Guidance Document on Mobile Sources – Revision

Presented by

Gabriel Krenzer and Jean-Marc André

(Transport and Mobility Department, Citepa)

Introduction (1)

The Executive Body, at its 43rd session, in December 2023, decided to launch a process to revise the Gothenburg Protocol, as amended in 2012, with the aim to conclude the revision by the EB_46 (Even if, the WGSR_63 has proposed to the revision of the time schedule to the 2027)

In line with the outcomes of the discussion within the WGSR_62, for the implementation of the Convention, it is necessary to have updated information on available technologies and their characteristics.

Introduction (2)

In 2024, TFTEI started the revision process of the Guidance Document on Stationary Sources, to be submitted to the 63rd WGSR in 2025, while the Guidance Document on Mobile Sources is being revised in 2025 and submitted to 64th WGSR in 2026.

In the second trimester of 2025, the UNECE secretariat contacted the Parties to create a list of experts to be involved in comments and possible integrations to the draft revised text.

Introduction (3)

In line with the process adopted for the review of the GD on Stationary Sources, the GD on Mobile Sources will be composed by:

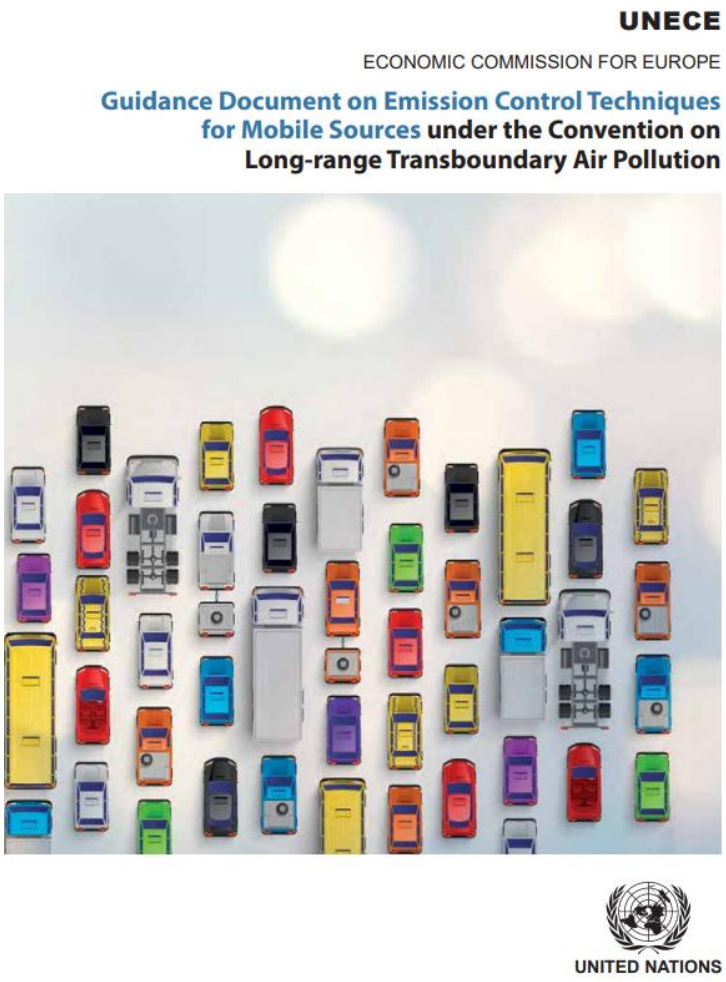
a) ***an official document (Summary)*** in line with the editorial limit (10,000 words)

➔ the Summary document only will be translated, discussed and approved by WGSR to be submitted to EB for adoption, in December 2026.

b) ***an informal complementary document*** on mobile sources

➔ the informal document, with complementary information, will NOT be translated, discussed and approved by WGSR or adopted by EB.

Introduction (4)



Motivations for revision:

- From 2016
- Outdated
- Euro 7
- Stimulate innovation

Agenda

1. Euro 7
2. Aftertreatment Techniques
3. Alternative Fuels and Power Sources
4. Mitigating Non-Exhaust Emissions

Agenda

1. **Euro 7**
2. Aftertreatment Techniques
3. Alternative Fuels and Power Sources
4. Mitigating Non-Exhaust Emissions

Euro 7 – Exhaust Emissions

https://fr.m.wikipedia.org/wiki/Fichier:Automobile_exhaust_gas.jpg

- **Passenger Vehicles**
  - No change on emission limits
- **Heavy-Duty Vehicles (HDV)**
  - CO: 62,5% reduction
  - NOx: 56,5% reduction
  - PM: 20% reduction
  - NH_3: 60mg/kWh (new)
  - Formaldehyde (CH_2O): potential limits to be introduced, difficult to measure
- **All**
  - PN_{23} → PN_{10} (diameter in nanometre)
- **Entry Into Force and Application**
  - 29/09/26: light vehicle production
  - 29/09/27: light vehicle sales
  - 29/05/28: Heavy-Duty Vehicle production
  - 29/05/29: HDV sales

Euro 7 – Non-Exhaust Emissions (NEW!)

https://doi.org/10.1787/4a4dc6ca-en

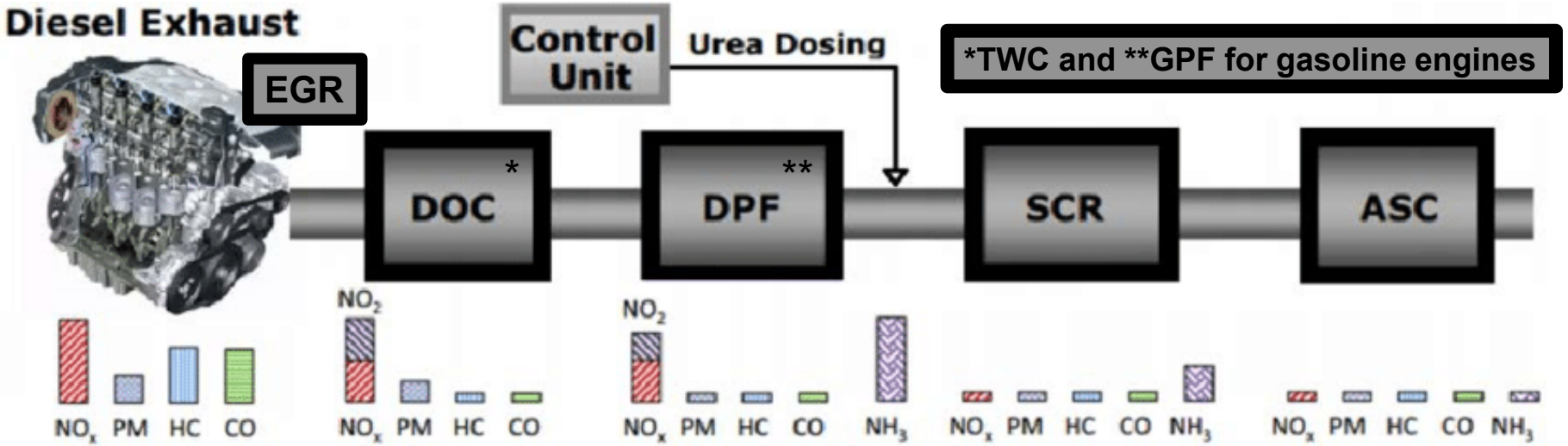
- **Brakes**
  - Source of Fe, Cu emissions
  - 3 mg/km (PM_{10}) for EVs; 7 mg/km for others (from 01/01/2030)
  - Then 3 mg/km for all (from 01/01/2035)
  - High fraction of ultrafine particles (<100 nm) → concerns about limits in mg/km
  - Non-homogenous distribution of elements emitted (45% Fe, but 1% Cu) → element-specific limits could be more efficient [1]
- **Tyres**
  - Microplastic emissions
  - No limits introduced yet
  - Uncertainty around measurements and quantifying emissions

