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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

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Technical Guidelines

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1. Introduction

1.1. Objective

These guidelines provide

- technical guidance for preparing applications for the approval and certification of innovative technologies (‘eco-innovations’) to reduce CO_2 emissions from passenger cars,
- case studies and
- In-put data for the preparation of testing and calculation methodologies.

1.2. Legal background

1.2.1. Regulation (EC) No 443/2009

Regulation (EC) No 443/2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light duty vehicles provides an average CO_2 emission target for new passenger cars of 130 g CO_2 / km from 2015 onwards to be phased-in from 2012. Specific emission targets are assigned to each manufacturer, based on the average specific emissions for each new passenger car registered in the preceding calendar year. Additional measures specified in Commission Communication (2007)19 final should bring a further reduction of 10 g CO_2 / km. From 2020 onwards, the average CO_2 emissions target is set at 95 g CO_2 / km.

Article 12 of Regulation (EC) No 443/2009 provides a possibility for manufacturers to take into account CO_2 savings from innovative technologies, "eco-innovations" in order to meet their specific CO_2 emissions targets. The maximum credit that may be given according to that Regulation is 7 g/km CO_2. The Commission will assess applications for the approval of technologies as "eco-innovations". Applications may be submitted by both manufacturers and suppliers. An approval decision may be used by manufacturers for the purpose of certifying the CO_2 savings as part of the type approval process.

Testing methodologies for eco-innovations that have been approved by the Commission will be available for manufacturers other than the holder of the approval and may be used for the certification of any relevant vehicle fitted with a technology corresponding to the approved eco-innovation, provided that the minimum savings threshold is met (see second subparagraph of Article 11(2) of Regulation (EU) No 725/2011). The approval decisions will be accessible on Eur-Lex as well as on the Commission website:
http://ec.europa.eu/clima/policies/transport/vehicles/cars/documentation_en.htm.

1.2.2. Commission Regulation (EU) No 725/2011

Commission Regulation (EU) No 725/2011 of 25 July 2011 establishing a procedure for the approval and certification of innovative technologies for reducing CO2 emissions from passenger cars pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council specifies the eligibility criteria and sets out the application procedure. These guidelines give additional information on how to prepare the application as well as practical examples of potential technologies and testing methodologies.

1.3. Demonstration of CO_2 savings (Article 5 of Regulation (EU) No 725/2011)

The reference method to demonstrate the CO_2 saving effect of an innovative technology should be to perform vehicle measurements on a chassis dynamometer. However, in accordance with Article 5(2), the ‘testing methodology’ to demonstrate the CO_2 savings could also include calculation or modelling methodologies.

1.3.1. European driving patterns (Article 6(1))

In order to ensure a level playing field and to have a common reference for all applications, the driving patterns specified in the ‘New European Driving Cycle’ (NEDC) set out in UN/ECE Regulation No 83 for the ‘Type I test’ should be used as a basis for the measurements pending the adoption of a new test cycle. The NEDC should therefore be used as test cycle for validation purposes within the testing methodologies in terms of velocity-over-time function. Test cycles or driving patterns with other speed/time profiles than the NEDC or the restriction or over-weighting of specific parts of that cycle would therefore not be accepted. The NEDC should therefore be followed as a whole, including an engine start at the beginning of the cycle.

Where it is clear that the CO_2 reducing effect of an innovative technology cannot be adequately demonstrated on a vehicle chassis dynamometer or from the use of the speed/time-profile of the NEDC, it should be assessed on a case by case basis whether a deviation from the NEDC is appropriate. A request for such deviation in the testing methodology should be supported by a detailed justification. The independent and certified body should confirm in its verification report that the deviations are appropriate.

Example A:
The CO_2 saving potential of a start/stop system depends on the number and duration of idling phases at the test cycle. A driving cycle with an overweighting of idling phases compared to the NEDC would not be considered representative.

Example B:
A technology results in CO_2 savings when the vehicle is operated under warm (start) conditions. The warming up of the vehicle should be done using the NEDC. The impact of the warm non-standard starting conditions should be demonstrated under the NEDC as well. The final CO_2 saving is the difference between the two test results.

Example C:
A technology shows its CO_2 reduction potential mainly at highest vehicle velocities. The maximum speed in the NEDC is 120 km/h, and only the CO_2 emission reduction up to 120 km/h should be considered for the application. An over-weighting of the 120 km/h part of the NEDC (> 7 seconds) would not be considered representative.

1.3.2. Calculation procedure (Article 8 of Regulation (EU) No 725/2011)

The generic procedure to determine the CO_2 savings of a particular innovative technology is described by eq. 1. This procedure, including vehicle testing on a chassis dynamometer, may be used by an applicant within the process of the 'comprehensive methodology' (see Chap. 4.1). The testing conditions (e.g. ambient conditions, temperatures, activation of safety devices, tyre pressure, etc.) specified for the testing methodology of an innovative technology may be modified from those defined for type approval[1].

$$C_{CO2} = ((B_{MC} - E_{MC}) - (B_{TA} - E_{TA})) \cdot UF \qquad \text{(eq. 1)}$$

C_{CO2}: CO_2 savings [g/km]
B_{MC}: CO_2 emissions of the **baseline technology** vehicle under **modified** testing conditions [g/km]
E_{MC}: CO_2 emissions of the **eco-innovation technology** vehicle under **modified** testing conditions [g/km]
B_{TA}: CO_2 emissions of the **baseline technology** vehicle under **type approval** testing conditions [g/km]
E_{TA}: CO_2 emissions of the **eco-innovation technology** vehicle under **type approval** testing conditions [g/km]
UF: Usage factor (temporal share of technology usage in normal operation conditions) [-]

Each of the four CO_2 emission values B_{MC}, E_{MC}, B_{TA} and E_{TA} represents an arithmetic mean of a measurement series of at least five individual and consecutive measurements. The testing conditions (e.g. temperature and humidity at the test cell) should be equal for all four measurement series and should be similar to the testing conditions of the type approval

[1] Pursuant to Commission Regulation (EC) No 692/2008 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

measurements (except those parameters naturally influencing the innovative technology's performance).

To avoid double counting, the CO_2 savings under modified testing conditions (B_{MC} - E_{MC}) have to be corrected by the CO_2 emissions difference of the same two vehicles measured under type approval testing conditions (B_{TA} - E_{TA}). When it is evident that type approval conditions do not result in differences between CO_2 emissions of baseline and eco-innovation technologies, calculations could be done without measurements under type approval conditions (B_{TA} and E_{TA}). In practice, it is recommended to perform measurements always for all four combinations of technology and testing condition, since this procedure eliminates all possible differences between the eco-innovation and the baseline vehicle **not** caused by the eco-innovation technology itself.

Measured CO_2 savings of technologies which are typically not activated for the whole time of the vehicle operation on the road should be corrected by a usage factor. Usage factors describe the mean share of usage of a particular technology in total vehicle usage and are derived from surveys and external data (see Chap. 5.4).

The uncertainty of the CO_2 savings determined in such a way has to be assessed by the use of appropriate statistical measures (see Chap. 4.3).

In addition to the procedure described above, these guidelines offer the possibility to use 'simplified approaches' (see Chap. 4.2) in providing averaged data and basic calculation methods.

2. Eligibility criteria

Innovative technologies have to fulfil the following criteria to qualify for an application for eco-innovation:

2.1. Integrated approach measures (Article 2(1) of Regulation (EU) No 725/2011)

Some individual CO_2 saving technologies have been regulated in EU legislation or are going to be developed within a short period of time. Regulation (EC) No 443/2009 explicitly excludes these technologies from the scope of eco-innovation procedure.

2.2. Innovativeness (Article 2(2)(a) of Regulation (EU) No 725/2011)

Technologies that are already well represented in the existing fleet should not qualify as eco-innovations. Incentives should only be given to new technologies with a real CO_2 reducing potential with the aim of facilitating their introduction and wide-spread penetration into the market.

According to the Regulation, technologies with a market penetration of 3% or less in new registered vehicles in Europe in the reference year 2009 may be considered meeting the innovativeness criterion. Where the innovative technology consists of a combination of several technologies with similar technical features and characteristics (referred to in these guidelines as a 'technology package')(see Chap. 2.4.2) each individual technology has to fulfil the innovativeness criterion defined above separately.

Applicants are asked to provide supporting information, such as the 2009 sales numbers of vehicles already equipped with the innovative technology, or the number of products including the innovative technology that were sold to vehicle manufacturers in that year. Where no such information is available due to the novelty of the technology, the applicant should provide a statement to that effect. It is recognised that precise data may not always be readily accessible. Where relevant data bases are not available, an estimate based on the best information available to the applicant, such as information about the applicant's own products, should be made. Well-argued expert judgements on market penetration would be considered. It should be noted that evidence provided to support this part of the application will be made public as part of the summary to be provided in accordance with Article 4(2)(c) of Regulation (EU) No 725/2011.

2.3. Necessity (non-comfort) (Article 2(2)(b) of Regulation (EU) No 725/2011)

An applicant should demonstrate that the technology does not serve purely for comfort, without any link to either the performance or the safety of the vehicle. A technology that improves the energy use of a vehicle compared to a baseline technology and that in addition is relevant for the transport function of the vehicle could however qualify as an eco-innovation. More precisely, technologies which are able to convert unused (internal or external) energy into usable energy or improve the energy storage capacity would be potentially eligible.

Example A:
Technologies like photo-voltaic elements applied on the vehicles (solar roof), heat recovery systems, more efficient generators and more efficient lighting (LED) may potentially qualify as eco-innovations.

Example B:
Technologies like efficient seat or cabin heating and efficient HiFi systems would not qualify for eco-innovations.

2.4. Verifiability (minimum threshold) (Article 4(2)(f)(i) of Regulation (EU) No 725/2011)

The CO_2 savings of an eco-innovation should be verifiable. Hence, the technical limits of determination of standard measurement equipment should not exceed the total CO_2 savings value. The savings should be calculated in accordance with the procedure described in Section 1.3.2 and should be 1 g CO_2 / km or more in order for the technology to be eligible. For this comparison, calculated CO_2 savings values must not be rounded up.

2.4.1. Statistical significance

The applicant should demonstrate that the minimum threshold is exceeded in a statistically significant way. A confidence interval of at least 84 % should be observed. This means, that the statistical error determined as described in Chap. 4.3 and indicated as a standard deviation should not be greater than the difference between the total CO_2 savings and the minimum threshold (see equation 2).

$$MT \leq C_{CO2} - \overline{\sigma_{C_{CO2}}} \qquad \text{(eq. 2)}$$

MT: minimum threshold
C_{CO2}: total CO_2 saving
$\overline{\sigma_{C_{CO2}}}$: standard deviation of the total CO_2 saving (see Chapter 4.3)

If the total CO_2 saving exceeds the minimum threshold but its standard deviation is greater than the difference between the total CO_2 saving and the minimum threshold, the verifiability criterion is not fulfilled. In this case, the applicant should undertake suitable measures to reduce the uncertainty of the total CO_2 saving, e.g. by increasing the number of measurements, by updating the measurement instrumentation resp. by improving the modelling method.

