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Directorate C - Energy, Climate and Transport
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Technical Guidelines

for the preparation of applications for the approval of innovative technologies pursuant to Regulation (EC) No 443/2009 and Regulation (EU) No 510/2011

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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 and from light commercial vehicles.
- Case studies.
- In-put data for the preparation of testing and calculation methodologies.

1.2. Legal background

1.2.1. Regulation (EC) No 443/2009 and Regulation (EU) No 510/2011

Regulation (EC) No 443/2009[1] 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[2] final should bring a further reduction of 10 g CO_2/km. A new target of 95 g CO_2/km will be phased in from 2020 and fully applicable from 2021.

Similarly Regulation (EU) No 510/2011[3] setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light duty vehicles, provides for a short term target of 175 g CO_2/km to be phased in from 2014 and a long term target of 147 g CO_2/km which will apply from 2020.

Article 12 of Regulation (EC) No 443/2009[1] and Regulation (EU) No 510/2011[3] provide 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 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. The maximum savings that a manufacturer may take into account for reducing the average emissions in a given calendar year is 7 g CO_2/km.

> *Example:*
>
> Manufacturer X fits, in year Y, an eco-innovation in 200 000 cars. Each eco-innovation brings a saving of 1.5 g CO_2/km. The total number of new vehicles registered in year Y of that manufacturer is 800 000. The total eco-innovation savings that the manufacturer X can use for reducing its average emissions are:
>
> $$1.5 \cdot \frac{200\,000}{800\,000} = 0.4 \ \mathrm{gCO_2/km}$$
>
> The average NEDC emissions in year Y of that fleet is 132.0 g CO_2/km. Since the total eco-

[1] Regulation (EC) No 443/2009: http://europa.eu/!tJ77dB

[2] Commission Communication (2007) 19: http://europa.eu/!xx84dR

3 Regulation (EU) No 510/2011: http://europa.eu/!Rd67Bu

innovation savings are less than 7 g CO_2/km, the average emissions can be reduced to 131.6 g CO_2/km.

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[4]). The approval decisions will be accessible on Eur-Lex as well as on the Commission website[5].

1.2.2. Commission Implementing Regulation (EU) No 725/2011 – eco-innovations for passenger cars

Commission Implementing Regulation (EU) No 725/2011[4] establishing a procedure for the approval and certification of innovative technologies for reducing CO_2 emissions from passenger cars pursuant to Regulation (EC) No 443/2009[1] 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.

1.2.3. Commission Implementing Regulation (EU) No 427/2014 – eco-innovations for light commercial vehicles

Commission Implementing Regulation (EU) No 427/2014[6] is in all essential elements similar to Commission Implementing Regulation (EU) No 725/2011[4]. Eco-innovation savings will be available for manufacturers of complete N1 vehicles, and in the case of multi-stage vehicles, the manufacturer of the base vehicle. These guidelines will apply also with regard to eco-innovations for N1 vehicles. However, it should be noted that the recording of eco-innovation savings in the certificates of conformity for N1 vehicles will be possible from 2016 only (see Directive 2007/46/EC[7]).

[4] Commission Implementing Regulation (EU) No 725/2011: http://europa.eu/!xC77mW

[5] DG CLIMA: http://europa.eu/!RG73tN

[6] Commission Implementing Regulation (EU) No 427/2014: http://europa.eu/!jT67kv

[7] Directive 2007/46/EC: http://europa.eu/!gf96mW

2. PROCEDURE

The eco-innovation procedure is composed of the following phases:

1. Informal discussions to prepare applications
2. Official application submission
3. Assessment of the application:
    a. Completeness check
    b. Qualitative pre-screening (if necessary)
    c. Technical assessment and approval of the eco-innovation
4. Publication of the Commission Implementing Decision
5. Type approval certification

The eco-innovation procedure and its duration are outlined in Figure 1 and explained in this Chapter.

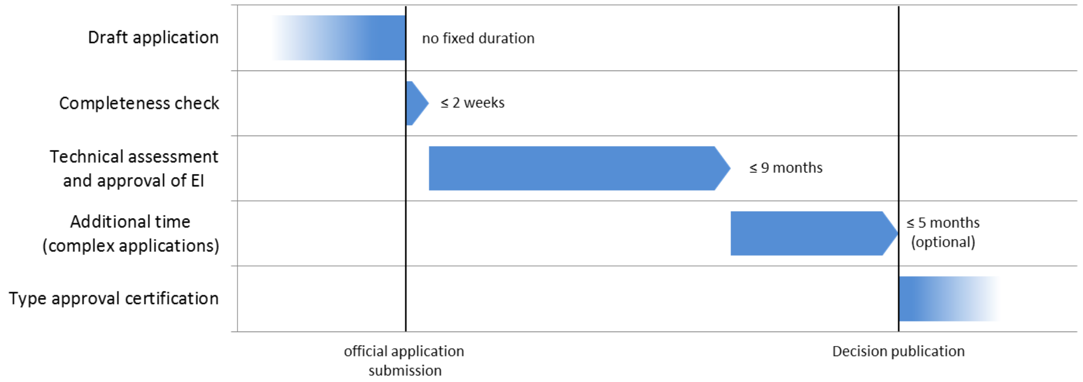

Figure 1: Eco-innovation procedure

2.1. Preparing applications

Before any submission, every applicant shall verify if existing decisions may apply to the proposed eco-innovative technology. In the case where these decisions are not generic (i.e. not directly applicable), the applicant shall use as a basis the testing methodologies from the existing decisions.

It is recommended to contact the Commission prior to submitting the application in order to ensure that the application meets all the conditions required to be considered complete. The following functional mailbox can be used: EC-CO2-LDV-IMPLEMENTATION@ec.europa.eu.

2.2. Application supporting documentation

Article 4 of Commission Implementing Regulation (EU) No 725/2011 and (EU) No 427/2014

Before submission, every applicant should ensure that the application includes the required supporting documentation. 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.

To facilitate the check on completeness, the sub-paragraph below (Chap 2.2.1), provides a detailed checklist of documents which must be provided by the applicant.

Checklist for the completeness of an application

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

1. Name and address and contact person of the applicant
2. A short description of the testing methodology, indicating whether the tests are conducted on components, systems or an entire vehicle.
3. A summary of the application for publication
4. List of supporting documentation
5. Technical description of the eco-innovation and the way it is fitted on a vehicle, described in writing and, where appropriate, by technical drawings
6. Supporting documentation demonstrating that the innovative technology does not exceed 3 % in the reference year 2009
7. Prediction on which vehicle segments the eco-innovation will be applied (estimate only)
8. Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale (estimate only)
9. Identification of the baseline technology for the envisaged vehicle segments
10. Technical description of the baseline technology[8]
11. Description of the technology characteristics that could lead to increased CO_2 emission (e.g. higher mass, higher drag resistance)
12. Check of possible deterioration effects
13. Description of testing methodology :
    a. Measurement or modelling condition and equipment
    b. Measurement or modelling procedure
    c. Method of calculation of CO_2 savings
    d. Identification of the uncertainties and description of the methodology to quantify the statistical uncertainties
14. Description of the case study. The case study is the particular vehicle or component used in the application to demonstrate the fulfilment of the verifiability criterion (see Chap. 4.4)
15. Application of the testing methodology for the case study and calculation of the corresponding resulting CO_2 savings (differentiated per envisaged vehicle segment, where relevant)
16. Application of uncertainty analysis and quantification of statistical uncertainties

[8]See Chapter 3.2 for baseline definition .

17. Check if all eligibility criteria specified in Article 2 and Article 4(2)(e), (f) and (g) of Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6], described in Chap. 4 of these guidelines, are fulfilled; reasons and evidential data have to be provided for each of them:

    a. Non-exceeding requirements in EU law

    b. Innovativeness of technology

    c. Necessity of technology (non-comfort)

    d. Verifiability of CO_2 saving (minimum threshold)

    e. Coverage by the CO2 (type approval tests)

    f. Accountability (influence of driver)

18. Verification report from an independent certification body, including:

    a. Testing protocols of all relevant measurements

    b. Check of fulfilment of the eligibility criteria

    c. Check of possible deterioration effects

    d. Check of suitability of the testing methodology for determining the CO_2 savings from the eco-innovation (for new testing methodologies only)

    e. Check of suitability of parametric function (if CO_2 saving depends on one or more vehicle parameters)[9]

19. Detailed technical data of case study vehicle(s), and/or components and/or hardware;
20. Data about experimental analyses of deterioration effects or sound argumentation in case of non-existence
21. Identification of interactions with existing technologies

2.3. Procedure for assessing the applications for eco-innovations

Article 10 of Commission Implementing Regulation (EU) No 725/2011 and (EU) No 427/2014

An OEM or a supplier sends in an application for the approval of an eco-innovation to the Commission. It is important to note that this application should also contain a report of an independent verifier.

After receipt of the application, the Commission starts the assessment. In practice this work is divided between the Joint Research Centre that carries out the technical assessment and the Directorate General for Climate Action that is responsible for preparing the final decision to be adopted by the Commission.

The first step in this process is a completeness check, i.e. whether all necessary documents to start the assessment have been provided with the application. The checklist to evaluate the completeness of the application is described in Chap. 2.2.1. This step should take a maximum of fifteen working days.

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[9] When the CO2 savings depend on the vehicle and/or technology parameters, the suitability of the function has to be demonstrated, otherwise not.

If the application is found to be complete, the Commission has nine months, from the date the complete application is received, to finalize the assessment and take a decision to approve or reject it. In case of complex applications, the Commission is entitled to ask for an extension of 5 months and has therefore 14 months to finalize the assessment.

If the application is incomplete, the assessment deadline is not activated and the applicant is asked to provide the missing information. Only when the application is found to be complete will be further assessed. It should also be underlined that if an application cannot be completed within three months from the initial submission, the application will be considered void and the applicant will be requested to submit a new complete application.

The technical assessment of the complete application may take several weeks, depending on the complexity of the technology and the testing methodology.

It may include further exchanges between the Commission and the applicant in order to clarify issues. Such questions are usually submitted to the applicant as a result of the qualitative pre-screening, whose main objective is to verify whether the proposed testing methodology fulfils the basic requirements laid down in section 6.2. The qualitative pre-screening is optional and given as a possibility for the applicant to improve some elements of its application.

The technical assessment should demonstrate that the eligibility criteria are met and that the testing methodology is fit for use. A draft decision is prepared outlining the reasons why the application should be approved or rejected. In case of an approval, the decision includes a description of the technology and the testing methodology or a reference to an already approved methodology. Following a consultation of other Commission services the decision is finally adopted by the Commission and is published in the Official Journal in all languages.

2.4. The recording of the eco-innovation savings in the certificate of conformity

Article 11 of Regulation (EC) No 443/2009[1] and (EU) No 510/2011[10]

A manufacturer can use eco-innovation CO_2 savings to lower its annual average CO_2 emissions in view of meeting its annual specific emission target. The maximum savings that can be taken into account for that purpose are 7 g CO_2/km per year. The manufacturer must submit a request for the certification of the CO_2 savings for an eco-innovation fitted in a vehicle version[11] to the type approval authority. In this request a reference must be given to the relevant approval Commission Implementing Decision. The type approval authority will certify the savings if the manufacturer can demonstrate that the savings for the relevant vehicle version[11] are 1 g CO_2/km or more. The certification request should be accompanied by a report with the CO_2 savings based on the specific testing methodology. The certified savings should be indicated in the certificate of conformity of the vehicles concerned.

Approval Commission Implementing Decisions are published in the EU Official Journal and on DG CLIMA website[5].

2.5. The monitoring of the implementation of eco-innovations

Every approved eco-innovation will get its own specific number which can be used to monitor the implementation of these eco-innovations. This monitoring is done by the Member States and the Commission in order to determine the performance of a manufacturer in meeting its annual targets.

[11] 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 CO_2 saving effect.

2.6. Information

Detailed information about legislation, approved eco-innovations, and monitoring can be found in the DG CLIMA website[5].

3. DEMONSTRATION OF CO_2 SAVINGS

3.1. Testing methodology

Article 6 of Regulations (EU) No 725/2011 and (EU) No 427/2014

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) of Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6], the 'testing methodology' to demonstrate the CO_2 savings could also include calculation or modelling methodologies.

European driving patterns

Article 6(1). of Regulations (EU) No 725/2011 and (EU) No 427/2014

In order to ensure a level playing field and to have a common reference for all applications, the type approval test laid down in UN/ECE Regulation No 83[12] for the 'Type I test' should be used as a basis for the measurements pending the adoption of a new testing procedure. This includes all the parameters of the testing conditions (e.g. temperature, humidity, vehicle conditioning, road load...) and is not limited to the driving pattern (NEDC).

For technologies whose functioning is influenced by the driving pattern, 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 shall 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 (>

[12] UN/ECE Regulation No 83: http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/r083r4e.pdf

7 seconds) would not be considered representative.

3.2. Calculation procedure

Article 8 of Regulations (EU) No 725/2011 and (EU) No 427/2014

The CO_2 savings of an innovative technology are obtained from one or several tests conducted under modified testing conditions and shall provide the difference between the innovative and the baseline technology.

The corresponding CO2 savings are weighted by a usage factor.

$$\Delta CO_{2_{MC,i}} = (B_{MC,i} - E_{MC,i}) \cdot UF_{MC,i} \qquad i = 1,2, \ldots$$

- $\Delta CO_{2_{MC,i}}$ represents the eco-innovation CO_2 benefits under the modified conditions i
- $B_{MC,i}$ represents the CO_2 emissions of the baseline vehicle under the modified conditions i
- $E_{MC,i}$ represents the CO_2 emissions of the baseline vehicle under the modified conditions i
- $UF_{MC,i}$ represents the usage factor for the modified conditions i

In addition to the above: when active under the type approval conditions, the eco-innovative and the baseline technologies must be tested to subtract the corresponding CO2. Subtracting the benefit of the technology under the type approval conditions, the above formula is generalized as:

Equation 1:

$$C_{CO_2} = \sum_{i=1,2,\ldots} \Delta CO_{2_{MC,i}} - \Delta CO_{2_{TA}}$$

Where:

$\Delta CO_{2_{TA}} = (B_{TA} - E_{TA}) \cdot UF_{TA}$

The parameters addressed by the usage factors shall be carefully assessed by the applicant on a case-by-case basis. In many cases, the above Equation 1 can be simplified (e.g. identical values for $UF_{MC,i}$ and UF_{TA}, UF_{TA}=1, ...).

The definition of the baseline technology/baseline vehicle is crucial for ensuring that the savings obtained are realistic and this will be a key element considered in the assessment of an application. The definition of baseline technology/baseline vehicle should be evaluated on a case by case basis. I.e. it may not be sufficient to simply deactivate the eco-innovation on the baseline vehicle without considering other negative impacts of the eco-innovation (e.g. increase in the mass of the vehicle or in the drag resistance). In circumstances where a baseline vehicle cannot be build up a simulation or expert judgment may be performed.

Each of the CO_2 emission values $B_{MC,i}$, $E_{MC,i}$, B_{TA} and E_{TA} represents an arithmetic mean of a measurement series of individual and consecutive measurements. The testing conditions (e.g. temperature and humidity at the test cell, battery state of charge, road load...) should be equal for all measurement series and should be identical to the testing conditions of the type approval measurements (except those parameters naturally influencing the innovative technology's performance).

