



# PARTICLE MEASUREMENT PROGRAMME

PMP-IWG

## **BRAKE EMISSIONS**

**DRAFT GTR – PROPOSED WAY FORWARD**

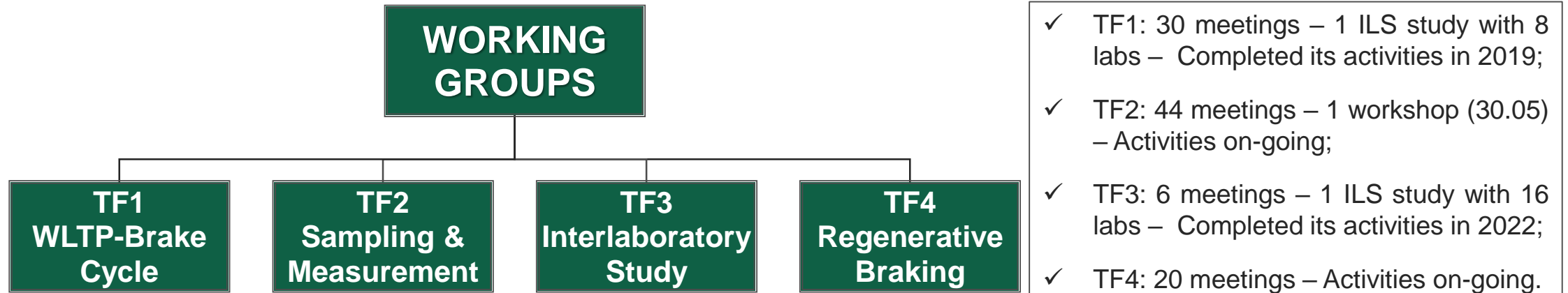
**Theo Grigoratos and Barouch Giechaskiel**

# BACKGROUND

- ✓ June 2016: **GRPE-73-15-Rev.1** Revised PMP ToR – Mandate for the development of a suggested common test procedure for sampling, measurement and characterization of brake wear particles;
- ✓ June 2019: **GRPE-79-14-Rev.1** Revised PMP ToR – The method development includes (a) Validation of the novel test cycle; (b) Definition of the requirements for brake particles generation and sampling; (c) Selection of the appropriate instrumentation; (d) Validation of the proposed approach;
- ✓ June 2020: **GRPE-81-13** Revised PMP ToR – Include all elements from June 2019 and (e) Extend the proposed methodology to include regenerative braking and future technologies;
- ✓ June 2021: **GRPE-83-10** Revised PMP ToR – “Development of a test procedure to be applied in a GTR for sampling and assessing brake wear particles both in terms of mass and number”.

*Overall, a there has been a development phase of almost five years – without taking into account 2020 when the activity was temporarily suspended for almost one year.*

# BACKGROUND



- ✓ A total of 100 technical group meetings, two completed interlaboratory campaigns, numerous testing campaigns that supported with data, and numerous exchanges over the last years;
- ✓ 17 non-exhaust related PMP meetings with more than 50 technical presentations on the topic of brake emissions that supported with data the method development;
- ✓ 1 dedicated workshop “Towards a regulation on brake wear emissions” organized at the 82<sup>nd</sup> GRPE session with more than 200 participants.

