# DECISIONS

## COMMISSION IMPLEMENTING DECISION (EU) 2020/1167

**of 6 August 2020**

**on the approval of the technology used in a 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter for use in conventional combustion engine and certain hybrid electric passenger cars and light commercial vehicles as an innovative technology pursuant to Regulation (EU) 2019/631 of the European Parliament and of the Council)**

**(Text with EEA relevance)**

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting $CO_2$ emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 ([1]), and in particular Article 11(4) thereof,

Whereas:

(1) On 10 October 2019, the supplier SEG Automotive Germany GmbH submitted a request ('the request') in accordance with Article 12a of the respective Commission Implementing Regulations (EU) No 725/2011 ([2]) and (EU) No 427/2014 ([3]) to amend Commission Implementing Decisions (EU) 2019/314 ([4]) and (EU) 2019/313 ([5]) with a view to taking into account the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) set out in Commission Regulation (EU) 2017/1151 ([6]).

(2) On 31 October 2019, the manufacturers Audi AG, Bayerische Motoren Werke AG, Daimler AG, FCA Italy S.p.A, Ford-Werke GmbH, Honda Motor Europe Ltd, Hyundai Motor Europe Technical Center GmbH, Jaguar Land Rover LTD, Renault, Toyota Motor Europe NV/SA, Volkswagen AG, Volkswagen Nutzfahrzeuge and the suppliers SEG Automotive Germany GmbH, Valeo Electrical systems and Mitsubishi Electric Corporation, submitted a joint application ('the application') for the approval as an innovative technology of the technology used in 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter for use in passenger cars and light commercial vehicles with conventional internal combustion powertrains (conventional ICE vehicles) and in certain not-off vehicle charging hybrid electric vehicles (NOVC-HEVs). The application refers to $CO_2$ emissions savings that cannot be demonstrated by measurements performed in accordance with the WLTP as set out in Regulation (EU) 2017/1151.

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([1]) OJ L 111, 25.4.2019, p. 13.

([2]) Commission Implementing Regulation (EU) No 725/2011 of 25 July 2011 establishing a procedure for the approval and certification of innovative technologies for reducing $CO_2$ emissions from passenger cars pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council (OJ L 194, 26.7.2011, p. 19).

([3]) Commission Implementing Regulation (EU) No 427/2014 of 25 April 2014 establishing a procedure for the approval and certification of innovative technologies for reducing $CO_2$ emissions from light commercial vehicles pursuant to Regulation (EU) No 510/2011 of the European Parliament and of the Council (OJ L 125, 26.4.2014, p. 57).

([4]) Commission Implementing Decision (EU) 2019/314 of 21 February 2019 on the approval of the technology used in SEG Automotive Germany GmbH High efficient 48V motor generator (BRM) plus 48V/12V DC/DC converter for use in conventional combustion engine and certain hybrid powered passenger cars as an innovative technology for reducing $CO_2$ emissions from passenger cars pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council (OJ L 51, 22.2.2019, p. 42).

([5]) Commission Implementing Decision (EU) 2019/313 of 21 February 2019 on the approval of the technology used in SEG Automotive Germany GmbH High efficient 48V motor generator (BRM) plus 48V/12V DC/DC converter for use in conventional combustion engine and certain hybrid powered light commercial vehicles as an innovative technology for reducing $CO_2$ emissions from light commercial vehicles pursuant to Regulation (EU) No 510/2011 of the European Parliament and of the Council (OJ L 51, 22.2.2019, p. 31).

([6]) Commission Regulation (EU) 2017/1151 of 1 June 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Commission Regulation (EC) No 692/2008 (OJ L 175, 7.7.2017, p. 1).

(3) The request and the application have been assessed in accordance with Article 11 of Regulation (EU) 2019/631, Implementing Regulations (EU) No 725/2011 and (EU) No 427/2014 and the Technical Guidelines for the preparation of applications for the approval of innovative technologies pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council ([7]) and (EU) No 510/2011 of the European Parliament and of the Council ([8]) (July 2018 version) ([9]). In accordance with Article 11(3) of Regulation (EU) 2019/631, the request and the application were accompanied by verification reports undertaken by independent and certified bodies.

