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 CO2 emissions from passenger cars pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council (Text with EEA relevance)

ANNEX

Methodology to determine the CO_2 savings of the SEG Automotive Germany GmbH High efficient 48V motor generator (BRM) plus the 48V/12V DC/DC converter fitted in vehicles in compliance with the conditions set out in Article 1

1. INTRODUCTION

In order to determine the CO_2 emission reductions that can be attributed to the use of the generation function of the SEG Automotive Germany GmbH High efficient 48V motor generator (BRM), hereinafter referred to as 48 V motor generator or motor generator, plus the 48V/12V DC/DC converter, for use in vehicles in compliance with the conditions set out in Article 1, it is necessary to specify the following:

(1) The test conditions;

(2) The test equipment;

(3) The procedure to determine the total efficiency;

(4) The procedure to determine the CO_2 savings;

(5) The procedure to determine the uncertainty of the CO_2 savings.

Two alternative methods can be used to determine the CO_2 savings. The methods are described as follows.

2. SYMBOLS, PARAMETERS AND UNITS

Latin symbols

C_{CO_2}	— CO_2 savings [g CO_2/km]
CO_2	— Carbon dioxide
CF	— Conversion factor (l/100 km) - (g CO_2/km) [gCO_2/l] as defined in Table 3
h	— Frequency as defined in Table 1
i	— Number of operating points
I	— Current intensity at which the measurement shall be carried out [A]
l	— Number of measurement of the sample for the 48V/12V DC/DC converter
m	— Number of measurement of the sample for the 48V motor generator
M	— Torque [Nm]
n	— Rotational frequency [min^{-1}] as defined in Table 1
P	— Power [W]
$s_{\bar{\eta}_{DCDC}}$	— Standard deviation of the 48V/12V DC/DC converter efficiency mean [%]
$s_{\eta_{MG}}$	— Standard deviation of the 48V motor generator efficiency [%]
$s_{\bar{\eta}_{MG}}$	— Standard deviation of the 48V motor generator efficiency mean [%]
$s_{\eta_{TOT}}$	— Standard deviation of the total efficiency [%]
$s_{C_{CO_2}}$	— Standard deviation of the total CO_2 savings [g CO_2/km]
U	— Test voltage at which the measurement shall be carried out [V]
v	— Mean driving speed of the New European Driving Cycle (NEDC) [km/h]
V_{Pe}	— Consumption of effective power [l/kWh] as defined in Table 2

Greek symbols

Δ	— Difference

η_B	—	Baseline alternator efficiency [%]
η_{DCDC}	—	48V/12V DC/DC converter efficiency [%]
$\bar{\eta}_{DC/DC}$	—	Mean of the 48V/12V DC/DC converter efficiency [%]
η_{MG}	—	48V motor generator efficiency [%]
$\bar{\eta}_{MG_i}$	—	Mean of the 48V motor generator efficiency at operating point i [%]
η_{TOT}	—	Total efficiency [%]

Subscripts

Index (i) refers to operating point

Index (j) refers to measurement of the sample

MG	—	Motor generator
m	—	Mechanical
RW	—	Real-world conditions
TA	—	Type approval (NEDC) conditions
B	—	Baseline

3. METHOD 1 (‘SEPARATE METHOD’)

3.1. **Efficiency of the 48V motor generator**

The efficiency of the 48V motor generator shall be determined in accordance with ISO 8854:2012, with the exception of the elements specified in this section.

Evidence shall be provided to the type approval authority that the rotational frequency ranges of the efficient 48V motor generator are consistent with those set out in Table 1. The measurements shall be conducted at different operating points, as set out in Table 1. The efficient 48V motor generator current intensity shall be defined as half of the rated current for all operating points. For each rotational frequency, the voltage and the output current of the motor generator shall be kept constant, the voltage at 52V.

TABLE 1

Operating points

Operating pointi	**Holding time[s]**	**Rotational frequencyn_i [min^{-1}]**	**Frequencyh_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 at each operating point shall be calculated in accordance with Formula 1:

Formula 1

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

All efficiency measurements are to be performed consecutively at least five (5) times. The average of the measurements at each operating point (

$\bar{\eta}_{MG_i}$

) shall be calculated.

The efficiency of the generation function (η_{MG}) shall be calculated in accordance with the following Formula 2:

Formula 2

$$\eta_{MG} = \sum_{i=1}^{4} h_i \times \bar{\eta_{MG_i}}$$

3.2. **Efficiency of the 48V/12V DC/DC converter**

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

— Output voltage of 14,3V

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

The nominal power of the 48V/12V DC/DC converter shall be the continuous output power at the 12V side guaranteed by the manufacturer of the DC/DC converter at the conditions specified in the ISO 8854:2012.

The efficiency of the 48V/12V DC/DC converter shall be measured at least five (5) times consecutively. The average of all the measurements (

$\bar{\eta_{DC/DC}}$

) shall be calculated and used for the calculations laid down in paragraph 3.3.