[1] A. Mirailler, *et al.*, *Transport Research Part D* (2025), **146**, 104864.

Agenda

1. Euro 7
2. **Aftertreatment Techniques**
3. Alternative Fuels and Power Sources
4. Mitigating Non-Exhaust Emissions

The Euro 6/VI Internal Combustion Engine (ICE) - focus of the previous guidance document



https://www.researchgate.net/figure/The-standard-Euro-VI-automotive-aftertreatment-system_fig1_328704368

EGR: Exhaust Gas Recirculation
DOC: Diesel Oxidation Catalyst
TWC: Three-Way Catalyst
DPF: Diesel Particle Filter
GPF: Gasoline Particle Filter
SCR: Selective Catalytic Reduction
ASC: Ammonia Slip Catamyst

- **Does it need to be updated?**
  - **PN_{10}:**
    - DPF and GPF very efficient in the sub-23 nm range [2]
    - Currently available state-of-the-art filters are enough
  - **HDVs:**
    - Engine and aftertreatment updates to achieve Euro VII emission reductions?
    - Other avenues: alternative fuels/power sources
  - **Formaldehydes:**
    - Formed through oxidation of unburned fuel on TWC/DOC, mostly Diesel engines
    - Aftertreatment devices not available yet.

[2] Z. Samaras, *et al.*, *Journal of Aerosol Science* (2022), **162**, 105957

Agenda

1. Euro 7
2. Aftertreatment Techniques
3. **Alternative Fuels and Power Sources**
4. Mitigating Non-Exhaust Emissions

Biofuels

https://www.jonellsystems.com/products/latest-technology/renewable-hydrocarbon-biofuels-filtration/

- **Advantages**
  - Cheap
  - Blends already approved; use as drop-in fuels
  - 70-80% CO_2 reduction well-to-wheel (RED III)
  - Engine CO, NOx, and PM reduction (depends on fuel)
- **Drawbacks**
  - Indirect Land Use Concerns (ILUC) – 1st gen
  - Hard-to-scale: limited sustainable feedstock
  - Aldehyde emissions (ethanol-based fuels)
  - Toxicity (methanol-based fuels)
- **Preferred applications**
  - All: drop-in fuels where other alternatives are not possible, or low fleet turnover, e.g. air, rail, waterway
- **Explore**
  - New mixing blends
  - New engines/after-treatment designed for biofuels (e.g. flexfuel E85)
  - Routes for scaling without ILUC: cellulosic (high Technology Readiness Level [TRL]), algae (low TRL)

Natural Gas (NG)

https://www.woodwayenergy.com/how-is-natural-gas-transported/

- **Advantages**
  - Gas infrastructure already exists
  - Widespread in shipping, used in all road vehicles (except L-cat)
  - Large NOx reduction (78%) with respect to diesel [3]
  - [Bio-]Synthetic NG (SNG) for reduced CO_2 emissions (renewable electricity needed)
- **Drawbacks**
  - Liquid NG production is energy intensive and expensive, SNG also has high production costs
  - Low volumetric density for Compressed NG
  - CO, NH_3 emissions increase with respect to diesel [3]
  - Methane slip risk
  - Higher fuel consumption than diesel, especially for light vehicles (+42%), less so for HDVs (+24%) [4]
- **Preferred applications**
  - More suited for heavy-duty transport (fuel efficiency)
  - Can be used as a drop-in fuel for road transport
  - Inland waterways and shipping

[3] R. Gioria, *et al.*, *Transport Reasearch Part D* (2024), **134**, 104349. [4] J. L. Breuer, *et al.*, *Energies* (2022), **15**, 1443.

Hybrid (HEV) & Plug-In Hybrid (PHEV)

https://www.parramattatoyota.com.au/blog/new-vehicles/how-does-the-toyota-hybrid-work/

- **Advantages**
  - No exhaust pollutants emitted when running on battery
  - Higher engine efficiency (up to 50%)
  - Regenerative braking
  - Mature technology
  - No limits on range (ICE)
- **Drawbacks**
  - Heavier than equivalent ICE vehicles
  - Share of electric driving mode is smaller than assumed in PHEV: real-world emissions 5 times higher than Worlwide harmonised Light vehicle Test Procedure (WLTP) emissions (2023) [5]
  - Lower efficiency of aftertreatment system due to longer warming-up time
  - Lower efficiency gains for vessels (approx. 5%) [3]
- **Preferred applications**
  - Road and rail – transition technology

[5] S. N. Gohlke, Briefing: Closing the growing PHEV loophole, Transport & Environment (2025).

Battery Electric Vehicles (BEV)

https://www.allensamuels.com/manufacturer-information/how-long-does-it-take-to-charge-an-electric-vehicle/

- **Advantages**
  - No exhaust pollutants
  - Regenerative braking
  - High engine efficiency
  - Mature technology
- **Drawbacks**
  - Low energy density
  - Average 20% increase in vehicle mass [6]
  - Charging infrastructure can be a bottleneck
  - Indirect emissions depending on source of electricity
- **Preferred applications**
  - Road: light vehicles (<3.5t), and buses, L-category
  - Rail: Non-electrified short-range lines
  - Navigation (inland & recreational): short-range passenger vessels
  - Air: short-range small-to-medium-sized (long-term), but modal shift preferred