(4) Considering that the request and the application refer to the same innovative technology and that the same conditions should apply for its use in the vehicle categories concerned, it is appropriate to address both the request and the application in one single decision.

(5) The 48 Volt motor-generator may operate as either an electric motor converting electrical energy into mechanical energy, or as a generator converting mechanical energy into electrical energy, i.e. as a standard alternator. The 48 Volt/12 Volt DC/DC converter enables the 48 Volt motor-generator to provide electric energy at the voltage required to power the 12 Volt electric power board of the vehicle and/or charging the 12 Volt battery.

(6) The technology used in the 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter supplied by SEG Automotive Germany GmbH has already been approved for use in conventional ICE powered and certain NOVC-HEV passenger cars by Implementing Decision (EU) 2019/314 as well as for use in conventional ICE powered and certain NOVC-HEV light commercial vehicles by Implementing Decision (EU) 2019/313, as an innovative technology capable of saving $CO_2$ emissions in a way that is only partially covered by the measurements performed as part of the emission test under the New European Driving Cycle (NEDC) set out in Commission Regulation (EC) No 692/2008 ([10]). The technology has also been approved as a generic innovative technology by reference to NEDC conditions by Commission Implementing Decision (EU) 2020/1102 ([11]).

(7) The request and the application refer, however, to the WLTP set out in Regulation (EU) 2017/1151. It has been demonstrated that the measurements performed as part of the emissions test under the WLTP only partially cover the $CO_2$ savings resulting from the technology used in 48 Volt efficient motor-generators combined with a 48 Volt/12 Volt DC/DC converter.

(8) Based on the experience gained from the assessment of the applications approved by Implementing Decisions (EU) 2019/313, (EU) 2019/314 and (EU) 2020/1102, and taking into account the information provided with the present request and application, it has been satisfactorily and conclusively demonstrated that the technology used in a 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter meets the criteria referred to in Article 11(2) of Regulation (EU) 2019/631 and the eligibility criteria specified in Article 9(1)(b) of Implementing Regulations (EU) No 725/2011 and (EU) No 427/2014.

(9) The innovative technology should be used in conventional ICE passenger cars or light commercial vehicles, or in NOVC-HEVs of those categories for which uncorrected measured fuel consumption and $CO_2$ emission values may be used in accordance with paragraph 1.1.4 of Appendix 2 to Sub-annex 8 to Annex XXI to Regulation (EU) 2017/1151.

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([7]) Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles (OJ L 140, 5.6.2009, p. 1).

([8]) Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light-duty vehicles (OJ L 145, 31.5.2011, p. 1).

([9]) https://circabc.europa.eu/sd/a/a19b42c8-8e87-4b24-a78b-9b70760f82a9/July%202018%20Technical%20Guidelines.pdf

([10]) Commission Regulation (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information (OJ L 199, 28.7.2008, p. 1).

([11]) Commission Implementing Decision (EU) 2020/1102 of 24 July 2020 on the approval of the technology used in a 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter for use in conventional combustion engine and certain hybrid electric passenger cars and light commercial vehicles as an innovative technology pursuant to Regulation (EU) 2019/631 of the European Parliament and of the Council and by reference to the New European Driving Cycle (NEDC) (OJ L 241, 27.7.2020, p. 38).

(10) Both the request and the application refer to the methodology for determining the $CO_2$ savings from the use of the 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter in passenger cars and light commercial vehicles set out in point 3 of the Annex to Implementing Decisions (EU) 2019/313 and (EU) 2019/314, i.e. the 'separate method'.

