European Commission

12th VERT FORUM 2022

Moving Targets in Nanoparticle Abatement

VERT® association

Brake Wear Particle Emissions

Current State of Play and Future Outlook

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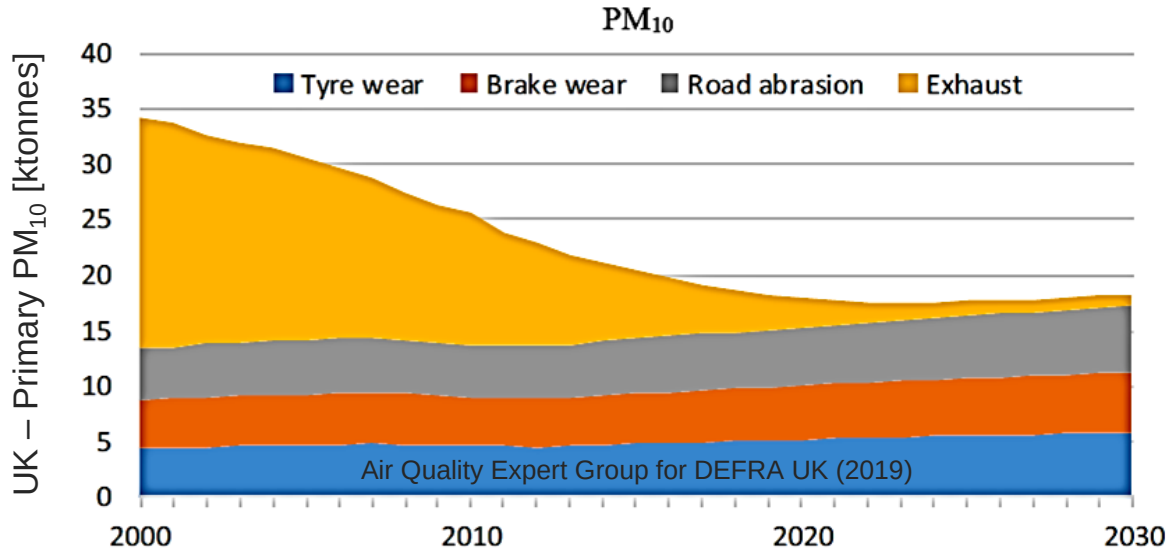
24 MARCH 2022

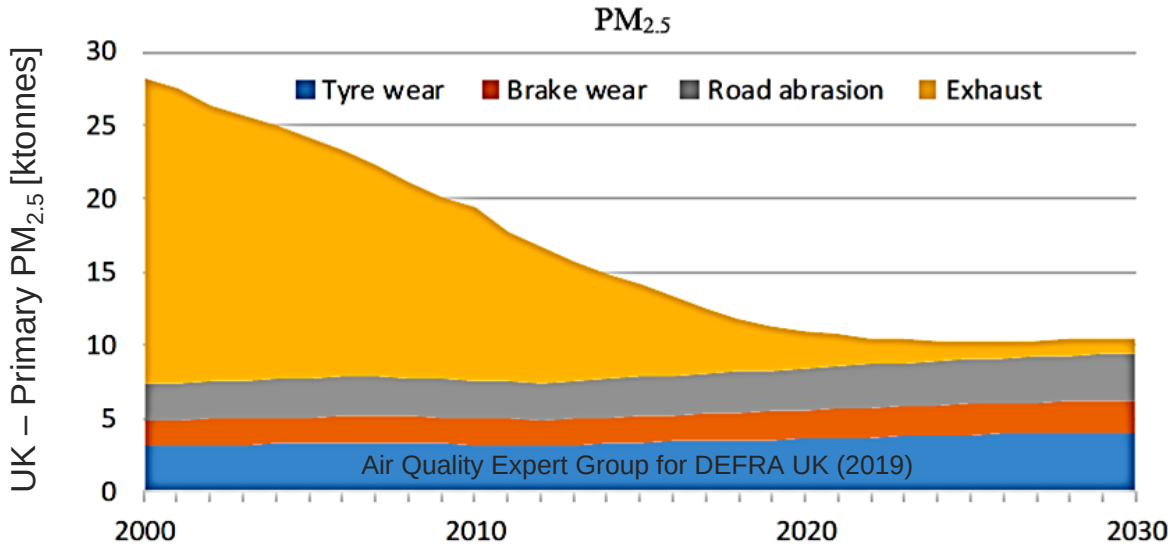
Joint Research Centre

OUTLOOK

- ✓ Short background on brake emissions
- ✓ Literature based LDVs brake PM EFs
- ✓ Development of a GTR on brake emissions
- ✓ Preliminary PMP-based findings
- ✓ Options to reduce brake emissions