Example:
The standard deviation of the CO_2 saving derived from chassis dynamometer measurements is 0.4 g CO_2/km (pursuant to Chap. 4.3). Therefore the determined figure of the total CO_2 savings has to be 1.4 g CO_2 / km or higher to exceed the minimum threshold of 1 g CO_2 / km with the given statistical significance.

If the total CO_2 savings depend on one or more vehicle-specific parameters, the applicant should demonstrate that the minimum threshold is exceeded significantly for each vehicle version[2] which

2 In terms of 'vehicle type, variant and version' as defined in Annex II B1 to Directive 2007/46/EC (type approval framework Directive)

is foreseen to be equipped with the eco-innovation. Where relevant, the demonstration should also include an assessment of the interaction between different eco-innovations and the resulting impact on the total savings.

> **Alternatively**, if the data situation does not allow applying the above mentioned method, the following procedure could be used:
>
> A minimum of five (5) vehicle tests with and without the eco-innovation should be carried out when vehicles are tested over the New European Drive Cycle (NEDC) on a chassis dynamometer. The standard deviation σ of the test results with and without eco-innovative technology should be such that the CO_2 saving is larger than three (3) times the standard deviation σ of the measured total CO_2 values over the NEDC.
>
> **Example:** A vehicle tested without eco-innovation emits over the NEDC as average 152.7 g CO_2 / km, and with eco-innovation 151.7 g CO_2/km. The saving is 1.0 g CO_2 / km. To be qualified as eco-innovation saving, the standard deviation of the two emission data must be equal or better than 0.3 g CO_2/km, in order to fulfil the requirement $3\sigma = 3 \cdot 0.3$ g CO_2 / km = 0.9 g CO_2 / km < 1 g CO_2 / km.
>
> For this example the test results in the verification report would be given as 152.7 ± 0.3 g CO_2 / km for the baseline vehicle without innovative technology, and as 151.7 ± 0.3 g CO_2 / km for the vehicle with innovative technology.

2.4.2. Technology package (Article 3(a))

The combination of different innovative technologies into one technology package to exceed the minimum threshold of 1 g CO_2/km should in principle be admissible. The individual technologies combined into one technology package should be tested using one and the same testing methodology and should therefore belong to the same technology class as specified in Chap. 3.

The total CO_2 savings should be determined taking into account the interaction between the technologies forming the package. The single CO_2 savings for each technology being part of the package may be shown in the verification report, but only one figure should be reported for the final total savings of the combined technologies, taking into account any potential interaction between the single technologies.

Example A:
A considered valid technology package is the combination of different lighting technologies.

Example B:
A combination of heat recovery and lighting system would not be considered a valid technology package.

2.5. Coverage (type approval procedure), Article 4(7)(f)(ii)

Incentives can be granted to technologies whose CO_2 saving is not already covered by the CO_2 type approval test procedure. If the CO_2 reducing effect of an eco-innovation is only partially covered by the type approval procedure, the granted CO_2 saving is the difference between the CO_2 saving at modified testing modalities and CO_2 saving under type approval conditions (see equation 1 in Chap. 1.3.2), i.e. any savings that can be demonstrated using the normal type approval procedure must be deducted from the total savings of the eco-innovation in order to avoid double counting. Technologies whose CO_2 reducing effects are fully covered by the EC type approval procedure will not qualify.

2.6. Accountability (influence of driver) Article (4)(7)(f)(iii)

CO_2 savings of eco-innovations must be accountable to the applicants, i.e. manufacturers or suppliers. All other possible influencing parameters should be excluded to ensure a verifiable and constant rate of activation. Where basic technical features are not activated permanently during a vehicle's operation, average usage factors should be derived from strong statistical data. Normally, such statistical surveys cannot be performed for new technologies before their market introduction.

In general, only technologies whose CO_2 saving effect is not under the influence of the driver's choice or behaviour would normally qualify. However, devices which can be switched on and off, but are normally activated or deactivated because of changing ambient conditions to ensure a safe operation of the vehicle would be eligible, provided that relevant statistical data can be provided to support the CO_2 reducing effect of the device (usage factor).

Example A:
Lighting as technology can be switched on and off by the user. However, the normal way of using lights will not change with the lighting technology. In this case the technology might be eligible.

Example B:
Amongst the possible technologies that **should not qualify** as eco-innovations are driver-aid systems indicating the "eco level" of a driver, eco-driving training and engine control systems for more ecological driving that can be switched on/off by the user.

3. Classes of potential eco-innovation technologies

Potential eco-innovation technologies have been grouped into classes of similar technical features and characteristics. The following list describes the current state of knowledge and must not be seen as finalised or completed.

3.1. Improved electrical components

3.1.1. Description

Any improvement of the efficiency of electrical components lowers the total electric power requirement. Hence, the mechanical workload of the alternator gets reduced and fuel consumption and CO_2 emissions fall. For calculation approaches it is essential to know the efficiencies of both alternator and engine. For electrical components which are not always activated during vehicle's operation, a particular temporal share of usage has to be taken into account. Possible opponent effects, e.g. caused by extra required control units, have to be taken into account when calculating the CO_2 benefit. Especially for electrical components it is important to check if the 'necessity' eligibility criteria are fulfilled since not every electrical device is essential for the operation of the vehicle.

3.1.2. Baseline technology

The baseline technology for improved electrical components should be as a rule the component with the highest market penetration at the reference period.

3.2. Improved mechanical components

3.2.1. Description

Any improvement of mechanical components which lowers the driving resistance of the vehicle leads directly to reductions of fuel consumption and CO_2 emissions. Measures of this class may reduce the rolling resistance, aerodynamic drag or the friction of mechanical devices. They may also improve the engine's efficiency.

3.2.2. Baseline technology

The baseline technology for improved mechanical components is the component with the highest market penetration at the reference period.

3.3. Use of ambient energy sources

3.3.1. Description

Ambient energy sources like solar radiation, wind, heat etc. may be transformed to usable energy by special devices. If these external energy flows are used directly for propulsion of the vehicle or are transformed to electric energy, the energy requirement from on-board fuels gets reduced.

3.3.2. Baseline technology

The baseline technology for the use of ambient energy sources is the same configuration of the testing vehicle just without the energy transforming device.

3.4. Energy storing systems

3.4.1. Description

Heat, kinetic or electric energy which cannot be used or only be used at a low efficiency level at a certain time may be stored and used afterwards at a more favourable opportunity. Also heat storage by measures of insulation may increase the temperature of vehicle parts and, hence, reduce friction of mechanical components.

3.4.2. Baseline technology

The baseline technology for the use of energy storing systems is the same configuration of the testing vehicle just without the energy storing device.

3.5. Heat-to-electricity converters

3.5.1. Description

Waste heat from the exhaust or from the coolant may be transformed to electricity and can therefore reduce the alternator's workload. Possible technologies are:

- heat exchanger, turbine and generator,
- turbo compressor and generator,
- heat exchanger and thermoelectric semiconductor, etc.

Exhaust heat recovery systems reduce the exhaust temperature and increase the exhaust back pressure. This counter-reaction has to be taken into account when determining the CO_2 saving effect of the system. Current standard vehicle models are not able to cover the complex interactions of these systems. Hence, the testing methodology should be based on measurements.

3.5.2. Baseline technology

The baseline technology for the use of heat-to-electricity converters is the same configuration of the testing vehicle just without the heat-to-electricity converting device.

3.6. Kinetic energy – to – electricity converters

3.6.1. Description

Kinetic energy may be transformed to additional electric energy in different ways, like efficiency improvements of the alternator, recuperation or converting energy from shock absorbers.

For road surface profiles ISO 8608 (ISO 8608: Mechanical vibration -- Road surface profiles -- Reporting of measured data) should be used or the applicant should provide sufficient data to support the use of a different road surface profile.

3.6.2. Baseline technology

The baseline technology for the use of kinetic energy – to – electricity converters is the same configuration of the testing vehicle just without the kinetic energy – to - electricity converting device. In case of efficiency improvement of an already existing converter, the baseline technology is the converter with the highest market penetration at the reference period.

3.7. Measures lowering engine speed

3.7.1. Description

Measures lowering engine speed may include changes in transmission ratios, different gear changing strategies or engine shut-off during idling phases. These measures are widely covered by the type approval test procedure or are influenced strongly by the behaviour of the driver. Hence, the fulfilment of the eligibility criteria has to be checked carefully.

3.7.2. Baseline technology

The baseline technology for measures lowering engine speed is the transmission strategy with the highest market penetration at the reference period.

4. Testing methodologies

The application for an approval of an innovative technology as eco-innovation has to include a testing methodology that is suitable to determine and quantify the CO_2 saving effect of the technology. The methodology should provide accurate and verifiable results. In principle, a measurement, a modelling approach or a combination of both may be applied. Occurring statistical errors resulting from uncertainties of the measurement or modelling techniques have to be quantified and reported.

The applicant may choose between two different possible approaches:

a) the **'comprehensive methodology';** the applicant should develop a testing methodology and where necessary base it on extensive vehicle data and hardware. This documentation should in principle be provided as part of the application and should be assessed by the independent and certified body for the purposes of the verification report.

b) the **'simplified approach'**; the applicant can use predefined functions and averaged data given in these guidelines. The verification report may in this case be limited to include the certified testing protocols and an assessment of possible interactions with other eco-innovations.

Chapter 5 of these guidelines provides a list of data sets that can be used for the 'simplified approach'. All assumptions - other than those given in Chapter 5 - used for calculating the CO_2 reduction potential of an innovative technology by a 'comprehensive methodology' need to be justified and, if applicable, should be accompanied by relevant data. Calculation methodologies and equations taken from open literature should be correctly cited. A detailed derivation of equations is in this case not needed.

A mixture of the 'comprehensive methodology' and the 'simplified approach' should in principle be avoided. However, where the generic data defined for the simplified approach in Chapter 5 is not vehicle specific (e.g. usage factors) it may be used also for the comprehensive methodology.

Where the 'simplified approach' is used, all relevant data in Chapter 5 should in principle be used. However, deviations from that rule could be permitted, where the applicant can justify this by providing data for a specific vehicle that is more realistic, based on robust statistical evidence. That data should be non-confidential.

The methodology should not exceed a certain level of complexity in order to ensure its reproducibility by third parties. Specific models owned by the applicant will in principle not be considered as valid basis for demonstrating CO_2 savings.

If the CO_2 savings depends on the vehicle version[3], a parametric function has to be developed and applied. Where such a parametric function cannot remove the differences between the vehicle versions completely, an appropriate security margin added to the resulting CO_2 savings should be taken into account. This ensures that all vehicle versions concerned by the specific eco-innovation application are covered by the proposed testing methodology. The eligibility of the parametric function should be checked by the independent and certified body. The results of this assessment should be included in the verification report (see Chap. 4.6). The derived equations should be used for the certification procedure for a specific vehicle version.

Example:
The CO_2 saving effect of a heat storage measure depends on the engine size of the vehicles. The connection can be described with the following equation:

$C_{CO2} = A + B \cdot$ (engine displacement [ccm]).

This equation has to be submitted together with the engine displacement of the specific vehicle version to the national type approval authority for certification of the CO_2 saving of a specific vehicle version.