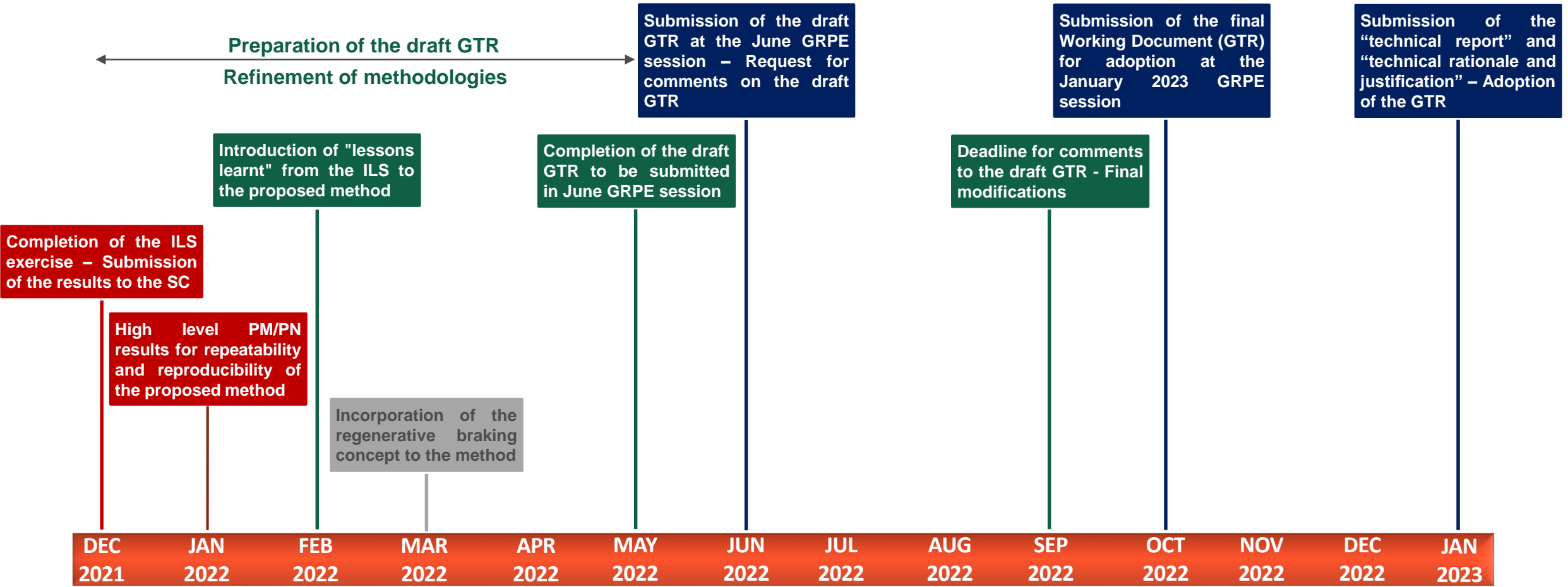
# AIMS AND STATUS OF THE GTR– ECE/TRANS/WP.29/2021/150 (1/2)

- (a) 06.2021: Timeline and framework for mandate request are presented in GRPE – **Item was completed on-time;**
- (b) 06.2021: Request for authorization submitted to AC.3 – **Item was completed on-time;**
- (c) 06.2021: TF2 finalizes the discussion on the definition of the minimum requirements for brake wear particles generation and sampling – ***Item was completed on 14.07.2021 – There was a delay of half month with no influence on the planned work;***
- (d) 06.2021: TF2 finalizes the selection of the appropriate instrumentation and sampling methodology for the measurement and characterization of brake wear particles – ***Item was completed on 14.07.2021 – There was a delay of half month with no influence on the planned work;***
- (e) 06–09.2021: PMP IWG (TF3) organizes the Round Robin exercise with the aim of collecting information and data on the proposed approach for the measurement and characterization of brake wear particles – **Item was completed on-time;**

# AIMS AND STATUS OF THE GTR– ECE/TRANS/WP.29/2021/150 (2/2)

- (f) 09–12.2021: PMP IWG (TF3) executes the RR exercise with the aim of collecting information and data on the proposed approach for the measurement and characterization of brake wear particles – ***Item completed on 31.01.2022 – 1 month delay with influence on the planned work;***
- (g) 12.2021 – 02.2022: Collection of the results and data processing from the Round Robin exercise – ***Item was completed on 31.03.2022 – There was an one month delay due to previous step with influence on the planned work;***
- (h) 03.2022 – 04.2022: Preparation of the PMP Brake protocol for sampling and measuring brake wear PM and PN emissions – ***Item is on-going – It is planned to be completed for full-friction brakes by 10.06 with approximately one month delay;***
- (i) 06.2022: Submission of informal document with draft GTR: ***On-going subject of discussion – It is proposed to be submitted by the end of June;***
- (j) 10.2022: Submission of working document with final GTR for January 2023 GRPE – **Foreseen to be submitted on-time.**