EXHAUST VS. NON-EXHAUST EMISSIONS



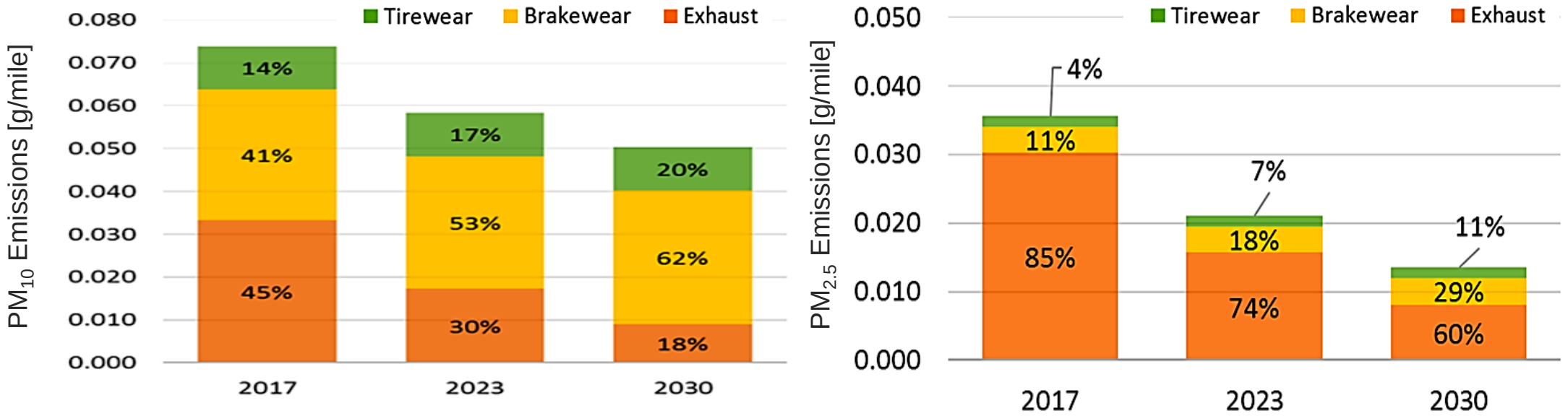


Main limitations

- ✓ PM_{10} and $PM_{2.5}$ emission estimations are based on type-approval tests. Real-world exhaust PM emissions are expected to be higher – Data better reflect the situation in countries with newer fleet composition
- ✓ Question regarding the underlying assumptions – There is a lack of standardized methods for characterizing non-exhaust emissions
- ✓ Question regarding to what extent the influence of the fleet electrification has been considered adequately in these studies

Despite the limitations – and the reported differences among studies – non-exhaust emissions have become much relevant for air pollution