4.1. Simplified approach

The main features of the 'simplified approach' are:

- averaged functions and factors defined in these guidelines
- security margins included to ensure coverage of all potentially qualifying vehicles, measurement / modelling uncertainties and deterioration effects

4.2. Comprehensive methodology

The main features of the comprehensive methodology are:

- measurements or modelling or a combinations of both;
- vehicle test results should in principle be reproducible by a third party on a standard chassis dynamometer equipped with standard measurement techniques
- modelling results should in principle be reproducible by a third party with commercial vehicle simulation software
- the applicant may have to provide hardware (both baseline and eco-innovation technologies) for validation
- the applicant may need to provide comprehensive vehicle data to be used for modelling approaches. A first list of possible data needs include:
    - engine: type, displacement, number of cylinders, number of strokes, idle speed, maximum speed, mass moment of inertia, heat capacity, full load characteristic
    - coolant temperature increase after engine start
    - CO_2 emission engine map
    - fuel consumption engine map
    - fuel density
    - efficiency map of alternator
    - gear box: type, number of gears, transmission ratios
    - efficiency map of gearbox
    - axle drive: transmission ratio, efficiency
    - curb weight
    - driving resistance parameters

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3 In terms of 'vehicle type, variant and version' as defined in Annex II B1 to Directive 2007/46/EC (type approval framework Directive). A vehicle version can differ, for instance in engine capacity, and power output. These differences can influence the CO2 saving effect.

- frontal area
- drag coefficient
- clutch: maximum transferable torque
- wheel: inertia moment, dynamic rolling radius
- alternator: inertia moment, nominal voltage, maximum current, efficiency curve, idle voltage, torque loss
- battery: nominal voltage, charge capacity, idle voltage, internal resistance
- *+ data specific for the individual eco-innovation technology*

4.2.1. Data quality and uncertainties – Comprehensive Methodology

(only to be taken into account for the 'comprehensive methodology')

The testing methodology should provide verifiable and accurate results. The resulting CO_2 savings have to be reproducible by a third party equipped with standard measurement and modelling techniques.

Statistical errors of the testing methodology's outcomes caused by measurement or modelling uncertainties should be quantified and given together with the determined CO_2 saving value. The format of the error value shall be a standard deviation being equivalent to a confidence interval of 68 % (see eq. 3).

$$s_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}} \qquad \text{(eq. 3)}$$

$s_{\bar{x}}$: standard deviation of arithmetic mean
x_i : measurement value
$\bar{x}$: arithmetic mean
n : number of measurements

All occurring statistical errors should be minimised by applying suitable measures, e.g. by using a driving robot for chassis dynamometer measurements. All measurements should be performed consecutively at least **five (5)** times. In case of high variation between the individual measurement values, the number of measurements should be further increased to reduce the uncertainty of the resulting mean value.

The uncertainty values of the individual measurement series shall be combined to a total statistical error value using the error propagation law (eq. 4) or a more sophisticated 'Monte Carlo' approach.

$$\overline{\Delta C_{CO2}} = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial C_{CO2}}{\partial x_i}\Delta x_i\right)^2} \qquad \text{(eq. 4)}$$

$\overline{\Delta C_{CO2}}$: mean total error of the CO_2 saving
$\partial C_{CO2} / \partial x_i$: sensitivity of calculated CO_2 saving related to input value x_i
Δx_i: error of input value x_i

The standard deviation of the determined total CO_2 saving of the proposed testing methodology should not exceed **0.5 g CO_2/km** (eq. 5).

$$\overline{\sigma_{C_{CO2}}} = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial C_{CO2}}{\partial x_i}\sigma_{x_i}\right)^2} \leq 0.5\,g\,CO_2\,/\,km \qquad \text{(eq. 5)}$$

$\overline{\sigma_{C_{CO2}}}$: standard deviation of the total CO_2 saving

σ_{x_i} : standard deviation of input value x_i

Concerning the check of the fulfilment of the verifiability criterion (see Chap. 2.4), the requirements on the statistical error may be stricter, depending on the distance between the minimum threshold of 1 g CO_2 / km and the resulting total CO_2 saving.

Example A:
The standard deviation of a single CO_2 measurement is 1.0 g CO_2 / km. Each of the 4 measurement series described at eq. 1 consists of 5 individual values. The total CO_2 saving (TS) is 3.0 g CO_2 / km without consideration of the usage factor. The usage factor UF is 0.7 with a standard deviation of 0.05. The total CO_2 saving (C_{CO2}) is therefore 2.1 g CO_2 / km (C_{CO2} = TS · UF).

- standard deviation of the arithmetic means of the 4 measurement series B_{MC}, E_{MC}, B_{TA} and E_{TA} (pursuant eq. 3):

$$\sigma_{B_{MC}} = \sigma_{E_{MC}} = \sigma_{B_{TA}} = \sigma_{E_{TA}} = \sigma_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n(n-1)}} = \sqrt{\frac{1}{n}}\cdot\sigma_x = \sqrt{\frac{1}{5}}\cdot 1\ g/km = 0.45\ g/km$$

- standard deviation of the total saving (TS) as linear combination of the 4 arithmetic means (pursuant eq. 4)

(TS = (B_{MC} - E_{MC}) – (B_{TA} - E_{TA})):

$$\sigma_{TS} = \sqrt{\sigma_{B_{MC}}{}^2 + \sigma_{E_{MC}}{}^2 + \sigma_{B_{TA}}{}^2 + \sigma_{E_{TA}}{}^2}$$
$$= \sqrt{\sum_{i=1}^{4}\Delta x_i{}^2} = \sqrt{4\cdot(0.45\ g/km)^2} = 0.89\ g/km$$

- standard deviation of the total CO_2 saving (C_{CO2} = TS · UF) (pursuant eq. 4):

$$\overline{\sigma_{C_{CO2}}} = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial C_{CO2}}{\partial x_i}\sigma_{x_i}\right)^2} = \sqrt{\left(\frac{\partial C_{CO2}}{\partial TS}\sigma_{TS}\right)^2 + \left(\frac{\partial C_{CO2}}{\partial UF}\sigma_{UF}\right)^2}$$
$$= \sqrt{(UF\cdot\sigma_{TS})^2 + (TS\cdot\sigma_{UF})^2}$$

The total standard deviation of the CO_2 saving determined with 0.64 g CO_2 / km exceeds the minimum requirement of 0.5 g CO_2 / km. Further efforts are necessary to lower the uncertainties.

Example B:
Compared to example A, the number of measurements per series is increased from 5 to 10. All other parameters remain unchanged.

$$\sigma_{B_{MC}} = \sigma_{E_{MC}} = \sigma_{B_{TA}} = \sigma_{E_{TA}} = \sigma_{\bar{x}} = \sqrt{\frac{1}{n}} \cdot \sigma_x = \sqrt{\frac{1}{10}} \cdot 1\ g/km = 0.32\ g/km$$

$$\sigma_{TS} = \sqrt{\sum_{i=1}^{4} \Delta x_i^{\,2}} = \sqrt{4 \cdot (0.32\ g/km)^2} = 0.63\ g/km$$

$$\overline{\sigma_{C_{CO2}}} = \sqrt{(0.7 \cdot 0.63\ g/km)^2 + (3.0\ g/km \cdot 0.05)^2} = 0.47\ g/km$$

The minimum requirement on data quality is fulfilled now (0.47 g CO_2 / km < 0.5 g CO_2 / km).

Example C:
Compared to example A, the standard deviation of a single CO_2 measurement is reduced to 0.6 g CO_2 / km by usage of a driving robot and a more precise exhaust gas volume meter. All other parameters remain unchanged.

$$\sigma_{B_{MC}} = \sigma_{E_{MC}} = \sigma_{B_{TA}} = \sigma_{E_{TA}} = \sigma_{\bar{x}} = \sqrt{\frac{1}{n}} \cdot \sigma_x = \sqrt{\frac{1}{5}} \cdot 0.6\ g/km = 0.27\ g/km$$

$$\sigma_{TS} = \sqrt{\sum_{i=1}^{4} \Delta x_i^{\,2}} = \sqrt{4 \cdot (0.27\ g/km)^2} = 0.54\ g/km$$

$$\overline{\sigma_{C_{CO2}}} = \sqrt{(0.7 \cdot 0.54\ g/km)^2 + (3.0\ g/km \cdot 0.05)^2} = 0.40\ g/km$$

Again, the minimum requirement on data quality is fulfilled now (0.40 g CO_2 / km < 0.5 g CO_2 / km).

4.2.2. Deterioration – Comprehensive Methodology

(only to be taken into account for the 'comprehensive methodology')

The certified CO_2 savings of a particular eco-innovation is related to an aged system. The ageing procedure and the criteria to reach the aged condition of the particular technology should be sufficient to reach the aged condition being equivalent to a total vehicle mileage of 160,000 km or, in case of expected exchange of the technology during a vehicle's lifetime, being equivalent to the innovative technology's expected lifetime. The use of fixed deterioration factors should not be allowed.

There is no need to age a complete vehicle system. It would also be sufficient to age the specific technology device under realistic burden. Even time reduced bench testing under tighter conditions (e.g. higher temperatures) could be feasible.

If there is no deterioration of the eco-innovation with time/mileage, the applicant should demonstrate it by suitable measurements or by sound argumentation (expert's judgement).

The assessment of the deterioration procedure and the influence of ageing effects to the CO_2 saving effect shall be part of the verification report undertaken by an independent and certified body.

4.3. Interactions

The testing methodology should include a check of possible interactions with CO_2 savings from other eco-innovations that are already certified, granted or envisaged for application. If such interactions cannot be ruled out, the interacting effect should be quantified for each interacting eco-innovation by using adequate testing procedures or by solid expert judgement.

The assessment of the interacting effects to the CO_2 saving should be part of the verification report undertaken by an independent and certified body.

4.4. Verification report

The applicant should provide a verification report established by an independent and certified body.

Simplified approach:

If the applicant follows a 'simplified approach' as set out in Chapters 5 and 8, the verification report may be limited to include the testing protocols on the measurements required in Chapter 8 and, where applicable, an assessment on possible interactions with other innovative technologies.

Comprehensive methodology:

The verification report should include a complete scrutiny of the fulfilment of the eligibility criteria and of the suitability of the testing methodology for determining the CO_2 savings from the eco-innovation. It should also include a confirmation that the structure of the testing methodology allows an independent verification of the resulting CO_2 saving by standard measurement techniques or commercial vehicle modelling software. The verification report should also, where appropriate, include assessments and results on possible interactions with other innovative technologies and on deterioration effects. If one or more parametric functions have to be applied, the verification report should confirm its suitability and its accuracy.

4.5. Summary of the application

When a complete application has been received by the Commission a summary of the application will be published on the Commission website. This summary is to be prepared by the applicant and should accompany the application. The following items should be included in the summary:

- Applicant name;
- Summary description of the technology;
- Evidence supporting that the innovativeness criterion of less than 3% market penetration set out in Article 2(2)(a) of Regulation (EU) No 725/2011 is met;
- Evidence supporting that the criterion set out in Article 2(2)(b) of Regulation (EU) No 725/2011 is met;
- Summary description of the testing methodology or a reference to the simplified approach in these Guidelines.