# ROADMAP TO THE GTR – TIMELINE PMP 01.12.2021



# **TF2 CURRENT STATUS BASED ON THE PLANNING PRESENTED AT THE PMP ON 29.03.2022 (1/2)**

- ✓ ***TF2 has engaged in weekly 2h meetings to improve and extend the set of the defined specifications in the protocol*** – So far, 9 meetings have been completed – More than 300 comments have been received for all clauses of the protocol – A workshop to finalize open items will take place on 30.05;
- ✓ The process includes: ***The preparation of a proposal for amendments in each clause of the original protocol based on the GRPE-81-12, the ILS data analysis, and the experiences gained during the ILS.*** As a second step, the proposal is presented to the TF2 members and feedback is requested. As a final step, a consolidated version with the group's feedback is prepared and submitted to the TF2;
- ✓ ***The overall aim is to make the protocol stricter – where necessary – and limit flexibilities with the aim of harmonizing it to the extend possible.***

# **TF2 CURRENT STATUS BASED ON THE PLANNING PRESENTED AT THE PMP ON 29.03.2022 (1/2)**

Clause	Item	Most important new or amended elements
Clause 1	WLTP-Brake Cycle	Specifications for initial temperature control, direction for handling of possible interruptions, introduction of cycle execution quality criteria
Clause 2	Cooling Adjustment	Definitions including LCVs, updated temperature targets, more detailed description of the cooling adjustment method, introduction of quality criteria
Clauses 3-4	Flow settings	Flow measurement specifications, stricter flow control requirements, newly introduced background limits, updated dyno climatics, newly defined reporting requirements
Clause 5	Temperature Measurement	Specifications for the embedded thermocouples, modification to the initial approach for the pad temperature measurement
Clause 6	Bedding Procedure	Accurate definition of the bedding protocol, requirements for initial temperature during cycles, requirements for rear brakes bedding
Clause 7	Enclosure	Design specifications, dimension specifications, restricted design options, validation of the enclosure, restriction of the flow direction and the caliper position
Clause 8	Losses in the duct	Used as a placeholder – Not applicable any longer
Clause 9	PM Measurement	Definition of the sampling plane, duct design requirements, nozzle, tubes, classifier requirements, flow and isokinetic sampling requirements, filters and weighing procedure, PM emission factors calculation
Clause 10	PN Measurement	Definition of the setup, TPN and SPN, sampling plane, nozzle, tubes, pre-classifier requirements, sample conditioning, flow and isokinetic sampling requirements, measurement devices, PN calculation
Clause 11	Reporting	Definition of the required types of files, registration requirements, test report and definition of the reported parameters