IMPORTANCE OF BRAKE EMISSIONS

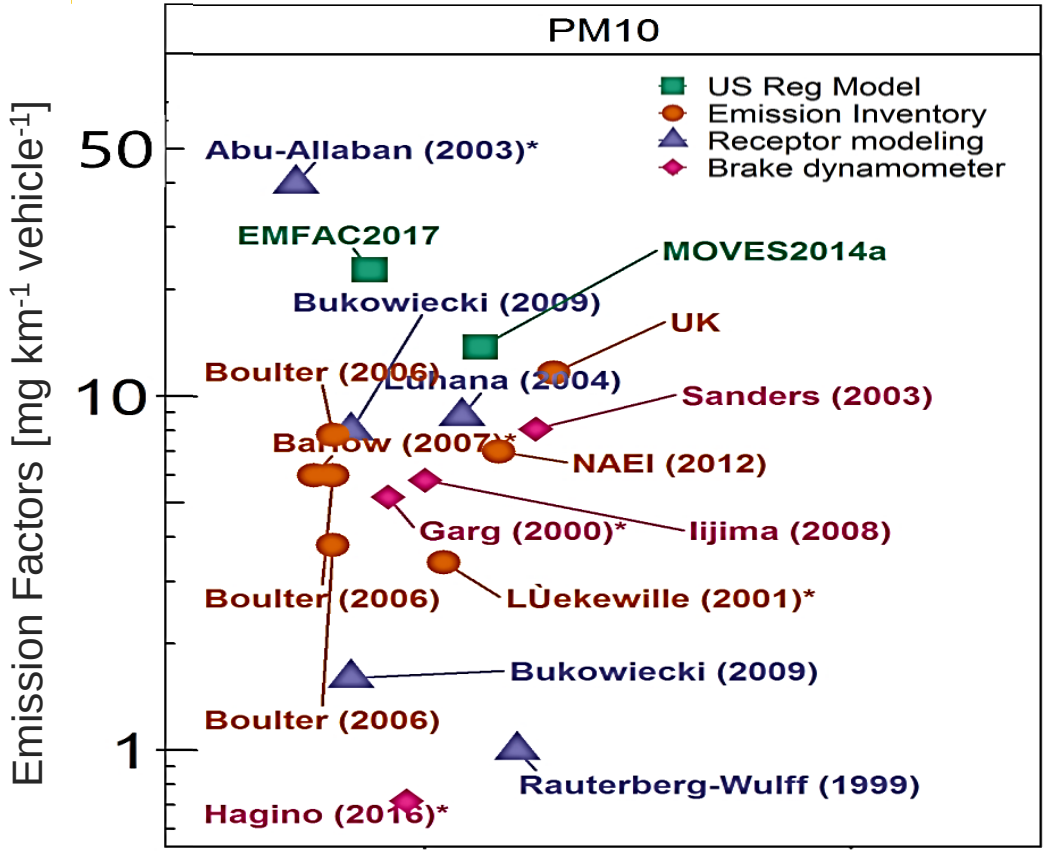


MOVES – Sonntag et al. (2020) HEI Virtual Workshop on non-tailpipe PM emissions and health

- ✓ Brake PM_{10} and $PM_{2.5}$ EFs are approximately 3 times higher compared to tire PM_{10} and $PM_{2.5}$ (road wear not included)
- ✓ Projections show similar brake/tire EFs ratio in 2030; however, calculations do not seem to take into account the electrification of fleet that will heavily affect all types of non-exhaust emissions

Despite the questionable projections – which do not seem to account for future technologies – brake emissions make up a significant fraction of non-exhaust emissions

LDV BRAKE EMISSION FACTORS – LEGACY



MOVES – Sonntag et al. (2020) – HEI Workshop

Limitations

1. Emission Inventories – Require accurate emission rate input data and – so far – do not take into account differences and technologies

2. Receptor Modelling – Requires the application of unique chemical tracers that seem not to be available in case of brake emissions

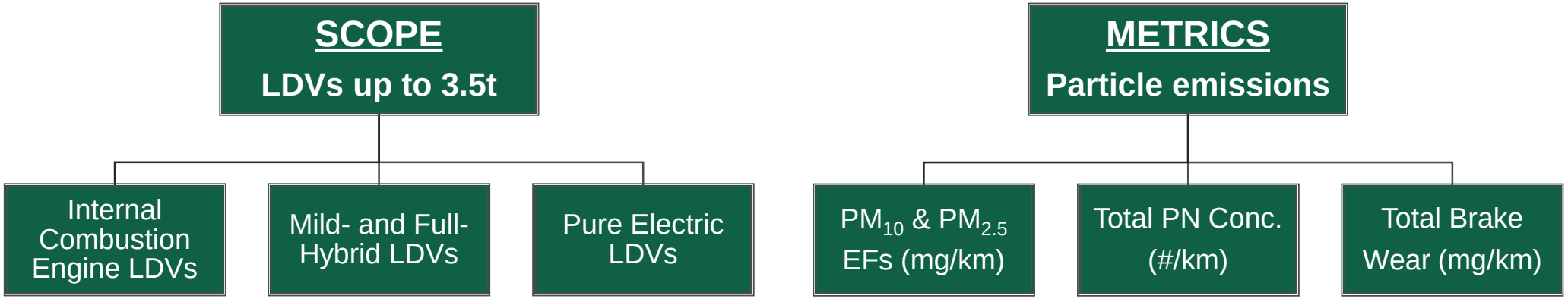
3. Brake dynamometer – No standardized or commonly accepted method available, yet