To avoid double counting, the CO_2 savings under modified testing conditions ($B_{MC,i}$ and $E_{MC,i}$ have to be corrected by the CO_2 emissions difference of the same two vehicles measured under type approval testing conditions (B_{TA} and 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.

To properly propose the modified conditions and the usage factors, the applicant shall proceed as indicated in Section 6 to properly justify:

- The parameters are influencing the functioning of the innovative technology;
- The parameters covered by the type approval test, the modified testing conditions and the usage factors.

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. 6.3).

4. ELIGIBILITY CRITERIA

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

4.1. Integrated approach measures

Article 2(1) of Regulations (EU) No 725/2011 and (EU) No 427/2014.

Some individual CO_2 saving technologies have been regulated in EU legislation or are going to be developed within a short period of time. Regulations (EC) No 443/2009[1] and (EU) No 510/2011[3] explicitly exclude these technologies from the scope of eco-innovation procedure.

Any technology falling within the scope of the following measures covered by the integrated approach, shall not be considered as innovative technologies:

– Efficiency improvements for air-conditioning systems
– Tyre pressure monitoring systems falling within the scope of Regulation (EC) No 661/2009[13]
– Tyre rolling resistance falling within the scope of Regulations (EC) No 661/2009[13] and (EC) No 1222/2009[14]
– Gear shift indicators falling within the scope of Regulation (EC) No 661/2009[13]
– Use of bio fuels

[13] Regulation (EC) No 661/2009: http://europa.eu/!Qq67yf

[14] Regulation (EC) No 1222/2009: http://europa.eu/!pp74pN

4.2. Innovativeness

Article 2(2)(a) of Regulations (EU) No 725/2011 and (EU) No 427/2014

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 Regulations, technologies with a market penetration of 3% or less in newly 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. 4.4.2) 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 Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6].

Example A (lighting technologies)

In order to determine the market penetration of lighting technologies, a reference was made to the *CLEPA Light Sight Safety*[15] initiative. As part of that initiative, suppliers of headlamps and rear lamps have individually estimated the penetration rates of innovative technologies in the different lighting applications, based on production in figures the EU for the year 2009.

In a subsequent market review these figures have been condensed to a single value per application and technology. The Commission considered this result as representative since the companies providing the information represent the majority of the actors present in the automotive lighting market in Europe (around 75%).

Type of lighting	**Technology**	**Estimated Fitting rate** ***(new cars, EU 2009)***
Low beam headlamp	LED	<1%
	Xenon (D1/D2) *Mercury-containing*	~13%
	Xenon (D3/D4) *Mercury-free*	~2%
	Xenon (D5/D6/D7) *Low-power (25W)*	0%
High beam headlamp	LED	<1%
	Xenon (D1/D2)	~13%

[15] *CLEPA Light Sight Safety*, March 2nd, 2012: http://www.clepa.eu/working-groups/lightsightsafety-initiative-lss/

	Mercury-containing	
	Xenon (D3/D4) *Mercury-free*	~2%
	Xenon (D5/D6/D7) *Low-power (25W)*	0%
Front position	LED	~2%
Fog – front	LED	<1%
Turn signal - front	LED	<2%
Rear position	LED	>15%
Fog – rear	LED	<1%
Turn signal – rear	LED	~3%
License plate	LED	<1%
Reversing	LED	<1%

Example B (engine bay encapsulation)

The market penetration of the engine encapsulation technology has been demonstrated on the report *Market penetration of an underhood encapsulation in the EU in 2009* created by the *Institute for Automotive Engineering – RWTH Aachen University*.

In the study the market penetration of combined thermal management measures in vehicle engine bays in the European Union was analysed for the year 2009. A thermal engine encapsulation is an example for a combined thermal management. Regarding combined thermal management, a market penetration of 0% was defined.

Additionally, the market penetration of active and advanced active thermal management was analysed. Active thermal management can be considered as an intermediate step towards combined thermal management. The market penetration of advanced active thermal management in the EU in 2009 was less than 3%. Overall, it can be found that the share of newly registered vehicles in the EU in 2009 equipped with advanced active thermal management, as well as combined thermal management, did not exceed 3%.

4.3. Necessity (non-comfort)

Article 2(2)(b) of Regulations (EU) No 725/2011 and (EU) No 427/2014

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. This would also include technologies which are able to convert unused (internal or external) energy into usable energy or improve the energy storage capacity. However, in order to accurately take into account the extent to which the energy use of a vehicle may be improved through such technologies, it is necessary to get a better understanding of the energy consumed for the operation of devices aimed at enhancing the comfort of the driver or the passengers.

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.

4.4. Verifiability (minimum threshold)

Article 4(2)(f)(i) of Regulations (EU) No 725/2011 and (EU) No 427/2014

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 Chap. 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 be rounded up and expressed to a maximum of two decimal places.

Each value used in the calculation of the CO_2 savings can be applied unrounded or must be rounded up and expressed to a minimum number of decimals which allows the maximum total impact (i.e. combined impact of all rounded values) on the savings to be lower than 0.25 gCO_2/km.

4.4.1. Statistical significance

Article 6(1) of Regulations (EU) No 725/2011 and (EU) No 427/2014

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 uncertainty determined as described in Chap. 6.3 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).

Equation 2:

$$\mathrm{MT} \leq \mathrm{C}_{\mathrm{CO_2}} - \mathrm{s}_{\mathrm{C}_{\mathrm{CO_2}}}$$

MT: Minimum threshold
$\mathrm{C}_{\mathrm{CO_2}}$: Total CO_2 saving
$\mathrm{s}_{\mathrm{C}_{\mathrm{CO_2}}}$: Standard deviation of the total CO_2 saving (see Chap. 6.3)

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, by improving the modelling method).

4.4.2. Technology package

Article 3(a) of Regulations (EU) No 725/2011 and (EU) No 427/2014

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. 5.

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'.

4.5. Coverage (type approval procedure)

Article 4(2)(f)(ii) of Regulations (EU) No 725/2011 and (EU) No 427/2014

Incentives can be granted to technologies whose CO_2 saving is not or partially 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): e.g. 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.

4.6. Accountability (influence of driver)

Article 4(2)(f)(iii) of Regulations (EU) No 725/2011 and (EU) No 427/2014

CO_2 savings of eco-innovations must be accountable to the applicants (e.g. 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.

As regards eco-driving devices it should be noted that these could be eligible only where the manufacturer or supplier can prove that these devices have a CO_2 reducing effect that is independent of the driver's behaviour. This could potentially be the case where the device ensures an eco-driving mode regardless of the choices of the driver, i.e. no switch on/off possible.

For any other type of device which depends on the driver behaviour, the manufacturer/supplier would have to demonstrate either that the mere existence of an eco-driving device in a vehicle has a positive and quantifiable effect on fuel consumption/CO_2 emissions. The causal link between the device, the driver's behaviour and the subsequent CO_2 reductions should be statistically proven to such a degree that variations in the driver’s behaviour would have an insignificant impact on the final savings (see Chap 6.3). In general, the driver should not be conscious of the existence of the technology.

5. 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, must not be seen as finalised or completed and should not exclude potential technologies belonging to other classes.

The following 9 classes are described:

Class 1: Improved electrical components

Class 2: Improved mechanical components

Class 3: Use of ambient energy sources

Class 4: Heat energy storing systems

Class 5: Kinetic energy storing systems

Class 6: Heat energy – to – electricity converters

Class 7: Kinetic energy – to – electricity converters

Class 8: Measures lowering engine speed

Class 9: Active aerodynamics

5.1. Improved electrical components

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.

5.2. Improved mechanical components

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.

5.3. Use of ambient energy sources

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.

5.4. Heat energy storing systems

Heat 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. E.g. heat storage by measures of insulation may increase the temperature of vehicle parts and, hence, reduce friction of mechanical components.

5.5. Kinetic energy storing systems

Kinetic 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.

5.6. Heat energy – to – electricity converters

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

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.

5.7. Kinetic energy – to – electricity converters

Kinetic energy may be transformed to additional electric energy in different ways, like efficiency improvements of the alternator.

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.

5.8. Measures lowering engine speed

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.

5.9. Active aerodynamics

Devices adapting the vehicle aerodynamic to the environmental conditions or vehicles parameters (e.g. speed, ambient temperature, engine temperature). These devices can modify the drag resistance and, as consequence, the coast down curve.

6. TESTING METHODOLOGIES

6.1. Introduction and general principles

The application for an approval of an innovative technology as eco-innovation has to include a testing methodology which is suitable to robustly quantify the CO_2 saving effect of the technology. The methodology shall provide accurate and verifiable results. In principle, a physical test, a modelling approach or a combination of both may be applied. Occurring statistical uncertainties resulting from the physical or virtual testing (modelling) have to be quantified and reported (see Chap. 6.3).

Where an application for approval concerns a technology for which a testing methodology has already been approved, it is recommended that the application refers to the approval decision setting out the relevant testing methodology. This means that the same testing methodology may be used for several eco-innovations (e.g. alternators, lighting systems), see also Chap 1.1. For information about approved eco-innovations see the DG CLIMA website[5]. The applicant shall always aim at improving the robustness of existing methodologies, using the best available knowledge and practices. When deviations with respect to the approved testing methodologies are proposed, they must be duly justified and the improvement of the robustness must be demonstrated.

Chap. 7 of these guidelines provides a list of reference values which can be used. All assumptions – other than those given in Chap. 7 – used for calculating the CO_2 reduction potential of an innovative technology by a testing methodology need to be justified and, if applicable, shall be accompanied by relevant data. Calculation methodologies and equations taken from open literature or technical standard shall be correctly cited. A detailed derivation of equations is in this case not needed.

When applicable, the reference values in Chap. 7 should in principle be used. However, deviations from that rule could be permitted, provided that the applicant justifies the deviation by providing data which are representative for the case of study, based on robust statistical evidence. In this case, a data collection shall be conducted and the data collection protocol and the methodology used to analyse the data shall both be publicly available[16]. The applicant shall demonstrate that the collected data is representative for the European Union. In case of driving data (e.g. speed, acceleration, deceleration, stop times….): the basic characteristics of the collected data must be compared with the ones from the EU WLTP database. The methodology used to analyse the data should not exceed a certain level of complexity in order to ensure its reproducibility by third parties. Specific simulation models owned by the applicant will in principle not be considered as valid basis for demonstrating CO_2 savings.

If the CO_2 savings depend on the vehicle version[11], 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. 6.6). The derived equations should be used for the certification procedure for a specific vehicle version.

[16] The requirement for the data to be publicly available applies only when questioning the reference values in Chap. 7

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:

$$C_{CO_2} = A + B \cdot (\text{engine displacement } [cm^3]).$$

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.

6.2. Testing methodology - Development steps

The testing methodology of an eco-innovation saving often consists of:

- A test (physical or virtual) of a component or a vehicle under modified testing conditions;

- Usage Factor(s) describing the mean share of the eco-innovative technology usage under real world conditions.

The purpose of the physical/virtual test is to evaluate the CO_2 reduction between the baseline and the innovative vehicles. The physical/virtual test shall be able to cover the influencing parameters of the eco-innovation technology.

The development of a new or the modification of an existing testing methodology shall be based on the three following steps:

Step 1: Identification of the independent parameter(s) influencing the EI savings: Applicants may use the list in Annex 1 to determine which parameters (or combination of parameters) primarily influence the technology activation and the associated level of savings.

Step 2: Definition of the (modified) conditions under which the eco-innovations savings are measured and/or calculated.

Step 3: Definition of the usage factor(s).

Step 4: Determination of the CO_2 benefits under the 'modified conditions' by means of component/vehicle testing and/or model calculation (physical or virtual testing).

Step 5: Calculation of the CO_2 savings (Multiplication of the tests results in Step 4 by the Usage Factor obtained at Step 3) and the uncertainty.

6.2.1. Step 1 - Parameter(s) identification and selection

In the first step, the applicant shall properly determine which parameter(s) are influencing the technology functioning (e.g. number of accelerations/decelerations, average speed, temperature, driver…). These parameters are responsible for the activation, de-activation and associated level of CO_2 savings. A non-exhaustive list of parameters is provided below and may be used as preliminary checklist.

Examples: Families of parameters and their importance for some technologies (non-exhaustive list)

Families of Parameters (Sub-parameters)	Efficient lightings[17]	Engine encapsulation	Slope predictive energy management
Vehicle (Mass, operating modes, power, fuel)	0	0	++ (Vehicle mass)
Ambient (temperature, humidity, day/night, weather)	+++	+++	0
Environment (Traffic, country, infrastructure)	0	++	+++
Driver (Speed, acceleration, usage of systems...)	+	+	+

At this step, it is not required to establish any relationship between the parameters and the associated levels of CO_2 savings. However, the applicant shall clearly demonstrate:

- The underlying motivations for neglecting some parameters;
- Which parameters have a 'negative effect', i.e. increase the CO_2 emissions of the vehicle.

According to the general principles laid down in paragraph 3.2, the type approval test has to be used "as test cycle for validation purposes within the testing methodologies in terms of velocity-over-time function". As a first step, the applicant shall assess which parameters play a role in the activation/deactivation and the level of savings of the technology to demonstrate:

- Whether the technology is active or inactive under the type approval conditions
- When the technology is active under the type approval conditions, which are the triggering parameter(s) and their values.

> *Example 1*
>
> For efficient lightings, the vehicle systems/lights are off under the type approval conditions. The speed/time profile of the NEDC and all the other parameters have no influence.
>
> *Example 2*
>
> For engine encapsulation, the vehicle is tested "cold" and its conditioning under the Type 1 does not allow the EI technology benefits

6.2.2. Step 2 - Definition of Modified conditions

The 'modified conditions' are intended as conditions under which the CO_2 benefits will be measured and/or calculated. The 'modified conditions' shall be defined in such a way that they trigger the activation of the

[17] Light Emitting Diode

proposed technology allowing for the calculation/measurement of the corresponding CO_2 savings in a robust manner.

The type approval Type 1 test must be used as reference test cycle to define the modified conditions. It provides the reference values (e.g. duration, distance, shares of driving conditions, maximum speed) to be considered for the definition of the modified conditions and the measurement/calculation of the CO_2 savings.

6.2.3. Step 3: Definition of the usage factor(s)

When proposing modified conditions which do not represent the full set of operating conditions for the eco-innovative technology, the 'usage factor' shall be used to represent the occurrence of parameter(s) which are not covered under the modified conditions. The usage factor' has to represent 'a mean share of technology usage'.

For example, the modified conditions might represent the EI technology usage due to one parameter (e.g. lights on/off, driving cycle characteristics) whereas the usage factor might represent the mean usage of the technology due to parameters which are different from the ones addressed under the modified conditions (e.g. driver, temperature, vehicle mode).

Usage factors must be developed avoiding the 'double counting': for instance, for modified testing conditions that exactly represent the real-world usage of the technology, the usage factor shall be equal to 1.