[6] Y. Liu et al., Journal of Hazardous Materials (2021), **420**, 126626,

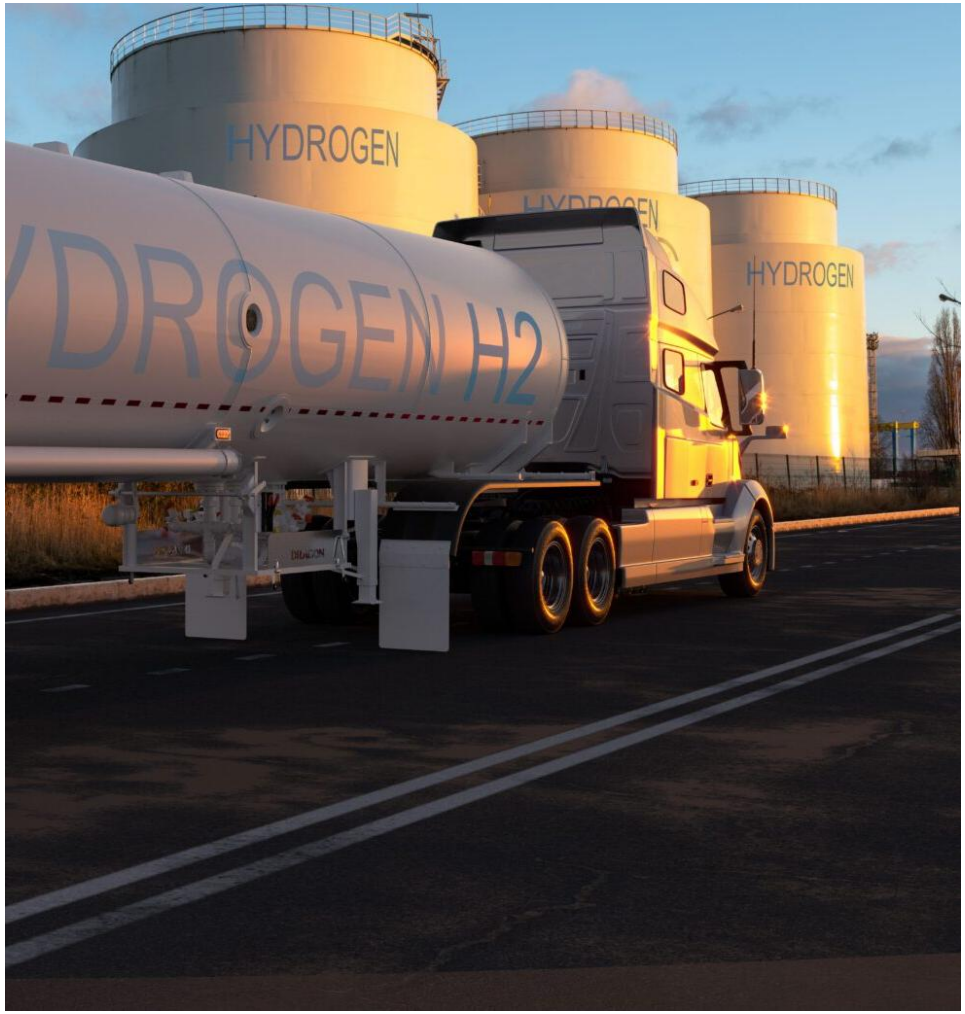
Synthetic Fuels (X-to-Liquid or XtL)

https://sugar-asia.com/ethanol-targets-sustainable-aircraft-fuel-development/

- **Advantages**
  - Blends already approved; use as drop-in fuels
  - CO_2 emission reductions
- **Drawbacks**
  - ILUC, if X=biomass (limited sustainable feedstock)
  - Power-to-Liquid is hard to scale:
    - Green hydrogen production required for syngas
    - Carbon capture infrastructure required
    - High green energy input required
- **Preferred applications [4]**
  - All: drop-in fuels where there are no other alternatives, or low fleet turnover, e.g. air, rail, waterway
- **Explore**
  - Air quality gains?
  - New mixing blends
  - New routes for scaling without ILUC: algae (low TRL)
  - Methanol-to-Kerosene

[4] J. L. Breuer, *et al.*, *Energies* (2022), **15**, 1443.

Hydrogen



https://www.breakthroughenergy.org/newsroom/articles/hydrogenstorage/

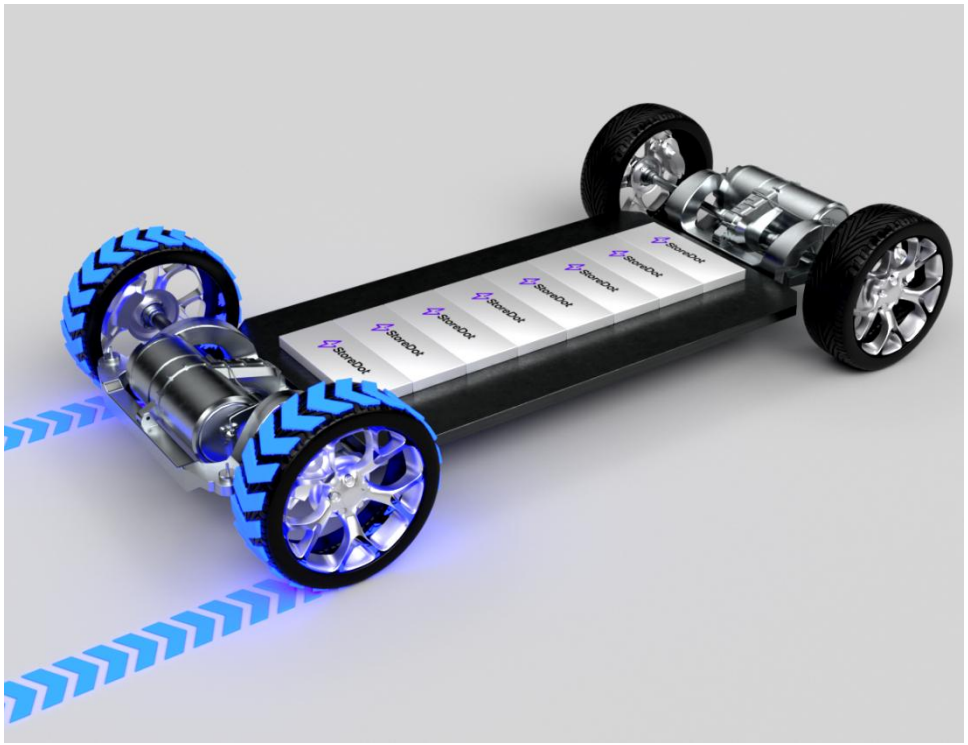
- **Advantages**
  - High gravimetric energy density
  - No pollutants emitted in Fuel-Cell Electric Vehicles (FCEV)
  - Regenerative breaking in FCEV
  - Fast charging
- **Drawbacks**
  - Large NOx emissions in ICE hydrogen
  - Significant challenges around infrastructure:
    - High cost
    - Concerns around storage and transport
    - Uncertainty around scaling-up green hydrogen
    - Charging points for FCEV
- **Preferred applications [4]**
  - Road: heavy-duty vehicles and passenger cars
  - Rail: non-electrified long-range lines
  - Inland: long-range freight vessels
  - Air: long-range small-to-medium-sized planes, potentially short-range large-sized planes (both long-term)

[4] J. L. Breuer, *et al*., *Energies* (2022), **15**, 1443.

