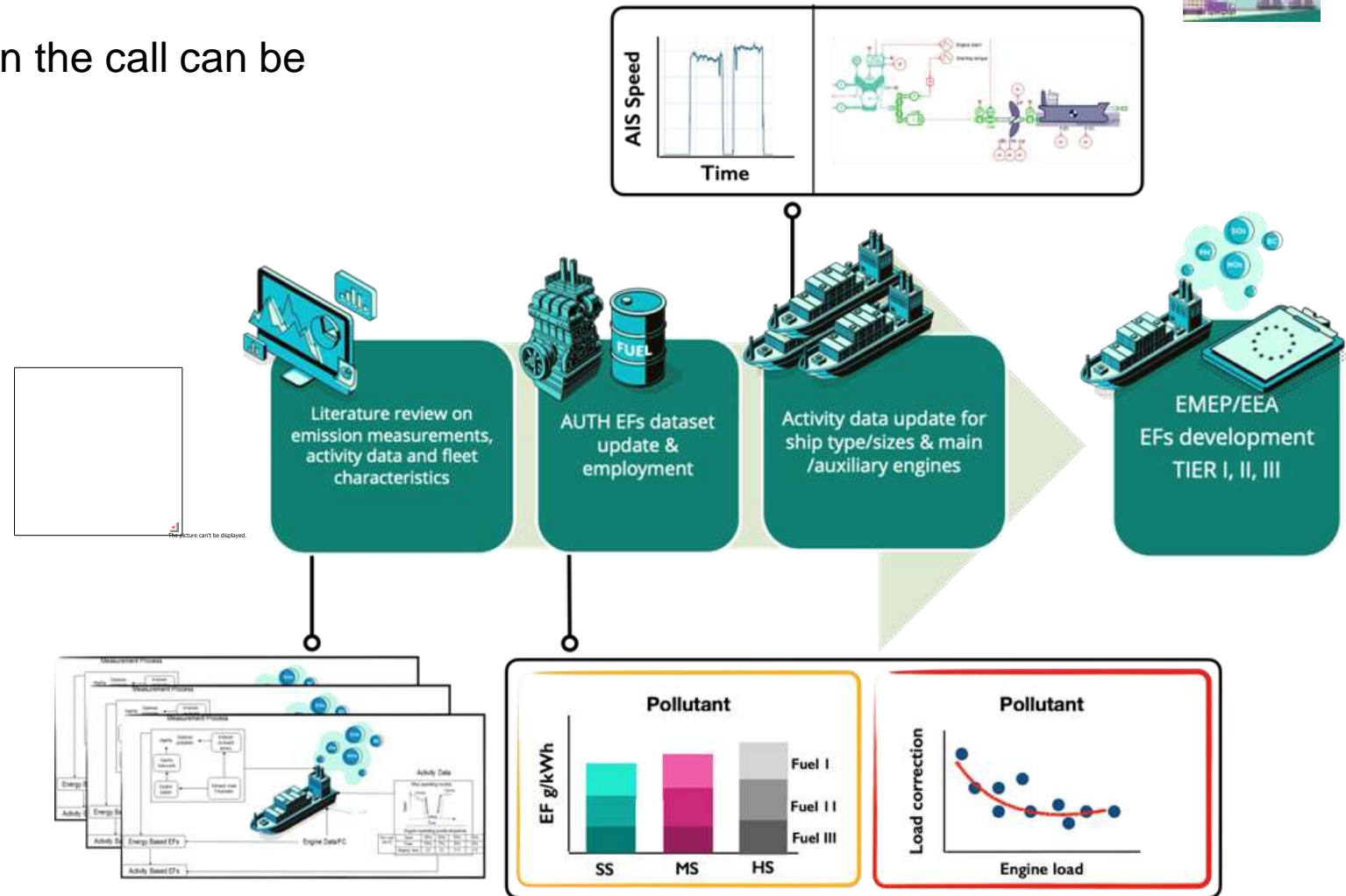
- The activity data subchapter of Tier 3 will be updated with:
  - ⋮ Typical average load factors and/or ranges for modern small diesel, older diesel and other drivetrain technology machines.
  - ⋮ Load profiles for diesel machinery of Stages IV and V in the power range from 56 to 560 kW, including assignment of load profiles to machine types
  
- Other aspects mentioned (system boundaries, trends, electric machinery): Texts will be updated accordingly

# Navigation (shipping)

# Overall methodology

The eight points of improvement defined in the call can be summarized in three main areas:

- 1. Emission factors new categorization:**  
A major change in the categorization of emission factors introducing ship types and sizes according to Eurostat classification
- 2. Activity profiles & fleet composition update:**  
A data revision on the fleet-average characteristics and activity profiles of the various ship types & sizes according to the new classification
- 3. Alternative fuels, missing pollutants:**  
Updates and additions to EFs for covering alternative fuels and emerging emission control technologies, as well as pollutant species missing from the chapter



**Main challenges are to define the new ship categorization and specify the activity profiles**

## 8 (30) Expanded ship categories

*“More detailed/expanded ship categories,  
consider Eurostat classification.”*

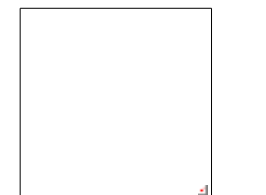
# Review of data sources



## Literature review on international and regional inventories as well as publications and reports

Recognized inventories

Source	Ship categories
EMEP/EEA Guidebook v.2023	Container, Dry bulk carriers, General cargo, General cargo, Liquid bulk ships, Other, Passenger, Ro ro cargo
Eurostat Aggregated	Liquid bulk carrier, Dry bulk ships, Container ship, Specialized carrier, General cargo non-specialized, Dry cargo barge, Passenger ship, Fishing, Offshore activities, Offshore activities, Tugs. Miscellaneous
Eurostat Detailed	Oil tankers, Chemical tankers, LG tanker, Tanker barge, Other barge, Bulk/oil carriers, Bulk carriers, Container ship, Vehicle carrier, Livestock carrier, Irradiated fuel carrier, Barge carrier, Chemical carrier, Reefer, Ro-Ro passenger, Ro-Ro container, Other Ro-Ro cargo, Combination carrier general cargo/passenger, Combination carrier general cargo/container, Deck barges, Hopper barges, Lash-seabee barges, Open dry cargo barges, Covered dry cargo barges, Other dry cargo barges, Passenger ship, Fishing, Drilling and exploration vessels, Offshore support vessels, Tugs, Dredgers, Research/survey vessels. Other vessels
MRV report	Bulk carrier, Chemical tanker, Combination carrier, Container ship, Container/Ro-Ro cargo ship, Gas carrier, General cargo ship, LNG carrier, Oil tanker, Other ship types, Other ship types (Offshore), Passenger ship, Passenger ship (Cruise Passenger ship), Refrigerated cargo carrier, Ro-pax ship, Ro-Ro ship, Vehicle carrier
IMO 4 <sup>th</sup> GHG study	Bulk carrier, Chemical tanker, Container, General cargo, Liquefied gas tanker, Oil tanker, Other liquids tankers, Ferry-pax only, Cruise, Ferry-RoPax, Refrigerated bulk, Ro-Ro, Vehicle, Yacht, Service-Tug, Miscellaneous-fishing, Offshore, Service-other, Miscellaneous-other
USEPA	Bulk Carrier, Chemical Tanker, Container Ship, Cruise, Ferry/Passenger, Ferry/Roll-on/Passenger, Fishing, General Cargo, Liquefied Gas Tanker, Miscellaneous, Offshore Support/Drillship, Oil Tanker, Other Service, Other Tanker, Refrigerated (Reefer), Roll-on/Roll-off (RORO), Vehicle Carrier, Yacht



## Indicative ship classification linkage

	Ship categories	Guidebook v.2023	EUROSTAT
Cargo	General cargo	x	
	Ro-Ro cargo	x	
	Cargo, non-specialized		x
	Cargo, specialized		x
	Dry cargo barge		x
	Liquid bulk ships	x	x
Passenger	Dry bulk carriers	x	x
	Container	x	x
	Passenger	x	
Other	Cruise passenger		x
	Passenger (excl. cruise)		x
	Fishing	x	x
	Offshore activities		x
	Other	x	
	Tug	x	x
	Miscellaneous		x

# Proposal for the improvement



- The proposed update will introduce an **enhanced ship categorization framework**, which will serve as the basis for revising technical specifications, activity profiles and emission factors.
- The development of the updated classification will be based on a systematic analysis of the reviewed literature and datasets, combined with the reporting needs of Member States.
- The process will be **supported by expert consultation**, including engagement with TFEIP, EMSA and other relevant stakeholders, such as inventory practitioners.
- The objective is to define a **harmonised and operationally meaningful** set of ship categories that balances **increased detail with practical applicability**.
  
- **Open issue:** Which ship categorisation should the updated Guidebook version ultimately adopt?