6.2.4. Step 4 - Determination of the CO2 benefits under the 'modified conditions' by means of component/vehicle testing and/or model calculation

Once the 'modified conditions' are defined as a result of Step 2, the CO_2 benefits can be quantified by means of semi or fully experimental approaches. The CO_2 benefits (ΔCO_2, difference between the CO_2 emissions of the vehicle with and without innovative technology) and the influencing parameters **must be quantified for the reference situations, i.e. both the type approval and the modified condition(s).** Depending on the considered technology and the level of accuracy required, the CO_2 benefits have to be quantified using one of the three following approaches:

- Test method type A: Component / vehicle function testing and estimation of corresponding CO_2 savings over fixed reference conditions;

- Test method type B: Vehicle testing under controlled conditions (both modified and type approval) and measurement or estimation of CO_2 savings;

- Test method type C: Vehicle / component testing under un-controlled conditions (e.g. real-world, vehicle equipped with a data logger and/or fuel consumption meter, PEMS CO_2 analyser).

Example 1

For efficient lightings, only the component is tested, measuring their power consumption and transforming it into CO_2 using the Willans' factors. The CO_2 savings are scaled to the duration of the type approval test, using its duration and distance.

Example 2

For engine encapsulation, the entire vehicle is tested at two specific testing conditions: cold and hot start at 14 °C; also the performance of the engine encapsulation is tested evaluating its temperature decay curve. A model is used to convert the testing results into CO_2 savings for each parking time situation.

- In all cases:

The 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
- 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

6.2.5. *Step 5: Calculation of the CO2 savings and the uncertainty.*

Upon completion of the physical or virtual tests, the final CO2 savings is quantified according to the calculation principles laid down in Section 3.2. The resulting uncertainties shall also be quantified according to the methods described in Section 6.3.

6.3. Data quality and uncertainties

The testing methodology should provide verifiable and accurate results as defined in of Article 6(1) Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6]. The resulting CO_2 savings have to be reproducible by a third party equipped with standard measurement and modelling techniques.

6.3.1. *Uncertainty quantification*

The uncertainty of the testing methodology's results (due to measurement or modelling uncertainties) should be quantified and delivered with the resulting CO_2 saving value.

To allow a straightforward statistical treatment of test results, it is assumed that the uncertainty distribution is characterized by its standard deviation (being equivalent, in the case of a normally distributed uncertainty, to a 68% confidence interval around the mean). Equation 3 shows the formula to quantify the uncertainty, as standard deviation of the mean.

Equation 3:

$$s_{\bar{x}} = \frac{s_x}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$$

$s_{\bar{x}}$: Standard deviation of the sample mean $\bar{x}$

s_x Standard deviation of the sample x

x_i: Sample data

$\bar{x}$: Mean of the sample data

n: Number of observations of the sample

The uncertainties should be minimised by applying suitable measures. 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.

6.3.2. *Propagation of the uncertainties*

The propagation of the uncertaintiesshould be taken into consideration.

The uncertainty values of the variables (e.g. individual measurement series) shall be combined to a total value using the uncertainty propagation law (Equation 4) or a more sophisticated 'Monte Carlo method'.

Equation 4:

$$s_{C_{CO_2}} = \sqrt{\sum_{j=1}^{m} \left(\left. \frac{\partial C_{CO_2}}{\partial x_j} \right|_{x_j=\bar{x}_j} \cdot s_{\bar{x}_j} \right)^2}$$

$s_{C_{CO_2}}$:	Standard deviation of the total CO_2 saving rounded to two decimal places
$\left. \frac{\partial C_{CO_2}}{\partial x_j} \right\|_{x_j=\bar{x}_j}$:	Sensitivity of calculated CO_2 saving related to the variable x_j
$s_{\bar{x}_j}$:	Standard deviation of $\bar{x}_j$
m:	Number of variables with uncertainty

6.3.3. Number of tests

All measurements should be validated by the independent verification body. Discarded tests have to be documented, and reasons for discarding them have to be given.

All measurements should be performed at least five (5) times.

In exceptional cases, when the applicant can demonstrate an inappropriate high effort in testing, a reduction on the minimum number of measurement could be proposed, pending the compliance with stricter requirements on the statistical uncertainty.

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 number or the accuracy of the tests should be increased until the following criteria are fulfilled:

- The value resulting from Equation 4 is not exceeding 0.5 g CO_2/km
- The minimum threshold (1g CO_2/km) is exceeded in a statistically significant way (i.e. fulfilling Equation 6) .

Uncertainty of the total CO_2 saving

The uncertainty determined for the total CO_2 saving of the proposed testing methodology should not exceed 0.5 g CO_2/km (Equation 5).

Equation 5:

$$s_{C_{CO_2}} = \sqrt{\sum_{j=1}^{m} \left(\left. \frac{\partial C_{CO_2}}{\partial x_j} \right|_{x_j=\bar{x}_j} \cdot s_{\bar{x}_j} \right)^2} \leq 0.5\ gCO_2/km$$

$s_{C_{CO_2}}$: Standard deviation of the total CO_2 saving rounded to two decimal places

$\left.\frac{\partial C_{CO_2}}{\partial x_j}\right|_{x_j=\bar{x}_j}$: Sensitivity of calculated CO_2 saving related to the variable x_j

$s_{\bar{x}_j}$: Standard deviation of $\bar{x}_j$

m: Number of variables with uncertainty

Minimum threshold statistical significance

Concerning the check of the fulfilment of the verifiability criterion (see Chap. 6.3.1), the uncertainty determined should not be greater than the difference between the total CO_2 savings and the minimum threshold of 1 g CO_2/km (see Equation 6).

Equation 6:

$$MT = 1\,gCO_2/km \leq C_{CO_2} - s_{C_{CO_2}}$$

MT: Minimum threshold of 1 g CO_2/km

C_{CO_2}: Total CO_2 saving, rounded maximum to two decimal places

$s_{C_{CO_2}}$ Standard deviation of the total CO_2 saving (see Chap. 6.3.2) rounded to two decimal places

6.3.4. Examples of uncertainty quantification

In this paragraph, examples about number of tests and uncertainties are described.

Further examples for specific technologies are provided in Chap. 9

Example A:

Uncertainty of the CO_2 saving criteria

Two vehicles are tested under modified conditions on a roller bench. The results are given in Table 1.

Each of the 2 measurement series described at Table 1 consists of 5 individual values.

The total CO_2 saving (TS) is:

$$TS = \overline{B_{MC}} - \overline{E_{MC}} = 3.57\,gCO_2/km$$

without consideration of the usage factor.

The usage factor $UF = 0.7$ has a standard deviation of the mean of $s_{UF} = 0.05$

The total CO_2 savings (C_{CO_2}) are therefore

$$C_{CO_2} = \Delta CO_{2_{MC}} = TS \cdot UF = 2.50\,gCO_2/km$$

Table 1

	B_{MC} [g CO_2/km]	E_{MC} [g CO_2/km]
Test 1	131.0	127.9
Test 2	133.7	130.4
Test 3	132.4	128.1
Test 4	134.4	130.8
Test 5	130.4	126.8
Arithmetic mean after 5 tests [g CO_2/km]	132.38	128.80
Uncertainty (Equation 4) [g CO_2/km]	0.76	0.77

Uncertainty of the $\Delta CO_{2_{MC}}$ is calculated as such (pursuant Equation 4)

$$s_{TS} = \sqrt{\sum_{j=1}^{m} \left(\left. \frac{\partial TS}{\partial x_j} \right|_{x_j=\bar{x}_j} \cdot s_{\bar{x}_j} \right)^2} = \sqrt{{s_{B_{MC}}}^2 + {s_{E_{MC}}}^2} =$$

$$s_{TS} = \sqrt{(0.76\, gCO_2/km)^2 + (0.77\, gCO_2/km)^2} = 1.08\ gCO_2/km$$

Uncertainty propagation for the total CO_2 saving (C_{CO_2}) (pursuant Equation 4):

$$s_{C_{CO_2}} = \sqrt{\sum_{j=1}^{m} \left(\left. \frac{\partial C_{CO_2}}{\partial x_j} \right|_{x_j=\bar{x}_j} \cdot s_{\bar{x}_j} \right)^2} = \sqrt{\left(\frac{\partial C_{CO_2}}{\partial TS} \cdot s_{TS} \right)^2 + \left(\frac{\partial C_{CO_2}}{\partial UF} \cdot s_{UF} \right)^2} =$$

$$s_{C_{CO_2}} = \sqrt{(UF \cdot s_{TS})^2 + (TS \cdot s_{UF})^2} =$$

$$s_{C_{CO_2}} = \sqrt{(0.7 \cdot 1.08)^2 + (3.57 \cdot 0.05)^2} = 0.78\, gCO_2/km$$

The uncertainty resulting from the error propagation law exceeds the minimum requirement of 0.5 g CO_2/km.

$$s_{C_{CO_2}} = 0.78 \nleq 0.5\, gCO_2/km$$

Further efforts are necessary to lower the uncertainties.

Minimum threshold statistical significance criteria

The uncertainties of the previous example have been decreased e.g. using a driving robot for chassis dynamometer measurements. All other parameters are unchanged.

The new standard deviations are:

$$s_{B_{MC}} = s_{E_{MC}} = 0.32\ gCO_2/km$$

Following the previous calculation, the uncertainty of the total saving (TS) is

$$s_{TS} = 0.45\ gCO_2/km$$

Uncertainty propagation for the total CO_2 saving (C_{CO_2}) (pursuant Equation 4):

$$s_{C_{CO_2}} = \sqrt{(UF \cdot s_{TS})^2 + (TS \cdot s_{UF})^2}$$

$$s_{C_{CO_2}} = \sqrt{(0.7 \cdot 0.45\ gCO_2/km)^2 + (3.57\ gCO_2/km \cdot 0.05)^2} = 0.36\ gCO_2/km$$

The minimum requirement on uncertainty is now fulfilled.

$$s_{C_{CO_2}} = 0.36\ gCO_2/km < 0.5\,gCO_2/km$$

Equation 6 is also fulfilled:

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

$$MT = 1\,gCO_2/km \leq 2.50\,gCO_2/km - 0.36\,gCO_2/km$$

Example B:

Uncertainty of the CO_2 saving

The efficiency of an alternator has been tested in accordance with the ISO 8854:2012 (see Chap 9.5.1 for details).

The test results are the efficiencies of the alternator ($\eta_{A\text{-}EI}$) at 4 different speeds in rounds per minute (rpm):

- At a speed of 1 800 rpm
- At a speed of 3 000 rpm
- At a speed of 6 000 rpm
- At a speed of 10 000 rpm

For each speed, 5 tests are performed as minimum requirement. The results are given in Table 2.

Table 2

Speed		**1 800 rpm**	**3 000 rpm**	**6 000 rpm**	**10 000 rpm**
Efficiency $\eta_{A\text{-}EI}$ [%]	Test 1	87.70	89.93	84.89	74.50
	Test 2	88.23	90.46	85.40	74.95
	Test 3	87.53	89.75	84.72	74.35
	Test 4	88.05	90.28	85.23	74.80
	Test 5	88.14	90.37	85.31	74.87

Arithmetic mean [%]	87.93	90.16	85.11	74.70
Uncertainty [%]	0.14	0.14	0.13	0.11

The efficiency of the alternator is calculated as follows.

$$\eta_{A-EI} = 0.25 \cdot \eta_{A@1\,800} + 0.40 \cdot \eta_{A@3\,000} + 0.25 \cdot \eta_{A@6\,000} + 0.10 \cdot \eta_{A@10\,000}$$

$$\eta_{A-EI} = 86.79\%$$

Applying Equation 3:

$$s_{\eta_{A-EI}} = \sqrt{\left(0.25 \cdot s_{\overline{\eta_{A@1\,800}}}\right)^2 + \left(0.40 \cdot s_{\overline{\eta_{A@3\,000}}}\right)^2 + \left(0.25 \cdot s_{\overline{\eta_{A@6\,000}}}\right)^2 + \left(0.10 \cdot s_{\overline{\eta_{A@10\,000}}}\right)^2} =$$

$$s_{\eta_{A-EI}} = 0.00073$$

Uncertainty for the total CO_2 saving (C_{CO_2}) (pursuant Equation 4):

$$s_{C_{CO_2}} = \sqrt{\left(\frac{\partial C_{CO_2}}{\partial \eta_{A-EI}} \cdot s_{\eta_{A-EI}}\right)^2}$$

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{{\eta_{A-EI}}^2} \cdot V_{Pe-P} \cdot CF_P / v \cdot s_{\eta_{A-EI}} = 0.00714\, gCO_2/km$$

$$s_{C_{CO_2}} < 0.5\, gCO_2/km$$

The minimum requirement on data quality is fulfilled.

Minimum threshold statistical significance criteria

The requirement that statistical uncertainty determined should not be greater than the difference between the total CO_2 savings and the minimum threshold is also fulfilled.

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

$$MT = 1\, gCO_2/km \leq 2.49\, gCO_2/km - 0.01\, gCO_2/km$$

6.4. Deterioration

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.

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

If there is expected to be no deterioration of the eco-innovation with time and mileage, the applicant should demonstrate this 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.

6.5. Interactions

The identification and quantification of interaction between eco-innovations have to be performed by an OEM when it applies for a type-approval certificate for a vehicle fitted with more than one eco-innovation.

Where interaction between eco-innovations cannot be ruled out, the manufacturer shall indicate this in the application to the type approval authority and shall provide a report from the independent and certified body on the impact of the interaction on the savings of the eco-innovations in the vehicle (see Article 11(4) of Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6]).

To evaluate the impact of the interactions on the savings, the type approval authorities should - when possible - develop a methodology according to the following principles:

- Apply the general formula (from paragraph 3.2) to calculate the CO2 savings;

- The baseline vehicle shall have no eco-innovations;

- The eco-innovative vehicle shall have all eco-innovations installed.

This approach can be used as long as the values in the general formula can be expressed as functions of the technology specific parameters. The JRC report on interactions provides guidance for such calculations.

6.6. Verification report

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

The verification report shall 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 shall 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. Where an improved testing methodology is concerned the verification report shall specify to what extent the proposed methodology is in contrast to the already approved one. The verification report shall also consider the deterioration effects. If one or more parametric functions have to be applied, the verification report shall confirm their suitability and accuracy.

The completeness of the verification report is checked together with the completeness of the application, in particular for the presence and the quality of the abovementioned elements.

6.7. 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

- Summary description of the testing methodology or a reference to an approved one
- Evidence supporting that the innovativeness criterion of less than 3% market penetration set out in Article 2(2)(a) of Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6] is met
- Evidence supporting that the criterion set out in Article 2(2)(b) of Commission Implementing Regulation (EU) No 725/2011[4] and (EU) No 427/2014[6] is met

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.

7. REFERENCE VALUES FOR TESTING METHODOLOGIES

This chapter contains reference values which may be used as input data for the testing methodologies. Unless specified, the reference values apply both to M1 and N1 vehicles.

The reference values are usually expressed as average values for mean European conditions on an annual time basis. Where technical data vary between different vehicle versions[11], a security margin is included in the listed values to ensure that all potential vehicles are covered. Another security factor is included where deterioration effects have to be taken into account.

The data sources of the dataset are described in Annex I of this document.