(11) The methodology proposed in the application differs, however, from the 'separate method' with regard to the voltage level to be used for the efficiency measurement of the 48 Volt motor-generator, which is proposed to be set to 48 Volt, instead of 52 Volt. In addition the output current for the efficiency measurement of the 48 Volt/12 Volt DC/DC converter is proposed to be set as half the nominal power of the DC/DC converter divided by 14,3 Volt, instead of the nominal power of the DC/DC converter divided by 14,3 Volt. Moreover, in the application it is proposed to introduce a run-in procedure for the 48 Volt motor-generator.

(12) With regard to the changes proposed to the 'separate method' set out in Implementing Decisions (EU) 2019/313 and (EU) 2019/314 regarding the voltage level of the efficiency measurement of the 48 Volt motor-generator and the output current of the efficiency measurement of the 48 Volt/12 Volt DC/DC converter, it is found that those changes may lead to less conservative results in terms of $CO_2$ savings. The applicants have claimed that the changes are justified as they would be more representative of real world driving conditions. The evidence provided in support of that claim can, however, not be considered sufficient, in particular due to the limited studies performed in support of the application and the absence of evidence supporting the change of the output current for the efficiency measurement of the 48 Volt/12 Volt DC/DC converter. Against that background, it is considered that these aspects of the 'separate method' set out in point 3 of the Annex to the respective Implementing Decisions (EU) 2019/313 and (EU) 2019/314 should not be changed based on the information provided in the applications.

(13) With regard to the proposed addition to the testing methodology of a run-in procedure for the 48 Volt motor-generator, the application does not set out with sufficient precision the details for how such run-in should be performed nor how the run-in effect should be taken into account. As the efficiency of the 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt converter is determined on the basis of the average of the measurement results, any run-in effects, positive or negative, may be adequately taken into account in the final efficiency determination, where necessary by increasing the number of measurements. Against that background, it is not appropriate to complement the testing methodology with an additional specific run-in procedure such as that proposed in the application.

(14) It is proposed in the request to modify the average speed from the one of the NEDC (33,58 km/h) to the one of the WLTP (46,6 km/h). As the conditions of the WLTP should be taken into account, the average speed should be set accordingly.

(15) It follows implicitly from the 'separate method' that the input voltage for testing the efficiency of the 48 Volt/12 Volt DC/DC converter should be the same as the output voltage of the 48 Volt motor-generator, i.e. 52 Volt. In order to ensure that the efficiency tests are performed in a harmonised way, it is appropriate to clarify in the testing methodology that the value of the input voltage should be set to 52 Volt.

(16) Manufacturers should have the possibility to apply to a type-approval authority for the certification of $CO_2$ savings from the use of the innovative technology where the conditions laid down in this Decision are met. Manufacturers should for that purpose ensure that the application for certification is accompanied by a verification report from an independent and certified body confirming that the innovative technology complies with the conditions laid down in this Decision and that the savings have been determined in accordance with the testing methodology referred to in this Decision.

(17) In order to facilitate a wider deployment of the innovative technology in new vehicles, a manufacturer should also have the possibility to submit a single application for the certification of the $CO_2$ savings from several 48 Volt efficient motor generators combined with a 48 Volt/12 Volt DC/DC converter. It is, however, appropriate to ensure that, where that possibility is used, a mechanism is applied that incentivises the deployment of only those innovative technologies that offer the highest $CO_2$ savings.

(18) It is the responsibility of the type-approval authority to verify thoroughly that the conditions for certifying the $CO_2$ savings from the use of an innovative technology as specified in this Decision are met. Where the certification is issued, the responsible type-approval authority should ensure that all elements considered for the certification are recorded in a test report and kept together with the verification report and that this information is made available to the Commission on request.

(19) For the purpose of determining the general eco-innovation code to be used in the relevant type-approval documents in accordance with Annexes I, VIII and IX to Directive 2007/46/EC of the European Parliament and of the Council ([12]), it is necessary to attribute an individual code to the innovative technology.