4. On-road measurement – Very challenging to isolate brake (or other non-exhaust) emissions

Real-world LDV Brake PM_{10} EFs at a vehicle level can vary as much as from a few to tens of mg/km. The most important influencing factors are: The vehicle technology, vehicle type and curb weight, the type of brake, the brake quality and materials, the brake size, etc.

UNECE GRPE MANDATE – GTR DEVELOPMENT

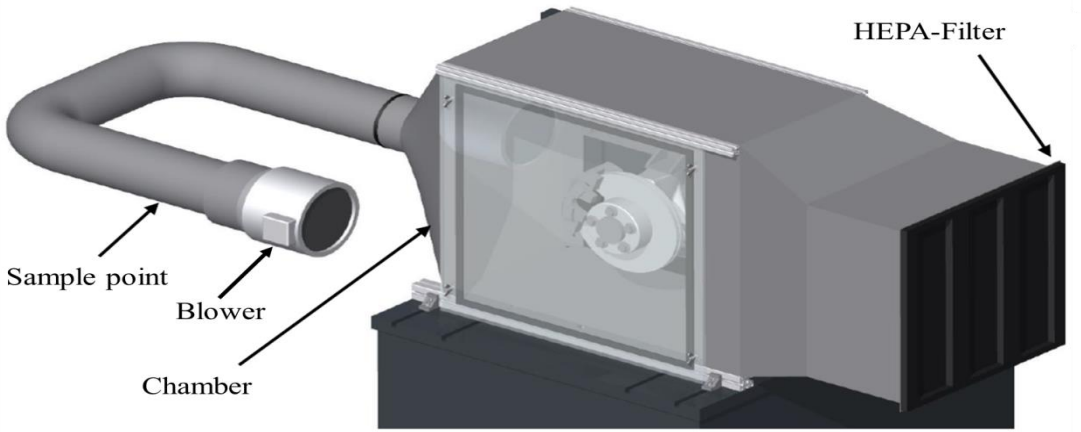
- ✓ June 2013: The PMP IWG started looking into non-exhaust emissions following a request from the Russian federation – DG-GROW requested to research also other non-exhaust sources
- ✓ June 2019: The GRPE approves the ToR mandating the PMP IWG to develop a laboratory based method for sampling and measuring brake particle emissions
- ✓ June 2021: The GRPE approves the ToR mandating the PMP IWG to develop a Global Technical Regulation (GTR) on brake particle emissions



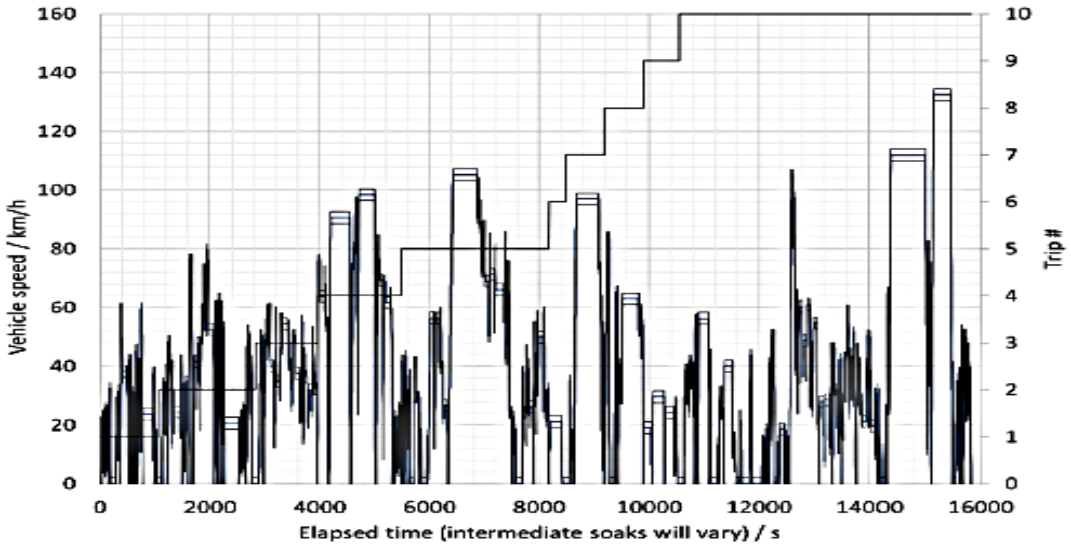
The GTR is expected to be adopted in the Euro-7 Standards regulation where emission limits for LDV brakes will be defined for the first time – Possible adoption in other parts of the world