7.1. Efficiencies

7.1.1. 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}	Unit
Petrol (V_{Pe-P})	0.264	l/kWh
Petrol Turbo (V_{Pe-PT})	0.28	l/kWh
Diesel (V_{Pe-D})	0.22	l/kWh
LPG (V_{Pe-LPG})	0.342	l/kWh
LPG Turbo (V_{Pe-LPG})	0.363	l/kWh
E85 (V_{Pe-E85})	0.367	l/kWh
E85 Turbo (V_{Pe-E85})	0.389	l/kWh
CNG (G20) (V_{Pe-NG})	0.259	m^3/kWh
CNG (G20) Turbo (V_{Pe-NG})	0.275	m^3/kWh

7.1.2. 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)[18]
0.67

[18] These values are calculated pursuant the ISO 8854:2012. These values can be used for calculating the effect of new electric devices. However, where the technology is fitted on an existing vehicle type, the baseline technology should be the alternator of the most recent version of that type placed on the market.

7.1.3. 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:

Component	Efficiency
DC/DC-converter[19]	0.92
Battery (charge and discharge)	0.94
Temperature, reflection and deterioration effects	0.88
Total solar system (η_{SS})[20]	0.76

7.2. Driving cycle characteristics

Cycle	Distance [m]	Duration [s]	Mean speed [km/h]
UDC	4 052	780	18.70
EUDC	6 955	400	62.60
NEDC	11 007	1 180	33.58

7.3. Fuel characteristics

7.3.1. Fuel densities

Type of fuel	Density at 15 °C [kg/m^3]
Petrol	743
Diesel	833
LPG	550
CNG	0.790
E85	786

[19] The value is valid in the range of 12V to 48V (secondary). Its applicability to other technologies than the solar roof must be demonstrated by the applicants.

[20] 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

7.3.2. Conversion fuel consumption – CO_2 emission

Type of fuel	Conversion factor l/100 km → g CO_2/km	
	[100 g CO_2/l]	[g CO_2/l]
Petrol	23.3	2330
Diesel	26.4	2640
LPG	16.3	1629
E85	16.6	1657
	[100 g CO_2/m^3]	[g CO_2/m^3]
CNG (G20)	18.0	1795

7.4. 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:

7.4.1. M1 Vehicle lighting

Type of lighting	Usage factor
Low beam headlamp	0.33
High beam headlamp	0.03
Daytime running light (DRL)[21]	--
Front position	0.36
Fog – front	0.01
Turn signal - front	0.15
Turn signal - side	0.15
Centre High-Mount Stop Light (CHMSL)[22]	--
Rear position	0.36
Stop[22]	--
Fog – rear	0.01
Turn signal – rear	0.15
License plate	0.36
Reversing	0.01

[21] 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.

[22] 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.

7.4.2. 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).

Type of vehicle	**Irradiation of solar panels Usage Factor**
M1 (UF_{IR-M1})[23]	0.51

7.4.3. Windscreen wipers

Speed of wiper motor	**Usage factor**
low speed (front wiper)	0.08
high speed (front wiper)	0.02

7.5. Power requirements of lighting types

7.5.1. Halogen tungsten

Type of lighting	**Number of lights**	**Halogen tungsten**	
		Nominal power per light [W] (12 V)	**Total electric power [W] (13.4 V)**
Low beam headlamp	2	55	137
High beam headlamp	2	60	150
Daytime running light (DRL)[21]	2	21	52
Front position	2	5	12
Fog – front	2	55	124
Turn signal – front	2[24]	21	13[25]
Turn signal – side	2[24]	5	3[25]
Centre High-Mount Stop Light (CHMSL)[22]	3	5	19
Rear position	2	5	12
Stop [22]	2	21	52
Fog – rear	1	21	26
Turn signal – rear	2[24]	21	13[25]
License plate	2	5	12
Reversing	2	21	52

[23] Conservative value derived from JRC analysis reported in Paper "Battery charging photovoltaic roofs on conventional combustion engine-powered passenger cars: CO_2 benefits for European vehicles".

[24] Only one side activated

[25] Assuming a 50/50 flashing cycle

7.5.2. Xenon gas discharge

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

7.6. Emissions due to extra weight[26]

The CO_2 correction coefficient due to the extra mass of the eco-innovative technology and, where applicable, the additional components needed.

Type of fuel	CO_2 correction coefficient due to the extra mass [g CO_2/km kg][27]
Petrol ($\Delta CO_{2_{mP}}$)	0.0277
Diesel ($\Delta CO_{2_{mD}}$)	0.0383

7.7. 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	Type of vehicle	Total electric power requirement [W]
Type-approval NEDC[28]	M1 (P_{TA-M1})	350
	N1 (P_{TA-N1})	350
Real-world driving	M1 (P_{RW-M1})	750
	N1 (P_{RW-N1})	750

7.8. Solar radiation

7.8.1. 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:

---

[26] Value derived from JRC analysis from Report "Parametrisation of fuel consumption and CO2 emissions of passenger cars and light commercial vehicles for modelling purposes, 2011."

[27] The values have been defined with the best available data in 2011 and should be revised as soon as new data is available

[28] All switchable electrical consumers off

Solar irradiation in Europe(P_{SR}) [W/m^2][29]	120

7.8.2. Solar correction coefficient

The gain of additional electric power depends on the electric on-board storage capacity. If the reserved capacity in the battery system on sunny and clear summer days is below 8 Wh (or 0.666 Ah for a 12V battery system) per Watt peak power of the PV panel, the arising solar radiation 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. For ratios between the given data points in the table below, the solar correction coefficient can be determined by linear interpolation.

Total storage capacity battery system (C_{N_Wh}) / PV peak power (P_P) [Wh/Wp]	1.2	2.4	3.6	4.8	6.0	7.2	> 8
Total storage capacity 12 V battery system (C_{N_Ah}) / PV peak power (P_P) [Ah/Wp][30]	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

7.9. Ambient temperature

The mean ambient air temperature in Europe is calculated considering the distribution of the cars on the European land surface and the car density of the Member States.

Since the temperature encountered by vehicles is dependent on their use, two main vehicle statuses are defined: driving time and parking time.

Driving ambient temperature

The value for the mean ambient air temperature during driving time includes a security margin to cover uncertainties caused by regional differences in ambient temperatures and in the driving distribution over the day.

Mean annual ambient air temperature in Europe during driving time for M1 vehicles (T_{Adt-M1}) [°C][31]	12

Mean monthly ambient air temperature in Europe during driving time for M1 vehicles (T_{Mdt-M1}) [°C]

[29] Conservative value derived from JRC analysis reported in Paper "Battery charging photovoltaic roofs on conventional combustion engine-powered passenger cars: CO_2 benefits for European vehicles".

[30] 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

[31] Reference value derived from JRC analysis reported in Malfettani, C. Lodi, T. Huld, and P. Bonnel, "Latest Developments on the European Eco-innovation Scheme for Reducing CO_2 Emissions from Vehicles: Average Input Data for Simplified Calculations", Transp. Res. Procedia, vol. 14, pp. 4113–4121, 2016.

January	February	March	April	May	June
3	3	7	12	15	19
July	August	September	October	November	December
22	21	17	13	8	4

Parking ambient temperature

The value for the mean ambient air temperature during parking time includes a security margin to cover uncertainties caused by regional differences of ambient temperatures, parking distribution over the day and share of vehicles parked inside garages at higher temperatures.

Mean annual ambient air temperature in Europe during parking time for vehicles (T_{Apt-M1}) [°C]	14

7.10. Parking time distribution

M1 vehicles

	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 %)

7.11. Mileages

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

Type of vehicle	Type of fuel	Mean annual mileage [km/y]
M1	Petrol (M_{P-M1})	12 700
	Diesel (M_{D-M1})	17 000
	LPG (M_{LPG-M1})	22 300

7.12. Road roughness

The road roughness coefficients for the road classes from A to C

Road class	Road roughness coefficient (Gr) [m·cycle]
A	$4 \cdot 10^{-7}$
B	$16 \cdot 10^{-7}$
C	$64 \cdot 10^{-7}$

7.13. Stiffness of one tire

The average stiffness of one tire

Type of vehicle	Stiffness (k_1) [N/m]
M1	200 000
N1	300 000

8. 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 Chap. 8.1. If a technology is assessed as 'potentially non-qualifying', the reasons for this assessment are cited in the table in Chap. 8.2.

8.1. Potentially qualifying technologies

No.	Technology	Technology class	Conditions
Q01	LED exterior lighting	1	Also packaging of different lighting types will fulfil 'verifiability' criterion
Q02	Battery charging solar roof	3	
Q03	Engine heat storage	4	
Q05	Predictive energy management	5	
Q06	Thermoelectric generator	6	Coverage criterion to be fulfilled
Q07	Efficient alternator	7	Verifiability criterion to be fulfilled

8.2. Potentially non-qualifying technologies

No.	Technology	Technology class	Reasons for non-qualification
N01	Recuperation	7	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	8	2.5 - 'Coverage' criterion not fulfilled
N08	Electronic valve gear	2	2.5 - 'Coverage' criterion not fulfilled
N09	Flywheel	5	2.5 - 'Coverage' criterion not fulfilled
N10	Eco-driving mode	8	2.6 - 'Accountability' criterion not fulfilled
N11	Gear shift indicator	8	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

9. EXAMPLES

In this chapter some calculation examples are provided.

The examples give advice to potential applicants on extent and level of detail of the submitted documents for individual technologies and on the calculation procedure. They are not exhaustively including all the required information and data.

The list of technologies currently cited is not finalised, and covers technologies that are already approved.

Generic data being defined in Chap. 7 is used here.

All data used for the following examples being not included in Chap. 7 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.

9.1. Class 1 – Improved electrical components

9.1.1. Efficient wiper motor

<u>*Introduction*</u>

In this example an efficient wiper motor has been considered.

<u>*Technical description of the innovative technology*</u>

Technical description of the eco-innovation and the way it is fitted on a vehicle described in writing and, when appropriate, by technical drawings.

- # *TO INSERT HERE: applicant provides technical description of the technology including technical drawings*

<u>*Innovativeness*</u>

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.*

<u>*Vehicle segment prediction*</u>

Prediction on which vehicle segments the eco-innovation will be applied.

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

<u>*Expected number of vehicles*</u>

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

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

<u>*Definition of the baseline technology*</u>

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.

> *Example*
>
> The electric power requirement of the fitted baseline wiper motor (operated at low power level) is:
>
> $$P_L^{base} = 100W$$
>
> The electric power requirement of the fitted baseline wiper motor (operated at high power level) is:
>
> $$P_H^{base} = 150W$$

<u>*Testing methodology*</u>

Procedure

Measurements are to be performed using a power supply unit and multi meters to measure the DC-current and the DC-voltage.

TO INSERT HERE: applicant provides the description of the methodology to evaluate the power consumption of the technology.

In total 5 measurements is to be done with the defined voltages.

TO INSERT HERE: applicant provides the vehicle working voltages.

Calculation of the power savings

For each of the 5 measurements the power which is used is to be calculated by multiplying the installed voltage with the measured current. This will result in 5 values. Each value must be expressed in 4 decimals. Then the mean value of the used power will be calculated, which is the sum of the 5 values for the power divided by 5.

The resulting power savings are to be calculated with the following formula:

Equation 7

$$\Delta P = P_B - P_E$$

ΔP: Saved electrical power [W]

P_B: Power of the baseline [W]

P_E: Mean value of the used power of the eco-innovation [W]

Calculation of the CO_2 savings

The total CO_2 savings of the wiper motor are to be calculated using the following equations.

For petrol-fuelled vehicle:

Equation 8

$$C_{CO_2} = (\Delta P_L \cdot UF_L + \Delta P_H \cdot UF_H) \cdot V_{Pe-P} / \eta_A \cdot CF_P / v$$

For Diesel-fuelled vehicle:

Equation 9

$$C_{CO_2} = (\Delta P_L \cdot UF_L + \Delta P_H \cdot UF_H) \cdot V_{Pe-D} / \eta_A \cdot CF_D / v$$

C_{CO_2}: CO_2 savings [g CO_2/km]

ΔP_L: Saved electric power at low power level [W]

ΔP_H: Saved electric power at high power level [W]

UF_L: Usage factor at low power level [-]

UF_H: Usage factor at high power level [-]

v: Mean driving speed of the NEDC (see Chap. 7.2) [km/h]

V_{Pe-P}: Consumption of effective power for petrol-driven vehicles [l/kWh]

V_{Pe-D}: Consumption of effective power for Diesel-driven vehicles [l/kWh]

η_A: Efficiency of the alternator [-]

CF_P: Conversion factor (l/100 km) - (g CO_2/km) for petrol fuel [gCO_2/l]

CF_D: Conversion factor (l/100 km) - (g CO_2/km) for Diesel fuel [gCO_2/l]

Calculation of the statistical uncertainty

The standard deviation of the CO_2 savings is to be calculated by means of the following equations.

TO INSERT HERE: applicant provides the description of the methodology to quantify the statistical uncertainties following the procedure described in Chap. 6.3.

<u>*Description of the case study*</u>

TO INSERT HERE: applicant provides short technical description of the case study.

<u>*Application of the testing methodology*</u>

> *Example*
>
> The electric power requirement of the fitted innovative wiper motor (operated at low power level) is:
>
> $$P_L^{eco} = 50W$$
>
> The electric power requirement of the fitted innovative wiper motor (operated at high power level) is:
>
> $$P_H^{eco} = 75W$$

The electric power requirement is not varying between different vehicle versions.

TO INSERT HERE: applicant provides technical explanation

Input data:

$\Delta P_L = P_L^{base} - P_L^{eco} = 100W - 50W = 50W$

$\Delta P_H = P_H^{base} - P_H^{eco} = 150W - 75W = 75W$

$UF_L = 0.08$ (see Chap. 7.4.3)

$UF_H = 0.02$ (see Chap. 7.4.3)

$v = 33.58\,km/h$ (see Chap. 7.2)

$V_{Pe-P} = 0.264\,l/kWh$ (see Chap. 7.1.1)

$\eta_A = 0.67$ (see Chap. 7.1.2)

$CF_P = 2330\,gCO_2/l$ (see Chap. 7.3.2)

Calculation of the CO_2 saving per petrol-engine vehicle:

$$C_{CO_2} = (\Delta P_L \cdot UF_L + \Delta P_H \cdot UF_H) \cdot V_{Pe-P}/\eta_A \cdot CF_P/v$$

$$C_{CO_2} = (50W \cdot 0.08 + 75W \cdot 0.02) \cdot \frac{0.264\,l/kWh}{0.67} \cdot \frac{2330\,gCO_2/l}{33.58\,km/h} = 0.1504\,gCO_2/km$$

Result, rounded to one decimal place:

$$C_{CO_2} = 0.2\,gCO_2/km$$

TO INSERT HERE: applicant provides the evaluation of the data quality and of the uncertainties following the procedure described in Chap. 6.3.

Check of eligibility criteria

1. Non-exceeding requirements in EU law:

Currently there is no legislation about CO2 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 rounded (maximum to two decimal places) CO_2 saving of the eco-innovation technology of 0.15 g CO_2/km, subtracted by its standard deviation, 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 CO2 type approval test procedure, since the activation of windscreen wipers is not included in the current CO2 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

<u>Total result</u>

In this example, the application **cannot** be granted because of non-compliance with the 'verifiability' criteria.

9.1.2. LED exterior lighting

<u>Introduction</u>

In this example an efficient exterior lighting system has been considered.