**9 (31) Emission factors update (alternative fuels, Tier III)**

***“Emission factor update, emphasis on alternative fuels and Tier III incompliance.”***

**10 (32) N<sub>2</sub>O, CH<sub>4</sub> for LNG vessels**

***“Addition of N<sub>2</sub>O, CH<sub>4</sub> – especially for LNG vessels.”***

**13 (38) Carbon Capture and Storage (CCS)**

***“Guidance on CCS and impact on emissions.”***

# Review of data sources

- **LAT/AUTH updates from v.2021 values**
- **New additions**

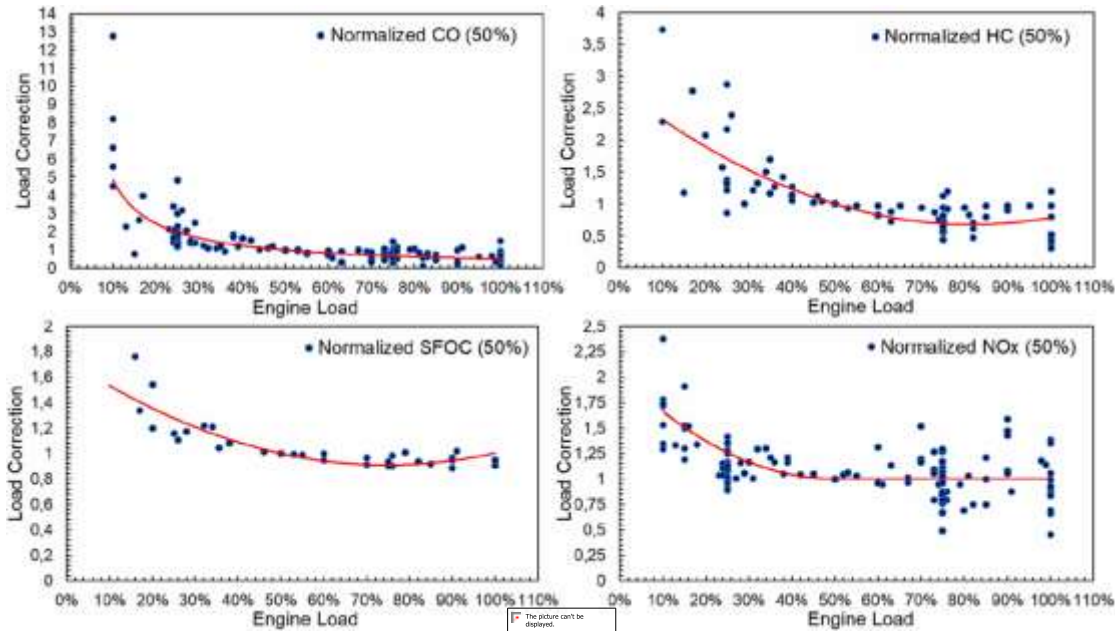
## Fuels

## Emission control technologies

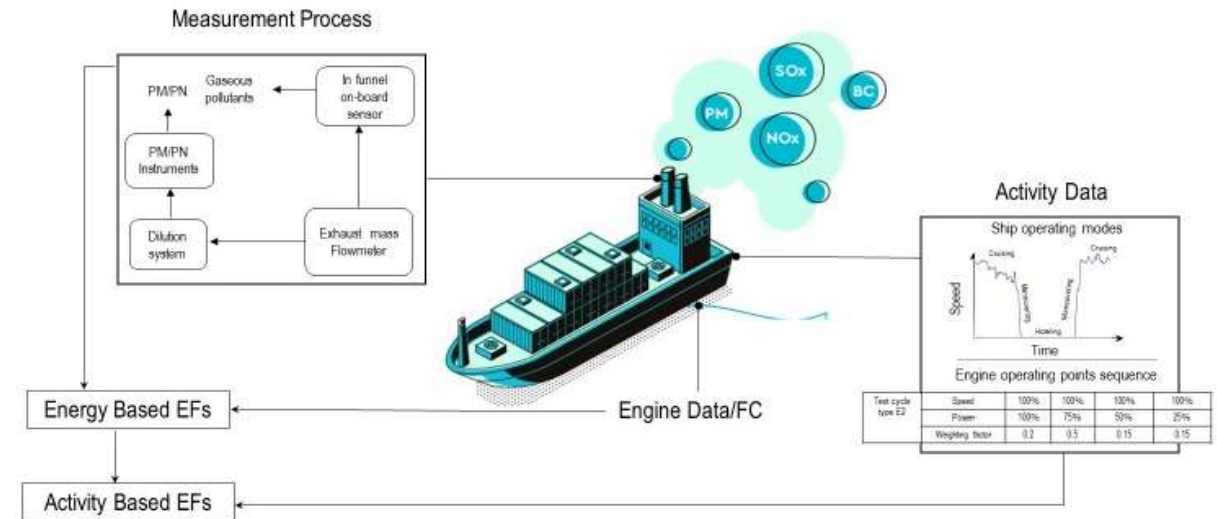
Fuel type	Pollutant	Sources
<b>Residual Distillate</b>	SFOC, CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, NO <sub>x</sub> , NH <sub>3</sub> , CO, HC, NMVOC, SO <sub>2</sub> , PM, PN,	(Agrawal et al., 2010; Agrawal, Malloy, et al., 2008; Agrawal, Welch, et al., 2008; Bai et al., 2020; Celo et al., 2015; T. Chountalas, 2023; Chu-Van et al., 2018; Cooper, 2001, 2003; Fridell et al., 2008; Fridell & Salo, 2016; Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Ioannidis, et al., 2021; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2021, 2022; Gysel et al., 2014, 2017; Hallquist et al., 2013; Huang et al., 2018; Jahangiri et al., 2018; Jayaram, Agrawal, et al., 2011; Johnson et al., 2018; Kalender & Ergin, 2017; Khan, Giordano, et al., 2012; Kristensen, 2012; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Kuittinen, et al., 2019; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Ntziachristos, et al., 2019; Lehtoranta et al., 2013; Liu et al., 2018; McCaffery et al., 2021; Moldanová et al., 2009, 2013; Murphy et al., 2009; Ntziachristos et al., 2016; Petzold et al., 2010, 2011; Ryu et al., 2016; Shen & Li, 2020; Sippula et al., 2014; Van et al., 2016; Wayne Miller et al., 2012; Winnes et al., 2016, 2020; Winnes & Fridell, 2009, 2010; Wu et al., 2018; Z. Yang et al., 2019; Zetterdahl et al., 2016; Zhang et al., 2016; J. Zhou et al., 2017)
<b>LNG</b>	SO <sub>4</sub> , OC, BC, Ash	(Anderson et al., 2015; T. Chountalas, 2023; Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2021, 2022; IMO, 2020; Lehtoranta et al., 2023; Mallouppas & Yfantis, 2021; MAN, 2016; MAN Energy Solutions, 2022; Nylund et al., 2016; Ushakov et al., 2019)
<b>Methanol</b>		(Andersson & Márquez, 2016; Fridell et al., 2021; Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; IMO, 2020; Timonen et al., 2022; H. Wang et al., 2020)
<b>Ammonia</b>		Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Hansson et al., 2020; Schwarzkopf et al., 2023; Voniati et al., 2023)
<b>Biofuels</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM	(Aakko-Saksa et al., 2016; Bendl et al., 2024; T. D. Chountalas, Founti, & Hountalas, 2023; T. D. Chountalas, Founti, & Tsalavoutas, 2023; T. Chountalas & Founti, 2021; Fischer et al., 2024; Graboski et al., 2003; Grigoriadis et al., 2026a; Gysel et al., 2014; Khan, Russell, et al., 2012; Kuittinen et al., 2021; Lloyd's Register, 2022; Petzold et al., 2011; Varatharajan & Cheralathan, 2012; Varuvel et al., 2012)
<b>Hydrogen</b>	SFOC	(Atilhan et al., 2021; Bicer & Dincer, 2018; McKinlay et al., 2021; Pan et al., 2014)

Fuel type	Pollutant	Sources
<b>Scrubber</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM, PN, OC, BC, SO <sub>4</sub> , Ash	(Fischer et al., 2024; Fridell & Salo, 2016; Grigoriadis et al., 2026a; Grigoriadis, Kousias, et al., 2024; Grigoriadis, Mamarikas, et al., 2024; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Jeong et al., 2023; Johnson et al., 2018; Karjalainen et al., 2022; Kuittinen et al., 2021; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Kuittinen, et al., 2019; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Ntziachristos, et al., 2019; Rutherford et al., 2016; Santos et al., 2022; Tran, 2017; Ushakov et al., 2020; Z. Wang et al., 2022; Winnes et al., 2020; J. Yang et al., 2021; J. Zhou et al., 2017)
<b>SCR</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM, PN, OC, BC, SO <sub>4</sub> , Ash	(Cooper, 2001; Fridell et al., 2008; Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, et al., 2024; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Hallquist et al., 2013; Jayaram, Nigam, et al., 2011; Kuittinen et al., 2021, 2024; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Kuittinen, et al., 2019; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Ntziachristos, et al., 2019; Lehtoranta et al., 2012, 2015, 2017; MAN, n.d.; Nuszkowski et al., 2009; Pirjola et al., 2014; South Coast Air Quality Management District, 2015; Timonen et al., 2022; Winnes & Fridell, 2010; Zetterdahl et al., 2016; S. Zhou et al., 2024)
<b>EGR</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM, PN	(T. Chountalas, 2023; Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Ushakov et al., 2020; Z. Wang et al., 2022; Zheng et al., 2004)
<b>DOC</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM, PN	(Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Guo et al., 2015; Karjalainen et al., 2022; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Kuittinen, et al., 2019; Lehtoranta, Aakko-Saksa, Murtonen, Vesala, Ntziachristos, et al., 2019; H. Wang et al., 2020)
<b>DPF</b>	SFOC, CO <sub>2</sub> , NO <sub>x</sub> , CO, HC, SO <sub>2</sub> , PM, PN	(Grigoriadis et al., 2026a; Grigoriadis, Mamarikas, Kalitsis, et al., 2022; Grigoriadis, Mamarikas, Ntziachristos, et al., 2022; Kuwahara et al., 2012; South Coast Air Quality Management District, 2015; Weiwei et al., 2019; J. Zhou et al., 2024)
<b>CCS</b>	CO <sub>2</sub>	Grigoriadis et al., (2024), Lee et al., (2021), Feenstra et al., (2019), Bureau Veritas, (2023), Ros et al., (2021), Wermuth et al., (2021), Ahmed et al., (2025), Long et al., (2021), Luo and Wang, (2017), DNV Maritime, (2023), Negri et al., (2022), Malmgren et al., (2021), Maersk Mc-Kinney Møller Center for Zero Carbon Shipping, (2022; 2023). Outcomes from EU-funded research projects, NAVGREEN and REALCHEM, in which LAT/AUTH participates.
<b>Hybrids Electrified</b>	Energy consumption	(Aletras et al., 2024; Balcombe et al., 2019; DNV Maritime, 2024; Kotrikla et al., 2025; Liora et al., 2025; Mamarikas et al., 2025; Nanaki & Koroneos, 2013)

# Emission factor development methodology



$$\text{Emission Factor} = \text{BEF} * f(\text{EL}) \left[ \frac{\text{g}}{\text{kWh}} \right]$$



Pollutant / Consumption	Base Emission (BEF) or Consumption (BCF) factor			
	Any type	SSD	MSD	HSD
NO <sub>x</sub> (g/kWh)	13,2 ± 3,98 (35)	14,4 ± 3,60 (15)	12,4 ± 4,08 (15)	11,7 ± 3,68 (5)
CO (g/kWh)	0,898 ± 0,571 (38)	0,714 ± 0,631 (14)	0,974 ± 0,530 (18)	1,10 ± 0,361 (6)
HC (g/kWh)	0,440 ± 0,350 (20)	0,358 ± 0,234 (7)	0,405 ± 0,204 (9)	0,662 ± 0,599 (4)
SFOC (MJ/kWh)	7,80 ± 0,743 (43)	7,57 ± 0,40 (36)	8,42 ± 0,493 (4)	9,74 ± 0,891 (3)