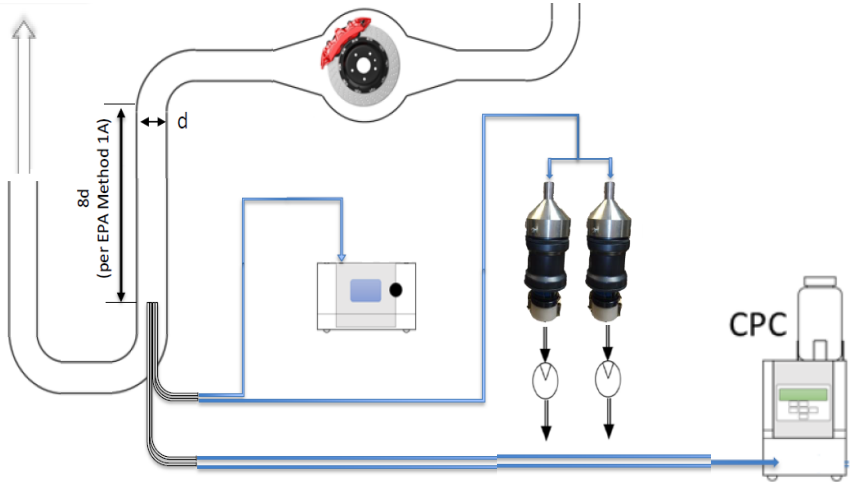
PMP METHOD – AT A GLANCE

Bandiera et al. – EuroBrake EB2021-STP-012



Hesse et al. 48th PMP Meeting (PMP Website)





Agudelo et al. – 30th TF2 Meeting (PMP Website)

PMP METHOD – VALIDATION – ILS EXERCISE

- ✓ Verify the feasibility of the proposed specifications and provide recommendations on further improving and/or extending the set of the defined specifications;
- ✓ Examine the repeatability and reproducibility of PM and PN emission measurements with the application of the proposed specifications;

Mandatory /Optional	M1 - Br1a	M2 - Br1b	M3 - Br2	O1 - Br3	O2 - Br4	O3 - Br5a	O4 - Br5b	O5 - Repeatability	O6 - Alt. Bedding
Lab-B	√	√	√	√				√	√
Lab-C	√	√	√	√					
Lab-D	√	√	√		√				
Lab-F	√	√	√	√	√	√	√		
Lab-G	√	√	√			√	√		
Lab-H	√	√	√						
Lab-J	√	√	√						
Lab-K	√	√	√					√	
Lab-L	√	√	√	√				√	√
Lab-M	√	√	√	√	√	√	√	√	
Lab-N	√	√		√	√	√	√		√
Lab-P	√	√	√						
Lab-Q	√	√	√					√	
Lab-R	√	√	√						
Lab-S	√	√	√	√					
Lab-T	√	√	√		√				
Lab-X	√	√	√			√	√		