LED exterior lighting systems have been approved as eco-innovations by Commission Decisions 2013/128/EU[32], 2014/128/EU[33] and 2015/206[34].

LED is an abbreviation of Light-Emitting Diode. It consists of semiconductors. When direct current (DC) is connected to these semiconductors light is produced. The efficacy of the lighting source is expressed in lm/W indicating the amount of produced luminous flux per used electric power.

In the table below the efficacy of some light sources[35] are given.

Light sources	**Lumen/Watt**
Tungsten light bulb	15
Tungsten/halogen	35
Arc xenon	50-55
LED	101.9
Theoretical limit (white LED with phosphorescence colour mixing)	260–300

[32] Commission Implementing Decision 2013/128/EU: http://europa.eu/!Ch46gt

[33] Commission Implementing Decision 2014/128/EU: http://europa.eu/!CU64Wd

[34] Commission Implementing Decision 2015/206: http://europa.eu/!kx66Gw

[35] Luminous efficacy: http://en.wikipedia.org/wiki/Luminous_efficacy

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 (see Directive 2008/89/EC[36]). 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 and technical drawings

Innovativeness

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

> *Example:*
>
> In order to determine the market penetration of LED lights, a reference is the *CLEPA Light Sight Safety* initiative. As part of that initiative, suppliers of headlamps and rear lamps have individually estimated the penetration rates of innovative technologies in the different lighting applications, based on production in figures the EU for the year 2009.

Type of lighting	**Estimated Fitting rate** ***(new cars, EU 2009)***
Low beam headlamp	<1%
High beam headlamp	<1%
Front position	~2%
Fog – front	<1%
Turn signal - front	<2%
Fog – rear	<1%
Turn signal – rear	~3%
License plate	<1%
Reversing	<1%

Vehicle segment prediction

Prediction on which vehicle segments the eco-innovation will be applied.

TO INSERT HERE: applicant provides an estimate

Expected number of vehicles

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

TO INSERT HERE: applicant provides an estimate

[36] Directive 2008/89/EC: http://europa.eu/!rW96Yv

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 electric power requirements of the fitted baseline technologies related to an on-board voltage of 13.4 V are (see Chap. 7.5):

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

Testing methodology

Conditions

The requirements of UN/ECE Regulation No 112[37] (1) on Uniform provisions concerning the approval of motor vehicle headlamps emitting an asymmetrical passing beam or a driving beam or both and equipped with filament lamps and/or light-emitting diode (LED) modules shall apply. For determining the power consumption, the reference is to be made to point 6.1.4 of Regulation No 112, and points 3.2.1 and 3.2.2 of Annex 10 of Regulation No 112.

Procedure

Measurements are to be performed using a power supply unit and multi meters to measure the DC-current and the DC-voltage.

In total 5 measurements is to be done with the defined voltages.

> # *TO INSERT HERE: applicant provides the vehicle working voltages.*

Calculation of the power savings

For each of the 5 measurements the power which is used is to be calculated by multiplying the installed voltage with the measured current. This will result in 5 values. Then the mean value of the used power will be calculated, which is the sum of the 5 values for the power divided by 5.

The resulting power savings are to be calculated with the following equation.

---

[37] E/ECE/324/Rev.2/Add.111/Rev.3 — E/ECE/TRANS/505/Rev.2/Add.111/Rev.3, 9 January 2013

Equation 10

$$\Delta P = P_B - P_{EI}$$

ΔP: Saved electrical power [W]

P_B: Power of the baseline [W]

P_{EI}: Mean value of the used power of the eco-innovation [W]

Calculation of the CO_2 savings

The total CO_2 savings of the lighting package are to be calculated using the following equations.

For petrol-fuelled vehicle:

Equation 11

$$C_{CO_2} = \left(\sum_{j=1}^{m} \Delta P_j \cdot UF_j\right) \cdot V_{Pe-P}/\eta_A \cdot CF_P/v$$

For Diesel-fuelled vehicle:

Equation 12

$$C_{CO_2} = \left(\sum_{j=1}^{m} \Delta P_j \cdot UF_j\right) \cdot V_{Pe-D}/\eta_A \cdot CF_D/v$$

C_{CO_2}: CO_2 savings [g CO_2/km]

ΔP_j: Saved electrical power of lighting type j [W]

UF_j: Usage factor of lighting type j [-]

m: Type of lighting

v: Mean driving speed of the NEDC [km/h]

V_{Pe-P}: Consumption of effective power for petrol-driven vehicles [l/kWh]

V_{Pe-D}: Consumption of effective power for Diesel-driven vehicles [l/kWh]

η_A: Efficiency of the alternator [-]

CF_P: Conversion factor (l/100 km) - (g CO_2/km) for petrol fuel [gCO_2/l]

CF_D: Conversion factor (l/100 km) - (g CO_2/km) for Diesel fuel [gCO_2/l]

Calculation of the statistical uncertainty

The standard deviation of the CO_2 savings is to be calculated by means of the following equations.

TO INSERT HERE: applicant provides the description of the methodology to quantify the statistical uncertaintiesfollowing the procedure described in Chap. 6.3.

<u>*Description of the case study*</u>

The types of lighting that have been tested are the following: low beam headlamp, high beam headlamp, front position, fog-front, turn signal-front, fog-rear, turn signal-rear, licence plate and reversing.TO INSERT HERE: applicant provides the description of the case study.

Example:

\# *TO INSERT HERE: applicant provides technical description of the measures applied including data on electrical power requirements and measurement protocols verified by an independent technical body*

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
Fog – rear	3
Turn signal – rear	1.5
License plate	2
Reversing	4

The electric power requirement is not varying between different vehicle versions.

\# *TO INSERT HERE: applicant provides technical explanation*

Calculation example for low beam headlamp

Input data:

$\Delta P = 137W - 40W = 97W$

$UF = 0.33$ (see Chap. 7.4.1)

$v = 33.58\,km/h$ (see Chap. 7.2)

$V_{Pe-P} = 0.264\,l/kWh$ (see Chap. 7.1.1)

$V_{Pe-D} = 0.22\,l/kWh$ (see Chap. 7.1.1)

$\eta_A = 0.67$ (see Chap. 7.1.2)

$CF_P = 2330\,gCO_2/l$ (see Chap. 7.3.2)

$CF_D = 2640\,gCO_2/l$ (see Chap. 7.3.2)

Calculation of the CO_2 saving per petrol-fuelled vehicle:

$$C_{CO_2} = \Delta P \cdot UF \cdot V_{Pe-P}/\eta_A \cdot CF_P/v = 97W \cdot 0.33 \cdot \frac{0.264\,l/kWh}{0.67} \cdot \frac{2330\,gCO_2/l}{33.58\,km/h} = 0.8752\,gCO_2/km$$

Calculation of the CO_2 saving per Diesel-fuelled vehicle:

$$C_{CO_2} = \Delta P \cdot UF \cdot V_{Pe-D}/\eta_A \cdot CF_D/v = 97W \cdot 0.33 \cdot \frac{0.22\,l/kWh}{0.67} \cdot \frac{2640\,gCO_2/l}{33.58\,km/h} = 0.8264\,gCO_2/km$$

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
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: $C_{CO_2} = 1.2989\,gCO_2/km$
- Diesel-fuelled vehicles: $C_{CO_2} = 1.2264\,gCO_2/km$

Results, rounded to one decimal place:

- Petrol-fuelled vehicles: $C_{CO_2} = 1.3\,gCO_2/km$
- Diesel-fuelled vehicles: $C_{CO_2} = 1.2\,gCO_2/km$

TO INSERT HERE: applicant provides the evaluation of the data quality and of the uncertainties following the procedure described in Chap. 6.3.

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:

In the table below 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 rounded (maximum to two decimal places) total CO_2 savings of the eco-innovation technology as a package, subtracted by its standard deviation, 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.

9.2. Class 3 – Use of ambient energy sources

9.2.1. Battery charging solar roof

Introduction

In this example a battery charging solar roof system has been considered.

Battery charging solar roof has been approved as eco-innovations by Commission Decisions 2014/806/EU[38] and 2015/279[39].

Photovoltaic panels consist of semiconducting materials. Sunlight consists of photons. A certain percentage of photons that hit the solar panel will be absorbed by the semiconducting materials. With the energy of the photons electrons can become detached from their atoms. And so the electrons are able to flow. Due to the semi conducting material the electrons can flow only in one direction and so forming direct current (DC). This current will be used to charge the battery.

Mainly at daytime and when the car is not parked inside or not parked in the shadow the solar roof will produce electricity. So it is important to collect statistical information about these parking situations and also to define a so-called shading factor. This factor reflects the percentage of time that the car is parked in a shaded situation. The JRC has conducted a study on these items.

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 the battery system of the vehicle. 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 including technical drawings

The electric power production depends on the surface area and efficiency 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 reserved electric storage capacity of the battery system. 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

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.

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[38] Commission Implementing Decision 2014/806/EU: http://europa.eu/!JY48Wf

[39] Commission Implementing Decision 2015/279: http://europa.eu/!kF44Rm

Vehicle segment prediction

Prediction on which vehicle segments the eco-innovation will be applied.

TO INSERT HERE: applicant provides an estimate

Expected number of vehicles

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

TO INSERT HERE: applicant provides an estimate

Definition of the baseline technology

There are three situations which can be distinguished:

1. A totally new version/vehicle equipped with a solar panel is brought on the EU market. In this situation the baseline vehicle is the vehicle with the solar panel installed but disconnected

2. An existing version is brought on the market in which the solar panel is installed. The baseline vehicle is the existing version without the solar panel. The difference in mass should be determined and the extra CO_2 emissions, calculated with the Equation 13 and Equation 14 should be subtracted

3. An existing version is brought on the market in which the solar panel and an extra battery are installed. The baseline vehicle is the existing version without the solar panel and the extra battery. The difference in mass should be determined and the extra CO_2 emissions, calculated with the formulae below, should be subtracted

Evaluation of negative effects

The difference in mass between the baseline vehicle and the eco-innovation vehicle due to the installation of the solar roof and where relevant, the extra battery, is to be taken into account by applying the mass correction coefficient. The baseline vehicle is to be a vehicle variant that in all aspects is identical to the eco-innovation vehicle with the exception of the solar roof and, where applicable, without the additional battery and other appliances needed specifically for the conversion of the solar energy into electricity and its storage.

For a new version of a vehicle in which the solar roof panel is installed the baseline vehicle is to be specified as follows: it is the vehicle in which the solar roof panel is disconnected and the change in mass due to the installation of the solar roof is taken into account. In case the solar roof panel is made of glass a correction for the change in mass is to be introduced. In case the solar roof panel is made of low weight synthetic material no correction for the change in mass has to be made. On this change of mass the manufacturer must hand over verified documentation to the Type-Approval Authority.

TO INSERT HERE: applicant provides technical explanation

The CO_2 correction coefficient due to the extra mass has to be calculated with Equation 13 and Equation 14[40].

[40] Parameterisation of fuel consumption and CO_2 emissions of passenger cars and light commercial vehicles for modelling purposes: http://europa.eu/!qN68wc

For petrol-fuelled vehicle:

Equation 13

$$\Delta CO_{2mP} = 0.0277 \cdot \Delta m$$

For Diesel-fuelled vehicle:

Equation 14

$$\Delta CO_{2mD} = 0.0383 \cdot \Delta m$$

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

Δm: Extra mass due to the installation of the solar roof and, where applicable, the additional battery and other appliances needed specifically for the conversion of the solar energy into electricity and its storage.

Testing methodology

Conditions

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[41] under supervision of an independent and certified body.

Procedure

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.

Equation 15

$$P_P = mP_P \cdot \cos \propto$$

P_P: Peak power of the photovoltaic panel [W_P]

mP_P: Measured peak power of the photovoltaic panel measured following norm IEC 61215 [W_P]

$\propto$: Lengthwise inclination of the car roof [°]

Calculation of the CO_2 savings

The evaluation of the CO_2 savings of the technology can be performed using the following equations.

[41] IEC 61215 – Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval

For petrol-fuelled vehicle:

Equation 16

$$C_{CO_2} = P_{SR} \cdot UF_{IR} \cdot \eta_{SS} \cdot\ P_P \cdot SCC \cdot V_{Pe-P}/\eta_A \cdot CF_P/M_P - \Delta CO_{2mP}$$

For Diesel-fuelled vehicle:

Equation 17

$$C_{CO_2} = P_{SR} \cdot UF_{IR} \cdot \eta_{SS} \cdot\ P_P \cdot SCC \cdot V_{Pe-D}/\eta_A \cdot CF_D/M_D - \Delta CO_{2mD}$$

C_{CO_2}: CO_2 savings [g CO_2/km]

P_{SR}: Mean solar irradiation [W/m^2]

UF_{IR}: Usage factor / shading effect [-]

η_{SS}: Efficiency of the solar system [-]

SCC: Solar correction coefficient [-]

V_{Pe-P}: Consumption of effective power for petrol-driven vehicles [l/kWh]

V_{Pe-D}: Consumption of effective power for Diesel-driven vehicles [l/kWh]

η_A: Efficiency of the alternator [-]

CF_P: Conversion factor (l/100 km) - (g CO_2/km) for petrol fuel [gCO_2/l]

CF_D: Conversion factor (l/100 km) - (g CO_2/km) for Diesel fuel [gCO_2/l]

M_P: Mean annual mileage for petrol-fuelled vehicles [km/a]

M_D: Mean annual mileage for diesel-fuelled vehicles [km/a]

The calculation of the solar correction coefficient is directly dependent on the power peak of the solar panel (P_P) and on the capacity in the battery system reserved of solar energy (C_N) as on table below.

Total storage capacity battery system (C_{N_Wh}) / PV peak power (P_P) [Wh/Wp]	1.2	2.4	3.6	4.8	6.0	7.2	> 8
Solar correction coefficient (SCC)	0.481	0.656	0.784	0.873	0.934	0.977	1

Calculation of the statistical uncertainty

The standard deviation of the CO_2 savings is to be calculated by means of the following equations.

TO INSERT HERE: applicant provides the description of the methodology to quantify the statistical uncertainties following the procedure described in Chap. 6.3.

<u>*Description of the case study*</u>

TO INSERT HERE: applicant provides short technical description of the case study. It should contain all necessary technical data (like surface area, curvature angles, materials, efficiencies etc.) to enable a clear identification of the PV panel.

<u>*Application of the testing methodology*</u>

Example:

The measurements of a dismantled PV module under IEC 61215[41] 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:

$$101.0\mathrm{W_P} \cdot \cos 8° = 100\mathrm{W_P}$$

> # *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.*

The battery system reserved for solar energy has a capacity of $\mathrm{C_{N\_Ah}} = 40\mathrm{Ah}$.