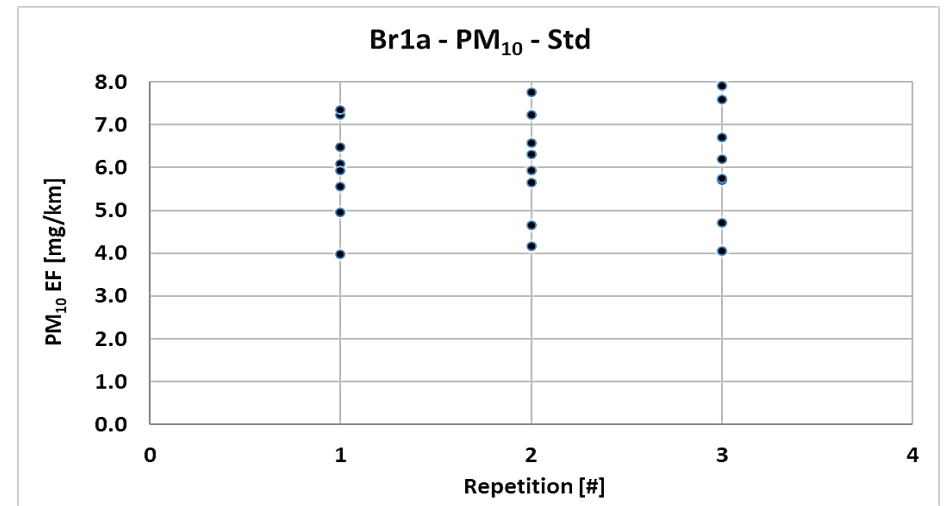
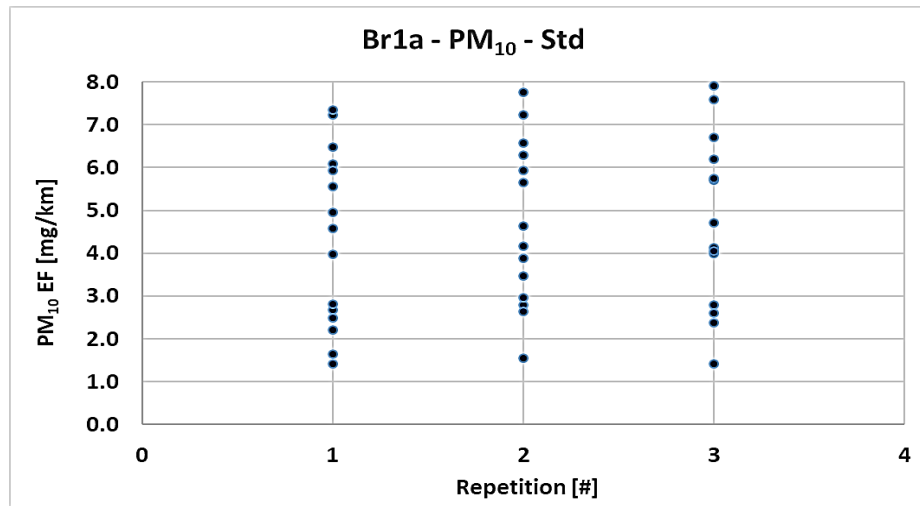
**TF2 Feedback completed**

**TF2 Feedback on-going**



# ILS HIGH-LEVEL PM RESULTS

The measurement variability for PM is high when all data are considered. **However, labs did not meet important specs of the TF2 protocol while others experienced significant issues** - Filtering the data shows a significant improvement in the overall measurement variability



PM10 EFs	Unfiltered Variability	Filtered Variability
Br1a	42.6%	19.5%
Br1b*	N/A	16.9%
Br2	40.6%	18.3%
Br3	48.8%	27.4%
Br5a	16.9%	16.9%
Br5b	16.6%	16.6%

**Lab-to-lab variability is expected to further decrease when the GTR becomes available because i. testing facilities will need to comply to the specifications and ii. stricter specifications and harmonization of several parameters already introduced will improve method's variability within and between testing facilities.**

\*Br1b emission behavior was not uniform – Data from 5 labs are reported here

# **TF4 PLANNING PRESENTED**

## **AT THE PMP ON 29.03.2022**

- ✓ The TF4 is working intensively on finalizing a proposal for incorporating the regen feature in the PMP procedure;
- ✓ There are two proposals that are being evaluated at the moment – Both of them incorporate best and worst case testing scenarios;
- ✓ The objective of TF4 is to submit its final proposal by the end of April – Still to be discussed if a short testing campaign including 2-3 labs will be feasible at this point;
- ✓ The final TF4 proposal on how to generalize the PMP procedure to vehicles with regen braking capabilities will be presented – along with the overall method – to a PMP meeting for feedback and the final approval of the group in the end of May

# TF4 CURRENT STATUS



## TF4: CURRENT METHODS UNDER DISCUSSION

### 27.01.22 0: ACEA-Method

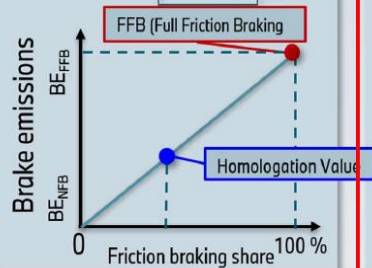
"simplified method"