(20) From 2021, manufacturers' compliance with their specific $CO_2$ emissions targets is to be established on the basis of $CO_2$ emissions determined in accordance with the WLTP. $CO_2$ savings from the innovative technology certified by reference to this Decision may therefore be taken into account for the calculation of manufacturers average specific $CO_2$ emissions from the calendar year 2021 onwards,

HAS ADOPTED THIS DECISION:

*Article 1*

**Innovative technology**

The technology used in a 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter is approved as an innovative technology within the meaning of Article 11 of Regulation (EU) 2019/631 taking into account that the $CO_2$ savings it delivers are only partially covered by the standard test procedure set out in Regulation (EU) 2017/1151, and provided that the technology conforms to the following:

(a) it is fitted in passenger cars ($M_1$) or light commercial vehicles ($N_1$) powered by internal combustion engines running on petrol or diesel (conventional ICE powered $M_1$ and $N_1$ vehicles) or in not-off-vehicle charging hybrid electric vehicles of category $M_1$ or $N_1$ for which uncorrected measured fuel consumption and $CO_2$ emission values may be used in accordance with paragraph 1.1.4 of Appendix 2, Sub-annex 8 to Annex XXI to Regulation (EU) 2017/1151;

(b) its efficiency, which is the product of the efficiency of the 48 Volt motor-generator and the efficiency of the 48 Volt/12 Volt DC/DC converter, determined in accordance with point 2.3 of the Annex, is at least

  (i) 73,8 % for petrol-fuelled vehicles other than turbo-charged;

  (ii) 73,4 % for turbo-charged petrol-fuelled vehicles;

  (iii) 74,2 % for diesel-fuelled vehicles.

*Article 2*

**Application for certification of $CO_2$ savings**

1. A manufacturer may apply to a type-approval authority for certification of the $CO_2$ savings from the use of the technology approved in accordance with Article 1 ('the innovative technology') by reference to this Decision.

2. The manufacturer shall ensure that the application for the certification is accompanied by a verification report from an independent and certified body confirming that the technology conforms to points (a) and (b) of Article 1.

3. Where $CO_2$ savings have been certified in accordance with Article 3, the manufacturer shall ensure that the certified $CO_2$ savings and the eco-innovation code referred to in Article 4(1) are recorded in the certificate of conformity of the vehicles concerned.

*Article 3*

**Certification of $CO_2$ savings**

1. The type-approval authority shall ensure that $CO_2$ savings achieved from the use of the innovative technology have been determined using the methodology set out in the Annex.

2. Where a manufacturer applies for the certification of the $CO_2$ savings for more than one type of 48 Volt motor-generator combined with a 48 Volt/12 Volt DC/DC converter in relation to one vehicle version, the type-approval authority shall determine which of the 48 Volt motor-generators combined with a 48 Volt/12 Volt DC/DC converter tested delivers the lowest $CO_2$ savings. That value shall be used for the purpose of paragraph 4.

([12]) Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive) (OJ L 263, 9.10.2007, p. 1).

3. The type approval authority shall record the certified $CO_2$ savings calculated in accordance with point 4 of the Annex, and the eco-innovation code referred to in Article 4(1) in the relevant type-approval documentation.

4. The type-approval authority shall record all the elements considered for the certification in a test report and keep that together with the verification report referred to in Article 2(2), and shall make that information available to the Commission on request.

5. The type-approval authority shall only certify $CO_2$ savings from the use of the innovative technology if it finds that the technology conforms with points (a) and (b) of Article 1, and if the $CO_2$ savings determined in accordance with point 3.5 of the Annex are 0,5 g $CO_2$/km or higher, as specified in Article 9(1)(b) of Implementing Regulation (EU) No 725/2011 in the case of passenger cars, or in Article 9(1)(b) of Implementing Regulation (EU) No 427/2014 in the case of light commercial vehicles.

*Article 4*

**Eco-innovation code**

1. The innovative technology approved by this Decision is attributed with the eco-innovation code 32.

2. The certified $CO_2$ savings recorded by reference to that eco-innovation code may be taken into account for the calculation of the average specific emissions of manufacturers starting from the calendar year 2021.

*Article 5*

**Entry into force**

This Decision shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Union*.