Input data:

$\mathrm{P_{SR}} = 120\,\mathrm{W/m^2}$ (see Chap. 7.8.1)

$\mathrm{UF_{IR}} = 0.51$ (see Chap. 7.4.2)

$\eta_{\mathrm{SS}} = 0.76$ (see Chap. 7.1.3)

$\mathrm{P_P} = 100\mathrm{W_P} = 100\mathrm{W}/1000\,\mathrm{W/m^2}$

$\mathrm{V_{Pe-P}} = 0.264\,\mathrm{l/kWh}$ (see Chap. 7.1.1)

$\mathrm{V_{Pe-D}} = 0.22\,\mathrm{l/kWh}$ (see Chap. 7.1.1)

$\eta_{\mathrm{A}} = 0.67$ (see Chap. 7.1.2)

$\mathrm{CF_P} = 2330\,\mathrm{gCO_2/l}$ (see Chap. 7.3.2)

$\mathrm{CF_D} = 2640\,\mathrm{gCO_2/l}$ (see Chap. 7.3.2)

$\mathrm{M_P} = 12\,700\,\mathrm{km/a} = 1449.8\,\mathrm{m/h}$ (see Chap. 7.11)

$\mathrm{M_D} = 17\,000\,\mathrm{km/a} = 1940.6\,\mathrm{m/h}$ (see Chap. 7.11)

Calculation of the solar correction coefficient:

$$\mathrm{C_{N\_Wh}} = 12\,\mathrm{V} \cdot 40\mathrm{Ah} = 480\mathrm{Wh}$$

$$\mathrm{C_{N\_Wh}}/\mathrm{P_P} = 480\,\mathrm{Wh}/100\mathrm{W_P} = 4.8\ \mathrm{Wh/W_P}$$

$$\mathrm{SCC} = 0.873$$

Calculation of the CO_2 saving per petrol-fuelled vehicle:

$$\mathrm{C_{CO_2}} = \mathrm{P_{SR}} \cdot \mathrm{UF_{IR}} \cdot \eta_{\mathrm{SS}} \cdot \mathrm{P_P} \cdot \mathrm{SCC} \cdot \mathrm{V_{Pe-P}}/\eta_{\mathrm{A}} \cdot \mathrm{CF_P}/\mathrm{M_P} - \Delta\mathrm{CO_{2mP}}$$

$$\mathrm{C_{CO_2}} = 2.5720\mathrm{gCO_2/km} - \Delta\mathrm{CO_2}_{\mathrm{mP}}$$

Calculation of the CO_2 saving per diesel-fuelled vehicle:

$$\mathrm{C_{CO_2}} = \mathrm{P_{SR}} \cdot \mathrm{UF_{IR}} \cdot \eta_{\mathrm{SS}} \cdot \mathrm{P_P} \cdot \mathrm{SCC} \cdot \mathrm{V_{Pe-D}}/\eta_{\mathrm{A}} \cdot \mathrm{CF_D}/\mathrm{M_D} - \Delta\mathrm{CO_{2mD}}$$

$$\mathrm{C_{CO_2}} = 1.8138\mathrm{gCO_2/km} - \Delta\mathrm{CO_2}_{\mathrm{mD}}$$

Results, rounded to one decimal place:

- Petrol-fuelled vehicles: $C_{CO_2} = 2.6\,gCO_2/km - \Delta CO_{2_{mP}}$
- Diesel-fuelled vehicles: $C_{CO_2} = 1.8\,gCO_2/km - \Delta CO_{2_{mD}}$

  # *TO INSERT HERE: applicant provides the evaluation of the data quality and of the uncertainties following the procedure described in Chap. 6.3.*

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 rounded (maximum to two decimal places) CO_2 savings of the eco-innovation technology, subtracted by its standard deviation, 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.

9.3. Class 4 – Energy storing systems

9.3.1. Engine heat storage

Introduction

In this example engine heat storage has been considered.

Engine heat storage system has been approved as eco-innovations by Commission Decisions 2013/451/EU[42].

The advantage of using the heat of an engine is that the friction of the engine will be lower, because of the better performance of the lubrication oil at higher temperatures of the power train. There are different ways of using the heat of the engine. One of these is engine encapsulation.

An engine compartment encapsulation system permits the reduction of heat loss after the vehicle is turned off by sealing the engine compartment and by closing of grille openings by a radiator shutter. The stored heat yields a delayed cool-down of the powertrain. The fuel consumption and CO_2 emissions of the vehicle after restarting is decreased due to lower friction caused by the higher powertrain temperature.

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 cut-off 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 including technical drawings

Innovativeness

The market penetration of the engine encapsulation technology has been demonstrated on the report Market penetration of an underhood encapsulation in the EU in 2009 created by the Institute for Automotive Engineering – RWTH Aachen University.

In the study the market penetration of combined thermal management measures in vehicle engine bays in the European Union was analysed for the year 2009. A thermal engine encapsulation is an example for a combined thermal management. Regarding combined thermal management, a market penetration of 0% was defined.

Additionally, the market penetration of active and advanced active thermal management was analysed. Active thermal management can be considered as an intermediate step towards combined thermal management. The market penetration of advanced active thermal management in the EU in 2009 was less than 3%. Overall, it can be found that the share of newly registered vehicles in the EU in 2009 equipped with advanced active thermal management, as well as combined thermal management, did not exceed 3%.

TO INSERT HERE: applicant provides proving documents and expert judgement document on the market share of the innovative technology in the reference year.

Vehicle segment prediction

[42] Commission Implementing Decision 2013/451/EU: http://europa.eu/!Jd88bP

Prediction on which vehicle segments the eco-innovation will be applied.

TO INSERT HERE: applicant provides an estimate

Expected number of vehicles

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

TO INSERT HERE: applicant provides an estimate

Definition of the baseline technology

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

In the case of a new version of the vehicle in which the eco-innovation is already installed, the baseline vehicle is the vehicle in which this energy storing device is deactivated.

Testing methodology

Determination of the cool-down curves

The cool-down curves of both the baseline and the eco-innovative 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 (see Chap. 7.9). The engine should be heated up to the maximum coolant temperature before cut-off 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 minutes after engine cut-off should be cut because of the untypical behaviour of the coolant temperature after switching off the coolant circuit.

Equation 18

$$T(t) = T_A + (T_0 - T_A)e^{-d \cdot t}$$

$T(t)$: Temperature over time [°C]

T_0: Temperature of the operating engine [°C]

T_A: Ambient temperature [°C]

d: Decay constant [1/h]

Determination of the hot start benefit (HSB)

The CO_2 saving effect depends on the temperature difference between the eco-innovative 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.

The hot start benefit (HSB) of the eco-innovative 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.

Equation 19

$$\mathrm{HSB} = 1 - \frac{\mathrm{CO_2(hot)}}{\mathrm{CO_2(cold)}}$$

HSB: Hot start benefits [-]

$\mathrm{CO_2(hot)}$: CO_2 emissions at hot start engine temperature $[\mathrm{gCO_2/km}]$

$\mathrm{CO_2(cold)}$: CO_2 emissions at cold start engine temperature $[\mathrm{gCO_2/km}]$

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 (see Chap. 7.9). 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%.

All measurements should be performed under supervision of an independent and certified body.

Calculation of the CO_2 savings

The relative CO_2 reduction potential $\Delta\mathrm{CO_2}(\mathrm{t_{pt}})$ for different parking times shall be calculated using the following equation.

Equation 20

$$\Delta\mathrm{CO_2}(\mathrm{t_{pt}}) = 1.443 \cdot \ln\left(\frac{\mathrm{e}^{-\mathrm{d_E}\cdot\mathrm{t_{pt}}} + 1}{\mathrm{e}^{-\mathrm{d_B}\cdot\mathrm{t_{pt}}} + 1}\right) \cdot \mathrm{HSB}$$

$\mathrm{d_E}$: Decay constant of the eco-innovative vehicle $[1/\mathrm{h}]$

$\mathrm{d_B}$: Decay constant of the baseline vehicle $[1/\mathrm{h}]$

$\mathrm{t_{pt}}$: Parking time [h]

The total CO_2 savings, weighted by the parking times $(\mathrm{t_{pt}})$ shall be calculated using the following equation.

Equation 21

$$\mathrm{C_{CO_2}} = \mathrm{TA_{CO_2}} \cdot \sum_{\mathrm{pt}=1}^{24} \Delta\mathrm{CO_2}(\mathrm{t_{pt}}) \cdot \mathrm{SVS_{pt}}$$

$\mathrm{C_{CO_2}}$: CO_2 savings [g CO_2/km]

$\mathrm{TA_{CO_2}}$: CO_2 emission under type approval procedure $[\mathrm{gCO_2/km}]$

$\mathrm{SVS_{pt}}$: Parking time distribution [-] (see Chap 7.10)

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:

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

$\mathrm{D_e}$: Engine displacement [cm^3]
$\mathrm{HSB_0}$: Hot start benefit (for petrol or diesel engines)
SF: Slope factor $[\%/(\mathrm{K} \cdot \mathrm{cm}^3)]$ (for petrol or diesel engines)

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

Calculation of the statistical uncertainty

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%.

TO INSERT HERE: applicant provides the description of the methodology used to quantify the statistical uncertainties following the procedure described in Chap. 6.3.

TO INSERT HERE: applicant demonstrates an inappropriate high effort in testing, and proposes a reduction on the minimum number of measurement pending the compliance with stricter requirements on the statistical uncertainty.

<u>*Description of the case study*</u>

TO INSERT HERE: applicant provides short technical description of the case study. It should contain all necessary technical data (chassis, engine etc.) to enable a clear identification of the surveyed vehicles.

<u>*Application of the testing methodology*</u>

> *Example:*
>
> The measured coolant curve has been measured 20 minutes after engine cut off to avoid the untypical behaviour of the coolant temperature.
>
> The measured coolant curve of the baseline vehicle (without heat storage measures) has been approached by a decay constant of $\mathrm{d_B} = 0.5\ \mathrm{h}^{-1}$. The measured coolant curve of the eco-innovative vehicle has been approached by a decay constant of $\mathrm{d_E} = 0.3\ \mathrm{h}^{-1}$.

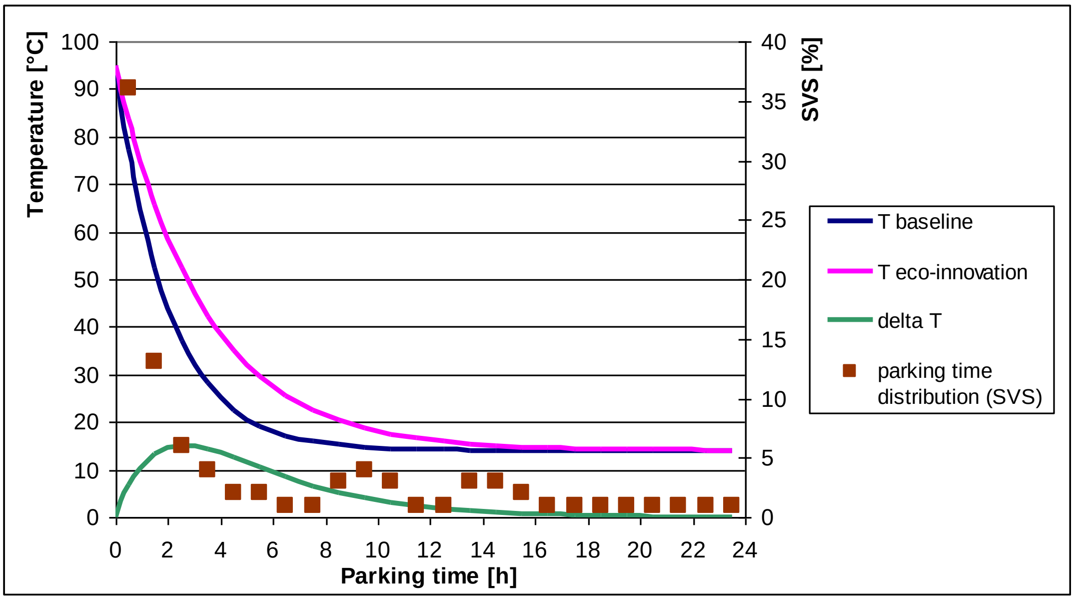

Figure 2: Cool-down curves of baseline and eco-innovation technologies, temperature differences and parking time distribution

\# *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.*

The measured CO_2 emissions in the different testing conditions are shown in the Table below.

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%

$$HSB = 1 - \frac{118\,gCO_2/km}{137\,gCO_2/km} = 13.87\%$$

\# *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.*

CO_2 emission under type approval procedure:

$$TA_{CO_2} = 130\,gCO_2/km$$

Calculation of the relative CO_2 reduction potential $\Delta CO_2(t_{pt})$ for different parking times.

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
$\mathbf{\Delta CO_2(t_{pt})}$ **[%]**	0.90	2.13	2.70	2.80	2.61	2.28	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
$\mathbf{\Delta CO_2(t_{pt})}$ **[%]**	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 (t_{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

$$C_{CO_2} = 130\,gCO_2/km \cdot 1.1392\% = 1.4810\,gCO_2/km$$

Result, rounded to one decimal place:

$$C_{CO_2} = 1.5\,gCO_2/km$$

TO INSERT HERE: applicant provides the evaluation of the data quality and the documentation that demonstrate the compliance with stricter requirements on the statistical uncertainty.

<u>*Check of eligibility criteria*</u>

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 rounded (maximum to two decimal places) total CO_2 saving of the eco-innovation technology, subtracted by its standard deviation, 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. Current legislation for testing prescribes a maximum engine starting temperature not exceeding the ambient test cell temperature by more than 2°C. Hence, effects of reduced engine cooling after engine cut-off 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.

9.4. Class 5 – Kinetic energy of the vehicle

9.4.1. Predictive energy management

Introduction

In this example a predictive energy management system has been considered.

Predictive energy management has been approved as eco-innovations by Commission Decisions 2013/529/EU[43].

The potential energy of a vehicle can be recuperated when the vehicle goes downhill. The energy can be used to charge the battery of hybrid electric vehicles, thus reducing the CO_2 emissions.

In order to increase the potential energy recuperation, navigation systems can be used to predict when a car will go uphill or downhill and consequently adapt the state of charge of the battery.

Technical description of the innovative technology

The innovative technology consists of a system for controlling the state of charge of a battery in a hybrid electric vehicle through a navigation system that continuously monitors the geospatial positioning of the vehicle and provides information on the slope profile of the driving route in order to estimate recuperation potentials on the route.

Based on this potential, the system adapts the state of charge of the battery so that maximal energy utilization and recuperation is realised: when the car goes uphill the electric power of the battery is used, and when the car goes downhill the potential energy of the slope of the road is used to charge the battery.

TO INSERT HERE: applicant provides technical description including technical drawings

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.

Vehicle segment prediction

Prediction on which vehicle segments the eco-innovation will be applied.

TO INSERT HERE: applicant provides an estimate

Expected number of vehicles

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

TO INSERT HERE: applicant provides an estimate

[43] Commission Implementing Decision 2013/529/EU: http://europa.eu/!kx84Pp

Definition of the baseline technology

The baseline technology is the standard technology without eco-innovation technology activated (i.e. without the predictive energy management system activated).

This deactivation can be established by not providing GPS-time data to the navigation system. For the purpose of the roller bench test, it must be possible to activate and deactivate the usage of the innovative technology

Testing methodology

Conditions

The following conditions shall be met:

a) The navigation system of the innovative technology has to be able to use the GPS-time data for performing the test cycle.

b) The roller test bench shall be able to test hybrid electric vehicles (PHEV/HEV) and shall be able to support road slope profiles. Given the variety of hybrid powertrain architectures, a four wheel enabled test bench is required.

Procedure

Since it is clear that the CO_2 reducing effect of the innovative technology cannot be demonstrated from the use of the speed/time-profile of the NEDC, a deviation from the NEDC was defined.