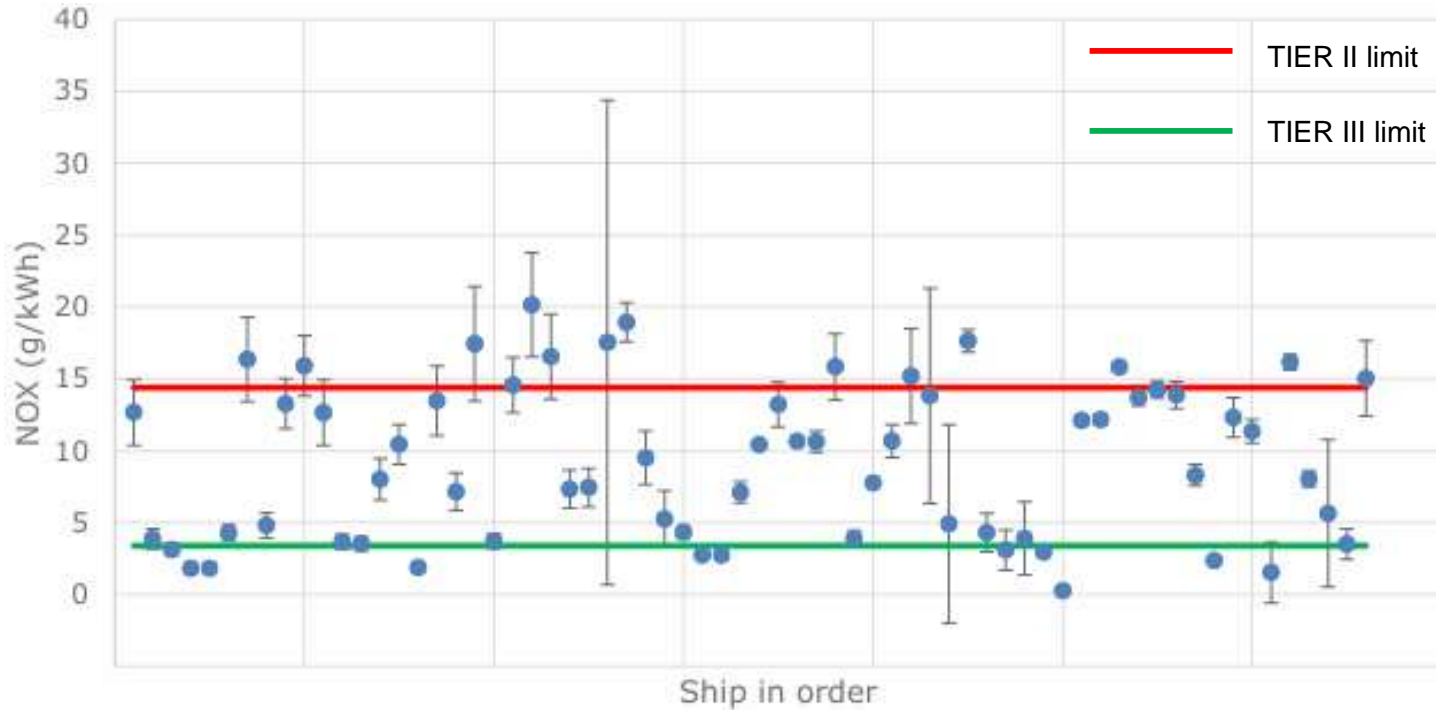
## Measurement methods:

- On-board
- Engine test-beds
- Remote sensing technologies

## Literature review:

- Collection of 325 publication
  - Use of 94 sources focused
  - Over 300 emission measurement results
- In-house measurement campaigns:**
- Over 150 engines tested
  - SFOC: 33 2-stroke ME and 132 4-stroke AE
  - Emissions: 12 ME and 13 AE
  - LNG, Methanol, Biofuels, Scrubber, SCR, EGR

# NOx TIER III incompliance rates



- Remote measurements at North Sea (Great Belt bridge, Wedel, Port of Rotterdam)
- High fraction of ships corresponds to brake specific NO<sub>x</sub> emissions which **exceed the Tier III limit with more than 50%**.
- Real-world NO<sub>x</sub> emission of many Tier III ships is above even the Tier II level.

Data are also available for **SOx compliance** even this is not requested by the call. Compliance for SOx is significantly higher than NOx.

**Source:** SCIPPER

# Proposal for the improvement



- Emission factors will be revised across **all Tier methods**, with primary emphasis on the Tier 3 approach. **Tier 3 emission factors** will be provided per pollutant and differentiated by:
  - ∴ **engine type**
  - ∴ **fuel type**
  - ∴ **operating mode**
  - ∴ **ship category**
- **Tier 1 and Tier 2 emission factors** will be recalculated through statistical aggregation of the refined Tier 3 dataset, taking into account:
  - ∴ updated fleet composition
  - ∴ engine type penetration
  - ∴ representative fleet operational characteristics
- All relevant emission factor tables will be revised to explicitly **include N<sub>2</sub>O and CH<sub>4</sub>**, across all Tier methods.
- **Guidance will be provided:**
  - ∴ for calculating the impact of CCS on GHGs/air pollutants
  - ∴ for the incompliance rate to correct NO<sub>x</sub> TIER III EFs

**11 (33) Load values**

***“Estimated % load of MCR for main and auxiliary engine (Table 3-20).”***

**12 (34) Improve guidance-activity data**

***“Improve guidance, examples, tables on power vs. GT, main/aux power, cruise speeds (Tables 3-9, 3-17, 3-19, 3-18, 3-10), also considering ETS data.”***

**30 (37) Anchoring phase**

***“Include anchoring phase.”***

## 2. Activity profiles & fleet composition limitations



➤ Indicative Guidebook tables that are **outdated** and require an **update**

Table 3-9 Estimated average main engine power (total power of all engines) by ship category

Ship category	Main engine power (kW)	
	1997 fleet	2010 fleet
Liquid bulk ships	6.695	6.543
Dry bulk carriers	8.032	4.397
Container	22.929	14.871
General cargo	2.657	2.555
Ro Ro Cargo	7.898	4.194
Passenger	3.885	10.196
Fishing	837	734
Other	2.778	2.469
Tug	2.059	2.033

Source: Trozzi, 2010

Table 3-19 Assumptions for the average cruise speed and average duration of in-port activities

Ship Type	Ave. Cruise Speed (km/h)	Manoeuvring time (hours)	Hotelling time (hours)
Liquid bulk ships	26	1.0	38
Dry bulk carriers	26	1.0	52
Container	36	1.0	14
General Cargo	23	1.0	39
Ro-Ro Cargo	27	1.0	15
Passenger	39	0.8	14
Fishing	25	0.7	60
Other	20	1.0	27

Source: Elaboration from Entec (2002)

Table 3-20 Estimated % load of MCR (Maximum Continuous Rating) of Main and Auxiliary Engine for different ship activity

Phase	% load of MCR Main Engine	% time all Main Engine operating	% load of MCR Auxiliary Engine
Cruise	80	100	30
Manoeuvring	20	100	50
Hotelling (except tankers)	20	5	40
Hotelling (tankers)	20	100	60

Source: Entec (2002)

### Main technical specs and activity limitations:

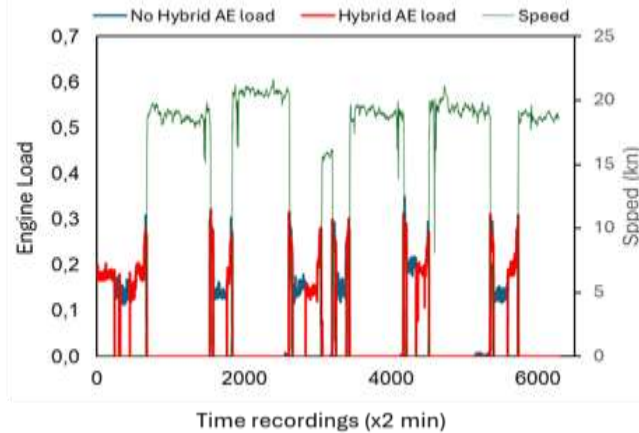
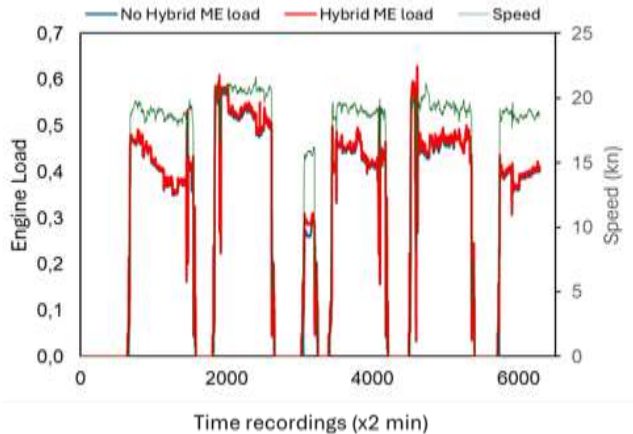
- ❖ **Fleet evolution**, including larger ships, higher installed power, advanced engine concepts, new marine fuels
- ❖ **New operational practices**, e.g. slow steaming, reduced load factors

# Review of data sources

**Table 3-20 Estimated % load of MCR (Maximum Continuous Rating) of Main and Auxiliary Engine for different ship activity**

Phase	% load of MCR Main Engine	% time all Main Engine operating	% load of MCR Auxiliary Engine
Cruise	80	100	30
Manoeuvring	20	100	50
Hotelling (except tankers)	20	5	40
Hotelling (tankers)	20	100	60

Source: Entec (2002)



Source: AENEAS

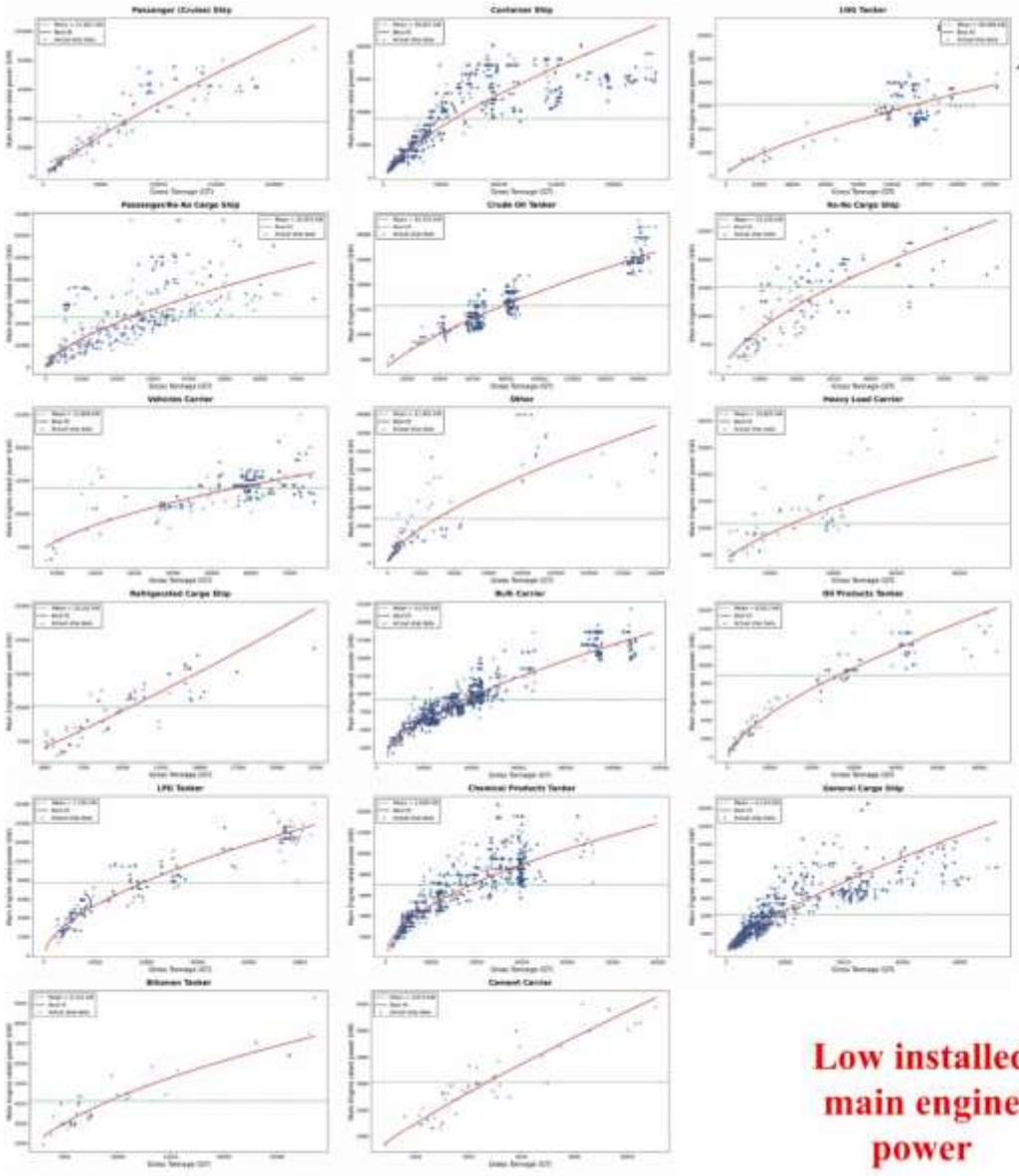
## Activity profile statistics based on 2022 EU-trading fleet