Done at Brussels, 6 August 2020.

*For the Commission*
*The President*
Ursula VON DER LEYEN

*ANNEX*

## Methodology to determine the $CO_2$ savings of the technology used in a 48 Volt efficient motor-generator combined with a 48 Volt/12 Volt DC/DC converter for conventional combustion engine and certain hybrid electric passenger cars and light commercial vehicles

1. INTRODUCTION

This Annex sets out the methodology to determine the $CO_2$ (carbon dioxide) emission savings from the use of a 48 Volt efficient motor-generator ('48V motor-generator'), combined with a 48 Volt/12 Volt DC/DC converter '48V/12V DC/DC converter'), in an $M_1$ or $N_1$ vehicle as specified in Article 1(a)).

2. DETERMINATION OF THE EFFICIENCIES

The efficiency of the 48V motor-generator and the 48V/12V DC/DC converter is to be determined separately as specified in points 2.1 and 2.2. The resulting values are to be used as input for the calculation of the total efficiency of the 48V motor-generator combined with the 48V/12V DC/DC converter in accordance with point 2.3.

### 2.1. 48V motor-generator efficiency

The efficiency of the 48V motor-generator shall be determined in accordance with ISO 8854:2012, with the following precisions.

The manufacturer shall provide evidence to the type-approval authority that the frequency ranges of the 48V motor-generator are the same as or equivalent to those set out in Table 1.

The efficiency of the 48V motor-generator shall be determined on the basis of measurements at each of the operating points listed in Table 1.

The current intensity of the 48V motor-generator at each operating point shall be half the rated current. For each operating point, the voltage and the output current of the 48V motor-generator shall be kept constant during the measurement, with the voltage at 52V.

*Table 1*

| Operating point i | Holding time [s] | Rotational frequency $n_i$ $[min^{-1}]$ | Frequency of operating points $h_i$ |
|---|---|---|---|
| 1 | 1 200 | 1 800 | 0,25 |
| 2 | 1 200 | 3 000 | 0,40 |
| 3 | 600 | 6 000 | 0,25 |
| 4 | 300 | 10 000 | 0,10 |

The efficiency of the 48V motor-generator at each operating point i ($\eta_{MG_i}$) [%] shall be calculated in accordance with Formula 1.

*Formula 1*

$$\eta_{MG_i} = \frac{60 \cdot U_i \cdot I_i}{2\pi \cdot M_i \cdot n_i} \cdot 100$$

where, for each operating point i,

$U_i$ is the voltage [V];

$I_i$ is the current intensity [A];

$M_i$ is the torque [Nm];

$n_i$ is the rotational frequency [$min^{-1}$].

For each operating point, the measurements are to be performed at least five times consecutively and the efficiency shall be calculated for each of those measurements ($\eta_{MG_{ij}}$) with j being the index referring to one set of measurements.

For each operating point, the average of those efficiencies ($\overline{\eta_{MG_i}}$) shall be calculated.

The efficiency of the 48V motor-generator ($\eta_{MG}$) [%] shall be calculated in accordance with Formula 2.

*Formula 2*

$$\eta_{MG} = \sum_{i=1}^{4} h_i \cdot \overline{\eta_{MG_i}}$$

where

$\overline{\eta_{MG_i}}$ is the mean efficiency of the 48V motor-generator determined for operating point i [%]

$h_i$ is the frequency of operating point i, as set out in Table 1.

2.2. **48V/12V DC/DC converter efficiency**

The efficiency of the 48V/12V DC/DC converter shall be determined under the following conditions:

— Input voltage of 52 V

— Output voltage of 14,3 V

— Output current: nominal power of the 48V/12V DC/DC converter divided by the output voltage of 14,3 V

The nominal power of the 48V/12V DC/DC converter shall be the continuous output power certified by the supplier in accordance with the requirements specified in ISO 8854:2012.

The efficiency of the 48V/12V DC/DC converter ($\eta_{DC/DC}$) [%] shall be calculated from the current and voltage intensity measurements according to Formula 3.