Agenda

1. Euro 7
2. After-Treatment Techniques
3. Alternative Fuels and Power Sources
4. **Mitigating Non-Exhaust Emissions**

Regenerative Braking



https://www.store-dot.com/blog/unleashing-the-power-of-regenerative-braking-with-xfc-technology

- **Reliance on friction brakes significantly reduced**
  - 88% brake PM emission reduction under WLTP [7]
  - Similar for rail transport

[7] W. Hicks *et al*., *Environmental Pollution* (2023), **336**, 122400.

Choosing the right material – Brakes [8]

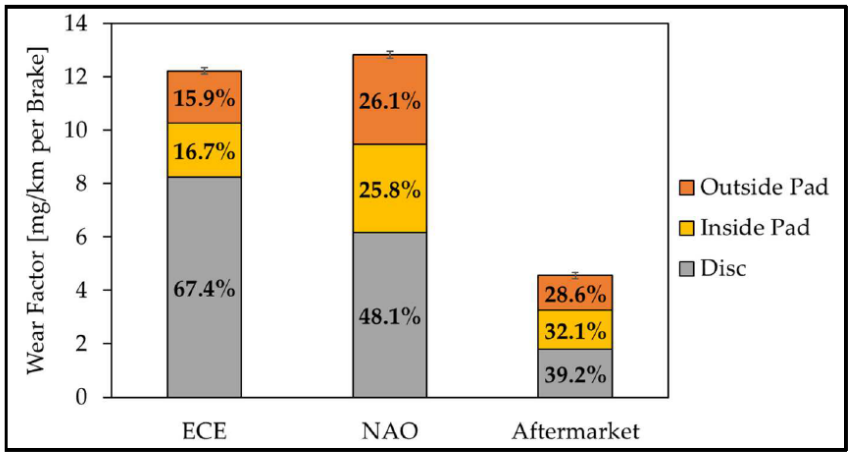


Figure 5. Wear factors of the three different brake pad compositions after 8x WLTP Brake Cycle.

- **Pads**
  - Low-steel (Europe) → more disc particles
  - Non-asbestos organic (USA/China) → more pad particles

[8] L. Storch *et al.*, *Atmosphere* (2023), **14**, 712.

Choosing the right material – Brakes [8]

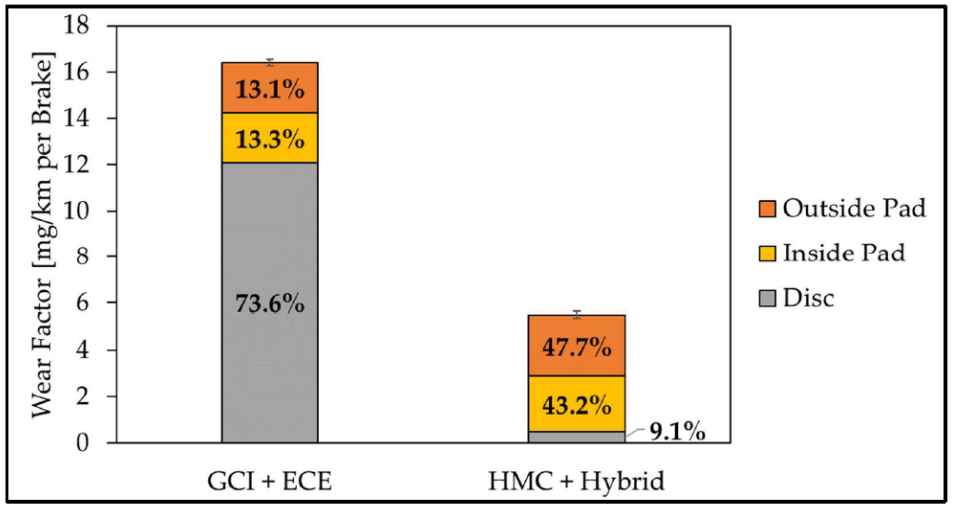


Figure 13. Wear factors of the HMC pairing compared to the GCI pairing after 8× WLTP Brake Cycle. HMB friction pairing with specially adapted hybrid lining.

- **Pads**
  - Low-steel (Europe) → more disc particles
  - Non-asbestos organic (USA/China) → more pad particles
- **Disc**
  - Grey cast iron
  - Tungsten-carbide coated → harder material

https://goodcar.com/car-safety/how-disc-brake-system-works

[8] L. Storch *et al.*, *Atmosphere* (2023), **14**, 712.

Choosing the right material – Brakes [8]

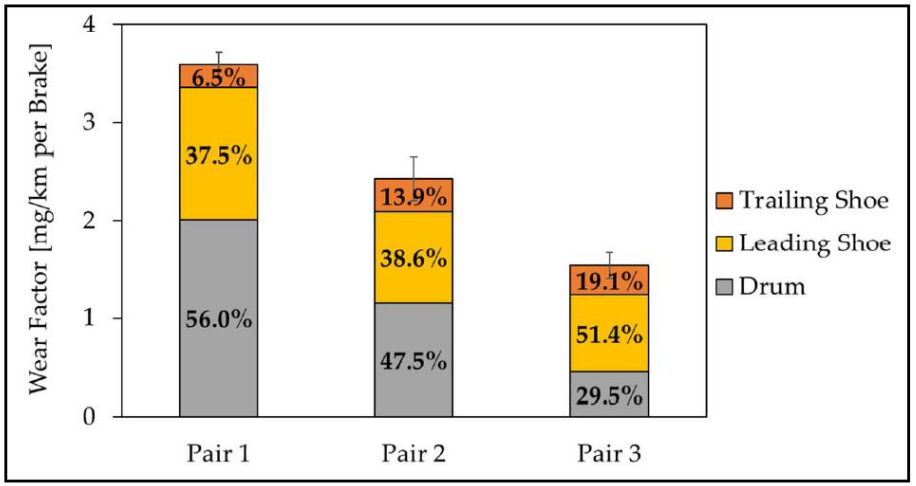


Figure 12. Wear factors of the three different drum brake shoe compositions after 8× WLTP Brake Cycle.

https://goodcar.com/car-safety/how-disc-brake-system-works

- **Pads**
  - Low-steel (Europe) → more disc particles
  - Non-asbestos organic (USA/China) → more pad particles
- **Disc**
  - Grey cast iron
  - Tungsten-carbide coated → harder material
- **Drum brake**
  - Lower PM emissions than disc brakes
  - PM mostly trapped inside the drum
  - Brake shoe material can also be optimised
  - Reduced braking power, but fine for rear-braking

Left: https://midwestbusparts.com/product/brake-drum-1660600c3-10032931/
Right: https://venturetrailers.com/product/hydraulic-drum-brake-7x-1-3-4-uniservo-e-coat-left/

[8] L. Storch *et al.*, *Atmosphere* (2023), **14**, 712.