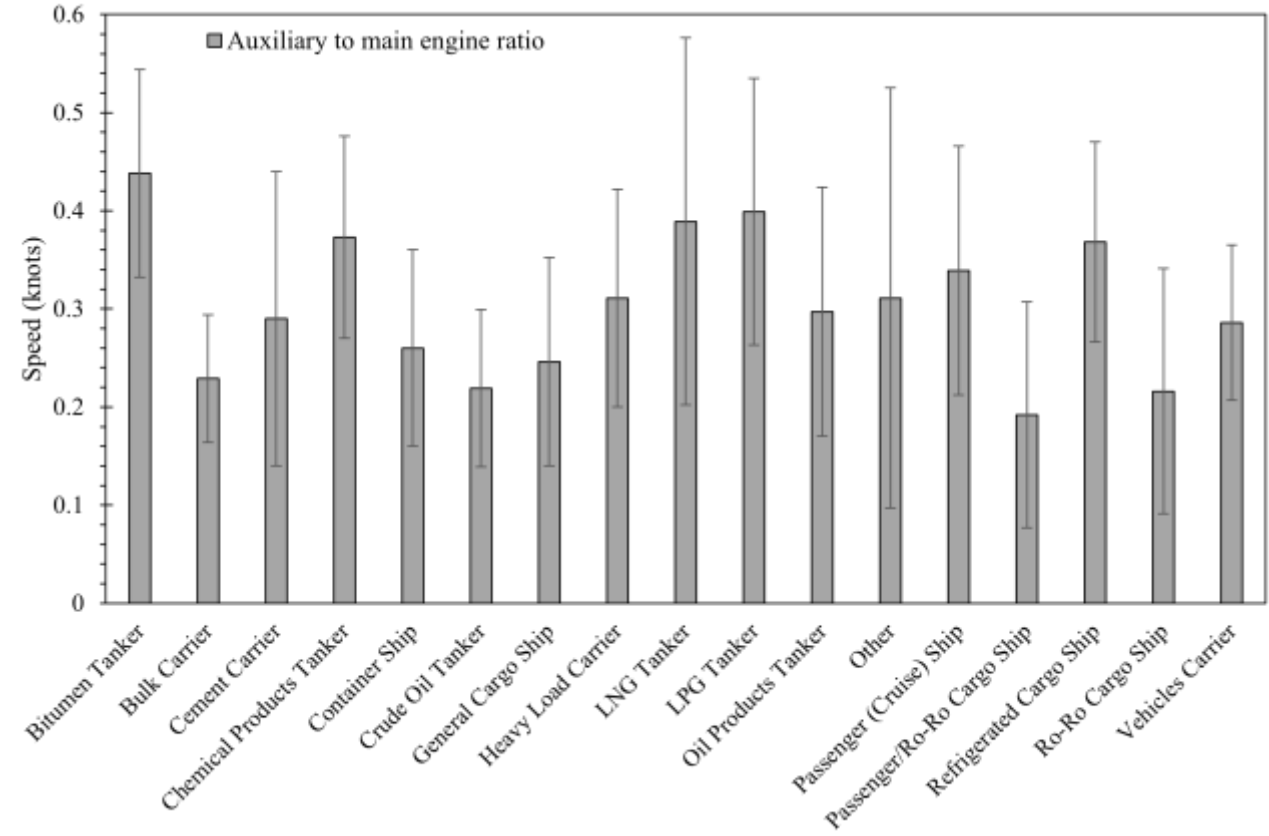
Ship category	Average Main engine load (%)	No of individual ships
Bitumen Tanker	65%	56
Bulk Carrier	57%	4062
Cement Carrier	60%	61
Chemical Products Tanker	58%	2121
Container Ship	33%	1899
Crude Oil Tanker	59%	1287
General Cargo Ship	60%	2547
Heavy Load Carrier	58%	85
LNG Tanker	53%	383
LPG Tanker	66%	406
Oil Products Tanker	54%	238
Other	52%	137
Passenger (Cruise) Ship	39%	190
Passenger/Ro-Ro Cargo Ship	47%	444
Refrigerated Cargo Ship	48%	143
Ro-Ro Cargo Ship	54%	279
Vehicles Carrier	50%	488

Source: [Grigoriadis et al., \(2026\)](#)

# Ship technical specifications improvement



Main and auxiliary engine specs statistics based on 2022 EU-trading fleet



Source: [Grigoriadis et al., \(2026\)](#)

# EMSA involvement & data provision



> Detailed list of all data required from EMSA to update the Guidebook navigation chapter

> Data resolution:

- ∴ Represent the Global or European-trading fleet (based on MRV)
- ∴ For at least one year, ideally the most recent one (e.g. 2024 or 2025)

## Fleet technical specifications data per ship

- IMO number
- Year build
- Gross Tonnage
- DWT
- Main engine rated power (kW)
- Main engine rated rotational speed (rpm)
- Number of main engines
- Auxiliary engine rated power (kW)
- Auxiliary engine rotational speed (rpm)
- Number of auxiliary engines
- Design speed (knots), design draft (m)
- Fuel type capabilities (alternative fuel ready)
- Aftertreatment system installed (scrubbers, SCR, EGR, DPF, DOC)
- Other equipment for energy consumption improvements (e.g. Shaft generators)
- Cold ironing capabilities

## Fleet aggregated activity data per ship

- Average speed (knots) or speed on various AIS timestamps
- Draught at departure
- Share of time distribution in operating phases, cruising, maneuvering, anchoring, berthing
- Total time spent in each operating phase
- Total distance travelled
- Number of individual voyages
- Average main and auxiliary engine load per operating phase
- Share of time in SECA and NECA and non-compliance rates regarding emission regulations
- Fuel type use distribution per trip (including alternative fuels)
- Aftertreatment use distribution
- Available (if any) information for auxiliary engines operating profile per ship type
- Available recordings (if any) for main and auxiliary engine mechanical outputs from ship recording systems

## Fleet detailed activity data to better address all requirements

- AIS data per ship or representative ships from major ship categories

# Proposal for the improvement



## The methodological approach will consist of the following steps:

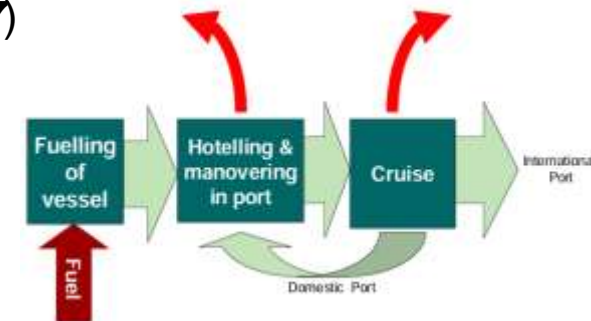
- › Finalisation of the updated ship categorization framework, forming the basis for all subsequent parameterization.
- › Statistical analysis and processing of technical and operational datasets derived from literature, AIS data and available fleet databases.

## The updated technical specification guidance will include per ship category:

- › Average installed main engine power (*update of Table 3-9*)
- › Parametric relationships between main engine power and gross tonnage (*update of Table 3-17*)
- › Ratios of auxiliary to main engine power (*update of Table 3-18*).

## The updated operational parameters will include:

- › Representative design and cruising speeds (*update of Table 3-19*)
- › Refined estimates of main engine load factors during cruising (*linked to Table 3-20 and associated Task 11*)
- › Statistical distributions of time spent in each operating phase namely cruising, manoeuvring, **anchoring** and hotelling (*update of Table 3-19*).



## **14 (40) International cross boundary emissions**

***“Inconsistent (or unclear) approach used by countries in reporting emissions from 1A3di(ii) International inland waterways vs. 1A3di(i) International maritime navigation (Memo Item). 1A3di(ii) can be a cross boundary issue, for example, Danube River runs across several Member States and it would be useful to provide guidance on how/where to source activity data, how to separate out activity between 1A3di(ii) and 1A3di(i) and how to estimate and report emissions for these sectors.”***

# Review of data sources



## Currently under investigation

- Review of the current reporting obligations & practices under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) & the EU National Emission Ceilings Directive (NECD)
  - ⋮ International sea traffic: emissions from bunker fuel sold for international sea traffic in the country of the reporting party. **The emissions are to be reported to both UNFCCC and UNECE for information only.**
  - ⋮ International inland shipping: emissions from bunker fuel sold for international inland shipping in the country of the reporting party. **The emissions are to be reported to UNECE within national totals and to UNFCCC for information only.**
- The updated activity data can support the spatial differentiation of vessel activity, while port statistics and Eurostat transport data provide complementary aggregated information.
- Guidance will be provided on how users can effectively separate out activity between 1A3di(ii) and 1A3di(i)

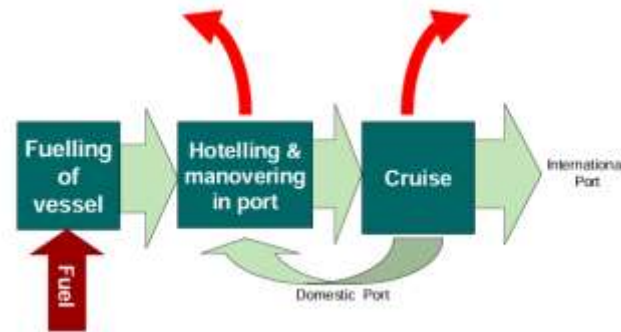


Table 2-1 Criteria for defining international or domestic navigation (applies to each segment of a voyage calling at more than two ports)\*

Journey type between two ports	Domestic	International
Departs and arrives in same country	Yes	No
Departs from one country and arrives in another	No	Yes

**Aviation**

## 15 (2) Non-regulated pollutants

*“The section reports the calculation of emissions of pollutants that are subject to regulation ( $\text{NO}_x$ , CO, HC, smoke, non-volatile particulate matter (nvPM), plus others that are directly proportional to fuel burn ( $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{SO}_x$ ). Engines also produce other pollutants that are not (currently) regulated. Reference should be made to these other pollutants.”*

# Review of data sources & summary of review



## > Focus on **reports, ongoing research** initiatives and **peer-reviewed literature**

- ∴ [ICAO Air Quality Manual](#)
- ∴ [REALCHEM](#), [LowC](#), [UNIC](#) projects
- ∴ Studies from [Owen et al. \(2022\)](#), [Heeb et al. \(2024\)](#), [Lee et al. \(2023\)](#) etc.