The emissions of CO_2, fuel consumption and electric energy consumption of the tested vehicles are to be measured in accordance with UN/ECE Regulation No 101. Only the speed profiles and the test bench settings shall be modified according to the following:

(a) Test bench

- The slope-time data shall be used as control input for the roller test bench.

- The speed-time data shall be used as instructions for the test driver for performing the test. The speed and time tolerances shall be in accordance with paragraph 1.4 of Annex 7 to UN/ECE Regulation No 101.

The reference test cycle that can be attributed to evaluate the CO_2 reduction of the innovative technology in is representative of the European situation is shown in Figure 3 and Figure 4[44].

The reference cycle contains speed and slope profiles and it is representative of the European situation. The deviation in the testing methodology from the NEDC speed/time profile has been considered appropriate since conservative for the evaluation of the benefits of the technology.

TO INSERT HERE: applicant provides proving documents demonstrating the appropriateness of the deviation from the NEDC speed/time profile.

[44] Further details in Commission Decisions 2013/529/EU

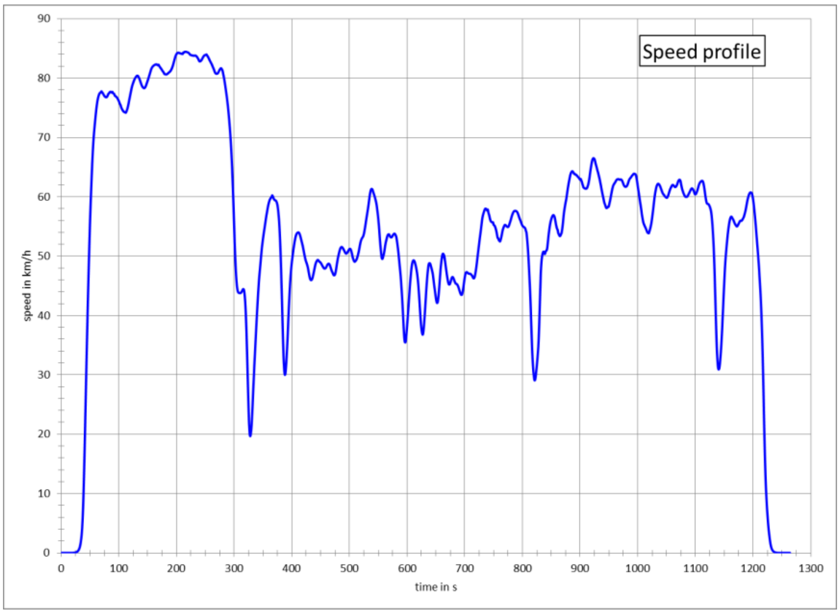

Figure 3: speed profile over time

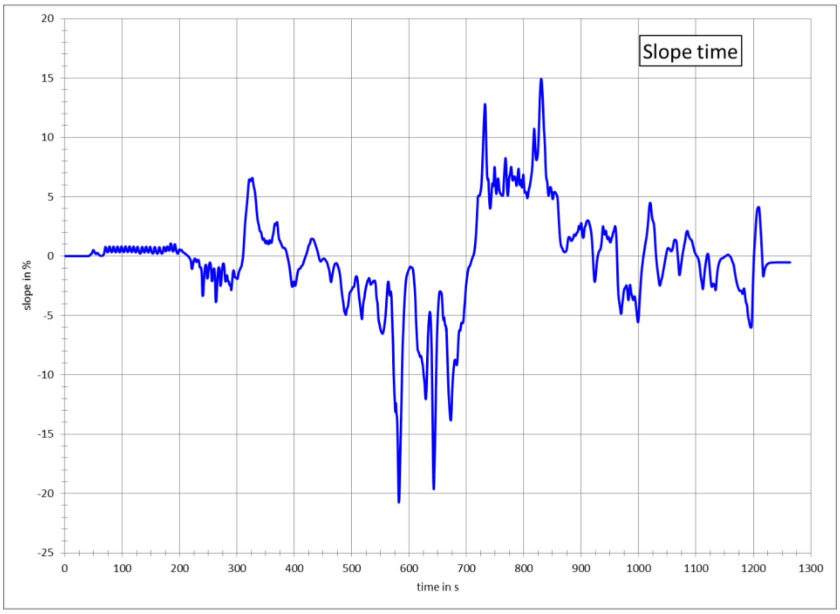

Figure 4: slope profile over time

(b) Pre-conditioning of the vehicle

One complete test cycle shall be performed with the innovative technology deactivated to reach the standard hot testing conditions of engine, electric motor and battery with regard to temperatures and state of charge, i.e. a state of charge of 50–60 percent.

(c) Navigation system

During the test of the eco-innovation vehicle, the navigation system has to simulate the GPS position of the vehicle using the GPS–time data provided using one of the following methodologies:

- The GPS-time data is provided to the navigation system using a data carrier (e.g. SD-Card, USB-Stick, DVD) plugged into the navigation device. The GPS data stored into the data carrier shall be as a text data in a file (e.g. '.csv') or as a file format comprehensibly generated from the GPS system.

- The GPS-time data is used as input for a GPS-Signal Generator that is part of the roller dynamometer setting. The GPS-Signal Generator and the roller dynamometer shall be synchronized on a time basis.

(d) Executing the test

To synchronise the roller dynamometer movement with the output of the navigation system, both systems (test bench and the navigation system) have to be started at the same point in time (± 1 s).

TO INSERT HERE: applicant provides proving documents (measurement protocols) on the predictive energy management system technology.

(e) Number of test

Two series of measurements have to be done using the reference test cycle. One series of measurements has to be done with the vehicle in which the predictive energy management system is activated. During the tests the navigation system has to simulate the GPS position of the vehicle using the GPS-time data of the reference cycle. The other series of measurements has to be done with the vehicle in which the predictive energy management system is not activated.

Calculation of the CO_2 savings

The formula to calculate the CO_2 savings is the following:

Equation 22

$$C_{CO_2} = (B_{MC} - E_{MC}) \cdot UF$$

C_{CO_2}: CO_2 savings [g CO_2/km]

E_{MC}: CO_2 emissions of the eco-innovation vehicle using the reference test cycle [g CO_2/km]

B_{MC}: CO_2 emissions of the baseline vehicle using the reference test cycle [g CO_2/km]

UF: Temporal share of the technology usage in normal operation conditions [-]

Calculation of the statistical uncertainty

The complete test procedure on the test bench shall be repeated at least two times. The arithmetic means of the CO_2 emissions from the eco-innovation vehicle, and of the baseline vehicle and the respective variation coefficients of the means shall be calculated. Further test repetitions on the dynamometer are required until the variation coefficients of both arithmetic means are below 1 %.

TO INSERT HERE: applicant provides the description of the methodology used to quantify the statistical uncertainties following the procedure described in Chap. 6.3.

TO INSERT HERE: applicant demonstrates an inappropriate high effort in testing and proposes a reduction on the minimum number of measurement pending the compliance with stricter requirements on the statistical uncertainty.

Application of the testing methodology

Example:

The results of the measurement performed using the reference test cycle are shown on the Table below.

C_{CO_2} [g CO_2/km]	B_{MC}	E_{MC}
Test 1	130	120
Test 2	129	119
Test 3	130	120
Arithmetic mean	130	120

It has been evaluated that the temporal share of the technology usage in normal operation conditions is the 12%.

TO INSERT HERE: applicant provides proving documents (measurement protocols) on the evaluation of the temporal share of the technology usage in normal operating conditions.

The calculate CO_2 savings are the following:

$$C_{CO_2} = (B_{MC} - E_{MC}) \cdot UF = (130 - 120) \cdot 0.12 = 1.20\, gCO_2/km$$

Result, rounded to one decimal place:

$$C_{CO_2} = 1.2 gCO_2/km$$

TO INSERT HERE: applicant provides the evaluation of the data quality and the documentation that demonstrate the compliance with stricter requirements on the statistical uncertainty.

Check of eligibility criteria

1. Non-exceeding requirements in EU law:

Currently there is no legislation about minimum requirement on potential energy recuperation for hybrid vehicles.

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:

This technology allows the potential energy recuperation into usable electric energy.

FULFILLED

4. Verifiability:

The rounded (maximum to two decimal places) CO2 savings of the eco-innovation technology, subtracted by its standard deviation, exceed the minimum threshold of 1 g CO2/km for hybrid vehicles with a mass in running order of 1 650 kg or more. For vehicles with a mass in running order below 1 650 kg, it has not been demonstrated that the savings are sufficiently high to meet the 1 g CO2/km threshold.

FULFILLED

5. Coverage:

The eco-innovation technology is not covered by the CO_2 type approval test procedure, since slope information is not available.

FULFILLED

6. Accountability:

The technology is not under the influence of the driver's choice, since the device is always active and the driver cannot switch it off intentionally or accidentally.

FULFILLED

Total result:

The application can be granted.

9.5. Class 7 – Kinetic energy – to – electricity converters

9.5.1. Efficient alternator

Introduction

In this example an efficient alternator has been considered.

Efficient alternators have been approved as eco-innovations by Commission Decisions 2013/341/EU[45], 2014/465/EU[46], 2015/158[47] and 2015/295[48].

An alternator is an electrical generator that converts mechanical energy to electrical energy in the form of alternating current (AC). Mostly also a rectifier is built in the alternator so that direct current (DC) is produced.

The efficiency of present to day alternators is in the order of magnitude of 67%. This means that about 33% of the energy is lost. The main losses are:

- Mechanical losses
- Rectifying losses
- Stator losses
- Iron losses
- Rotor losses

This means that the efficiency of the alternator can be improved by reducing (combinations) of these losses.

Technical description of the innovative technology

> *Example*
>
> The efficiency of an alternator has been improved by 20 %.
>
> # *TO INSERT HERE: applicant provides technical description of the measures applied including technical drawings*
>
> The efficiency of the new alternator (η_{A-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-

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[45] Commission Implementing Decision 2013/341/EU: http://europa.eu/!Nx99mr

[46] Commission Implementing Decision 2014/465/EU: http://europa.eu/!gu34tt

[47] Commission Implementing Decision 2015/158: http://europa.eu/!Jk96vB

[48] Commission Implementing Decision 2015/295: http://europa.eu/!RW48yw

world' driving exceeds that one of NEDC testing. Therefore the total CO_2 saving is not fully reflected by the type approval results.

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.

Vehicle segment prediction

Prediction on which vehicle segments the eco-innovation will be applied.

TO INSERT HERE: applicant provides an estimate

Expected number of vehicles

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale.

TO INSERT HERE: applicant provides an estimate

Definition of the baseline technology

The baseline technology is an alternator with 67% efficiency in the case the innovative technology is fitted on a new vehicle type.

Where the alternator is fitted to an existing vehicle type, the baseline technology should be the alternator of the most recent version of that type placed on the market.

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.

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

Testing methodology

Procedure

The efficiency of the alternator must be determined by doing measurements in accordance with the ISO 8854:2012.

The test bench is to be a 'direct drive' alternator test bench. The alternator is to be directly linked to the torque meter and to the shaft of the drive train. The alternator is to be loaded with a battery and an electronic load.

At each speed the alternator is charged at 50 % of the rated current.

A result of this test is the efficiencies of the alternator ($\eta_{A\text{-}EI}$) at 4 different speeds in rounds per minute (rpm):

- At a speed of 1 800 rpm
- At a speed of 3 000 rpm
- At a speed of 6 000 rpm
- At a speed of 10 000 rpm

This leads to the following equation.

Equation 23

$$\eta_{A-EI} = 0.25 \cdot \eta_{A@1\,800} + 0.40 \cdot \eta_{A@3\,000} + 0.25 \cdot \eta_{A@6\,000} + 0.10 \cdot \eta_{A@10\,000}$$

η_{A-EI}: Average efficiency of the alternator [-]

$\eta_{A@1\,800}$: Efficiency of the alternator at 1 800 rpm and 0.5 rated current [-]

$\eta_{A@3\,000}$: Efficiency of the alternator at 3 000 rpm and 0.5 rated current [-]

$\eta_{A@6\,000}$: Efficiency of the alternator at 6 000 rpm and 0.5 rated current [-]

$\eta_{A@10\,000}$: Efficiency of the alternator at 10 000 rpm and 0.5 rated current [-]

Calculation of the share of saved mechanical power savings

The high efficient alternator leads to the saved mechanical power which is to be calculated in two steps. In the first step the saved mechanical power is to be calculated under ‘real world’ conditions. The second step is to calculate the saved mechanical power under type approval conditions. Subtracting these 2 mechanical power savings is to result in the accountable share of the saved mechanical power.

Equation 24

$$\Delta P_m = \Delta P_{m-RW} - \Delta P_{m-TA}$$

Where the saved mechanical power under ‘real-world’ conditions is

Equation 25

$$\Delta P_{m-RW} = \frac{P_{RW}}{\eta_{A-B}} - \frac{P_{RW}}{\eta_{A-EI}}$$

and the saved mechanical power under type-approval conditions is

Equation 26

$$\Delta P_{m-TA} = \frac{P_{TA}}{\eta_{A-B}} - \frac{P_{TA}}{\eta_{A-EI}}$$

P_{RW}: Power requirement under ‘real-world’ conditions [W]

P_{TA}: Power requirement under type-approval conditions [W]

η_{A-B}: Efficiency of the baseline alternator [-]

η_{A-EI}: Efficiency of the eco-innovative alternator [-]

Calculation of the CO_2 savings

The testing methodology to evaluate of the CO_2 savings of the technology can be evaluated using the following equations.

For petrol-fuelled vehicle:

Equation 27

$$C_{CO_2} = \Delta P_m \cdot V_{Pe-P} \cdot CF_P / v$$

For Diesel-fuelled vehicle:

Equation 28

$$C_{CO_2} = \Delta P_m \cdot V_{Pe-D} \cdot CF_D / v$$

C_{CO_2}: CO_2 savings [g CO_2/km]

ΔP_m: Share of saved mechanical power [W]

v: Mean driving speed of the NEDC [km/h]

V_{Pe-P}: Consumption of effective power for petrol-driven vehicles [l/kWh]

V_{Pe-D}: Consumption of effective power for Diesel-driven vehicles [l/kWh]

CF_P: Conversion factor (l/100 km) - (g CO_2/km) for petrol fuel [gCO_2/l]

CF_D: Conversion factor (l/100 km) - (g CO_2/km) for Diesel fuel [gCO_2/l]

Calculation of the statistical uncertainty

The standard deviation of the CO_2 savings is to be calculated by means of the following equations.