It is important that the applicant indicates clearly which parts of the application should be considered as confidential commercial information and provides the relevant justifications. The testing methodology will however be publicly accessible once the eco-innovation is approved.
A template for the summary is provided in the Appendix to these Guidelines.

5. Data sets for simplified approaches

This chapter contains a collection of data that should be used as input data for the simplified approaches of the testing methodologies described in Chapter 4.2. The data sets represent average values for mean European conditions on an annual time basis. Where technical data vary between different vehicle versions[4], a security margin is included in the listed values to

[4] In terms of 'vehicle type, variant and version' as defined in Annex II B1 to Directive 2007/46/EC (type approval framework Directive).

ensure that all potential vehicles are covered by the simplified approach. Another security factor is included where deterioration effects have to be taken into account.

5.1. Efficiencies

5.1.1. Efficiency of engine

A reduction of electrical or mechanical power requirement lowers fuel consumption rates and CO_2 emissions. The 'consumption of effective power' V_{Pe} describes the reduced fuel consumption with a reduction of required power at a particular point of the engine map and represents the marginal engine's efficiency. Following the 'Willans approach', the 'consumption of effective power' is nearly constant and almost independent from engine speed at low engine loads.

Type of engine	**Consumption of effective power V_{Pe} [l/kWh]**
Petrol **(V_{Pe-P})**	0,264
Petro Turbo	0,28
Diesel **(V_{Pe-D})**	0,22

5.1.2. Efficiency of alternator

The knowledge about the efficiency of the alternator is essential for the conversion from mechanical into electric power and vice versa:

Efficiency of alternator **(η_A)**[5]	0.67

5.1.3. Electrical solar system efficiency

The conversion of solar radiation into electric energy, the DC-DC transformation, the storage in a battery and the use by an electrical consumer is linked with energy losses:

Efficiency of the DC-DC-converter	0.92
Efficiency of the battery (charge and discharge)	0.94
Temperature, reflection and deterioration effects	0.88
Total efficiency of the solar system **(η_{SS})**[6]	0.76

5.2. Driving cycle characteristics

Cycle	**Distance [km]**	**Duration [s]**	**Mean speed [km/h]**
UDC	4.052	780	18.70
EUDC	6.955	400	62.60
NEDC	11.007	1180	33.58

5.3. Fuel characteristics

[5] This value is calculated pursuant to the "VDA approach". This value can be used for calculating the effect of new electric devices. It, however, may not be used as a baseline value for the calculation of CO_2 savings caused by alternators with improved efficiency. The formula of the VDA-approach is explained in paragraph 5.1.2 of this document.

[6] The total efficiency of the solar system does not include the efficiency of the PV cells which is already covered by the PV peak power value.

5.3.1. Fuel densities

Type of fuel	Density at 15 °C [kg/m^3]
Petrol	743
Diesel	833

5.3.2. Conversion fuel consumption ↔ CO_2 emission

Type of fuel	Conversion factor (l / 100 km) → (g CO_2 / km) [100 g / l]
Petrol	23.3 (= 2330 g CO_2 / l)
Diesel	26.4 (= 2640 g CO_2 / l)

5.4. Usage factors

If a technology is not activated to full extent during the whole time of vehicle's operation, a usage factor UF should be applied to the measured or modelled results of CO_2 savings:

5.4.1. Vehicle lighting

Type of lighting	usage factor UF
Low beam headlamp	0.33
High beam headlamp	0.03
Daytime running light (DRL)[7]	--
Front position	0.36
Fog – front	0.01
Turn signal - front	0.15
Turn signal - side	0.15
Centre High-Mount Stop Light (CHMSL) [8]	--
Rear position	0.36
Stop [10]	--
Fog – rear	0.01
Turn signal – rear	0.15
License plate	0.36
Reversing	0.01

5.4.2. Shading of solar panels

Vehicles equipped with photovoltaic panels may be shaded by buildings, trees, garages, etc. Hence, the maximum amount of solar radiation cannot be achieved. In this case the usage factor is: (1 – share of shading).

[7] DRL is mandatory for newly type-approved M1 and N1 vehicles since 7 February 2011 (Directive 2008/89/EC and Annex III to Regulation (EC) No 692/2008). DRL is automatically activated with running engine. Potential improvements of DRL technologies are therefore fully covered by the type approval measurements and cannot qualify for an eco-innovation.

[8] The temporal share of deceleration phases during the NEDC amounts to 15.1% in relation to roughly 11% of braking during 'real-world' conditions. Potential improvements of brake lights technologies are therefore fully covered by the type approval measurements and cannot qualify for an eco-innovation.

Effect	usage factor[9]
Irradiation of solar panels **(UF_{IR})**	0.51

5.4.3. Windscreen wipers

Speed of wiper motor	usage factor UF
low speed (front wiper)	0.08
high speed (front wiper)	0.02

5.5. Power requirements of lighting types

5.5.1. Halogen tungsten

Type of lighting	Number of lights[10]	Halogen tungsten	
		Nominal power per light [W] (12 V)	Total electric power [11] [W] (13.4 V)
Low beam headlamp	2	55	137
High beam headlamp	2	60	150
Daytime running light (DRL)[12]	2	21	52
Front position	2	5	12
Fog – front	2	55	124[13]
Turn signal – front (*)	2	21	13
Turn signal – side (*)	2	5	3
Centre High-Mount Stop Light (CHMSL) [14]	3	5	19
Rear position	2	5	12
Stop [15]	2	21	52
Fog – rear	1	21	26
Turn signal – rear (*)	2	21	13
License plate	2	5	12
Reversing	2	21	52

9 This usage factor is based on research done by the JRC in September 2012. It consists of two parts: 1. Average shading during parking 57%, 2. Average shading during driving 20%.

10 Turn signals (*): only one side activated

11 Turn signals (*): assuming a 50/50 flashing cycle

12 DRL is mandatory for newly type-approved M1 and N1 vehicles since 7 February 2011 (Directive 2008/89/EC and Annex III to Regulation (EC) No 692/2008). DRL is automatically activated with running engine. Potential improvements of DRL technologies are therefore fully covered by the type approval measurements and cannot qualify for an eco-innovation.

13 Based on input from CLEPA Light Sight Safety given in December 2012

14 The temporal share of deceleration phases during the NEDC amounts to 15.1% in relation to roughly 11% of braking during 'real-world' conditions. Potential improvements of brake lights technologies are therefore fully covered by the type approval measurements and cannot qualify for an eco-innovation.

5.5.2. Xenon gas discharge[15]

Type of lighting	Number of lights	Xenon high intensity gas discharge (HID)		
		Power per light [W]	Electronic driver [W]	Total electric power [W]
Low / high beam "Xenon 35 W"	2	35	5	80
Low / high beam "new Xenon 25 W"	2	25	5	60

5.6. Total electric power requirements

The vehicle's total electric power requirement during the NEDC testing under type-approval conditions differs from that one of averaged "real-word" driving.

Driving condition	Total electric power requirement [W]
Type-approval NEDC **(P_{TA})**[16]	350
Real-world driving **(P_{RW})**	750

5.7. Solar radiation

5.7.1. Solar radiation in Europe

Applications for technologies converting solar radiation into usable electric energy may use a uniform value. The annual average horizontal solar radiation for Europe on the earth's surface is:

Solar irradiation in Europe [W/m^2] **(P_{SR})**[17]	120

5.7.2. Solar correction coefficient

The gain of additional electric power depends on the electric on-board storage capacity. If the capacity is below 0.666 Ah per Watt peak power of the PV panel, the solar radiation arising on sunny and clear summer days cannot be used completely because of fully charged batteries. In this case a correction coefficient has to be applied to derive the usable share of the incoming solar energy.

Total storage capacity (12 V) / PV peak power [Ah/Wp][18]	0.10	0.20	0.30	0.40	0.50	0.60	> 0.666
Solar correction coefficient **(SCC)**	0.481	0.656	0.784	0.873	0.934	0.977	1

[15] The figures in this table are based on input from CLEPA Light Sight Safety given in December 2012.

[16] All switchable electrical consumers off.

[17] This minimum value covers more than 80 % of the population of the EU-27 countries.

[18] 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.

5.8. Ambient temperature

Mean ambient air temperature in Europe [°C] **(T_A)**[19]	14

5.9. Parking time distribution

	Parking times [h]											
	< 1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Share of vehicle stops [%] **(SVS)**	36	13	6	4	2	2	1	1	3	4	3	1

	Parking times [h]											
	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
Share of vehicle stops [%] **(SVS)**	1	3	3	2	1	1	1	1	1	1	1	1

(> 24 h: 7 %)

5.10. Mileages

The mean annual driven mileages for passenger cars in Europe (EU-27) are:

Type of fuel	Mean annual mileage [km/a]
Petrol **(M_P)**	12,700
Diesel **(M_D)**	17,000
LPG **(M_L)**	22,300

6. Qualification of technologies

In the following, a first, preliminary and not binding, assessment on the potential qualification of vehicle technologies as "eco-innovation" is given. 'Potentially qualifying' technologies may be linked to certain conditions that are cited in the table in Chapter 6.1. If a technology is assessed as 'potentially non-qualifying', the reasons for this assessment are cited in the table in Chapter 6.2.

6.1. Potentially qualifying technologies

No.	Technology	Technology class	Conditions
Q01	Engine heat storage	4	
Q02	LED lighting	1	Also packaging of different lighting types will fulfil 'verifiability' criterion
Q03	Battery charging solar roof	3	
Q04	Efficient alternator	6	Verifiability criterion to be fulfilled
Q05	Thermoelectric generator	5	Coverage criterion to be fulfilled

6.2. Potentially non-qualifying technologies

[19] This value includes a security margin to cover uncertainties caused by regional differences of ambient temperatures and uncertainties on the share of vehicles parked inside garages at higher temperatures.

No.	Technology	Technology class	Reasons for non-qualification
N01	Recuperation	6	2.2 - ‘Innovativeness’ criterion not fulfilled
N02	Efficient seat heating	1	2.3 - ‘Necessity’ criterion not fulfilled
N03	Efficient HiFi system	1	2.3 - ‘Necessity’ criterion not fulfilled
N04	Efficient PTC cabin heater	1	2.3 - ‘Necessity’ criterion not fulfilled
N05	Efficient cabin lighting	1	2.4 - ‘Verifiability criterion not fulfilled
N06	Efficient wiper motor	1	2.4 - ‘Verifiability criterion not fulfilled
N07	Start/Stop system	7	2.5 - ‘Coverage’ criterion not fulfilled
N08	Electronic valve gear	2	2.5 - ‘Coverage’ criterion not fulfilled
N09	Flywheel	4	2.5 - ‘Coverage’ criterion not fulfilled
N10	Eco-driving mode	7	2.6 - ‘Accountability’ criterion not fulfilled
N11	Gear shift indicator	7	2.1 - ‘Integrated approach measure’ + 2.6 - ‘Accountability’ criterion not fulfilled
N12	Efficient air-conditioning system	2	2.1 - ‘Integrated approach measure’ + 2.3 - ‘Necessity’ criterion not fulfilled
N13	Tyre pressure monitor	2	2.1 - ‘Integrated approach measure’ + 2.6 - ‘Accountability’ criterion not fulfilled
N14	Low rolling resistance tyres	2	2.1 - ‘Integrated approach measure’ + 2.5 - ‘Coverage’ criterion not fulfilled
N15	Daytime running lights (DRL)	1	2.5 - ‘Coverage’ criterion not fulfilled
N16	Brake lights	1	2.5 - ‘Coverage’ criterion not fulfilled

7. Application procedure - checklist

Before submission, every applicant should ensure that the application includes the items indicated in Article 4 of Regulation (EU) No 725/2011. It should be stressed that the assessment of the application will only start if it is complete. The application should also clearly indicate any parts that are confidential.