## > **Key** information/data needed:

- ∴ Definition of pollutants, calculation methods, emission factors, general information etc.

## > We produced a 2-page summary in the Tasks 1&2 report with a **comprehensive overview** of the sources

## > **Summary of review:**

- ∴ **Comprehensive overview** of non-regulated exhaust pollutants from aircraft engines, including vPM, ultrafine particles (as a standalone), aldehydes, PAHs, nitrated PAHs and other HAPs
- ∴ **Secondary** aerosol formation, aerosol-cloud interactions and contrail-related effects, reflecting the climatic and environmental relevance of these emissions
- ∴ Detailed **measurement methodologies** and **emerging datasets**, with emission factors remaining limited to several non-regulated species
- ∴ Solid **basis** for adding a new section to the Guidebook

# Proposal for the improvement



- We recommend a **dedicated explanatory section** (as Annex, ~ 2 pages) addressing non-regulated and emerging aircraft exhaust pollutants
- **Sections 2.1 and 2.6** already describe the regulated pollutants, ICAO standards and environmental concerns, therefore make a **short reference** to non-regulated pollutants in these sections, pointing readers to the relevant Annex for more detailed information
- Explanatory section would focus on defining relevant **pollutant groups**, summarizing potential **proxy approaches** without introducing default emission factors and clarifying current **methodological limitations** and uncertainties
- **Eurocontrol** suggested updating **chapter 2.6**, providing a document that streamlined updates in the **regulatory framework** based on recent updates from the CAEP/13 meeting (Feb. 2025)

## **19 (7) Tier 3B update to IMPACT tool**

***“Description of Tier 3B references the Eurocontrol AEM model. However, this has been superseded by the IMPACT model.”***

# Review of data sources & summary of review



## Main source:

### > Direct communication with Eurocontrol

- ∴ 2 meetings held (15 Dec. 2025 & 16 Mar. 2026)
- ∴ Multiple bilateral e-mail exchanges

## Supporting sources:

- > Eurocontrol's **website** ([AEM](#) and [IMPACT](#) models)
- > We produced a 1.5-page summary in the Tasks 1&2 report summarizing **exchanged information**

## Summary of review:

### > Eurocontrol clarified that:

- ∴ **AEM remains the underlying modelling framework** referenced in the Tier 3B methodology, **concerns** about statement that ““AEM has been superseded by the IMPACT model”
- ∴ AEM continues to be used in existing applications and has undergone only **incremental updates** since the latest Guidebook version (e.g., new PM method), **short explanations** were included in the **text** drafted by Eurocontrol
- > Evidence suggests that the main issue is potential **misinterpretation** of the relationship between the two tools rather than a methodological gap, core of the models remains unchanged

# Proposal for the improvement



- Eurocontrol explicitly stated that that **chapter 3.4** of the Guidebook (Tier 3B methodology) should remain **unchanged**
- We are expecting the **review of the 2nd note in p. 26** of the current version of the Guidebook
- Eurocontrol suggested and drafted an **updated text for Annex 4**, including also a revised Table A4.1, and incorporated relevant references
  - ❖ 1.5 pages in length, consistent with current version of Guidebook
  - ❖ No additional drafting needed, only final integration during SR16 editorial drafting

EMEP/EEA air pollutant emission inventory guidebook 2023  
T.A.3.a, T.A.5.b Annex

## Annex 4: EUROCONTROL Fuel Burn and Emissions Inventory System

EUROCONTROL's Fuel Burn and Emissions Inventory System (FEIS) estimates the total mass of fuel burnt by aircraft operating to and from airports within ECAC Member States, covering jet fuel for turbojet, turbofan, and turbo-prop-powered aircraft, as well as aviation gasoline for piston-engine aircraft. Alongside fuel consumption, the system also estimates the resulting masses of gaseous emissions and particulate matter (PM). Developed in support of both EEA member countries and the wider group of ECAC states, the FEIS provides the methodological and computational backbone for the estimates described in this annex.

The system draws exclusively on FIR flight movement data within EUROCONTROL's zone of coverage, excluding VFR, military, and special operations flights. Where trajectories extend beyond this zone, they are reconstructed using commercial aircraft schedule databases to ensure complete coverage.

At the heart of the FEIS is EUROCONTROL's Advanced Emission Model (AEM), which is designed to handle the large volumes of flight movement data the system requires.

AEM is used as outlined below:

- AEM processes flight movements, each representing an aircraft's complete airborne trajectory along a four-dimensional path to estimate fuel consumption and the resulting engine emissions.
- Above 3,000 ft, the profile consists of a sequence of straight-line segments drawn from flight plan data managed by the EUROCONTROL Network Manager Operations Centre or generated for flight movements outside EUROCONTROL's zone of coverage. Fuel burn for each segment is calculated using aircraft performance data from Base of Aircraft Data (BADA), an Aircraft Performance Model developed and maintained by EUROCONTROL, covering altitude- and altitude-dependent performance for more than 250 aircraft types. Once the amount of fuel burnt is calculated for each segment, the Boeing Fuel Flow Method 2 (BFFM2) is used to correct the amount of fuel that is burnt before multiplying by the EF<sub>s</sub>.
- Below 3,000 ft, where flight trajectory data are insufficiently precise, AEM calculates fuel burn using the ICAO LTO cycle methodology, defined by the ICAO Engine Certification specifications modelling each flight movement as a sequence of prescribed thrust settings and corresponding times in mode across the LTO cycle phases. Fuel burn for each phase is derived from the ICAO Aircraft Engine Emissions Database (AAED), which provides emission indices and fuel flow data for a large number of aircraft engines. To link each flight movement to a specific engine, EUROCONTROL maintains a mapping table that associates aircraft models with their typical engine types, identified by Unique Identification Number (UIC) as listed in the AAED. This allows AEM to retrieve the appropriate engine-specific data for every flight processed. A standard LTO cycle lasts approximately 32.9 minutes, of which 26 minutes are spent at idle thrust during taxi operations (nominally 19 minutes taxi-out and 7 minutes taxi-in). Since actual taxi times

<sup>1</sup> BADA: An advanced aircraft performance model for present and future ATM systems. <https://air.ecmwf.int/10/1002/eca/1176>

of European airports frequently differ from this standard, EUROCONTROL improves accuracy by substituting the ICAO default taxi times with actual taxi-in and taxi-out times derived from CDDA statistics, drawing on reported operators and other available data sources where applicable (e.g. AFD, ADOF, DPISIR, ETRMS). Once fuel burn for a given LTO phase is known, the associated emissions can be calculated accordingly.

Table A4.1 – AEM fuel burnt and corresponding emissions calculation method

Height (feet)	Fuel burnt	NO <sub>x</sub> , UHCs and CO	CO <sub>2</sub> , H <sub>2</sub> O and SO <sub>x</sub>	VOCs	PM
> 3,000 (ICD)	BADA	BFFM2	Proportional to the mass of fuel burnt	Proportional to the mass of UHCs generated	Mission Emissions Estimation Methodology (MEEM v1) <sup>1</sup>
< 3,000	AAED and other databases				AAED and other databases

As such, the FEIS implements a methodology that lies somewhere between a Tier 3A and a Tier 3B fuel and emissions inventory methodology.

The FEIS generates reports for two international environmental agreements: the UNFCCC and the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). While both address atmospheric emissions, they differ in focus and scope: the UNFCCC deals with greenhouse gases and climate change on a global scale, whereas CLRTAP targets transboundary air pollutants across the broader UNECE region, which encompasses Europe, North America, and Central Asia.

The FEIS is updated annually with the previous year's flight movement data (and the associated fuel and emissions estimations), and historical data since 2005 are maintained. If methodology changes result in a change of more than 0.5% from the previous year's estimated emissions, the data are recalculated.

A more detailed description of the EUROCONTROL FEIS is available on request from the EEA.

<sup>1</sup> <https://air.ecmwf.int/10/1116/eca/2023/11/27/>

## **22 (11) CO<sub>2</sub> and PM EFs**

***“Summary and example tables  
(Table 3-3, 3-10, 3-11, 3-12).”***

# Review of data sources



## > Focus on **relevant sources** to assess consistency, scope and data availability:

- ∴ Annex 1 master emissions calculator
- ∴ Annex 2 LTO calculator
- ∴ [FOCA Aircraft Piston Database](#)
- ∴ [REALCHEM](#), [UNIC](#) projects
- ∴ Studies from [Zhang et al. \(2022\)](#), [Hickman et al. \(1999\)](#), [Rindlisbacher and Chabbey \(2015\)](#) etc.
- ∴ Discussions with Eurocontrol

## > **Key** information/data needed:

- ∴ Harmonized and internally-consistent CO<sub>2</sub> and PM emission factors for all tables

## > We produced a 3.5-page summary in the Tasks 1&2 report with a **detailed review per table**

### Review of data sources

The review of relevant sources assessed the consistency, scope and data availability to support the CO<sub>2</sub> and PM emission factor tables within the aviation chapter of the Guidebook, focusing on Tables 3-3, 3-10, 3-11 and 3-12.

Specifically, the analysis of Table 3-3 indicated that the emission factors refer to aviation gasoline fuels typically used by reciprocating (piston) engines, although this is not explicitly stated. Verification using the Annex 1 master emissions calculator [81] showed strong agreement between calculated and reported gaseous pollutant values when piston-engine data were applied, confirming the intended scope. However, PM emission factors for piston engines are not available in the calculator, creating a methodological gap.

The Annex 2 LTO emissions calculator [82] confirms that CO<sub>2</sub> emission factors are largely invariant with operating conditions, whereas PM emissions exhibit variability by aircraft type and flight phase. Literature-derived PM emission factors for piston engines [86] were identified as the only source of PM emission data for piston engines, enabling provisional estimation within the existing methodological framework, but associated uncertainties remain high (often spanning 1-2 orders of magnitude).