For petrol-fuelled vehicle:

Equation 29

$$s_{C_{CO_2}} = \sqrt{\left(\frac{\partial C_{CO_2}}{\partial \eta_{A-EI}} \cdot s_{\eta_{A-EI}}\right)^2} = \frac{(P_{RW} - P_{TA})}{{\eta_{A-EI}}^2} \cdot V_{Pe-P} \cdot CF_P / v \cdot s_{\eta_{A-EI}}$$

For Diesel-fuelled vehicle:

Equation 30

$$s_{C_{CO_2}} = \sqrt{\left(\frac{\partial C_{CO_2}}{\partial \eta_{A-EI}} \cdot s_{\eta_{A-EI}}\right)^2} = \frac{(P_{RW} - P_{TA})}{{\eta_{A-EI}}^2} \cdot V_{Pe-D} \cdot CF_D / v \cdot s_{\eta_{A-EI}}$$

\# *TO INSERT HERE: applicant provides the description of the methodology to quantify the statistical uncertainties s following the procedure described in Chap. 6.3.*

Implementation

For determining the CO_2 savings to be certified by the type approval authority, the manufacturer of the M1 vehicle in which the alternator is fitted has to designate an eco-innovation vehicle fitted with the eco-innovative alternator and either of the following baseline vehicles:

- if the eco-innovation is fitted to a new vehicle type which will be submitted to a new type approval, the baseline vehicle is to be the same as the new vehicle type in all respects except with regard to the alternator which is to be an alternator with an efficiency of 67 %, or

- if the eco-innovation is fitted to an existing vehicle version for which the type approval will be extended following the replacement of the existing alternator by the eco-innovation, the base vehicle is to be the same as the eco-innovation vehicle in all respects except with regard to the alternator which is to be the alternator of the existing vehicle version.

<u>*Application of the testing methodology*</u>

Example

Input data:

$P_{RW} = 750W$ (see Chap. 7.6)

$P_{TA} = 350W$ (see Chap. 7.6)

$v = 33.58\,km/h$ (see Chap. 7.2)

$V_{Pe-P} = 0.264\,l/kWh$ (see Chap. 7.1.1)

$V_{Pe-D} = 0.22\,l/kWh$ (see Chap. 7.1.1)

$\eta_{A-B} = 0.67$ (see Chap. 7.1.2)

$\eta_{A-EI} = 0.87$

$CF_P = 2330\,gCO_2/l$ (see Chap. 7.3.2)

$CF_D = 2640\,gCO_2/l$ (see Chap. 7.3.2)

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

$$\Delta P_{m-RW} = \frac{P_{RW}}{\eta_{A-B}} - \frac{P_{RW}}{\eta_{A-EI}} = \frac{750W}{0.67} - \frac{750W}{0.87} = 255.28W$$

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

$$\Delta P_{m-TA} = \frac{P_{TA}}{\eta_{A-B}} - \frac{P_{TA}}{\eta_{A-EI}} = \frac{350W}{0.67} - \frac{350W}{0.87} = 119.13W$$

Calculation of the accountable share of saved mechanical power:

$$\Delta P_m = \Delta P_{m-RW} - \Delta P_{m-TA} = 255.28W - 119.13W = 136.15W$$

Calculation of the CO_2 saving per petrol-fuelled vehicle:

$$C_{CO_2} = \Delta P_m \cdot V_{Pe-P} \cdot CF_P / v = 136.15W \cdot 0.264\,l/kWh \cdot \frac{2330\,gCO_2/l}{33.58\,km/h} = 2.4949\,gCO_2/km$$

Calculation of the CO_2 saving per diesel-fuelled vehicle:

$$C_{CO_2} = \Delta P_m \cdot V_{Pe-D} \cdot CF_D / v = 136.15 W \cdot 0.22\, l/kWh \cdot \frac{2640\, gCO_2/l}{33.58\, km/h} = 2.3548\, gCO_2/km$$

Results, rounded to one decimal place:

- Petrol-fuelled vehicles: $C_{CO_2} = 2.5\, gCO_2/km$
- Diesel-fuelled vehicles: $C_{CO_2} = 2.4\, gCO_2/km$

TO INSERT HERE: applicant provides the calculation of the evaluation of the data quality and of the uncertainties following the procedure described in Chap. 6.3.

For petrol-fuelled vehicle:

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{\eta_{A-EI}{}^2} \cdot V_{Pe-P} \cdot CF_P / v \cdot s_{\eta_{A-EI}} = 0.01\, gCO_2/km$$

For Diesel-fuelled vehicle:

$$s_{C_{CO_2}} = \frac{(P_{RW} - P_{TA})}{\eta_{A-EI}{}^2} \cdot V_{Pe-D} \cdot CF_D / v \cdot s_{\eta_{A-EI}} = 0.01\, gCO_2/km$$

Check of the standard deviation of the total CO_2 saving criteria:

$$s_{C_{CO_2}} < 0.5\, gCO_2/km$$

<u>*Check of eligibility criteria*</u>

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 rounded (maximum to two decimal places) CO_2 savings of the eco-innovation technology, subtracted by its standard deviation exceed the minimum threshold of 1 g CO_2/km.

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

6. Accountability:

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 can be granted.

Considerations

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.

> *Example 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
>
> $$\Delta P_{m-TA} = \frac{P_{TA}}{\eta_A} - \frac{P_{TA}}{\eta_{A-EI}} = \frac{350W}{0.67} - \frac{350W}{0.77} = 67.8W$$
>
> When this alternator replaces a baseline alternator of 71%, then you will get
>
> $$\Delta P_{m-TA} = \frac{P_{TA}}{\eta_A} - \frac{P_{TA}}{\eta_{A-EI}} = \frac{350W}{0.71} - \frac{350W}{0.77} = 38.4W$$
>
> The difference between the two alternators is 43.3 %.

Example 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:

$$C_{CO_2} = \Delta P_m \cdot UF \cdot V_{Pe-P} / \eta_A \cdot CF_P / v = 97W \cdot \frac{0.264\,l/kWh}{0.67} \cdot \frac{2330\,gCO_2/l}{33.58\,km/h} = 0.8752\,gCO_2/km$$

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

$$C_{CO_2} = \Delta P_m \cdot UF \cdot V_{Pe-P} / \eta_A \cdot CF_P / v = 97W \cdot \frac{0.264\,l/kWh}{0.71} \cdot \frac{2330\,gCO_2/l}{33.58\,km/h} = 0.8259\,gCO_2/km$$

The difference between the two alternators 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.

Appendix I – Template for an application

APPLICANT CONTACTS

Name and address and contact person of the applicant

TESTING METHODOLOGY

Description of the testing methodology, providing the information required to complete the steps described in section 6.2.

SUMMARY OF THE APPLICATION

Summary of the application for publication on the DG CLIMA website[5]. The summary should not contain confidential information.

A template for the summary of the application can be found in the Appendix II.

SUPPORTING DOCUMENTATION

List of supporting documentation.

TECHNICAL DESCRIPTION

Technical description of the eco-innovation and the way it is fitted on a vehicle described in writing and, when appropriate, by technical drawings.

INNOVATIVENESS

Supporting documentation demonstrating that the innovative technology does not exceed 3 % in the reference year 2009 (Chap 4.2).

VEHICLE SEGMENTS PREDICTION

Prediction on which vehicle segments the eco-innovation will be applied (estimate only).

EXPECTED NUMBER OF VEHICLES

Expected number of vehicles per vehicle segment equipped with the particular eco-innovation coming to the market with expected timescale (estimate only).

DEFINITION OF THE BASELINE TECHNOLOGY

Identification of the baseline technology for the envisaged vehicle segments.

Technical description of the baseline technology.

EVALUATION OF NEGATIVE EFFECTS

Description of the technology characteristics that could lead to increased CO_2 emission (e.g. higher mass, higher drag resistance).

DETERIORATION EFFECTS

When relevant, experimental analyses of deterioration effects or sound argumentation should be evaluated (see Chap. 6.2).

TESTING METHODOLOGY

Description of the testing methodology, including measurement/modelling condition and equipment, measurement/modelling procedure and method of calculation of the CO_2 savings (see Chap. 3).

Identification of the uncertainties and description of the methodology to quantify the statistical uncertainties (see Chap 4.4.1).

DESCRIPTION OF THE CASE STUDY

Description of the case study (see Chap. 3).

In case of comprehensive methodology, further detailed technical data of case study vehicle(s) should be provided (see Chap. 6.2)

APPLICATION OF THE TESTING METHODOLOGY

Application of the testing methodology for the case study and calculation of the corresponding resulting CO_2 savings (differentiated per envisaged vehicle segment, where relevant) (see Chap. 3).

UNCERTAINTY ANALYSES

Application of uncertainty analysis and quantification of statistical uncertainties .

CHECK IF ALL ELIGIBILITY CRITERIA

Check if all eligibility criteria specified in Article 2 and Article 4(2)(e), (f) and (g) of Commission Implementing Regulation (EU) No 725/2011 and (EU) No 427/2014[6] and described in Chap. 4 of these guidelines are fulfilled; reasons and evidential data have to be provided for each of them:

1. Non-exceeding requirements in EU law
2. Innovativeness of technology
3. Necessity of technology (non-comfort)
4. Verifiability of CO_2 saving (minimum threshold)
5. Coverage (type approval procedure)
6. Accountability (influence of driver)

VERIFICATION REPORT

Verification report from an independent certification body (Chap 6.6)

1. Testing protocols of all relevant measurements
2. Check of fulfilment of the eligibility criteria
3. Check of possible deterioration effects
4. Check of suitability of the testing methodology for determining the CO_2 savings from the eco-innovation (only comprehensive approach)
5. Check of suitability of parametric function (if CO_2 saving depends on one or more vehicle parameters) (only comprehensive approach)

Appendix II – Template for the summary description of the application

TITLE OF THE INNOVATIVE TECHNOLOGY

CONTACT DETAILS

Applicants name:	

SUMMARY

Brief description of the innovative technology and its potential CO_2 savings:

INNOVATIVENESS

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

NECESSITY

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

TESTING METHODOLOGY

Description of the testing methodologyor reference to an existing methodology:

Annex I – Data sources of Chapter 7

1. EFFICIENCIES

Efficiency of engine

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

European Association of Automobile Suppliers (CLEPA)

ECE/TRANS/WP.29/2014/27

Efficiency of alternator

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

'VDA approach':

$$\eta_A = 0.25 \cdot \eta_{1\,800rpm,0.5I_N} + 0.40 \cdot \eta_{3\,000rpm,0.5I_N} + 0.25 \cdot \eta_{6\,000rpm,0.5I_N} + 0.10 \cdot \eta_{10\,000rpm,0.5I_N}$$

ISO 8854:2012 Alternators with regulators - Test methods and general requirements[49]

European Association of Automobile Suppliers (CLEPA)

Electrical solar system efficiency

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Vehicle Emissions Laboratory (VELA)
European Solar Test Installation (ESTI)[50]
- Internal measurements based on:

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.

2. DRIVING CYCLE CHARACTERISTICS

UN/ECE Regulation No. 83: Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements[51].

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[49] ISO 8854:2012:

[50] European Solar Test Installation (ESTI): http://re.jrc.ec.europa.eu/esti/

[51] UN/ECE Regulation No 83: http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/r083r4e.pdf

3. FUEL CHARACTERISTICS

Fuel densities

European Commission - Joint Research Centre
Institute for Energy and Transport

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[52]

Hass, H.; Huss, A.; Maas, H.: Tank-to-Wheels Report Report – Version 4.a. JRC Technical Reports[53]

Conversion fuel consumption - CO_2 emission

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

4. USAGE FACTORS

Vehicle lighting

European Association of Automobile Suppliers (CLEPA)

Shading of solar panels

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Vehicle Emissions Laboratory (VELA)
- Internal calculations, based on vehicles GPS-data in the city of Modena.

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.

Windscreen wipers

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

5. POWER REQUIREMENTS OF LIGHTING TYPES

Halogen tungsten

European Association of Automobile Suppliers (CLEPA)

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[52] Regulation (EC) No 692/2008: http://europa.eu/!Fp86uj

[53] Tank-to-Wheels Report: http://europa.eu/!tU34TV

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

Xenon gas discharge

European Association of Automobile Suppliers (CLEPA)

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

Total electric power requirements

European Automobile Manufacturers' Association (ACEA) / Verband der Automobilindustrie (VDA)
European Association of Automobile Suppliers (CLEPA)

6. EMISSIONS DUE TO EXTRA WEIGHT

Mellios, G.; Hausberger, S.; Keller, M.; Samaras C.; Ntziachristos L.; Dilara P.: Fontanas G.: Parametrisation of fuel consumption and CO_2 emissions of passenger cars and light commercial vehicles for modelling purposes. JRC Scientific and Technical Reports.
European Commission - Joint Research Centre
Institute for Energy and Transport

7. SOLAR RADIATION

Solar radiation in Europe

European Commission - Joint Research Centre
Institute for Energy and Transport
Renewable Energy Unit
- Photovoltaic Geographical Information System (PVGIS)[54]

Solar correction coefficient

European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Renewable Energy Unit
Vehicle Emissions Laboratory (VELA)
- Internal calculations based on measurements of solar radiation in Europe by the BSRN Network[55]

8. AMBIENT TEMPERATURE

European Environment Agency
European Commission - Joint Research Centre
Institute for Energy and Transport
Sustainable Transport Unit
Renewable Energy Unit
- Internal calculation based on:

Global and European temperature (CSI 012). Assessment published June 2010[56]

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[54] Photovoltaic Geographical Information System (PVGIS): http://re.jrc.ec.europa.eu/pvgis/

[55] World Radiation Monitoring Center (WRMC): www.bsrn.awi.de

[56] Global and European temperature (CSI 012/CLIM 001): http://europa.eu/!KW77kj

Corine Land Cover 2006[57]
ECMWF operational forecast data[58]
TRACCS transport data collection[59]

9. Engine starting temperature

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

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[60]

Infras AG: Handbook emission factors for road transport (HBEFA). Version 3.1. Parking time distribution for Switzerland[61]

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 (Calculations for Euro 3, Euro 4 and Euro 5 passenger cars in 2010)[62]

TRACCS transport data collection[63]

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[57] Corine Land Cover 2006: http://europa.eu/!mK84bQ

[58] ECMWF: http://old.ecmwf.int/research/ifsdocs/CY38r1/

[59] TRACCS: http://traccs.emisia.com/

[60] Uncertainties in the arithmetical determination of pollutant emissions from road traffic and demands on future models: http://elib.uni-stuttgart.de/opus/volltexte/2004/2079/

[61] HBEFA: http://www.hbefa.net/e/index.html

[62] TREMOVE economic transport and emissions model: http://www.tmleuven.be/methode/tremove/home.htm

[63] TRACCS: http://traccs.emisia.com/

12. ROAD ROUGHNESS

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

Zuo, L.; Nayfeh, S.A.: Structured H2 Optimization of Vehicle Suspensions Based on Multi-Wheel Models. Vehicle System Dynamics, Vol. 40, No. 5, pages 351 – 371

Greco, G.; Nepote, A.; Van Grootveld, G.; Martini, G.: Kinetic Energy to Electric Energy Conversion Using Regenerative Shock Absorbers. FISITA 2014 World Automotive Congress p. F2014-IVC-020[64]

13. STIFFNESS OF ONE TIRE

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

van Zyl, S.; van Goethem, S.; Kanarachos S.; Rexeis, M.; Hausberger, S.; Smokers, R.: Study on Tyre Pressure Monitoring Systems (TPMS) as a means to reduce Light-Commercial and Heavy-Duty Vehicles fuel consumption and CO_2 emissions. Final Report. TNO 2013 R10986[65]

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[64] FISITA 2014 World Automotive Congress p. F2014-IVC-020: http://www.fisita2014.com/programme/sessions/F2014-IVC-020

[65] TNO 2013 R10986: http://europa.eu/!uC94hG