Not Completed **Completed**

75
Completed tests
89%

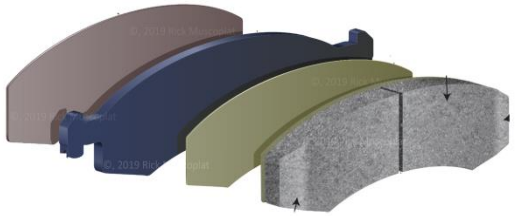
BRAKE PM EFs – PRELIMINARY FINDINGS

- ✓ The measurement variability for PM_{10} and $PM_{2.5}$ is high when all data are considered. However, some Labs experienced significant issues, while others did not meet important specs of the TF2 protocol;
- ✓ There is a need to appropriately filter the data in order to allow for a robust statistical analysis and enable the identification of possible significant correlations in the remaining dataset;
- ✓ $PM_{2.5}$ is approximately a third of PM_{10} emissions regardless the type of brake tested – Additionally, PM_{10} emission levels are approximately 40-50% of total wear emissions regardless the type of brake
- ✓ The tested drum brake emits significantly lower PM_{10} and $PM_{2.5}$ compared to its conventional counterparts – Additionally, PM emissions from the NAO pads are much lower compared to typical European ECE pads
- ✓ Total PN emission levels seem to be low compared to existing exhaust limit for solid particles – An unfiltered average of $8x10^9$ #/km per brake was calculated; however, certain labs exhibited very high background concentrations

OPTIONS FOR REDUCING BRAKE EMISSIONS

Friction Materials – LS vs. NAO

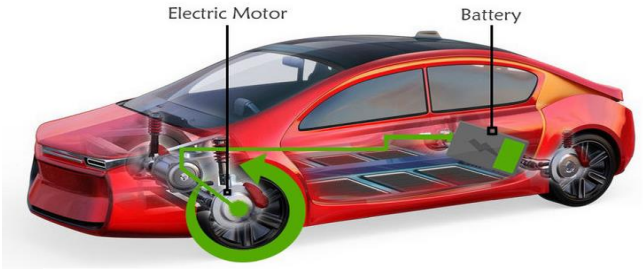
(Sin et al. – EuroBrake EB2021-EBS-012)



PM reduction potential	Cost-effectiveness	Market readiness
+++	++	+++

Regenerative Braking

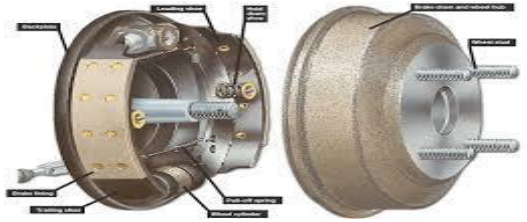
(Picture taken from circuitdigest.com)



PM reduction potential	Cost-effectiveness	Market readiness
+++	++	+++

Drum Brakes

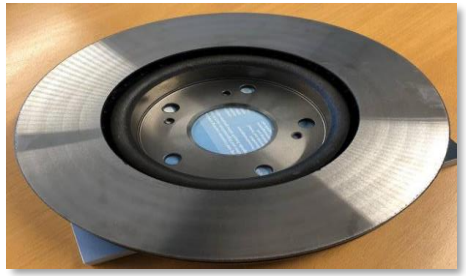
(Sin et al. – EuroBrake EB2021-EBS-012)



PM reduction potential	Cost-effectiveness	Market readiness
+++	+++	+++

Options for reducing brake emissions

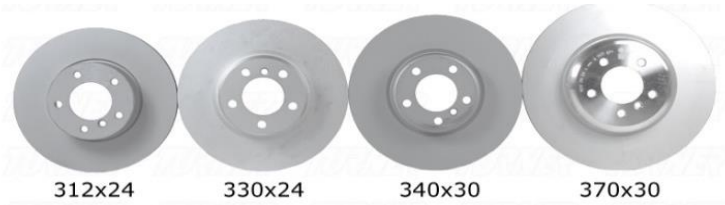
PM reduction potential	Cost-effectiveness	Market readiness
+++	+	+



Brake Disk Coating

(Eibl et al. – EuroBrake EB2021-MDS-003)

PM reduction potential	Cost-effectiveness	Market readiness
++	++	+++



Brake Sizing

(Sin et al. – EuroBrake EB2021-EBS-012)

PM reduction potential	Cost-effectiveness	Market readiness
++	++	+

Brake Filters

(Sin et al. – EuroBrake EB2021-EBS-012)

Thank you

European Commission