7.1. Application

The following documents and data should be provided with an application for assessment of an innovative technology:

- name and address and contact person of the applicant
- choice of type of testing methodology:
  - simplified approach
  - comprehensive methodology
- a summary of the application for publication (template summary description of the application is provided in Appendix)
- list of supporting documentation
- technical description of the eco-innovation and the way it is fitted on a vehicle, verbalised and by technical drawings
- prediction on which vehicle segments the eco-innovation will be applied (estimate only)
- expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale (estimate only)
- identification of the baseline technology for the envisaged vehicle segments
- technical description of the baseline technology
- check if all eligibility criteria specified in Article 2 and Article 4(2)(e), (f) and (g) of Regulation (EU) No 725/2011 and described in Chapter 2 of these guidelines are fulfilled; reasons and evidential data have to be provided for each of them
  - non-exceeding requirements in EU law
  - innovativeness of technology
  - necessity of technology (non-comfort)
  - verifiability of CO_2 saving (minimum threshold)
  - coverage (type approval procedure)
  - accountability (influence of driver)
- description of testing methodology (modelling / measurements)
- description of the calculation procedure for the case study
- resulting CO_2 savings (differentiated per envisaged vehicle segment, where relevant)
- check and quantification of possible interactions with CO_2 savings from other eco-innovations that are already granted or envisaged for application
- verification report from an independent certification body, including
  - testing protocols of all relevant measurements
  - check of possible interactions with other innovative technologies
- In the case of the comprehensive methodology the applicant should also provide:
  - detailed technical data of case study vehicle(s) (see Chap. 4.1)
  - data about experimental analyses of deterioration effects or sound argumentation in case of non-existence
  - comprehensive uncertainty analyses and quantification of statistical errors
  - a verification report including the following additional tasks:
    - check of suitability of the testing methodology for determining the CO_2 savings from the eco-innovation
    - check of possible deterioration effects
    - check of suitability of parametric function (if CO_2 saving depends on one or more vehicle parameters)
    - check of fulfilment of the eligibility criteria

8. Examples

The calculation examples in this chapter are following the ‘simplified approach’. They give advice to potential applicants on extent and level of detail of the submitted documents for individual technologies and on the calculation procedure. Generic data being defined in Chapter 5 is used here. The list of technologies currently cited is not finalised and may be complemented on demand.

All data used for the following examples being not included in Chapter 5 must be seen as purely arbitrary. The values might not be taken for the applications. Instead, profound data justified by measurements or from other reliable sources has to be used.

8.1. Efficient wiper motor

Technical description of the innovative technology
The efficiency of the wiper motor has been improved by 50 % by applying the following measures:
- ***TO INSERT HERE***: *applicant provides technical description of the measures applied including technical drawings*

The electric power requirement of the fitted innovative wiper motor (operated at low power level) is: **50 W**.
The electric power requirement of the fitted innovative wiper motor (operated at high power level) is: **75 W**.

The electric power requirement is not varying between different vehicle versions.
- ***TO INSERT HERE***: *applicant provides technical explanation*

Market Segment

The expected up-take of the innovative technology in different segments.

- ***TO INSERT HERE***: *applicant provides an estimate*

Innovativeness

The market share of the innovative technology does not exceed 3 % in the reference year 2009.
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the innovative technology in the reference year.*

Definition of the baseline technology

The baseline wiper motor with the highest market penetration in the reference year is:
- TO INSERT HERE*: applicant provides label and short technical description of the baseline technology*
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the baseline technology in the reference year.*

The electric power requirement of the fitted baseline wiper motor (operated at low power level) is: **100 W**.
The electric power requirement of the fitted baseline wiper motor (operated at high power level) is: **150 W**.

Calculation procedure

Input data:
- saved electric power:
    - low power level: $\boldsymbol{\Delta P_L}$ = 100 W – 50 W = **50 W**
    - high power level: $\boldsymbol{\Delta P_H}$ = 150 W – 75 W = **75 W**

- usage factors (Chap. 5.4.3):
    - low power level: **UF_L = 0.08**
    - high power level: **UF_H = 0.02**

- mean driving speed of the NEDC (Chap. 5.2): **v = 33.58 km/h**

- consumption of effective power for petrol-driven vehicles (Chap. 5.1.1): **$V_{Pe\text{-}P}$ = 0.264 l/kWh**

- efficiency of the alternator (Chap. 5.1.2): **η_A = 0.67**

- conversion factor (l / 100 km) → (g CO_2 / km) for petrol fuel (Chap. 5.3.2): **CF_p = 2330 g CO_2 / l**

Calculation of the CO_2 saving per petrol-engined vehicle:

- $\mathbf{C_{CO2} = (\Delta P_L \cdot UF_L + \Delta P_H \cdot UF_H) \cdot V_{Pe\text{-}P} / \eta_A \cdot CF_p / v}$
  $= (50\ W \cdot 0.08 + 75\ W \cdot 0.02) \cdot 0.264\ l/kWh / 0.67 \cdot 2330\ g/l / 33.58\ km/h$
  $= 0.1504\ g\ CO_2 / km$

Result, rounded to one decimal place:

C_{CO2} = 0.2 g CO_2 / km

Check of eligibility criteria

1. Non-exceeding requirements in EU law:
Currently there is no legislation about CO_2 saving requirements on wiper motors.

→ FULFILLED

2. Innovativeness:
It has been demonstrated that the market penetration of the eco-innovation technology does not exceed 3 % in the reference year.

→ FULFILLED

3. Necessity:
Windscreen wipers are essential for the safe operation of the vehicle (no further documents necessary)

→ FULFILLED

4. Verifiability:
The unrounded CO_2 saving of the eco-innovation technology of 0.1504 g CO_2 / km does not exceed the minimum threshold of 1 g CO_2 / km.

→ **NOT FULFILLED**

5. Coverage:
The eco-innovation technology is not covered by the CO_2 type approval test procedure, since the activation of windscreen wipers is not included in the current CO_2 type approval test procedure.

→ FULFILLED

6. Accountability:
Windscreen wipers are under the influence of the driver's choice, but they belong to devices which have to be activated because of changing ambient conditions (rainfall) to ensure a safe operation of the vehicle.

→ FULFILLED

Total result:
The application cannot be granted because of non-compliance with the 'verifiability' criteria.

8.2. LED exterior lighting

Technical description of the innovative technology

For different types of exterior lighting the baseline halogen tungsten lamps are replaced by LED lamps. The combination of different lighting types is considered as a technology ‘package’.

- Daytime running lights (DRL) cannot be included in such a package since they became mandatory for newly type-approved M1 and N1 vehicles on 7 February 2011. Therefore DRL are fully covered by type approval measurements and do not qualify for an innovative technology.

- Brake lights cannot be included since their temporal share of activation during the NEDC fully covers the average use during on-road operation.

- ***TO INSERT HERE****: applicant provides technical description of the measures applied including data on electrical power requirements and technical drawings*

By this example, the electric power requirements of the fitted innovative LED technologies inclusive of required control and cooling units are:

Type of lighting	**Electric power [W]**
Low beam headlamp	40
High beam headlamp	40
Front position	2
Fog – front	25
Turn signal - front	2.5
Turn signal - side	0.5
Fog – rear	3
Turn signal – rear	1.5
License plate	2
Reversing	4

- ***TO INSERT HERE****: applicant provides measurement protocols verified by an independent technical body*

The electric power requirement is not varying between different vehicle versions.
- ***TO INSERT HERE****: applicant provides technical explanation*

Market Segment

The expected up-take of the innovative technology in different segments.

- ***TO INSERT HERE****: applicant provides an estimate*

Innovativeness

The market share of the innovative technology does not exceed 3 % in the reference year 2009.
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the innovative technology in the reference year.*

Definition of the baseline technology

The baseline lighting technology with the highest market penetration in the reference year is:
- TO INSERT HERE*: applicant provides label and short technical description of the baseline technology for each type of lighting. The table in this paragraph which is called ‘Innovative lighting technologies and estimated fitting rates in 2009’ can be used as an input for that.*
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the baseline technology in the reference year for each type of lighting*

The electric power requirements of the fitted baseline technologies related to an on-board voltage of 13.4 V are (Chap. 5.5.1):

Type of lighting	**Electric power [W]**
Low beam headlamp	137
High beam headlamp	150
Front position	12
Fog – front	124
Turn signal - front	13
Turn signal - side	3
Fog – rear	26
Turn signal – rear	13
License plate	12
Reversing	52

Calculation procedure
(Example: low beam lighting)

Input data:

- saved electric power: **ΔP** = 137 W – 40 W = **97 W**
- usage factor (Chap. 5.4.1): **UF = 0.33**
- mean driving speed of the NEDC (Chap. 5.2): **v = 33.58 km/h**
- consumption of effective power for petrol-fuelled vehicles (Chap. 5.1.1): $\mathbf{V_{Pe\text{-}P} = 0.264}$ **l/kWh**
- consumption of effective power for diesel-fuelled vehicles (Chap. 5.1.1): $\mathbf{V_{Pe\text{-}D} = 0.22}$ **l/kWh**
- efficiency of the alternator (Chap. 5.1.2): η_A **= 0.67**
- conversion factor (l / 100 km) → (g CO_2 / km) for petrol fuel (Chap. 5.3.2): $\mathbf{CF_p}$ **= 2330 g** $\mathbf{CO_2}$ **/ l**
- conversion factor (l / 100 km) → (g CO_2 / km) for diesel fuel (Chap. 5.3.2): $\mathbf{CF_D}$ **= 2640 g** $\mathbf{CO_2}$ **/ l**

Calculation of the CO_2 saving per petrol-fuelled vehicle:

- $\mathbf{C_{CO2} = \Delta P \cdot UF \cdot V_{Pe\text{-}P} / \eta_A \cdot CF_p / v}$
  = 97 W · 0.33 · 0.264 l/kWh / 0.67 · 2330 g/l / 33.58 km/h
  = 0.8752 g CO_2 / km

Calculation of the CO_2 saving per diesel-fuelled vehicle:

- $\mathbf{C_{CO2} = \Delta P \cdot UF \cdot V_{Pe\text{-}D} / \eta_A \cdot CF_D / v}$
  = 97 W · 0.33 · 0.22 l/kWh / 0.67 · 2640 g/l / 33.58 km/h
  = 0.8264 g CO_2 / km

Results for all types of exterior lighting:

Type of lighting	Usage factor	CO_2 saving petrol [g/km]	CO_2 saving diesel [g/km]
Low beam headlamp	0.33	0,8752	0,8264
High beam headlamp	0.03	0,0902	0,0852
Front position	0.36	0,0985	0,0929
Fog – front	0.01	0,0270	0,0255
Turn signal - front	0.15	0,0431	0,0407
Turn signal - side	0.15	0,0102	0,0096
Fog – rear	0.01	0,0062	0,0059
Turn signal – rear	0.15	0,0471	0,0445
License plate	0.36	0,0985	0,0929
Reversing	0.01	0.0131	0.0124

Total CO_2 savings as sum of savings of all individual types of lighting (package):

- Petrol-fuelled vehicles: $\mathbf{C_{CO2}}$ = 1.3091 g CO_2 / km
- Diesel-fuelled vehicles: $\mathbf{C_{CO2}}$ = 1.2360 g CO_2 / km

Results, rounded to one decimal place:

Petrol: **C_{CO2} = 1.3 g CO_2 / km**

Diesel: **C_{CO2} = 1.2 g CO_2 / km**

Check of eligibility criteria

1. Non-exceeding requirements in EU law:
Currently there is no legislation about CO_2 saving requirements on exterior lighting.