3.3. **Total efficiency and saved mechanical power**

The total efficiency of the 48 V motor generator plus the 48V/12V DC/DC converter shall be calculated using Formula 3:

Formula 3

$$\eta_{TOT} = \eta_{MG} \times \bar{\eta_{DC/DC}}$$

The 48 V motor generator plus the 48V/12V DC/DC converter generation function lead to saved mechanical power under real-world conditions (ΔP_{mRW}) and type approval NEDC conditions (ΔP_{mTA}) as set out in Formula 4.

Formula 4

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

Where the saved mechanical power under real-world conditions (ΔP_{mRW}) shall be calculated in accordance with Formula 5 and the saved mechanical power under type-approval NEDC conditions (ΔP_{mTA}) in accordance with Formula 6:

Formula 5

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

Formula 6

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

where

P_{RW}	:	Power requirement under 'real-world' conditions [W], which is estimated at 750W
P_{TA}	:	Power requirement under NEDC type-approval conditions [W], which is estimated at 350W
η_B	:	Efficiency of the baseline alternator [%], which is 67 %

3.4. **Calculation of the CO_2 savings**

The CO_2 savings of the 48 V motor generator plus the 48V/12V DC/DC converter shall be calculated in accordance with Formula 7:

Formula 7

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

Where:

v	:	Mean driving speed of the NEDC [km/h], which is 33,58 km/h
V_{Pe}	:	Consumption of effective power specified in Table 2:

TABLE 2

Consumption of effective power

Type of engine	**Consumption of effective power (V_{Pe})[l/kWh]**
Petrol	0,264
Petrol Turbo	0,280
Diesel	0,220

CF	:	Conversion factor (l/100 km) - (g CO_2/km) [gCO_2/l] as defined in Table 3

TABLE 3

Fuel conversion factor

Type of fuel	**Conversion factor (l/100 km) - (g CO_2/km) (CF)[gCO_2/l]**
Petrol	2 330
Diesel	2 640

3.5. **Calculation of the statistical margin**

The statistical margin of the results of the testing methodology caused by the measurements shall be quantified. For each operating point the standard deviation shall be calculated in accordance with Formula 8:

Formula 8

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

The standard deviation of the efficiency value of the efficient 48V motor generator (
$s_{\eta_{MG}}$
) shall be calculated in accordance with Formula 9:

Formula 9

$$s_{\eta_{MG}} = \sqrt{\sum_{i=1}^{4} \left(h_i \times s\eta \bar{MG} i\right)^2}$$

The standard deviation of the efficiency value of the 48V/12V DC/DC converter (
$s\eta \bar{DC} / DC$
) shall be calculated in accordance with Formula 10:

Formula 10

$$s\eta \bar{DC} / DC = \sqrt{\frac{\sum_{1}^{j=1} \left(\eta_{DC/DC_{ij}} - \eta_{\bar{DC}/DC_i} \right)^2}{l(l-1)}}$$

The standard deviation of the motor generator efficiency (
$s_{\eta_{MG}}$
) and of the 48V/12V DC/DC converter (
$s_{\eta_{\bar{DC}/DC}}$
) lead to an uncertainty in the CO_2 savings (
$s_{C_{CO_2}}$
). That uncertainty is calculated in accordance with Formula 11:

Formula 11

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

4. METHOD 2 ('COMBINED METHOD')

4.1. **Efficiency of the 48V motor generator plus the 48V/12V DC/DC converter**

The efficiency of the 48V motor generator plus the 48V/12V DC/DC converter shall be determined in accordance with ISO 8854:2012, with the exception of the elements specified in this section.

Evidence shall be provided to the type approval authority that the speed ranges of the efficient 48V motor generator are consistent with those set out in Table 1.

The measurements shall be conducted at different operating points, as set out in Table 1. The efficient 48V motor generator plus the 48V/12V DC/DC converter current intensity shall be defined as half of the rated current of the 48V/12V DC/DC converter for all operating points.

The rated current of the 48V/12V DC/DC converter is defined as the output nominal power of the 48V/12V DC/DC converter divided by 14,3V. The nominal power of the 48V/12V DC/DC converter shall be the continuous output power at the 12V side guaranteed by the manufacturer of the DC/DC converter at the conditions specified in the ISO 8854:2012.

For each speed the voltage and the output current of the motor generator shall be kept constant, the voltage at 52 V.

The efficiency at each operating point shall be calculated in accordance with Formula 12:

Formula 12

$$\eta_{TOT_i} = \frac{60 \times U_i \times I_i}{2\pi \times M_i \times n_i} \times 100$$

All efficiency measurements are to be performed consecutively at least five (5) times. The average of the measurements at each operating point (
$\bar{\eta}_{TOT_i}$
) shall be calculated.

The efficiency of the generation function (η_{TOT}) shall be calculated in accordance with Formula 13:

Formula 13

$$\eta_{TOT} = \sum_{i=1}^{4} h_i \times \bar{\eta}_{TOT_i}$$

The measurement set up has to allow the measurement of the 48V motor generation efficiency alone.