*Formula 3*

$$\eta_{DC/DC} = \frac{U_{12V} \cdot I_{12V}}{U_{48V} \cdot I_{48V}}$$

where

$U_{48V}$ is the input voltage, which shall be set to 52 [V]

$I_{48V}$ is the current intensity measured on the input side [A]

$U_{12V}$ is the output voltage, which shall be set to 14,3 [V]

$I_{12V}$ is the current intensity measured on the output side, which should be equal to the nominal power of the 48V/12V DC/DC converter divided by the output voltage [A]

The measurements and efficiency calculations shall be repeated at least five (5) times consecutively.

The average of those efficiencies shall then be the efficiency of the 48V/12V DC/DC converter ($\overline{\eta_{DC/DC}}$) [%].

2.3. **Combined efficiency**

The efficiency of the 48V motor generator combined with the 48V/12V DC/DC converter ($\eta_{TOT}$) [%] is calculated in accordance with Formula 4.

*Formula 4*

$$\eta_{TOT} = \eta_{MG} \cdot \overline{\eta_{DC/DC}}$$

$\eta_{MG}$ : is the efficiency of the 48V motor-generator, as determined in point 2.1 [%]

$\overline{\eta_{DC/DC}}$ is the efficiency of the 48V/12V DC/DC converter, as determined in point 2.2 [%]

3. CALCULATION OF THE $CO_2$ SAVINGS

3.1. **Saved mechanical power**

The difference $(\Delta P_m)$ [W] between the saved mechanical power when using the 48V motor generator combined with the 48V/12V DC/DC converter under real-world conditions $(\Delta P_{mRW})$ and the saved mechanical power when using the 48V motor generator combined with the 48V/12V DC/DC converter under type-approval conditions $(\Delta P_{mTA})$ shall be calculated in accordance with Formula 5.

*Formula 5*

$$\Delta P_m = \Delta P_{mRW} - \Delta P_{mTA}$$

where

$\Delta P_{mRW}$ shall be calculated in accordance with Formula 6 and $\Delta P_{mTA}$ in accordance with Formula 7.

*Formula 6*

$$\Delta P_{mRW} = \frac{P_{RW}}{\eta_B} - \frac{P_{RW}}{\eta_{TOT}}$$

*Formula 7*

$$\Delta P_{mTA} = \frac{P_{TA}}{\eta_B} - \frac{P_{TA}}{\eta_{TOT}}$$

where,

$\eta_{TOT}$ is the efficiency of the 48V motor-generator combined with the 48V/12V DC/DC converter, as determined in point 2.3 [%]

$P_{RW}$ is the power requirement under 'real-world' conditions, which is 750 W

$P_{TA}$ is the power requirement under 'type-approval' conditions, which is 350 W

$\eta_B$ is the efficiency of the baseline alternator, which is 67 %

3.2. **Calculation of the $CO_2$ savings**

The $CO_2$ savings of the 48V motor-generator combined with the 48V/12V DC/DC converter $(C_{CO_2})$ $[g\ CO_2/km]$ shall be calculated in accordance with Formula 8.

*Formula 8*

$$C_{CO_2} = \Delta P_m \cdot \frac{V_{Pe} \cdot CF}{v}$$

where,

$\Delta P_m$ is the difference between the saved mechanical power under real-world conditions and the saved mechanical power under type-approval conditions, as determined in point 3.1

$v$ is the mean driving speed of the WLTP, which is 46,6 km/h

$V_{Pe}$ is the consumption of effective power as specified in Table 2 [l/kWh]

CF is the conversion factor as set out in Table 3 $[gCO_2/l]$

*Table 2*

| Type of engine | Consumption of effective power ($V_{Pe}$) [l/kWh] |
|---|---|
| Petrol-fuelled other than turbo-charged | 0,264 |
| Turbo-charged petrol-fuelled | 0,280 |
| Diesel-fuelled | 0,220 |

*Table 3*

| Type of fuel | Conversion factor (CF) [$gCO_2/l$] |
|---|---|
| Petrol | 2 330 |
| Diesel | 2 640 |

3.3. **Calculation of the uncertainty of the $CO_2$ savings**

The uncertainty of the $CO_2$ savings calculated in accordance with point 3.2 shall be quantified.