Choosing the right material – Brakes [8]

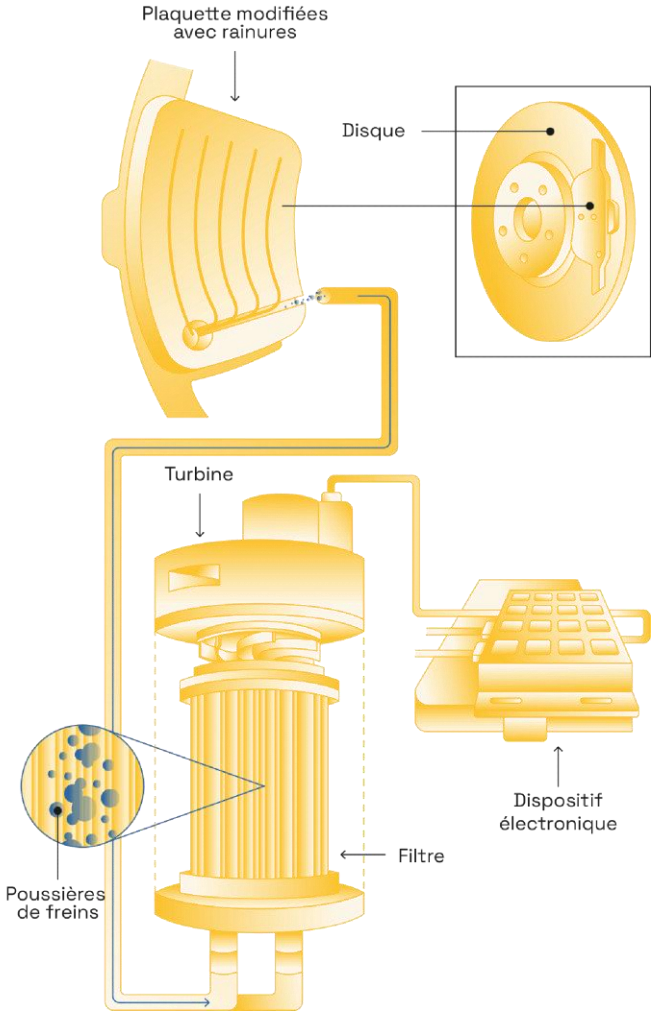
https://goodcar.com/car-safety/how-disc-brake-system-works

- **Pads**
  - Low-steel (Europe) → more disc particles
  - Non-asbestos organic (USA/China) → more pad particles
- **Disc**
  - Grey cast iron
  - Tungsten-carbide coated → harder material
- **Drum brake**
  - Lower PM emissions than disc brakes
  - PM mostly trapped inside the drum
  - Brake shoe material can also be optimised
  - Reduced braking power, but fine for rear-braking

Left: https://midwestbusparts.com/product/brake-drum-1660600c3-10032931/
Right: https://venturetrailers.com/product/hydraulic-drum-brake-7x-1-3-4-uniservo-e-coat-left/

[8] L. Storch *et al.*, *Atmosphere* (2023), **14**, 712

Particle Capture Systems



- **TAMIC (Tallano) [9]**
  - Brake PM: 70% reduction
  - Can be used on passenger vehicles, HDVs, railway transport

[9] https://www.tallano-technologies.com/

Particle Capture Systems

- **TAMIC (Tallano) [9]**
  - Brake PM: 70% reduction
  - Can be used on passenger vehicles, HDVs, railway transport
- **Passive filter (MANN+HUMMEL) [10]**
  - Captures particles directly inside a filter
  - Active version (similar to TAMIC) also available

Mostly for further reductions in heavy or commerical vehicles, ideal for bus or refuse truck (high amount of start and stop). Also trains !

[10] https://oem.mann-hummel.com/en/oem-products/fine-dust-filters/brake-dust-particle-filter.html

Choosing the right material – Tyres [11]

https://www.tyrepress.com/2023/06/tyre-silica-to-remain-a-solvay-business-following-company-split/ (Solvay)

- **Silica as filler (instead of carbon black)**
  - Increased abrasion resistance
  - Improved wet grip and rolling resistance

[11] Ilka Gehrke *et al.*, *Science of the Total Environment (*2023), **904**, 166537

Choosing the right material – Tyres [11]

https://hankooktireblog662734652.wordpress.com/2020/06/01/what-are-those-little-rubber-hairs-on-a-tire-anyway/

- **Silica as filler (instead of carbon black)**
  - Increased abrasion resistance
  - Improved wet grip and rolling resistance
- **Vent spews**
  - Increased material loss over the first kilometres
  - No technical significance

[11] Ilka Gehrke *et al.*, *Science of the Total Environment (*2023), **904**, 166537

Choosing the right material – Tyres [11]

- **Silica as filler (instead of carbon black)**
  - Increased abrasion resistance
  - Improved wet grip and rolling resistance
- **Vent spews**
  - Increased material loss over the first kilometres
  - No technical significance
- **Summer/Winter/Studded**
  - Winter = 2,2-2,7 times more PM than summer
  - Studded = 4,4-100 times more PM than summer
  - Studded = 2-60 times more PM than winter

Left: https://www.carr-repair.be/en/article/dos-and-donts-of-winter-tyres
Right: https://www.carr-repair.be/en/article/dos-and-donts-of-winter-tyres

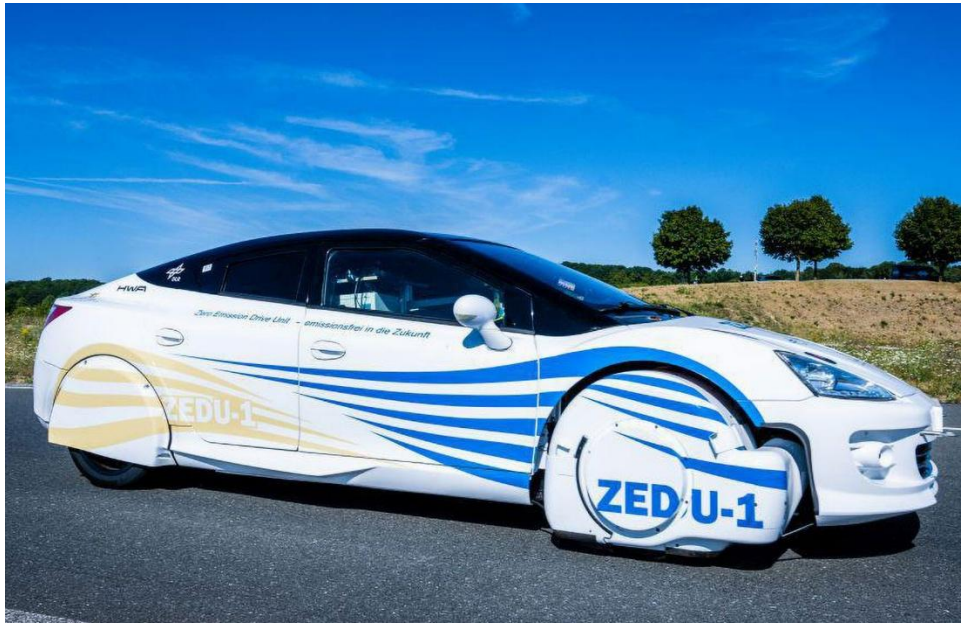
[11] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Particle Capture Systems