Detailed background calculations, where applicable, for CO<sub>2</sub> and PM emission factors for Tables 3-3 and 3-10 are shown in the accompanying Excel sheet entitled 'CO<sub>2</sub> & PM Calculations 22 (11)' [83], [102].

For Tables 3-11 and 3-12, the review identified additional limitations. Helicopters and military aircraft are not represented in the available calculators and military aviation is reported under a different NFR category. Literature review provided limited CO<sub>2</sub> information and PM data for these aircraft categories [88], [99]. Discussions with Eurocontrol confirmed that the two tables, as well as Table 3-10, contain outdated information and that underlying databases are confidential, although provision of generic emission factors may be possible. Ongoing research activities may provide future data but are not yet available [97], [101].

Overall, the evidence highlights ambiguity in table scope, missing PM emission factors for piston aircraft and insufficient data for helicopters and military aviation.

All relevant details of the review, organised per table, are available as follows:

# Summary of review & proposal for the improvement



## > Summary of review:

- ∴ Evidence highlights **ambiguity** in table scope, **limited** PM emission factors for **piston aircraft** and **insufficient** data for **helicopters** and **military aviation**

## > Proposal for the improvement:

- ∴ **Numerical** and **structural** rather than textual (i.e., minor accompanying text adjustments may be required only to clarify scope and data availability), aiming primarily to improve completeness, transparency and usability of the emission factor tables
- ∴ No substantial increase in chapter **length** is expected, as the improvement is limited to table revisions (estimated **extra space** requirement is approximately **0.5-page equivalent**)
- ∴ Where data is **unavailable** or **highly uncertain**, this will be transparently reflected within the tables rather than expanded in the text
- ∴ Overall **drafting effort** is expected **low** - emission factors calculations have already been completed and drafting will mainly involve **formatting and integration** within the tables

## 24 (13) PM<sub>10</sub> vs. PM<sub>2.5</sub>

***“Section 4.8.3 says ‘it is assumed that all PM emissions from aircraft can be viewed as PM<sub>10</sub>’. The general understanding is that all PM emissions from aircraft engines fall into the finest category, so this should be phrased as ‘it is assumed that all PM emissions from aircraft can be viewed as PM<sub>2.5</sub>’ as PM<sub>2.5</sub> is a subset of PM<sub>10</sub>.”***

# Overview



> Focus on **peer-reviewed literature** (reviews, field measurements):

∴ [Austin et al. \(2021\)](#), [Maes et al. \(2025\)](#), [Trebs et al. \(2023\)](#), [Owen et al. \(2022\)](#), [Riley et al. \(2021\)](#)

> **Key** information/data needed:

∴ Relevant evidence to support the phrasing “it is assumed that all PM emissions from aircraft can be viewed as PM2.5”

*“Particulate matter emissions from aircraft engines are dominated by ultrafine particles (UFPs), typically with diameters in the range of 10 - 60 nm, which are entirely within the PM2.5 size fraction”*

*“The majority of aircraft-related particulate matter research focuses on PM2.5 or smaller particles, reflecting the fine nature of aircraft exhaust emissions”*

> We produced a 1-page summary in the Tasks 1&2 report with a **summary of the literature**

> The **recommended change** in section 4.8.3 is to phrase “*it is assumed that all PM emissions from aircraft can be viewed as PM10*” as “*it is assumed that all PM emissions from aircraft can be viewed as PM2.5*”, **scientific references** may be included for support, only **text clarification** with **no structural changes**

## 23 (12) 'Surrogate' aircraft excel tool

***“The Excel tools provided as Annex 5 to the Guidebook provide emissions data on a number of aircraft/engine combinations. However, there may be a need to model different aircraft/engine combinations in an inventory calculation. Guidance on the selection of a 'surrogate' aircraft type to use, and any adjustments to make to the emissions, is required.”***

# Review of data sources



## > Direct communication with **Eurocontrol**

- ∴ 2 meetings held (15 Dec. 2025 & 16 Mar. 2026)

## > Data provided from **Eurocontrol**

- ∴ Table “Departing flights from ECAC per aircraft type”
  - ∴ Number of movements by aircraft type in **2025**
  - ∴ Covers more than 85% of all flights
- ∴ Latest version of “ICAO DOC 8643 - Aircraft Type Designators”
  - ∴ Designators for aircraft types commonly provided with air traffic service (ATS)
  - ∴ Information about engine types
  - ∴ Covers more than 10,000 unique aircraft models

# Proposal for the improvement



- › Tools provided in Annex 5 can only be updated by Eurocontrol
- › No modifications and adjustments on the emission values will be addressed
  
- › **Guidance** on data availability gaps is suggested to be added in a **small paragraph** in the Guidebook
  - ∴ Missing aircraft type → Select from the most representative from the table with number of movements
  - ∴ Missing engine type → Use the DOC 8643 and find the most representative engine type
  
- › Suggest changes in tools of Annex 5
  - ∴ Update the sheet “Aircraft Type Designators” with the most recent data of DOC 8643
  - ∴ Update links to the description of data extraction to <https://www.icao.int/operational-safety/doc-8643-aircraft-type-designators/search>
  - ∴ Change 2022 to 2025 in the description cell “engine types listed are those most commonly associated with each aircraft model as of 2022 2025”

## **17 (4) Update/improve nvPM and vPM emissions**

***“Non-volatile and volatile particulate matter emissions (nvPM and vPM) are of increasing importance, both for local air quality and for climate impacts (with the role of PM in the formation of contrails and contrail-induced cirrus clouds being recognized). The section mentions the agreement on regulation of nvPM, and the availability of certification data in the EEDB, but other references (including Annex 2 and Annex 3) are out of date, as they describe the use of other sources of data for PM.”***

# Review of data sources



- Increasing importance of **nvPM & vPM emissions** in aviation.
- **Eurocontrol** recommended a full update in PM emissions, because there is limited reference in current Guidebook.
- Current limitations in Guidebook
  - ⋈ Lack of clear:
    - ⋈ Definitions
    - ⋈ Calculation Methods
    - ⋈ Measurement techniques
  - ⋈ Emission Factors (EFs)
    - ⋈ Not clearly clarified & documented
  - ⋈ Annex 1 & 2
    - ⋈ Outdated data
    - ⋈ Require extensive review of literature
- Data sources and methodologies
  - ⋈ **ICAO Annex 16** – certification standards
  - ⋈ **EEDB** – emission data for LTO & CCD cycle
  - ⋈ **SAE ARP6320** – measurement basis (mass & number)
  - ⋈ **ICAO Doc 9889** – vPM number estimation
- Calculation approaches
  - ⋈ smaller and non-regulated engines
    - ⋈ Smoke Number (SN) → FOA4 and SCOPE11
  - ⋈ nvPM measurements unavailable → SN methods
  - ⋈ CCD cycle emissions, above 3,000 ft:
    - ⋈ BFFM2, MEEM, MEEM2
    - ⋈ EIM (improved method)
- **Uncertainties**
  - ⋈ vPM – Very high uncertainty (up to ×10)
  - ⋈ Need for improved estimation of CCD emissions

# Proposal for the improvement



- Methodological improvements
  - ⋆ Introduce clear PM calculation methods in Guidebook (chapter 3).
  - ⋆ Include explicit methodologies for **nvPM & vPM emissions**
  - ⋆ Reference to ICAO standards.
- Data Gaps in EEDB: Significant lack of PM data for specific engine categories:
  - ⋆ **Piston Engines:** no data in ICAO EEDB → FOCA provides preliminary calculations (only for LTO cycle).
  - ⋆ **Turboprops:** emission factors largely unknown.
  - ⋆ **Military & Helicopters:** limited data (only for LTO cycle).
- Update of tables & tools
  - ⋆ Table 3.10 → add nvPM EFs for piston engines.
  - ⋆ Table 3.11 & 3.12 → Emission factors of nvPM for helicopters and military flights.
  - ⋆ Improve EEDB emission calculators.
- Revision of Annexes
  - ⋆ Annex 2:
    - ⋆ move from SN-based methods to certified measurement and advanced modeling for non-LTO cycle (MEEM, EIM)
    - ⋆ inclusion of vPM emission
  - ⋆ Annex 3: Entirely remove

## **31 (1) Update ICAO emission factors**

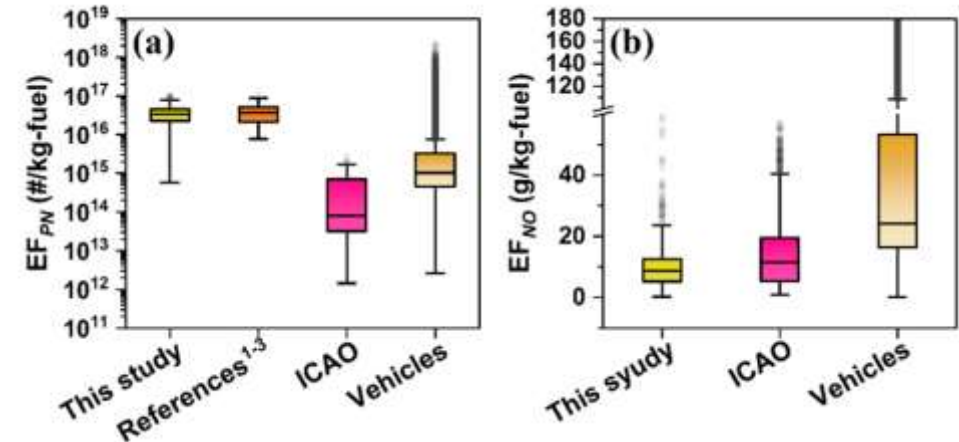
***“The section reports the use of emissions data from the ICAO Engine Emissions Data Bank (EEDB). These emissions are measured by manufacturers as part of certification tests for compliance with environmental regulations and may not be fully representative of emissions in normal operations.”***

# Review of data sources



Comparison of certification ICAO EEDB and real-world aircraft emissions.

- > A 10-year study, in engine test cell ([AGEAIR II report, 2023](#))
- > In-service commercial turbofan engines:
  - ∴ CFM56-7B, CFM56-5B, CFM56-5C, Pratt & Whitney PW4000-94 and PW4000-100
- > **Gaseous Emissions:**
  - ∴ **NO<sub>x</sub>**: Excellent agreement with ICAO EEDB (within 25%).
  - ∴ **CO**: Generally consistent, with minor discrepancies in low-thrust.
- > **PM & HC:**
  - ∴ **HC**: 25% - 40% higher than certified values.
  - ∴ **nvPM**: Underestimated by ICAO, Smoke Number is an unreliable predictor.
- > Real-world LTO study by [Bo Li et al. \(2026\)](#), using roadside measurements
- > Aircraft types:
  - ∴ A320, A321, A319, B737, B747, ARJ21.
- > **Gaseous Emissions:**
  - ∴ **NO**: Close to ICAO values (peaks during take-off).
- > **Particle Number (PN):**
  - ∴ Huge Gap: 2–3 orders of magnitude higher than EEDB due to (semi-)volatile particles - PN peaks during taxi-out.