For this, the following calculations are needed.

First, the standard deviation of the efficiency of the 48V motor-generator at each operating point ($s_{\overline{\eta_{MG_i}}}$) [%] shall be calculated in accordance with Formula 9.

*Formula 9*

$$s_{\overline{\eta_{MG_i}}} = \sqrt{\frac{\sum_{j=1}^{m}\left(\eta_{MG_{ij}} - \overline{\eta_{MG_i}}\right)^2}{m(m-1)}}$$

where

$m$ is the number of measurements j undertaken at each operating point i for the 48V motor-generator efficiency, as referred to in point 2.1

$\eta_{MG_{ij}}$ is the efficiency of the 48V motor-generator calculated for an individual measurement j at operating point i as referred to in point 2.1 [%]

$\overline{\eta_{MG_i}}$ is the average efficiency of the 48V motor-generator calculated for an operating point i, as determined in point 2.1 [%]

Next, the standard deviation of the efficiency of the 48V motor-generator ($s_{\eta_{MG}}$) [%] shall be calculated in accordance with Formula 10.

*Formula 10*

$$s_{\eta_{MG}} = \sqrt{\sum_{i=1}^{4}(h_i \cdot s_{\overline{\eta_{MG_i}}})^2}$$

where

$s_{\overline{\eta MG_i}}$ is as determined by Formula 9 [%]

$h_i$ is the frequency of operating point i, as set out in Table 1.

Then, the standard deviation of the efficiency of the 48V/12V DC/DC converter $(s_{\overline{\eta DC/DC}})$ [%] shall be calculated in accordance with Formula 11.

*Formula 11*

$$s_{\overline{\eta DC/DC}} = \sqrt{\frac{\sum_{l=1}^{L}\left(\eta_{DC/DC_l} - \overline{\eta_{DC/DC}}\right)^2}{L(L-1)}}$$

where

L is the number of measurements l undertaken for the 48V/12V DC/DC converter, as referred to in point 2.2

$\eta_{DC/DC_l}$ is the efficiency of the 48V/12V DC/DC converter calculated for an individual measurement l as referred to in point 2.2 [%]

$\overline{\eta_{DC/DC}}$ is the efficiency of the 48V/12V DC/DC converter, as determined in point 2.2 [%]

Finally, the uncertainty in the $CO_2$ savings $(s_{C_{CO_2}})$ $[g\ CO_2/km]$ of the 48V motor-generator combined with the 48V/12V DC/DC converter shall be calculated in accordance with Formula 12 and shall not exceed 30 % of the $CO_2$ savings.

*Formula 12*

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{\eta_{TOT}} \cdot \frac{V_{Pe} \cdot CF}{v} \cdot \sqrt{\left(\frac{s_{\eta MG}}{\eta_{MG}}\right)^2 + \left(\frac{s_{\overline{\eta DC/DC}}}{\overline{\eta_{DC/DC}}}\right)^2}$$

where

$P_{RW}$ is the power requirement under 'real-world' conditions, which is 750 W

$P_{TA}$ is the power requirement under type-approval conditions, which is 350 W

$\eta_{TOT}$ is the total efficiency of the 48V motor-generator combined with the 48V/12V DC/DC converter as determined in point 2.3 [%]

$V_{Pe}$ is the consumption of effective power as specified in Table 2 [l/kWh]

$CF$ is the fuel conversion factor as specified in Table 3 $[gCO_2/l]$

$v$ is the mean driving speed of the WLTP, which is 46,6 km/h

$s_{\eta MG}$ is standard deviation of the efficiency of the 48V motor-generator as determined in accordance with Formula 10 [%]

$\eta_{MG}$ is the efficiency of the 48V motor-generator, as determined in point 2.1 [%]