- **The Tyre Collective [12]**
  - Uses electrostatics and airflow
  - Tyre PM: 10% on roads, 80% in the lab

[12] https://thetyrecollective.com

Particle Capture Systems



- **The Tyre Collective [12]**
  - Uses electrostatics and airflow
  - Tyre PM: 10% on roads, 80% in the lab
- **ZEDU-1 Project [11, 13]**
  - Airflow through the wheel arch (cooling effect)
  - Tyre PM: potential for 90% reduction
  - Retrofit possible?

[13] https://www.dlr.de/en/fk/research-and-transfer/projects/alternativ-energy-concepts/zero-emission-drive-unit-generation-1-zedu-1

Particle Capture Systems

- **The Tyre Collective [12]**
  - Uses electrostatics and airflow
  - Tyre PM: 10% on roads, 80% in the lab
- **ZEDU-1 Project [11, 13]**
  - Airflow through the wheel arch (cooling effect)
  - Tyre PM: potential for 90% reduction
  - Retrofit possible?
- **Rooftop/Underbody Filter (MANN+HUMMEL) [11, 14]**
  - Captures both tyre particles and particles due to resuspension captured (max. 70% reduction)

Mostly for further reductions in HDVs because space is needed underneath the car to fit most technologies (except for the rooftop filter).

[14] https://oem.mann-hummel.com/en/oem-products/fine-dust-filters/fine-dust-particle-filter-roof-box-pureair.html

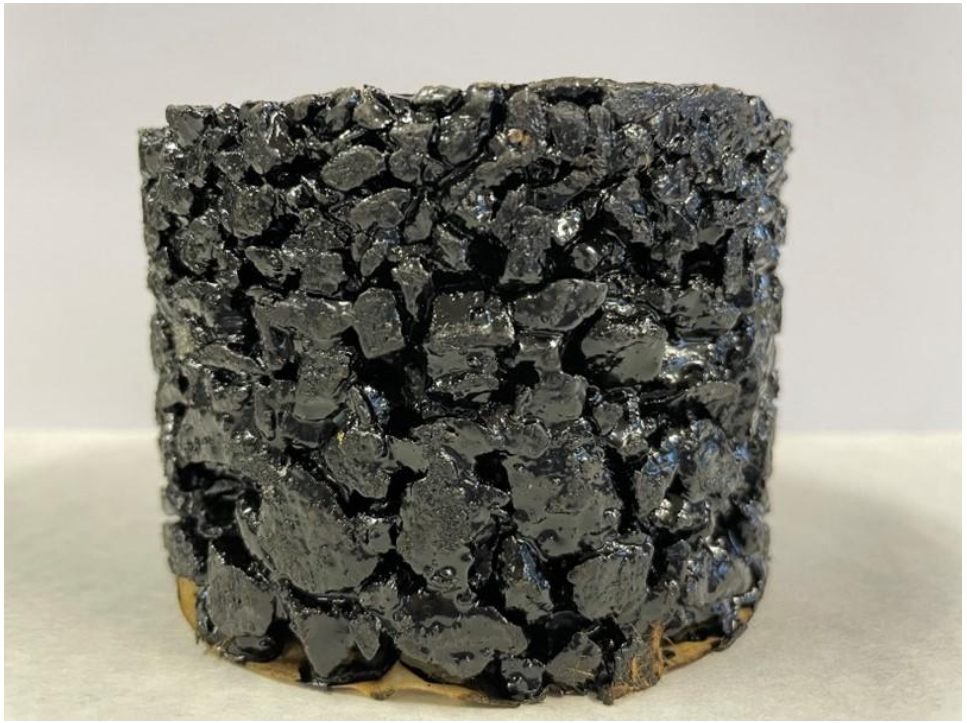
Research Avenues: Other Non-Exhaust Emission Sources in Railway Transport

https://www.trains.com/mrr/beginners/ask-trains/why-are-wheel-flanges-on-the-inside-of-train-wheels/

https://www.macproducts.net/blog/what-is-the-difference-between-pantograph-and-trolley-shoe-catenary-collectors

- Relatively underexplored so far
- Research projects starting soon: SNCF, Deutsche Bahn
- Initial results show that non-exhaust emissions are dominated by brake PM, closely followed by wheel-rail PM.
- The share of catenary-pantograph emissions is small in comparison
- Welcoming any information on the topic!

Choosing the Right Material – Roads [10]

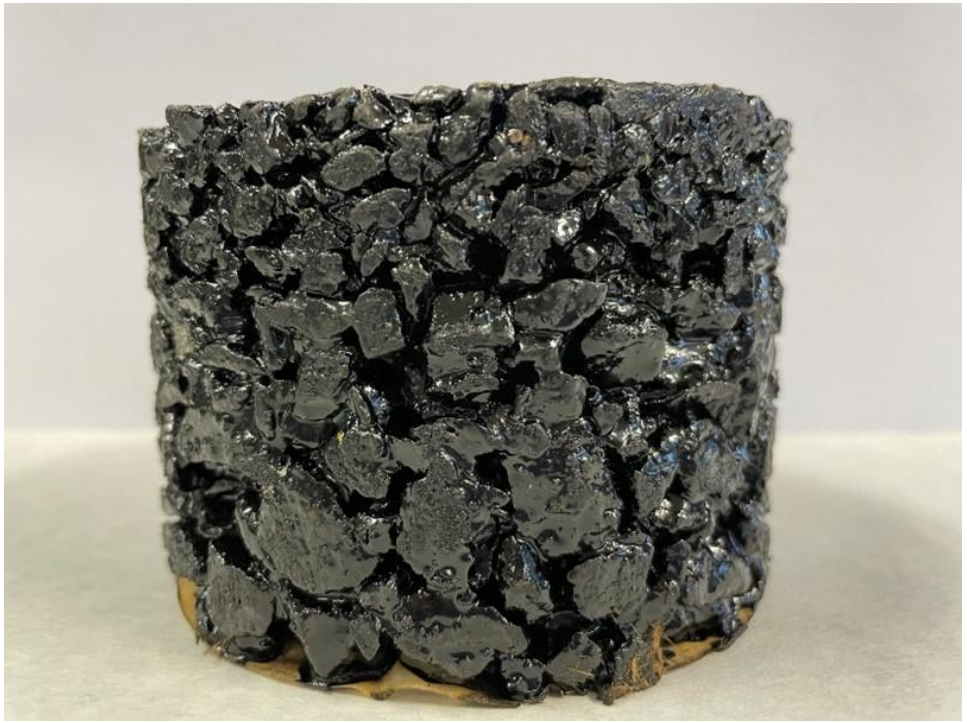


https://nemo-cities.eu/road-surface-that-cleans-the-air-and-reduces-noise-and-emissions/