# Proposal for the improvement



- The comprehensive literature review is still ongoing and further research is required to identify and investigate additional discrepancies.
- Following communication with **Eurocontrol**, it was determined that **no updates** to the ICAO EEDB emission factors are required at this stage, only further review.

## ➤ Identified Issues

- ⋆ Differences between:
  - ⋆ Certification vs real-world conditions
  - ⋆ Standardized testing (ISA, LTO, new engines)
- ⋆ Underestimation of:
  - ⋆ HC emissions
  - ⋆ Particle emissions (PN, nvPM)
- ⋆ Modelling methods:
  - ⋆ BFFM2 extrapolates EEDB emission indices to other thrust settings, but does not capture full real-world variability

## **16 (3) Review/update taxi times**

***“The section describes ICAO ‘default’ taxi times (used in certification tests) and the average taxi times for European airports embedded in the calculator. The latter taxi times should be reviewed to identify whether updates are required (and values for key European airports could be presented as an Annex).”***

# Review of data sources & proposal for improvement



➤ EUROCONTROL compiled and provided TAXI-times in two airport-size categories:

## 2 Airport categories (Period: 2023-2025)

Airport size (All ECAC)	Movements p.a.
Medium and Small	14.999 to 150.000
Large and Very Large	>150.000

## 5 Airport categories (Period: 2019 - 2025)

Airport size (All ECAC)	Movements p.a.
Other	<15.000
Small	39.000 – 15.000
Medium	149.999 – 40.000
Large	250.000 – 150.000
Very Large	>250.000

➤ Proposal for new table in section 2.2.2 *Phases of flight*:

- Mean values for Taxi-In and Taxi-Out times for different (2 or 5) ECAC airport categories of the most recent available year or years as comparison for the ICAO default taxi time
- This would allow an initial way to estimate the taxi times for the selected airport outside the calculation tool provided in Annex 5

Year	Airport size A <sup>1</sup>		Airport size B <sup>2</sup>		Airport size C <sup>n</sup>	
	Taxi-in [min]	Taxi-out [min]	Taxi-in [min]	Taxi-out [min]	Taxi-in [min]	Taxi-out [min]
2019	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD
..	..	..	..	..	..	..
2025	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD	Mean value ± SD

<sup>1</sup> Airport size A: xx movements p.a. (CODA observations)

<sup>2</sup> Airport size B: xx movements p.a. (CODA observations)

<sup>n</sup> Airport size C: xx movements p.a. (CODA observations)

## **18 (6) Review/update to 2024 movements**

***“Table 2-1 provides information on numbers of movements by aircraft type in 2022. These could be updated to 2024 movements. Further, the table does not provide the context of the relative contribution to emissions (several types in the table would make negligible contributions to emissions, while some large aircraft types are not included at all).”***

# Review of data sources & proposal for improvement



- EUROCONTROL compiled and provided the updated data from 2025 for Table 2-1 *Departing flights from ECAC per aircraft type* in section 2.2.1 *Aircraft engines*
  
- Proposal:
  - Update Table 2-1 *Departing flights from ECAC per aircraft type* to most recent data from 2025
  - We are not recommending a new column in Table 2-1 with fuel consumption or CO<sub>2</sub> emission data for the following reasons:
    - The already complex Table 2-1 becomes more cluttered and difficult to read
    - If this information is needed, we would propose an extension or secondary table to table 2-1, which includes all relevant emission shares per relevant aircraft type
    - For CO<sub>2</sub> and non-CO<sub>2</sub> emissions, the distance-based cruise/CCD phase is decisive

## 20 (8) Alternative fuels SAF

***“Alternative fuels, in particular (drop-in) Sustainable Aviation Fuel (SAF), are seen as key to the decarbonization of aviation. The impacts of using such fuels (blended with conventional kerosene, Jet A and Jet A-1) on pollutant emissions should be included.”***

# Review of data sources



- EU & GB SAF-mandates recently implemented; Global mandates remain limited
- SAF currently only available for conventional jet fuel (Jet A-1)
  - Currently no certified SAF-production pathway for piston engine fuels (AVGAS)
- Ongoing research projects with results expected in the next years
  - EU-projects: REALCHEM, PACIFIC, UNIC, A4CLIMATE, etc.
- Operational emission data and other in-flight measurement campaigns are still limited
- Recent studies show, that the absence of sulfur and aromatic components and high hydrogen content in HEFA-SPK (Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene) provide non-CO<sub>2</sub> climate and air quality benefits:
  - Non-volatile particulate matter (nvPM): Reduction of ~41% at low, ~29% at typical and ~22% at high cruise engine power settings on a modern large-turbofan engine with 100% HEFA-SPK
  - Volatile particle (vPM) and sulfur oxides (SO<sub>x</sub>): Low sulfur content of HEFA-SPK reduces vPM concentrations and SO<sub>2</sub>-derived emissions
  - Contrail effects: Reduction of available ice nuclei by 40-70 %, depending on reference fuel and measurement conditions
  - Air quality: Quantitative impacts still require further assessment

# Proposal for the improvement



- We propose a dedicated new *Annex Sustainable Aviation Fuels* as a basic guidance and structure for further Guidebook updates:
  - General introduction
  - Regulatory mandates, policy frameworks and differences
  - Fuel properties, raw material, production pathways and blending limits
  - CO<sub>2</sub> and lifecycle climate effects – (link to item 21)
  - Non-CO<sub>2</sub> climate effects

## 21 (9) WTW CO<sub>2</sub>

***“Note that SAF does not reduce the tank-to-wake (TTW) CO<sub>2</sub> emissions from engines, but delivers overall (lifecycle or well-to-wake, WTW) emissions reductions through the absorption of atmospheric CO<sub>2</sub> (or other sources such as wastes) as part of the production process. Thus, when reporting CO<sub>2</sub> emissions it is important to capture the impact on WTW emissions as well as TTW.”***

# Review of data sources



- Life Cycle Assessment (LCA) is currently not the scope and therefore not included in the guidebook
  - General guidance is needed in inventory chapter to outline the scope of the EMEP/EEA Guidebook
- Literature review has shown that there are existing methodologies and frameworks with different scope and base values:
  - ICAO CORSIA Methodology for Calculating Actual Life Cycle Emissions Values
  - EU Renewable Energy Directive II/III (RED)
  - Count Emission EU

	ICAO CORSIA	EU RED/ReFuel EU Aviation
<b>Obligation</b>	Aircraft operator	Fuel supplier
<b>Fossil comparator</b>	89 gCO <sub>2</sub> e/MJ	94 gCO <sub>2</sub> e/MJ
<b>GHG saving threshold for biofuels</b>	Min. 10%	65% <sup>1</sup> (for installations from 2021)
<b>Feedstock eligibility</b>	Positive list (ICAO Council approval)	Annex IX RED, ReFuelEU excluded food/feedstock crops, intermediate crops, palm fatty acid distillate, palm and, soy-derived materials
<b>GHG saving threshold for synthetic fuels</b>	Min. 10%	Min. 70%
<b>Primary data source</b>	CORSIA default values	Actual LCA values

<sup>1</sup> 60% from 2017, 50% pre-2015

# Proposal for the improvement



- Due to the complexity of this topic, we would propose to include a more general overview and guidance as well as references on existing methodologies
- Proposed structure of the new LCA subsection:
  - General description/introduction
  - Definitions, system boundaries and differentiation
  - Regulatory frameworks and scope (Link to Item 20)
  - Fuel types and classifications (Link to Item 20)
  - Emission factors and key parameters (to be updated when data is available)
  - References to calculation methodologies
  - SAF accounting
  - Reporting and interpretation

# Proposal for the improvement



► Furthermore, we propose to include two new figures:

Figure 1 would visually illustrate the individual process steps of upstream emissions (WTT) and how they differ from combustion emissions (TTW):

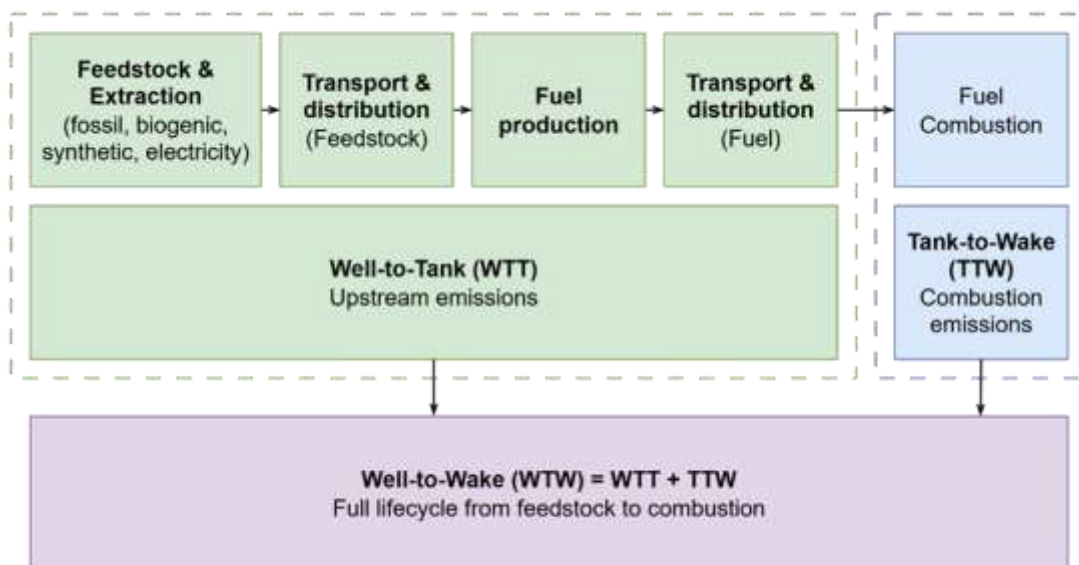
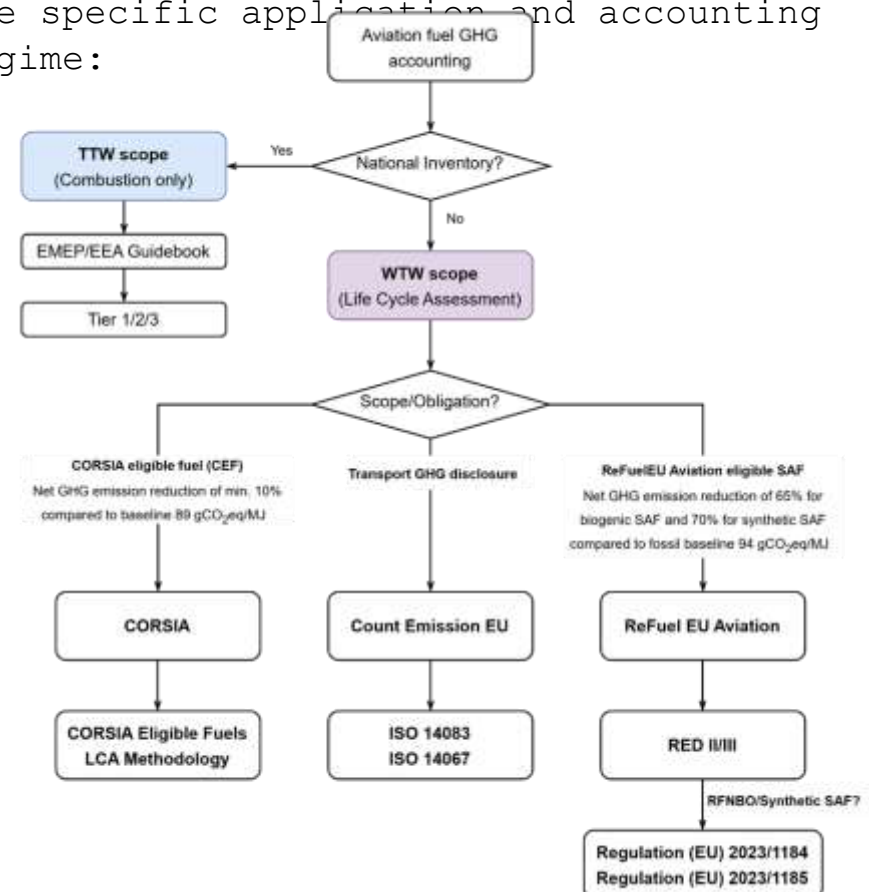


