Commission Implementing Decision (EU) 2016/1926 of 3 November 2016 on the approval of the battery-charging photovoltaic roof 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 BATTERY CHARGING PHOTOVOLTAIC ROOFS

1. INTRODUCTION

In order to determine the CO_2 emission reductions that can be attributed to a battery charging photovoltaic (PV) roof for use in an M_1 vehicle, it is necessary to establish the following:

(1) the testing conditions

(2) the test equipment;

(3) the determination of the peak power output;

(4) the calculation of the CO_2 savings;

(5) the calculation of the statistical margin of the CO_2 savings.

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*
M	— Mean annual mileage [km/year] as defined in *Table 4*
$\bar{mP}_P$	— Measured average solar PV roof peak power output [W]
n	— Number of measurements of the solar PV roof peak power output, which is at least 5
SCC	— Solar correction coefficient [-] as defined in *Table 1*
$s_{C_{CO_2}}$	— Statistical margin of the total CO_2 savings [g CO_2/km]
S_{IR}	— Yearly European mean solar irradiation [W/m^2], which is 120 W/m^2
S_{IR_STC}	— Global irradiation at Standard Test Conditions (STC) [W/m^2], which is 1 000 W/m^2
$s_{\bar{mP}_P}$	— Standard deviation of the arithmetic mean of the solar PV roof peak power output [W]
UF_{IR}	— Usage factor (shading effect), which is 0,51
V_{Pe}	— Consumption of effective power [l/kWh] as defined in *Table 2*
$\frac{\partial C_{CO_2}}{\partial \overline{mP}_P}$	— Sensitivity of calculated CO_2 savings related to the average solar PV roof peak power output

Greek symbols

ΔCO_{2m}	— CO_2 correction coefficient due to the extra mass of the solar system [g CO_2/km] as defined in *Table 5*
Δm	— Extra mass due to the installation of the solar system [kg]
η_A	— Alternator efficiency [%], which is 67 %
η_{SS}	— Solar system efficiency [%], which is 76 %
Φ	— Lengthwise inclination of the solar panel [°]

Subscripts

Index (i) refers to measurement of the PV roof peak power output

3. MEASUREMENTS AND DETERMINATION OF THE PEAK POWER OUTPUT

The measured average peak power output
$\left(\mathrm{m}\bar{\mathrm{P}}_P\right)$
of the PV roof is to be determined experimentally for each vehicle variant. Initial stabilisation of the tested device is to be done in accordance with the methodology specified in the international standard IEC 61215-2:2016[(1)]. The measurements of the peak power output shall be performed at standard test conditions as defined in the international standard IEC/TS 61836:2007[(2)].

A dismantled complete PV roof is to be used. The four corner points of the panel are to touch the measurement plane.

The measurements of the peak power output shall be performed at least five times and the arithmetic mean (
$\mathrm{m}\bar{\mathrm{P}}_P$
) has to be calculated.

4. CALCULATION OF THE CO_2 SAVINGS

The CO_2 savings of the PV roof are to be calculated by Formula 1 [M1]

Marginal Citations

M1 ... [Editorial note: Annex para. 4 footnote omitted (31.12.2020) by virtue of The Road Vehicle Carbon Dioxide Emission Performance Standards (Cars and Vans) (Amendment) (EU Exit) Regulations 2019 (S.I. 2019/550), regs. 1, **25(3)**; 2020 c. 1, Sch. 5 para. 1(1)]

Formula 1

$$C_{CO_2} = S_{IR} \times UF_{IR} \times \eta_{SS} \times \frac{m\bar{P}_P}{S_{IR\_STC}} \times SCC \times \frac{V_{Pe}}{\eta_A} \times \frac{CF}{M} \times \cos\Phi - \Delta CO_{2m}$$

Where:

C_{CO_2}	:	CO_2 savings [g CO_2/km]
S_{IR}	:	Yearly European mean solar irradiation [W/m^2], which is 120 W/m^2
UF_{IR}	:	Usage factor (shading effect) [-], which is 0,51
η_{SS}	:	Efficiency of the photovoltaic system [%], which is 76 %
$\mathrm{m}\bar{\mathrm{P}}_P$	:	Measured average PV roof peak power output [W]
S_{IR_STC}	:	Global irradiation at Standard Test Conditions (STC) [W/m^2], which is 1 000 W/m^2
SCC	:	Solar correction coefficient [-] as defined in Table 1. Total available storage capacity of the battery system or the SCC value is to be supplied by the vehicle manufacturer.