- **Porous asphalt**
  - 40% of all tyre PM captured (Netherlands), mostly >=PM_{10}
  - Expensive and long (35 years process in the Netherlands)
  - Need to be cleaned to maintain efficiency
  - Higher microplastics concentration in road runoff
  - More vulnerable to frost damage (not suitable for colder countries)

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Choosing the Right Material – Roads [10]



https://nemo-cities.eu/road-surface-that-cleans-the-air-and-reduces-noise-and-emissions/

- **Porous asphalt**
  - 40% of all tyre PM captured (Netherlands), mostly >=PM_{10}
  - Expensive and long (35 years process in the Netherlands)
  - Need to be cleaned to maintain efficiency
  - Higher microplastics concentration in road runoff
  - More vulnerable to frost damage (not suitable for colder countries)
- **Dust binders**
  - Increases mass, moisture, and aggregation of deposited particle (40% PM reduction possible)
  - Works best under cold conditions
  - Expensive
  - Impervious surface under rainy conditions
  - Potentially harmful to aquatic environments

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

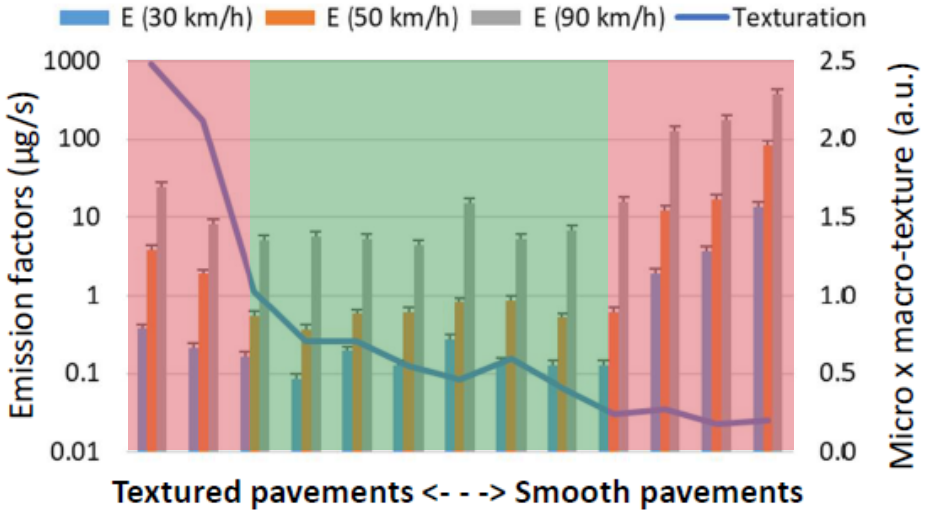
Choosing the Right Material – Roads [10]

https://nemo-cities.eu/road-surface-that-cleans-the-air-and-reduces-noise-and-emissions/

- **Porous asphalt**
  - 40% of all tyre PM captured (Netherlands), mostly >=PM_{10}
  - Expensive and long (35 years process in the Netherlands)
  - Need to be cleaned to maintain efficiency
  - Higher microplastics concentration in road runoff
  - More vulnerable to frost damage (not suitable for colder countries)
- **Dust binders**
  - Increases mass, moisture, and aggregation of deposited particle (40% PM reduction possible)
  - Works best under cold conditions
  - Expensive
  - Impervious surface under rainy conditions
  - Potentially harmful to aquatic environments
- **Shredded scrap tyre additives**
  - Mixed opinions in the literature

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Choosing the Right Material – Roads [10]

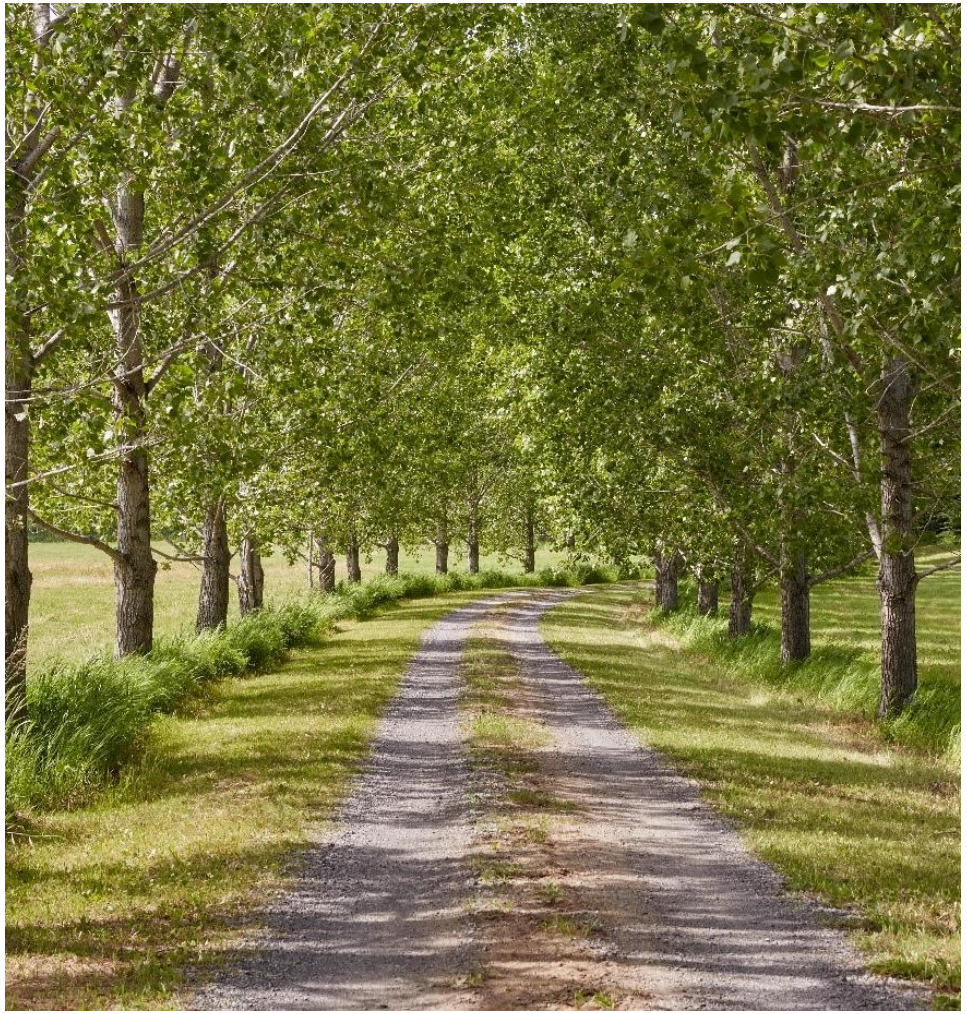


Schematic courtesy of Bogdan Muresan: https://doi.org/10.1016/j.scitotenv.2024.170578