Figure 2 would take the form of a decision tree intended to help identify the appropriate accounting scope (TTW or WTW) depending on the specific application and accounting regime:



## **25 (14) Update to IMPACT and EEDB**

***“The tools provided as Annex 5 should be updated to use the latest versions of the IMPACT model and the latest EEDB.”***

# Review of data sources & proposal for improvement



- › During the first bilateral meeting with EUROCONTROL and the aviation project consortium on December 15<sup>th</sup>, 2025, it was confirmed that the tools provided in Annex 5 can only be updated by EUROCONTROL

## 26 (15) European Aviation Environmental Report 2025

*“Annex 1 presents projections based on the European Aviation Environment Report (EAER) 2022, although it also says that it is mainly based on the 2016 version. The 2025 version of the EAER has now been published.”*

# Review of data sources & proposal for improvement

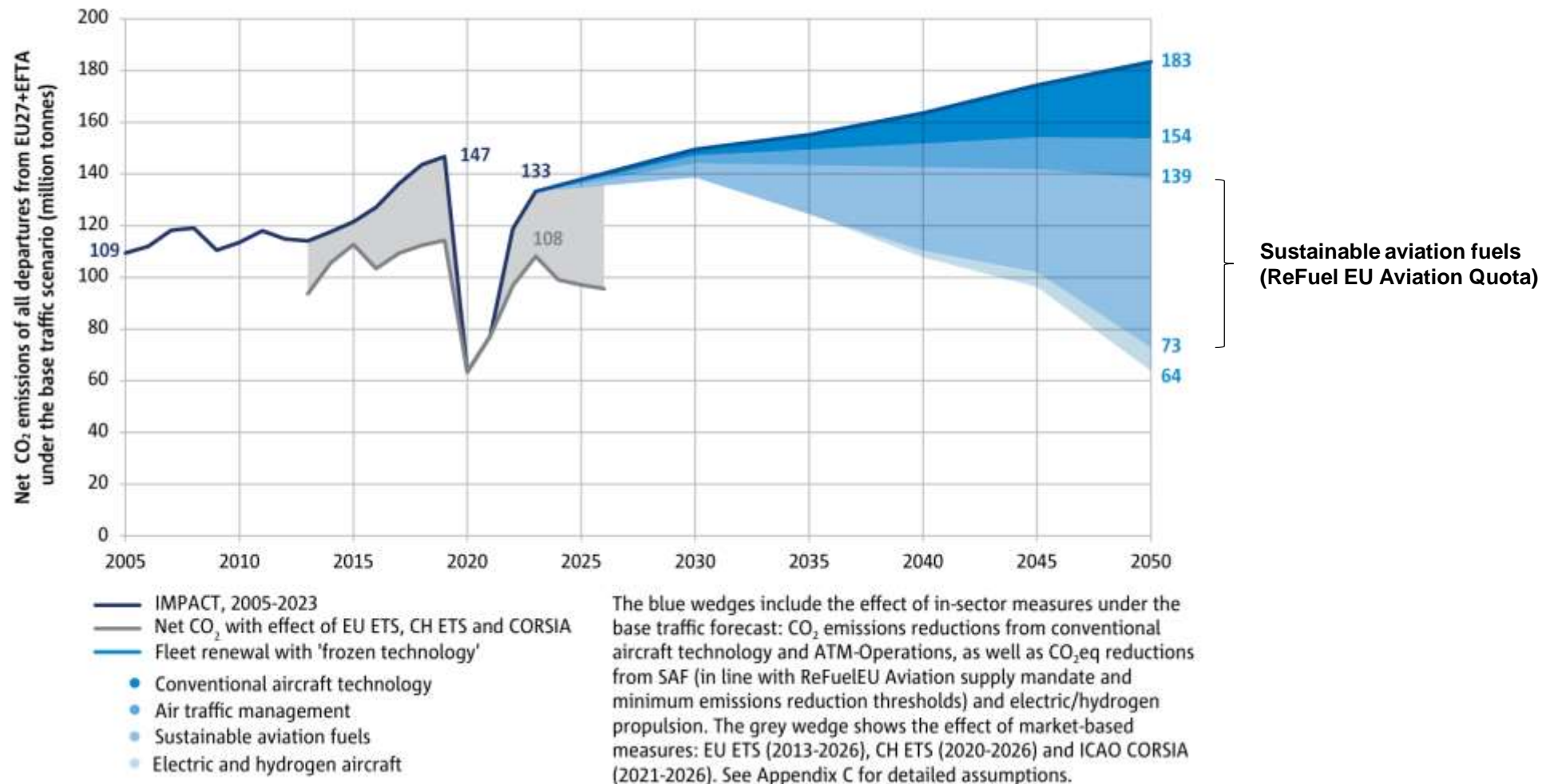


- The European Aviation Environmental Report 2025 provides the most recent forecasts and include figures for European air traffic, traffic growth and CO<sub>2</sub> and NO<sub>x</sub> emissions, a summary of full-flight emissions indicators and the mean aircraft age.
- The figures in Annex 1, including figure captions and accompanying text will be updated to the most recent data as presented in the European Aviation Environmental Report 2025:
  - Air traffic forecast (Figure A.1.1)
  - Projections of CO<sub>2</sub> and NO<sub>x</sub> emissions depending on traffic growth (Figure A1.2)
  - Summary of full-flight emissions indicators (Figure A.1.3)
  - Mean aircraft age (Figure A.1.4)
- A new element is the inclusion of the emission reduction potential associated with SAF-deployment

# Review of data sources & proposal for improvement

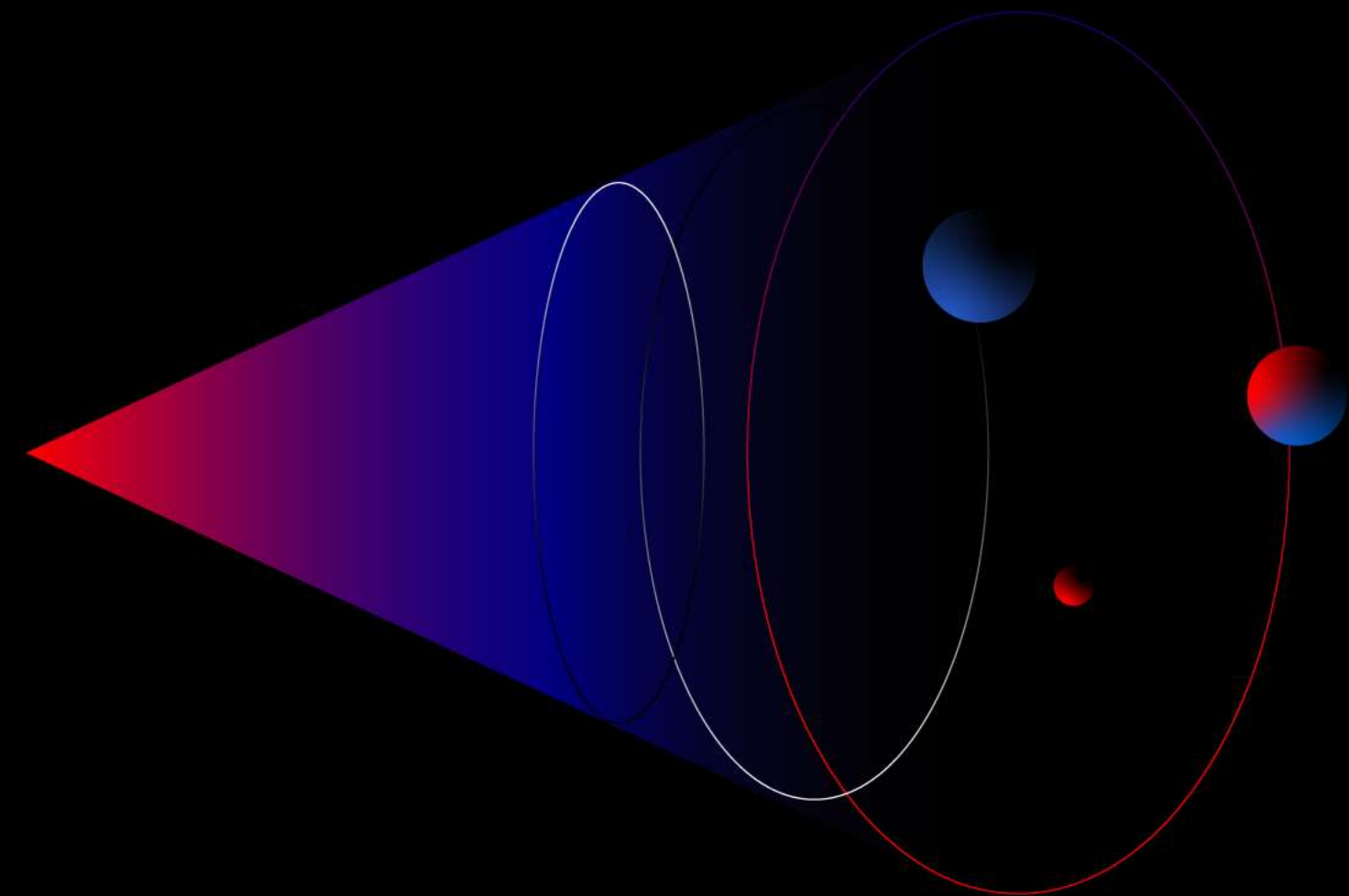


**Figure 1.10(b)** Meeting the SAF supply mandate would cut net CO<sub>2</sub> emissions by at least 47% in 2050



Source: EASA, EEA, EUROCONTROL (2025): **European Aviation Environmental Report 2025**

e:misia



**THANK YOU FOR YOUR  
ATTENTION**