$s_{\overline{\eta DC/DC}}$ is the standard deviation of the efficiency of the 48V/12V DC/DC converter, as determined in accordance with Formula 11 [%]

$\overline{\eta_{DC/DC}}$ is the efficiency of the 48V/12V DC/DC converter as determined in point 2.2 [%]

3.4. **Rounding**

The $CO_2$ savings $(C_{CO_2})$ calculated in accordance with point 3.2 and the uncertainty of the $CO_2$ savings $(s_{C_{CO_2}})$ calculated in accordance with point 3.3 shall be rounded to a maximum of two decimal places.

Each value used in the calculation of the $CO_2$ savings can be applied unrounded or must be rounded to the minimum number of decimal places which allows the maximum total impact (i.e. combined impact of all rounded values) on the savings to be lower than 0,25 $gCO_2/km$.

3.5. **Check against the minimum $CO_2$ savings threshold**

The type-approval authority shall ensure for each vehicle version fitted with the 48V motor-generator combined with the 48V/12V DC/DC converter that the minimum threshold criterion as specified in Article 9(1)(b) of Implementing Regulation (EU) No 725/2011 and Implementing Regulation (EU) No 427/2014 is met.

When verifying whether the minimum threshold criterion is met, the type-approval authority shall take into account, in accordance with Formula 13, the $CO_2$ savings determined in point 3.2, the uncertainty determined in point 3.3 and, where applicable, a $CO_2$ correction, in the case of a positive mass difference (Δm) between the 48V motor-generator combined with the 48V/12V DC/DC converter and the baseline alternator.

For the purpose of the positive mass correction, the mass of the baseline alternator shall be set to 7 kg.

The manufacturer shall provide to the type approval authority information on the mass of the 48V motor-generator combined with the 48V/12V DC/DC converter as certified by the supplier.

*Formula 13*

$$\left(C_{CO_2} - s_{C_{CO_2}} - \Delta CO_{2_m}\right) \geq MT$$

where,

MT is 0,5 g $CO_2/km$ as specified in Article 9(1)(b) of Implementing Regulation (EU) No 725/2011 and Commission Implementing Regulation (EU) No 427/2014

$C_{CO_2}$ is the $CO_2$ savings as determined in point 3.2 $[g\ CO_2/km]$

$s_{C_{CO_2}}$ uncertainty of the total $CO_2$ savings as determined in point 3.3 $[g\ CO_2/km]$

$\Delta CO_{2_m}$ $CO_2$ correction, in the case of a positive mass difference (Δm) [kg] between the 48V motor-generator combined with the 48V/12V DC/DC converter and the baseline alternator, calculated in accordance with Table 4: $[g\ CO_2/km]$

*Table 4*

| Type of fuel | $CO_2$ correction $(\Delta CO_{2_m})$ $[gCO_2/(km)]$ |
|---|---|
| Petrol | 0,0277 Δm |
| Diesel | 0,0383 Δm |

4. CERTIFICATION OF $CO_2$ SAVINGS

The $CO_2$ savings to be certified by the type-approval authority in accordance with Article 11 of Implementing Regulations (EU) No 725/2011 or (EU) No 427/2014 $(CS_{CO_2})$ are those calculated in accordance with Formula 14. The $CO_2$ savings shall be recorded in the type approval certificate for each vehicle version fitted with the 48V motor-generator combined with the 48V/12V DC/DC converter.

*Formula 14*

$$CS_{CO_2} = \left(C_{CO_2} - s_{C_{CO_2}}\right)$$

where,

| | |
|---|---|
| $C_{CO_2}$ | is the $CO_2$ savings as determined in accordance with Formula 8 under point 3.2 $[g\ CO_2/km]$ |
| $s_{C_{CO_2}}$ | is the uncertainty in the $CO_2$ savings of the 48V motor-generator combined with the 48V/12V DC/DC converter calculated in accordance with Formula 12 under point 3.3 $[g\ CO_2/km$ |