TABLE 1

Solar correction coefficient

Total available	0,10	0,20	0,30	0,40	0,50	0,60	> 0,666

a The total storage capacity includes a mean usable storage capacity of the starter battery of 10 Ah (12 V). All values refer to a mean annual solar radiation of 120 W/m^2, a shading share of 0,49 and a mean vehicle driving time of 1 hour per day at 750 W electric power requirement.

storage capacity of (12 V) battery system/ average PV roof peak power output [Ah/ W][a]							
Solar correction coefficient (SCC)	0,481	0,656	0,784	0,873	0,934	0,977	1

a The total storage capacity includes a mean usable storage capacity of the starter battery of 10 Ah (12 V). All values refer to a mean annual solar radiation of 120 W/m^2, a shading share of 0,49 and a mean vehicle driving time of 1 hour per day at 750 W electric power requirement.

V_{Pe} : Consumption of effective power [l/kWh] as defined 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

η_A : Efficiency of the alternator [%], which is 67 %;

CF : Conversion factor (l/100km) — (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

M : Mean annual mileage [km/year] as defined in Table 4

TABLE 4

Mean annual mileage for M_1 vehicles

Type of fuel	Mean annual mileage (M) [km/year]
Petrol	12 700
Diesel	17 000

Φ : Lengthwise inclination of the solar panel [°]. This value is to be supplied by the vehicle manufacturer

ΔCO_{2m} : CO_2 correction coefficient due to the extra mass of the solar roof and, where applicable, the additional battery and other appliances needed specifically for the conversion of the solar energy into electricity and its storage [g CO_2/km] as defined in Table 5.

TABLE 5

CO_2 correction coefficient due to the extra mass

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

In Table 5 Δm is the extra mass due to the installation of the photovoltaic system, composed by the PV roof and, where applicable, the additional battery and other appliances needed specifically for the conversion of the solar energy into electricity and its storage.

In particular, Δm is the positive difference between the mass of the photovoltaic system mass and the mass of a standard steel roof. The mass of a standard steel roof is assumed equal to 12 kg. In case the weight of the solar system is lower than 12 kg, no correction for the change in mass has to be made.

5. CALCULATION OF THE STATISTICAL MARGIN

The standard deviation of the arithmetic mean of the peak power output is to be calculated by Formula 2.

Formula 2

$$s_{\bar{mP}_P} = \sqrt{\frac{\sum_{i=1}^{n}\left(mP_{P_i} - \bar{mP}_P\right)^2}{n(n-1)}}$$

Where:

$s_{\bar{mP}_P}$: Standard deviation of the arithmetic mean of the peak power output [W]

mP_{P_i} : Measurement value of the peak power output [W]

$\bar{mP}_P$: Arithmetic mean of the peak power output [W]

n : Number of measurements of the peak power output, which is at least 5

The standard deviation of arithmetic mean of the PV roof peak power output leads to a statistical margin in the CO_2 savings

$\left(s_{C_{CO_2}}\right)$

. This value is to be calculated in accordance with Formula 3.

Formula 3

$$s_{C_{CO_2}} = \sqrt{\left(\frac{\partial C_{CO_2}}{\partial \overline{mP_r}} \cdot s_{\overline{mP_r}}\right)^2} = S_{IR} \cdot \frac{1}{S_{IR\_STC}} \cdot UF_{IR} \cdot \eta_{SS} \cdot SCC \cdot \frac{V_{Pe}}{\eta_A} \cdot \frac{CF}{M} \cdot \cos\Phi \cdot s_{\overline{mP_r}}$$

6. STATISTICAL SIGNIFICANCE

It has to be demonstrated for each type, variant and version of a vehicle fitted with the battery charging PV roof that the minimum threshold of 1 gCO_2/km is exceeded in a statistically significant way, as specified in Article 9(1) of Implementing Regulation (EU) No 725/2011. As a consequence, Formula 4 is to be used.

Formula 4

$$MT \leq C_{CO_2} - s_{C_{CO_2}}$$

Where:

MT	:	Minimum threshold [g CO_2/km], which is 1 g CO_2/km
$s_{C_{CO_2}}$	:	Statistical margin of the total CO_2 savings [g CO_2/km]

Where the CO_2 emission savings, as a result of the calculation using Formula 4, are below the threshold specified in Article 9(1) of Implementing Regulation (EU) No 725/2011, the second subparagraph of Article 11(2) of that Regulation shall apply.

(**1**) The International Electrotechnical Commission (IEC), IEC 61215-2:2016 standard for 'Terrestrial photovoltaic (PV) modules — Design qualification and type approval'

(**2**) The International Electrotechnical Commission (IEC), IEC 61836-2007 standard for 'Solar photovoltaic energy systems — Terms, definitions and symbols'

Changes to legislation:
There are currently no known outstanding effects for the Commission Implementing Decision (EU) 2016/1926.