Calculation of emissions based on regeneration share of power

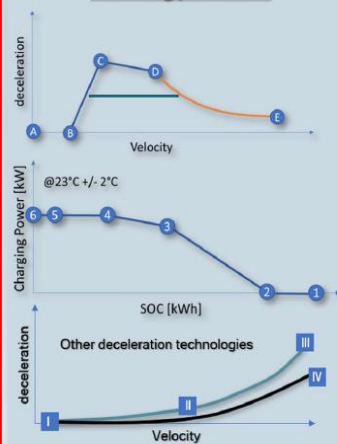
$$W_{total} = \int_0^{t_{test}} P_{total} dt$$

$$W_{regen} = \int_0^{t_{test}} P_{regen} dt$$

$$\text{regeneration share: } \text{Ratio} = \frac{W_{regen}}{W_{total}}$$

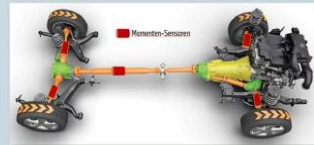


### 1: Energy Method



Homologation:  
 $f_0, f_1, f_2$   
 A, B, C, D, E  
 $SOC_1, SOC_2, SOC_3, \dots$   
 I, II, III, IV, ...

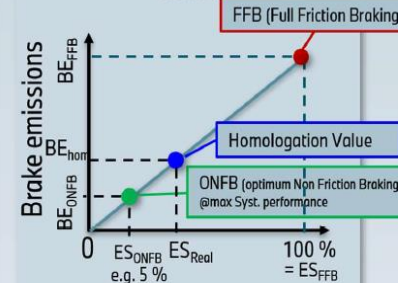
### 2: Torque Method



Homologation:  
 $f_0, f_1, f_2$   
 Momentum =  $f(t)$  @ 10 Hz @  
 WLTP Brake

### NEW 3: JRC Method

As of 07.04. 15:00  
 Interpolation & weighting factors



$$BE_{hom} := w_a * BE_{FFB} + (1 - w_a) * BE_{ONFB}$$

$$100\% * w_a + 5\% * w_b = ES_{Real}$$

with  $(w_a + w_b) = 1$

- ES: Energy Share
- $w_x$ : weighing factors
- $ES_{ONFB}$ : Energy Share of Friction Braking @ max Syst. performance
- X-axis: FFB / ONFB from simulation
- Y-axis: red & green: measured @ brake dyno
- $ES_{Hom}$ : Homologation value (calculated)

- ✓ Currently, there are two proposals that are being elaborated;
- ✓ There are still several elements required to finalize the proposal(s);
- ✓ We need first to reach an agreement at the TF4 level and then submit the proposal(s) to the PMP for the final decision;
- ✓ Still to be discussed if a short testing campaign including 2-3 labs will be feasible.

**Overall, it is not possible to have a method ready for incorporating regenerative braking to the protocol in the next couple of months. However, it is absolutely feasible to have it ready by the end of the year.**

# GTR ON BRAKE EMISSIONS – PROPOSAL (1/2)

***Submit the draft GTR for FULL-FRICTION brakes of LDVs as an informal document to the upcoming GRPE session – The document will need to be submitted with 1 month delay at the end of June.***