- **Porous asphalt**
  - 40% of all tyre PM captured (Netherlands), mostly >=PM_{10}
  - Expensive and long (35 years process in the Netherlands)
  - Need to be cleaned to maintain efficiency
  - Higher microplastics concentration in road runoff
  - More vulnerable to frost damage (not suitable for colder countries)
- **Dust binders**
  - Increases mass, moisture, and aggregation of deposited particle (40% PM reduction possible)
  - Works best under cold conditions
  - Expensive
  - Impervious surface under rainy conditions
  - Potentially harmful to aquatic environments
- **Shredded scrap tyre additives**
  - Mixed opinions in the literature
- **Road texture**
  - Sweet spot can be achieved, to be maintained

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Reducing Particle Resuspension – Roads [10]



https://thewaterchannel.tv/thewaterblog/the-potential-of-roadside-trees-to-offset-co2/

- **Resuspension**
  - **Vegetation**
    - By the road reduces PM dispersing further away
    - On rooftops where space is limited

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Reducing Particle Resuspension – Roads [10]

https://www.newportlandreclamation.co.uk/road-sweeper/

- **Resuspension**
  - **Vegetation**
    - By the road reduces PM dispersing further away
    - On rooftops where space is limited
  - **Road/Street Cleaning**
    - Most effective at reducing resuspension
    - Two options:
      - Mechanical sweepers
      - Vacuum/regenerative air sweepers
    - Frequency is important
    - Focus on high-traffic roads
    - PM need to be collected to avoid runoff

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Preventing Road Runoff [10]

https://www.asllimited.co.uk/drainage-blog/road-gully-cleaning-essential-insights

- **Runoff**
  - **Water collection systems**
    - On-site collection: roadside gully pots, subsurface treatment units
    - Semi-centralised collection: retention/detention basins, wetlands
    - Centralised: wastewater treatment plant

https://trapbag.com/blog/detention-basin-retention-basin-pros-cons/

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Preventing Road Runoff [10]

https://www.beaumont.ab.ca/home-neighbourhood/roads-trails/snow-ice-control/

- **Runoff**
  - **Water collection systems**
    - On-site collection: roadside gully pots, subsurface treatment units
    - Semi-centralised collection: retention/detention basins, wetlands
    - Centralised: wastewater treatment plant
  - **Snow collection systems**
    - Snow typically dumped in water bodies contributing to pollution of aquatic environment
    - Should be treated beforehand (Sweden)
    - **Clewat**: snow melting and filtering technology

https://clewat.com/en/snow-control/

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Preventing Road Runoff [10]

https://beyondpesticides.org/dailynewsblog/2023/07/biosolids-sewage-sludge-widely-used-without-complete-safety-assessment/

- **Runoff**
  - **Water collection systems**
    - On-site collection: roadside gully pots, subsurface treatment units
    - Semi-centralised collection: retention/detention basins, wetlands
    - Centralised: wastewater treatment plant
  - **Snow collection systems**
    - Snow typically dumped in water bodies contributing to pollution of aquatic environment
    - Should be treated beforehand (Sweden)
    - **Clewat**: snow melting and filtering technology
  - **Sewage sludge**
    - Used as a fertiliser in agriculture
    - 31k-42k tons of microplastics in European soils yearly
    - Already banned in Switzerland

[10] Ilka Gehrke *et al.*, *Science of the Total Environment* (2023), **904**, 166537

Next steps

End of December, the draft revised GD on Mobile Sources will be sent to the experts.

The experts will have three weeks to provide their feedbacks and comments.

While the comments could cover both documents, TFTEI will work to include comments and feedbacks as in the following timeframe:

- as for the official document: by early February 2026, in time for translation ahead of the WGSR_64;
- as for the informal complementary document: by April 2026, to be finalized for consideration of the WGSR_64.

List of references

[1] A. Mirailler, *et al.*, *Transport Research Part D* (2025), 146, 104864.
[2] Z. Samaras, *et al.*, *Journal of Aerosol Science* (2022), **162**, 105957.
[3] R. Gioria, *et al.*, *Transport Reasearch Part D* (2024), **134**, 104349.
[4] J. L. Breuer, *et al.*, *Energies* (2022), **15**, 1443.
[5] S. N. Gohlke, Briefing: Closing the growing PHEV loophole, Transport & Environment (2025).
[6] Y. Liu et al., Journal of Hazardous Materials (2021), **420**, 126626.
[7] W. Hicks *et al.*, *Environmental Pollution* (2023), **336**, 122400.
[8] L. Storch *et al.*, *Atmosphere* (2023), **14**, 712.
[9] https://www.tallano-technologies.com/
[10]https://oem.mann-hummel.com/en/oem-products/fine-dust-filters/brake-dust-particle-filter.html
[11] Ilka Gehrke *et al.*, *Science of the Total Environment (*2023), **904**, 166537
[12] https://thetyrecollective.com
[13]https://www.dlr.de/en/fk/research-and-transfer/projects/alternativ-energy-concepts/zero-emission-drive-unit-generation-1-zedu-1
[14] https://oem.mann-hummel.com/en/oem-products/fine-dust-filters/fine-dust-particle-filter-roof-box-pureair.html

List of acronyms

ASC: Ammonia Slip Catalyst
BEV: Battery Electric Vehicle
DOC: Diesel Oxidation Catalyst
DPF: Diesel Particle Filter
EGR: Exhaust Gas Recirculation
FCEV: Fuel Cell Electric Vehicle
GPF: Gasoline Particle Filter
HDV: Heavy-Duty Vehicles
ICE: Internal Combustion Engine
ILUC: Indirect Land Use Concerns
NG: Natural Gas
SCR: Selective Catalytic Reduction
SNG: Synthetic Natural Gas
TRL: Technology Readiness Level
TWC: Three-Way Catalyst
WLTP: Worldwide harmonized Light vehicle Test Procedure

Thank you for your attention

Contacts :
Gabriel Krenzer: gabriel.krenzer@citepa.org
Jean-Marc André: jean-marc.andre@citepa.org