→ FULFILLED

2. Innovativeness:
It has been demonstrated that the market penetration of the eco-innovation technologies included in the technology package do not exceed 3 % in the reference year. → FULFILLED

3. Necessity:
Exterior lighting is essential for the safe operation of the vehicle (no further documents necessary).

→ FULFILLED

4. Verifiability:
The unrounded total CO_2 savings of the eco-innovation technology as a package exceed the minimum threshold of 1 g CO_2 / km.

→ FULFILLED

5. Coverage:
The eco-innovation technology is not covered by the CO_2 type approval test procedure, since the activation of exterior lighting is not included in the current CO_2 type approval test procedure (except DRL and brake lights).

→ FULFILLED

6. Accountability:
Exterior lightings are under the influence of the driver's choice, but they belong to devices which have to be activated because of changing ambient conditions (e.g. darkness) and to ensure a safe operation of the vehicle.

→ FULFILLED

Total result:
The application can be granted.

Innovative lighting technologies and estimated fitting rates in 2009

Application	**Technology**	**Estimated Fitting rate*** *(new cars, EU 2009)*
Low beam	LED	<1%
	Xenon (D1/D2) *Mercury-containing*	~13%
	Xenon (D3/D4) *Mercury-free*	~2%
	Xenon (D5/D6/D8) *Low-power (25W)*	0%
High beam	LED	<1%
	Xenon (D1/D2) *Mercury-containing*	~13%
	Xenon (D3/D4) *Mercury-free*	~2%
	Xenon (D5/D6/D8) *Low-power (25W)*	0%
Front position	LED	~2%
Front Fog	LED	<1%
Turn signal, front	LED	<2%
Tail	LED	>15%
Rear Fog	LED	<1%
Turn signal, rear	LED	~3%
License plate	LED	<1%
Reversing	LED	<1%

* The headlamp and rear lamp suppliers of the *Light.Sight.Safety*-initiative have individually estimated the penetration rates of innovative technologies in the different lighting applications, based on the production numbers in the EU for the year 2009. In a subsequent market review these numbers have been condensed to a single value per application and technology.
The result can be considered as representative because the above mentioned companies cover roughly ¾ of the total automotive lighting market in Europe. *Light.Sight.Safety* does not see any other method or possibility, which would deliver more relevant numbers – especially regarding the uncertainty between "new car registration" and "lamp production".

CLEPA *Light.Sight.Safety*
March 2nd, 2012

8.3. Battery charging solar roof

Technical description of the innovative technology

A photovoltaic (PV) panel is integrated in the roof of the vehicle. The incoming solar radiation during the day is converted to electric energy which is stored in a supplementary battery. During the operation of the vehicle the stored energy is fed into the on-board grid and the alternator's burden gets reduced.

- ***TO INSERT HERE****: applicant provides technical description of the measures applied including technical drawings*

The electric power production depends on the surface area of the PV panel. Variations between different vehicle versions have to be taken into account by the usage of a parametric function.

- ***TO INSERT HERE****: applicant provides technical explanation*

The usable share of the incoming solar radiation depends on the electric storage capacity of the supplementary battery. Variations between different vehicle versions have to be taken into account by the usage of a parametric function.

- ***TO INSERT HERE****: applicant provides technical explanation*

Market Segment

The expected up-take of the innovative technology in different segments.

- ***TO INSERT HERE****: applicant provides an estimate*

Innovativeness

The market share of the innovative technology does not exceed 3 % in the reference year 2009.

- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the innovative technology in the reference year.*

Definition of the baseline technology

The baseline technology is the standard technology without eco-innovation technology (PV panel roof and supplementary battery).

Measurements:

The peak power output of the PV panel has to be determined experimentally for each vehicle variant. This is because of the individual characteristics concerning PV roof surface area, curvature, materials and panel efficiencies. Measurements should be performed following norm IEC 61215 under supervision of an independent and certified body. A dismantled complete PV panel should be used. The four corner points of the panel should touch the horizontal measurement plane. A possible lengthwise inclination of the car roof may be corrected mathematically afterwards by applying a cosine function.

Example:

The measurements of a dismantled PV module under IEC 61215 result in a peak power output of 101.0 Wp. The lengthwise inclination of the implemented solar roof is 8°. The peak power output of the PV panel used for the certification process may be calculated by:

101.0 Wp x cos (8°) = 100.0 Wp

- TO INSERT HERE*: applicant provides proving documents (measurement protocols) on the peak power output of a specific PV roof panel. The protocol should be attested by an independent and certified body. It should contain all necessary technical data (like surface area, curvature angles, materials, efficiencies etc.) to enable a clear identification of the PV panel.*

Calculation procedure

Input data:

- mean solar irradiation (Chap. 5.7.1): $\mathbf{P_{SR} = 120\ W/m^2}$
- usage factor / shading effect (Chap. 5.4.2): $\mathbf{UF_{IR} = 0.51}$
- efficiency of the solar system (Chap. 5.1.3): $\mathbf{\eta_{SS} = 0.76}$

- peak power of the photovoltaic panel: $\mathbf{P_P = 100\ Wp = 100\ W / 1000\ W/m^2}$

- nominal capacity of the supplementary battery (12 V): $\mathbf{C_N = 30\ Ah}$
- total storage capacity including a mean usable capacity of the starter battery of 10 Ah (12V):
  $C_N + 10\ Ah = 40\ Ah$
- $\mathbf{(C_N + 10\ Ah) / P_P = 0.4\ Ah/Wp}$ → solar correction coefficient (Chap. 5.7.2): **SCC = 0.873**

- consumption of effective power for petrol-fuelled vehicles (Chap. 5.1.1): $\mathbf{V_{Pe\text{-}P} = 0.264\ l/kWh}$
- consumption of effective power for diesel-fuelled vehicles (Chap. 5.1.1): $\mathbf{V_{Pe\text{-}D} = 0.22\ l/kWh}$

- efficiency of the alternator (Chap. 5.1.2): $\mathbf{\eta_A = 0.67}$

- conversion factor (l / 100 km) → (g CO_2 / km) for petrol fuel (Chap. 5.3.2): $\mathbf{CF_p = 2330\ g\ CO_2 / l}$
- conversion factor (l / 100 km) → (g CO_2 / km) for diesel fuel (Chap. 5.3.2): $\mathbf{CF_p = 2640\ g\ CO_2 / l}$

- mean annual mileage for petrol-fuelled vehicles (Chap. 5.11): $\mathbf{M_P = 12{,}700\ km/a = 1449.8\ m/h}$
- mean annual mileage for diesel-fuelled vehicles (Chap. 5.11): $\mathbf{M_D = 17{,}000\ km/a = 1940.6\ m/h}$

Calculation of the CO_2 saving per **petrol**-fuelled vehicle:

- $\mathbf{C_{CO2} = P_{SR} \cdot UF_{IR} \cdot \eta_{SS} \cdot P_P \cdot SCC \cdot V_{Pe\text{-}P} / \eta_A \cdot CF_p / M_P}$
  $= 120\ W/m^2 \cdot 0.51 \cdot 0.76 \cdot 100\ W / 1000\ W/m^2 \cdot 0.873 \cdot 0.264\ l/kWh / 0.67 \cdot 2330\ g/l / 1449.8\ m/h$
  $= 2.5720\ g\ CO_2 / km$

Calculation of the CO_2 saving per **diesel**-fuelled vehicle:

- $\mathbf{C_{CO2} = P_{SR} \cdot UF_{IR} \cdot \eta_{SS} \cdot P_P \cdot SCC \cdot V_{Pe\text{-}D} / \eta_A \cdot CF_D / M_D}$
  $= 120\ W/m^2 \cdot 0.51 \cdot 0.76 \cdot 100\ W / 1000\ W/m^2 \cdot 0.873 \cdot 0.22\ l/kWh / 0.67 \cdot 2640\ g/l / 1940.6\ m/h$
  $= 1.8169\ g\ CO_2 / km$

Results, rounded to one decimal place:

Petrol: $\mathbf{C_{CO2} = 2.6\ g\ CO_2 / km}$
Diesel: $\mathbf{C_{CO2} = 1.8\ g\ CO_2 / km}$

Check of eligibility criteria

1. Non-exceeding requirements in EU law:
Currently there is no legislation about mandatory solar roofs.
→ FULFILLED

2. Innovativeness:
It has been demonstrated that the market penetration of the eco-innovation technology does not exceed 3 % in the reference year. → FULFILLED

3. Necessity:
Photovoltaic panels convert ambient energy (solar radiation) into usable electric energy.
→ FULFILLED

4. Verifiability:

The unrounded CO_2 savings of the eco-innovation technology exceed the minimum threshold of 1 g CO_2 / km.

→ FULFILLED

5. Coverage:
The eco-innovation technology is not covered by the CO_2 type approval test procedure, since the process of battery charging by solar radiation during parking time is not included in the current CO_2 type approval test procedure.

→ FULFILLED

6. Accountability:
The processes of charging a supplementary battery by solar radiation and discharging this battery under driving conditions are not under the influence of the driver's choice.

→ FULFILLED

Total result:
The application can be granted.

8.4. Efficient alternator

Technical description of the innovative technology
The efficiency of an alternator of the output class ≤ 135 A has been improved by 5 % by optimising the rectification by the use of "high efficient diodes" and by "active rectification".
- ***TO INSERT HERE****: applicant provides technical description of the measures applied including technical drawings*

The efficiency of the new alternator **($\eta_{A\text{-}EI}$)** is: **0.72** (determination pursuant to the VDA methodology).
- ***TO INSERT HERE****: applicant provides measurement protocols verified by an independent technical body*

The CO_2 saving effect is restricted to vehicles that are equipped with this special type of alternator. It does not vary between different vehicle versions, if the vehicles' consumption on electric power does not differ. The effect is partially covered by the type-approval test procedure. The electric power demand during "real-world" driving exceeds that one of NEDC testing. Therefore the total CO_2 saving is not fully reflected by the type approval results.