## Timeline

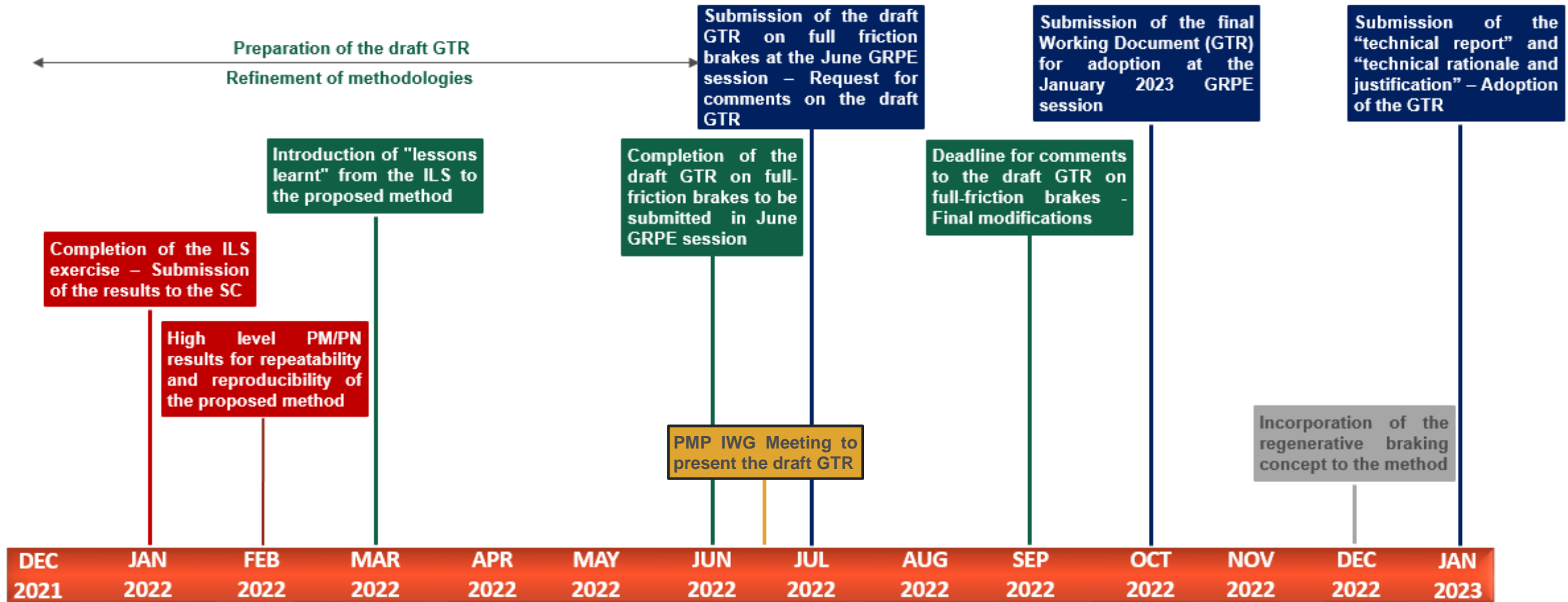
- ✓ 02 June 2022: Presentation of the status at the GRPE – Inform the GRPE that the informal document with the draft GTR on full-friction brakes will be submitted in the beginning of July;
- ✓ 15 June 2022: Presentation of the draft GTR to the PMP – Request for feedback and finalization of the draft GTR for full-friction brakes by the end of June;
- ✓ 01 July 2022: Submission of the draft GTR to the GRPE – Feedback and comments by beginning of September – Preparation of a consolidated version of the final GTR;
- ✓ Beginning of October 2022: Submission of the working document of the GTR for full-friction brakes;
- ✓ Mid-December: Preparation and submission of informal document amending the working document to include regenerative braking;
- ✓ January 2023 GRPE session: Adoption of the working document with the GTR on brake emissions.

# GTR ON BRAKE EMISSIONS – PROPOSAL (2/2)

## Why submit it now?

- ✓ The submission of the draft GTR now will give the chance to external entities and third parties to carefully examine the proposal and provide their feedback for further improvements without losing more time;
- ✓ The submission of the draft GTR will give the chance to the testing facilities to start programming and equipping their laboratories accordingly to meet the new demanding specifications;
- ✓ Substantial changes with respect to the previous protocol have been applied; therefore, the testing facilities will use this time to adopt to the changes and check the new requirements;
- ✓ Further delaying the submission of the draft GTR will not help improve the technical specifications or further reduce lab-to-lab variability since no testing facility actually carries out tests with the new specifications as we speak;
- ✓ Further delaying the submission of the draft GTR might induce a further delay to the finalization of the method to test regenerative braking since there will be no reference protocol to follow – Furthermore, the submission of the draft GTR for full friction brakes does not cause any negative impact to the development of the method for regenerative braking.

# ROADMAP TO THE GTR – UPDATED TIMELINE



# Thank you



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