4.2. **Demonstration of conservativeness of the 48V motor generator plus 48V/12V DC/DC converter efficiency determination**

In order to use the procedure specified in 4.1 for the determination of η_{TOT}, it has to be demonstrated that the efficiency of the 48V motor generator alone obtained with the conditions specified in 4.1 is lower than the efficiency obtained with the conditions specified in 3.1.

4.3. **Saved mechanical power**

The 48 V motor generator plus the 48V/12V DC/DC converter generation function lead to saved mechanical power under real-world conditions (ΔP_{mRW}) and type approval conditions (ΔP_{mTA}) as set out in Formula 14.

Formula 14

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

Where the saved mechanical power under real-world conditions (ΔP_{mRW}) shall be calculated in accordance with Formula 15 and the saved mechanical power under type-approval conditions (ΔP_{mTA}) in accordance with Formula 16:

Formula 15

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

Formula 16

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

where

P_{RW}	:	Power requirement under 'real-world' conditions [W], which is estimated at 750W
P_{TA}	:	Power requirement under type-approval NEDC conditions [W], which is estimated at 350W
η_B	:	Efficiency of the baseline alternator [%], which is 67 %

4.4. **Calculation of the CO_2 savings**

The CO_2 savings of the 48 V motor generator plus the 48V/12V DC/DC converter shall be calculated in accordance with Formula 17:

Formula 17

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

Where:

v	:	Mean driving speed of the NEDC [km/h], which is 33,58 km/h
V_{Pe}	:	Consumption of effective power specified in Table 2
CF	:	Conversion factor (l/100 km) - (g CO_2/km) [gCO_2/l] as defined in Table 3

4.5. **Calculation of the statistical margin**

The statistical margin of the results of the testing methodology caused by the measurements shall be quantified. For each operating point the standard deviation shall be calculated in accordance with Formula 18:

Formula 18

$$s_{\bar{\eta_{TOT_i}}} = \frac{s_{\eta_{TOT_i}}}{\sqrt{m}} = \sqrt{\frac{\sum_{m}^{j=1}\left(\eta_{TOT_{i_j}} - \bar{\eta_{TOT_i}}\right)^2}{m(m-1)}}$$

The standard deviation of the efficiency value of the efficient 48V motor generator plus the 48V/12V DC/DC converter (
$s_{\eta_{TOT}}$
) shall be calculated in accordance with Formula 19:

Formula 19

$$s_{\eta_{TOT}} = \sqrt{\sum_{i=1}^{4}\left(h_i \times s\eta \bar{\mathrm{TOT}}\, i\right)^2}$$

The standard deviation of the motor generator and of the 48V/12V DC/DC converter efficiency leads to an uncertainty in the CO_2 savings (
$s_{C_{CO_2}}$
). That uncertainty is calculated in accordance with Formula 20:

Formula 20

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{\eta_{TOT}^{2}} \times \frac{V_{Pe} \times CF}{v} \times s_{\eta_{TOT}}$$

5. ROUNDING

The calculated CO_2 savings value (
C_{CO_2}
) and the statistical margin of the CO_2 saving (
$s_{C_{CO_2}}$
) must 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.

6. STATISTICAL SIGNIFICANCE (for both methods)

It shall be demonstrated for each type, variant and version of a vehicle fitted with the efficient 48V motor generator that the uncertainty of the CO_2 savings calculated in accordance with Formula 7 or Formula 17 is not greater than the difference between the total CO_2 savings and the minimum savings threshold specified in Article 9(1) of Implementing Regulation (EU) No 725/2011 and Commission Implementing Regulation (EU) No 427/2014[(1)] (see Formula 21).

Formula 21

$$\mathrm{MT} < C_{CO_2} - s_{C_{CO_2}} - \Delta CO_{2_m}$$

Where:

MT	:	minimum threshold [g CO_2/km]
C_{CO_2}	:	total CO_2 saving [g CO_2/km]
$s_{C_{CO_2}}$	:	standard deviation of the total CO_2 saving [gCO_2/km]
ΔCO_{2_m}	:	CO_2 correction coefficient due to the positive mass difference between the efficient 48V motor generator plus 48V/12V DC-DC converter and the baseline alternator. For ΔCO_{2_m} the data in Table 4 is to be used.

TABLE 4

CO_2 correction coefficient due to the extra mass

Type of fuel	CO_2 correction coefficient due to the positive mass difference (ΔCO_{2_m})[g CO_2/km]
Petrol	0,0277 · Δm
Diesel	0,0383 · Δm

Δm (in Table 4) is the extra mass due to the installation of the 48V motor generator and the 48V/12V DC-DC converter. It is the positive difference between the mass of the 48V motor generator plus the 48V/12V DC-DC converter and the mass of baseline alternator. The mass of the baseline alternator is 7 kg. The extra mass is to be verified and confirmed in the verification report to be submitted to the type approval authority together with the application for certifications.

(**1**) 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).