Market Segment

The expected up-take of the innovative technology in different segments.
- ***TO INSERT HERE****: applicant provides an estimate*

Innovativeness

The market share of the innovative technology does not exceed 3 % in the reference year 2009.
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the innovative technology in the reference year.*

Definition of the baseline technology
The baseline alternator of the specific output class with the highest market penetration in the reference year is:
- TO INSERT HERE*: applicant provides label and short technical description of the baseline technology*
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the baseline technology in the reference year.*

The efficiency of the baseline alternator **(η_A)** is: **0.67** (determination pursuant to the VDA methodology).
- ***TO INSERT HERE****: applicant provides measurement protocols verified by an independent technical body*

Calculation procedure

Input data:

- vehicle's total electric power requirement under "real-world" conditions (Chap. 5.6): **P_{RW} = 750 W**
- vehicle's total electric power requirement under type-approval conditions (NEDC): **P_{TA} = 350 W**

- mean driving speed of the NEDC (Chap. 5.2): **v = 33.58 km/h**

- Consumption of effective power for petrol-fuelled vehicles (Chap. 5.1.1): **$V_{Pe\text{-}P}$ = 0.264 l/kWh**
- Consumption of effective power for diesel-fuelled vehicles (Chap. 5.1.1): **$V_{Pe\text{-}D}$ = 0.22 l/kWh**

- Conversion factor (l / 100 km) → (g CO_2 / km) for petrol fuel (Chap. 5.3.2): **CF_p = 2330 g CO_2 / l**
- Conversion factor (l / 100 km) → (g CO_2 / km) for diesel fuel (Chap. 5.3.2): **CF_D = 2640 g CO_2 / l**

Calculation of the saved mechanical power under "real-world" conditions:

- $\Delta P_{m\text{-}RW} = (P_{RW} / \eta_A) - (P_{RW} / \eta_{A\text{-}El})$
  $= (750\ W / 0.67) - (750\ W / 0.72) = 77.74\ W$

Calculation of the saved mechanical power under type-approval conditions:

- $\Delta P_{m\text{-}TA} = (P_{TA} / \eta_A) - (P_{TA} / \eta_{A\text{-}El})$
  $= (350\ W / 0.67) - (350\ W / 0.72) = 36.28\ W$

Calculation of the accountable share of saved mechanical power:

- $\Delta P_m = \Delta P_{m\text{-}RW} - \Delta P_{m\text{-}TA}$
  $= 77.74\ W - 36.28\ W = 41.46\ W$

Calculation of the CO_2 saving per **petrol**-fuelled vehicle:

- $C_{CO2} = \Delta P_m \cdot V_{Pe\text{-}P} \cdot CF_p / v$
  $= 41.46\ W \cdot 0.264\ l/kWh \cdot 2330\ g/l / 33.58\ km/h$
  $= 0.7595\ g\ CO_2 / km$

Calculation of the CO_2 saving per **diesel**-fuelled vehicle:

- $C_{CO2} = \Delta P_m \cdot V_{Pe\text{-}D} \cdot CF_D / v$
  $= 41.46\ W \cdot 0.22\ l/kWh \cdot 2640\ g/l / 33.58\ km/h$
  $= 0.7171\ g\ CO_2 / km$

Results, rounded to one decimal place:

Petrol: **C_{CO2} = 0.8 g CO_2 / km**
Diesel: **C_{CO2} = 0.7 g CO_2 / km**

Check of eligibility criteria

1. Non-exceeding requirements in EU law:
Currently there is no legislation about minimum requirements on efficiencies of alternators.

→ FULFILLED

2. Innovativeness:

It has been demonstrated that the market penetration of the eco-innovation technology does not exceed 3 % in the reference year. → FULFILLED

3. Necessity:
Alternators are essential for the on-board production of electric energy and, therefore, are essential for the safe operation of the vehicle (no further documents necessary).
→ FULFILLED

4. Verifiability:
The unrounded CO_2 savings of the eco-innovation technology of 0.7595 g CO_2 / km (petrol-fuelled) resp. 0.7171 g CO_2 / km (diesel-fuelled) do not exceed the minimum threshold of 1 g CO_2 / km.
→ **NOT FULFILLED**

5. Coverage:
The eco-innovation technology is partially covered by the CO_2 type approval test procedure, since the alternator is also activated during the NEDC to compensate the power requirement of all non-switchable electric devices. The CO_2 saving effect occurring under type-approval conditions has been subtracted from the total "real-world" effect.
→ FULFILLED

The on-board energy management and the activation of the alternator are not under the influence of the driver's choice.
→ FULFILLED

Total result:

The application cannot be granted because of non-compliance with the 'verifiability' criteria.

Below two calculations are given on fictive examples to illustrate that value of the baseline alternator is rather sensitive when this baseline alternator is replaced by an alternator with a higher efficiency.

A. An alternator is replaced by an alternator with a higher efficiency.

An alternator with an efficiency of 77% is introduced.
When this alternator replaces a baseline alternator with an efficiency of 67%, then you will get

$\mathbf{\Delta P_{m\text{-}TA} = (P_{TA} / \eta_A) - (P_{TA} / \eta_{A\text{-}El})}$ = (350 W / 0.67) – (350 W / 0.77) = 67.9 W ……….. 1)

When this alternator replaces a baseline alternator of 71%, then you will get

$\mathbf{\Delta P_{m\text{-}TA} = (P_{TA} / \eta_A) - (P_{TA} / \eta_{A\text{-}El})}$ = (350 W / 0.71) – (350 W / 0.77) = 38.5 W ……….. 2)

The difference between 1) and 2) is 43.3 %.

B. The CO_2-effect of a new electric device is calculated (for instance LED).

Due to LED lighting a saving is realized of 97 W.
With a baseline alternator with an efficiency of 67% this leads to:

$\mathbf{C_{CO2} = \Delta P \cdot UF \cdot V_{Pe\text{-}P} / \eta_A \cdot CF_p / v}$
= 97 W · 0.33 · 0.264 l/kWh / 0.67 · 2330 g/l / 33.58 km/h = 0.8752 g CO_2/km................ 3)

And with a baseline alternator of 71% this leads to:

$\mathbf{C_{CO2} = \Delta P \cdot UF \cdot V_{Pe\text{-}P} / \eta_A \cdot CF_p / v}$

= 97 W · 0.33 · 0.264 l/kWh / 0.71 · 2330 g/l / 33.58 km/h = 0.8259 g CO_2 / km .... 4)

The difference between 3) and 4) is 5.6 %.

The conclusion is that the value of the baseline alternator is rather sensitive when an alternator is replaced by another alternator. For the calculation of the benefits of electric devices this effect is less sensitive.
Therefor two measurements are needed when an alternator replaces another alternator: the measurement of the baseline alternator and the measurement of the high efficient alternator.

8.5 Engine heat storage

Technical description of the innovative technology
The vehicle's engine gets enclosed by insulating material to delay heat dissipation. The cooling down process of the engine after cutoff gets decelerated. Hence, re-starting the engine after a certain parking time can be done at a higher engine temperature which reduces friction losses and fuel consumption.
- ***TO INSERT HERE****: applicant provides technical description of the measures applied including technical drawings*

The cooling behaviour of a vehicle's engine after cutoff can be described mathematically by the following equation:

$$T(t) = (T_O - T_A) \cdot e^{(-d \cdot t)} + T_A$$

with:
T(t): temperature over time [°C]
T_O: temperature of the operating engine [°C]
T_A: ambient temperature [°C]
d: decay constant [1/h]

The CO_2 saving effect depends on the temperature difference between the eco-innovation (EI) vehicle with and the baseline vehicle without insulated engine after a certain parking time. The temperature difference gets multiplied by a CO_2 reduction factor (RFT) which describes the relation between CO_2 reduction and increased starting temperature. Finally the temporally resolved CO_2 reductions have to be aggregated by weighting with an averaged parking time distribution.

Market Segment

The expected up-take of the innovative technology in different segments.
- ***TO INSERT HERE****: applicant provides an estimate*

Innovativeness

The market share of the innovative technology does not exceed 3 % in the reference year 2009.
- TO INSERT HERE*: applicant provides proving documents and/or data or an expert judgement on the market share of the innovative technology in the reference year.*

Definition of the baseline technology
The baseline technology is the standard technology without eco-innovation technology (without engine compartment encapsulation).

Measurements:
I) The **cool-down curves** of both the baseline and the EI vehicle have to be determined experimentally for each vehicle variant. This is because of the individual characteristics concerning heat capacities, engine bay packaging and engine heat insulation. Continuous measurements of representative coolant temperatures by means of a thermocouple should be performed at constant ambient temperature of at least 14°C over 24 hours (Chap. 5.8.). The engine should be heated up to the maximum coolant temperature before cutoff by a sufficient

number of consecutive NEDC cycles. After preconditioning, for deactivation of all pumps and fans, the ignition should be switched off and the dash key pulled out. The car's bonnet should be closed completely. Any artificial ventilation systems inside the test cell should be switched off. All measurements should be performed under supervision of an independent and certified body. The resulting measurement curves should be converged by the mathematical approach described by the formula above. The least squares method should be used for the fitting of the two curves. To do that, the temperature measurement data of the first 20 minutes after engine cutoff should be cut because of the untypical behaviour of the coolant temperature after switching off the coolant circuit.

Example:
The measured coolant curve of the baseline vehicle (without heat storage measures) has been approached by a decay constant of d_B = 0.5 /h. The measured coolant curve of the EI vehicle has been approached by a decay constant of d_E = 0.3 /h.

***- TO INSERT HERE**: applicant provides proving documents (measurement protocols) on the cool-down curves and the converged mathematical functions including decay constants. The documents should be attested by an independent and certified body. They should contain all necessary technical data (chassis, engine etc.) to enable a clear identification of the surveyed vehicles.*

II) The **hot start benefit (HSB)** of the EI vehicle has to be determined experimentally. This value describes the difference of CO_2 emissions between a cold start and a hot start NEDC test in relation to the cold start result:

$$HSB = 1 - \frac{CO_2(hot)}{CO_2(14°C)}$$

The coolant temperature at the beginning of the cold start test and the ambient temperature in the test cell should not be below 14°C (Chap. 5.8). The hot start NEDC test should be conducted following the cold start NEDC test. It is possible to perform one or two preconditioning NEDC tests between the cold start and the hot start NEDC test. It should be ensured and documented that the state of charge (SOC) (e.g. CAN signal) of the starter battery after each test is within 5%. The complete test procedure should be repeated at least two times. Arithmetic means of the cold start and of the hot start CO_2 results and the respective variation coefficients of the means should be calculated. Further test repetitions of the NEDC tests are required as long as the variation coefficients of both arithmetic means are below 1%. All measurements should be performed under supervision of an independent and certified body.

Example:

CO_2 [g/km]	**Cold start NEDC (14°C)**	**Hot start NEDC**
1. Test	136	116
2. Test	140	120
3. Test	134	119
Arithmetic mean	136.7	118.3
Variation coefficient of mean	1.29%	1.02%
4. Test	138	117
Arithmetic mean	137	118
Variation coefficient	0.94%	0.80%

HSB = 1 – 118 g/km / 137 g/km = 13.87%

***- TO INSERT HERE**: applicant provides proving documents (measurement protocols) on the cold and hot start NEDC tests including coolant temperatures at the beginning of the test and SOC at the beginning and the end of each test. The documents should be attested by an independent and certified body. They should contain all necessary technical data (chassis, engine etc.) to enable a clear identification of the surveyed vehicle.*

<u>Calculation procedure</u>

Input data:

- decay constant of baseline vehicle: **d_B = 0.5 /h**
- decay constant of eco-innovation (EI) vehicle: **d_E = 0.3 /h**
- hot start benefit: **HSB = 13.87 %**
- parking time distribution (share of vehicle stops): **SVS** - see Chap. 5.10
- CO_2 type approval value: **TA_{CO2} = 130 g/km**

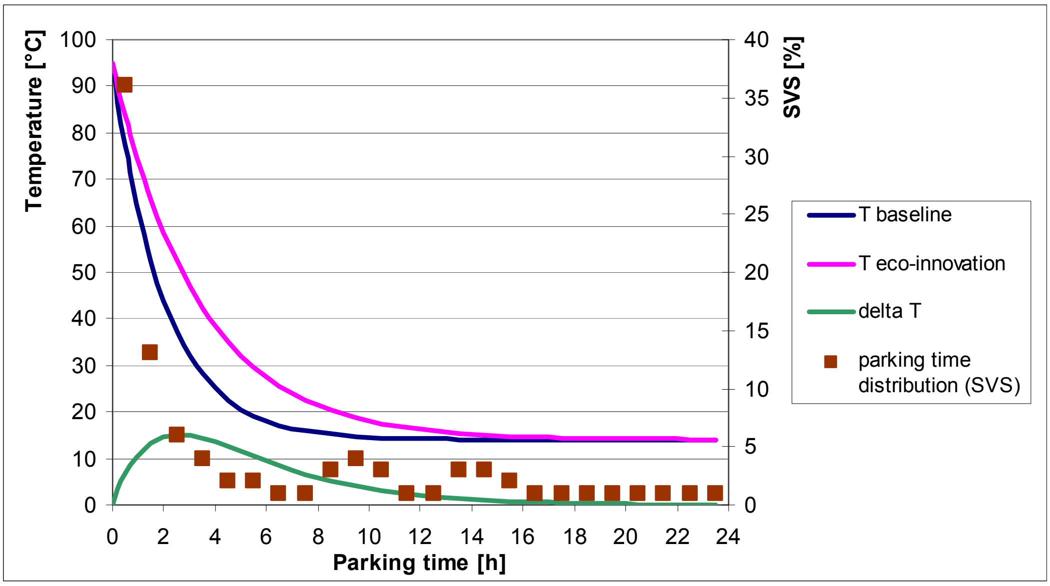

Figure 1: Cool-down curves of baseline and eco-innovation technologies, temperature differences and parking time distribution

Calculation of the relative CO_2 reduction potential $\Delta CO_2(t)$ for different parking times:

$$\Delta CO_2 = 1{,}443 \cdot \ln\left(\frac{e^{(-d_E \cdot t)} + 1}{e^{(-d_B \cdot t)} + 1}\right) \cdot HSB$$

Parking time [h]	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
$\Delta CO_2(t)$ [%]	0.90	2.13	2.70	2.80	2.61	2..8	1.90	1.54	1.22	0.95	0.73	0.56

Parking time [h]	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5
$\Delta CO_2(t)$ [%]	0.43	0.32	0.24	0.18	0.14	0.10	0.08	0.06	0.04	0.03	0.02	0.02

Calculation of the total CO_2 saving, weighted by the parking times (pt):

$$C_{CO2} = TA_{CO2} \cdot \sum_{pt=1}^{24} \Delta CO_2(t)_{pt} \cdot SVS_{pt}$$

Parking time [h]	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
SVS [%]	36	13	6	4	2	2	1	1	3	4	3	1

Parking time [h]	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5
SVS [%]	1	3	3	2	1	1	1	1	1	1	1	1

- C_{CO2} = 130 g/km · 1.1392 %
  = 1.4810 g CO_2 / km

Result, rounded to one decimal place:

$$\boxed{C_{CO2} = 1.5 \text{ g } CO_2 \text{ / km}}$$

Check of eligibility criteria

1. Non-exceeding requirements in EU law:
Currently there is no legislation about minimum requirements on engine heat storage systems.
→ FULFILLED

2. Innovativeness:
It has been demonstrated that the market penetration of the eco-innovation technology does not exceed 3 % in the reference year. → FULFILLED

3. Necessity:
The combustion engine is an essential device for the safe operation of the vehicle. Engine compartment encapsulation reduces heat dissipation and improves the over-all engine efficiency (no further documents necessary).
→ FULFILLED

4. Verifiability:
The unrounded total CO_2 saving of the eco-innovation technology exceeds the minimum threshold of 1 g CO_2 / km.
→ FULFILLED

5. Coverage:
The eco-innovation technology is not covered by the CO_2 type approval test procedure. Current legislation for testing prescribes a maximum engine starting temperature not exceeding the ambient test cell temperature by more than 2 K. Hence, effects of reduced engine cooling after engine cutoff are not reflected in the CO_2 type approval results.
→ FULFILLED

6. Accountability:
Engine compartment encapsulation does not require any manual activation or deactivation. Its effect on CO_2 emissions of the vehicle is not under the influence of the driver's choice.
→ FULFILLED

Total result:
The application can be granted.

Parametric function

The CO_2 saving of an engine heat storage device depends on the 'hot start benefit' (HSB) as a relation between CO_2 NEDC results with cold and hot engine at test start. This parameter might vary between different vehicle versions because of different engine types and sizes. To cover mathematically different vehicle versions with varying engine types and sizes, a parametric function may be applied. This function would replace the experimental determination of the HSB by performing hot and cold (14°C) start NEDC tests.

To describe the dependencies of the HSB on the type of engine (petrol or diesel) and the engine size (engine displacement), a linear parametric function could be used:

$$\boxed{HSB = HSB_0 + SF \cdot D_e}$$

with:
D_e: engine displacement [cc^m]
HSB_0: hot start benefit (for petrol or diesel engines)
SF: slope factor [% / (K · cm^3)] (for petrol or diesel engines)

The parameters HSB_0 and SF have to be determined experimentally by the applicant. The applicability of such a linear approach should be checked carefully.

Annex 1 - Data sources of Chapter 5

5.1 Efficiencies

5.1.1 Efficiency of engine

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Vehicle Emissions Laboratory (VELA)
- internal measurements

5.1.2 Efficiency of alternator

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Vehicle Emissions Laboratory (VELA)
- internal measurements

"VDA approach":

$\eta_A = 0.25 \cdot (\eta\ @1800rpm\ @0.5 \cdot I_N) + 0.40 \cdot (\eta\ @3000rpm\ @0.5 \cdot I_N) + 0.25 \cdot (\eta\ @6000rpm\ @0.5 \cdot I_N) + 0.10 \cdot (\eta\ @10{,}000rpm\ @0.5 \cdot I_N)$

5.1.3 Electrical solar system efficiency

European Commission - Joint Research Centre
Institute for Energy and Transport
Renewable Energy Unit
European Solar Test Installation (ESTI)
- internal measurements
http://re.jrc.ec.europa.eu/esti/index_en.htm

Hacker, F.; Zimmer, W.; Vonk, W.; Bleuanus, S.: Assessment of eco-innovation technologies - Final report. On behalf of the European Commission, framework contract no.: ENV/C.5/FRA/2006/0071. 18 May 2010.

5.2 Driving cycle characteristics

UNECE Regulation No. 83: Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements.
http://live.unece.org/trans/main/wp29/wp29regs81-100.html

5.3 Fuel characteristics

5.3.1 Fuel densities

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

5.3.2 Conversion fuel consumption ↔ CO_2 emission

European Automobile Manufacturers' Association (ACEA) / Verband der Automobilindustrie (VDA)
Notice in writing

5.4 Usage factors

5.4.1 Vehicle lighting

European Association of Automobile Suppliers (CLEPA)
Notice in writing

5.4.2 Shading of solar panels

Hacker, F.; Zimmer, W.; Vonk, W.; Bleuanus, S.: Assessment of eco-innovation technologies - Final report. On behalf of the European Commission, framework contract no.: ENV/C.5/FRA/2006/0071. 18 May 2010.

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Based on calculations on GPS-data of vehicles in the city of Modena.

5.4.3 Windscreen wipers

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Expert judgement

5.5 Power requirements of lighting types

5.5.1 Halogen tungsten

European Association of Automobile Suppliers (CLEPA)
Notice in writing

5.5.2 Xenon gas discharge

European Association of Automobile Suppliers (CLEPA)
Notice in writing

5.6 Total electric power requirements

European Automobile Manufacturers' Association (ACEA) / Verband der Automobilindustrie (VDA)
Notice in writing

5.7 Solar radiation

5.7.1 Solar radiation in Europe

European Commission - Joint Research Centre
Institute for Energy and Transport
Renewable Energy Unit
Photovoltaic Geographical Information System (PVGIS)
http://re.jrc.ec.europa.eu/pvgis/

5.7.2 Solar correction coefficient

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
- internal calculations

based on:
- Measurements of solar radiation in Europe by the BSRN Network (www.bsrn.awi.de), processed by European Commission - Joint Research Centre, Institute for Energy, Renewable Energy Unit

5.8 Ambient temperature

European Environment Agency
Global and European temperature (CSI 012)
- Assessment published June 2010
http://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature/global-and-european-temperature-assessment-3

5.9 Engine starting temperature

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Vehicle Emissions Laboratory (VELA)
- internal measurements

5.10 Parking time distribution

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Expert judgement

based on:
- Kühlwein, J.: Unsicherheiten bei der rechnerischen Ermittlung von Schadstoffemissionen des Straßenverkehrs und Anforderungen an zukünftige Modelle. - Dissertation, University of Stuttgart, 30.11.2004. http://elib.uni-stuttgart.de/opus/volltexte/2004/2079/.
- Infras AG: Handbook emission factors for road transport (HBEFA). Version 3.1. Parking time distribution for Switzerland. http://www.hbefa.net/e/index.html

5.11 Mileages

University of Stuttgart, Germany
Institute for Energy Economics and the Rational Use of Energy
Unit for Technology Assessment and Environment

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
- internal calculations

based on:
- Transport & Mobility Leuven, Belgium: TREMOVE: an EU-wide transport model http://ec.europa.eu/environment/air/pollutants/models/tremove.htm
(Calculations for Euro 3, Euro 4 and Euro 5 passenger cars in 2010)

Appendix: Template for the summary description of the application (Section 4:5)

1) Contact details

Applicant

Applicants name:	

2) Summary

Brief description of the innovative technology and its potential CO2 savings:

3) Innovativeness

Market penetration of the new technology based on the reference year 2009:

4) Necessity

Information whether the innovative technology is intrinsic to the efficient operation in terms of performance and/or safety of the vehicle:

5) Measurement methodology

Description of the measurement methodology or reference to a methodology set out in the Technical Guidelines.
