Technical Support for the Development of the HDV CO2 Certification (Remaining HDV)

Final report

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Final Report

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Technical Support for the Development of the HDV CO_2 Certification

(Remaining HDV)

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List of Abbreviations

AAUX	……..	VECTO Advanced Auxiliary Model
ACEA	……..	Association des Constructeurs Européens d'Automobiles
ACEA AEG	……..	ACEA Aero Expert Group
ADAS	……..	Advanced Driver Assistance Systems
AMT	……..	Automated Manual Transmission
AP	……..	Air Pollutants (here: other regulated exhaust gas components than CO_2)
APT	……..	Automated Powershift Transmission
BEV	……..	Battery Electric vehicle
CBA	……..	Cost Benefit Analysis
CFD	……..	Computational Fluid Dynamics
CIF	……..	Customer Information File
CLCCR	……..	International Association of the Body and Trailer Building Industry
FA	……..	Frontal Area
CoP	……..	Conformity of Production
CST	……..	Constant Speed Test (procedure to determine the air drag of HDV)
FTE	……..	Full Time Equivalent
HDE	……..	Heavy Duty Engine with type approval according to Regulation (EC) 595/2009
HDV	……..	Vehicles with type approval according to Regulation (EC) 595/2009
HEV	……..	Hybrid Electric Vehicle
IEPC	……..	Integrated Electric Powertrain Component
IHPC	……..	Integrated Hybrid Powertrain Component
ISC	……..	In Service Conformity
ISO	……..	International Organization for Standardization
ISV	……..	In Service Verification
LDV	……..	Vehicles with type approval according to Regulation (EC) 715/2007 These are officially called "Light Passenger and Commercial vehicles"
LHV	……..	Lower Heating Value
MAM	……..	Maximum Authorised Mass
MAW	……..	Moving average Window method, used for evaluation of pollutant emissions measured in ISC tests for HDVs
MPR	……..	Minimum Performance Requirements
MRF	……..	Manufacturers Records File
OEM	……..	Original Equipment Manufacturer
PCC	……..	Predictive Cruise Control
PEV	……..	Pure Electric Vehicle
PHEV	……..	Plug-In Hybrid Electric Vehicle (battery recharged from the grid also)
VIF	……..	Vehicle information file

PP	……..	Pilot Phase
REESS	……..	Rechargable Electric Energy Storage System
RM	……..	Reference Mass = mass in running order -75kg (driver) +100kg
SOH	……..	State of Health (of a battery)
TPMLM	……..	Technical Permissible Maximum Laden Mass
UITP	……..	International Association of Public Transport
VECTO	……..	Vehicle Energy Consumption calculation TOol
VTP	……..	Verification Testing Procedure
WLTC	……..	Worldwide harmonized Light duty driving Test Cycle
WLTP	……..	Worldwide harmonized Light vehicle emissions Test Procedure
xEV	……..	Vehicles with electrified powertrains

Executive Summary

This final report gives a documentation of the work performed in the project on "Technical Support for the Development of the HDV CO_2 Certification (Remaining HDV)" by the consortium of TU Graz, Ricardo and TNO Automotive as well as TÜV Nord Mobilität as a subcontractor of TU Graz.

Furthermore, the working documents on the individual Annexes of Regulation 2017/2400 represent key deliverables of this contract. The documents were sent to DG GROW between March and May 2021. Further punctual changes to the texts were made in the consolidated document submitted to the TCMV in July 2021.

Task 1: Technical support for implementation of Regulation (EU) 2017/2400

Task 1 should provide support to the Commission for all technical questions concerning the determination of the CO_2 emissions and fuel consumption of heavy-duty vehicles, including N, M, O3 and O4 vehicles. During the project, eleven requests have been received and answered by the consortium.

Task 2: CO_2 determination of buses and vans

Task 2.1.1: Pilot phases for CO_2 certification of buses and medium lorries

In task 2.1.1 work was performed related to the organisation, coordination and evaluation of a stepwise sequence of three pilot phases for the CO_2 determination of buses and medium lorries over the duration of the project. These pilot phases were held from April 2019 until the end of the project to fulfil the following tasks:

- Review of draft technical annexes
- Run and analyse new component tests
- Run VECTO software and give feedback
- Validation of general approach for the new vehicle categories heavy buses and medium lorries
- Gather data on VTP development (tolerances, how to handle pollutant emissions etc.)

The main outcomes from the pilot phases are:

- Verified approaches for CO_2 determination for medium lorries and heavy buses. For heavy buses this includes a validation of the "factor method"[1] approach which was found to be within +/1% accuracy for most and +/-2% for nearly all vehicle configurations.
- Verified approaches for extending the VTP to conventional medium lorries and heavy buses of type "high floor" (i.e. coaches). For those vehicles it is proposed to apply the same C_{VTP} tolerance than currently applicable for heavy lorries (7.5%) but in combination with different, vehicle category specific trip provisions. It is additionally

[1] The factor method is an algorithm that allows the simulation of fuel consumption and CO_2 emissions of a vehicle split into simulation steps at two different manufacturing stages of the vehicle without having to share confidential data like engine maps between the manufacturers.

proposed that the provisions on trip composition and payloads as elaborated for medium lorries shall also apply to heavy lorries in groups 1s, 1, 2 and 3.

- On the application of VTP for conventional low floor buses no conclusions can be drawn at this point as no test data was available from the pilot phases and the matter is technically more complex than for high floor buses.
- For a later application of the VTP test as an in-service verification test procedure performed by third parties, it is recommended to apply a further pilot phase. This should aim to find out if the assumed sensitivity with transient driving conditions does not lead to fails that are only due to the test conditions and the methodology and not to the performance of the vehicle.
- Verified approach for CO_2 determination as well as VTP for vehicles with dual-fuel engine technology
- Verified approach for CO_2 determination vehicles with Waste Heat Recovery (WHR) engine technology. A VTP was not carried out for such vehicles but it is estimated that for the C_{VTP} same tolerances can be applied to vehicles with WHR.
- Merging verification of CO_2 emissions and pollutant emissions in the VTP: most of the boundary conditions as set out in the Euro VI ISC pollutant type approval test, e.g. on vehicle mileage, trip requirements and data evaluation were found to be not compatible with the corresponding provisions in the VTP. Therefore, for EURO VI vehicles as a matter of principle, no parallel pass/fail assessment of CO_2 emissions as well as pollutant emissions can be carried out from a VTP measurement without introducing additional provisions with regard to pollutant emission verification. In order to nevertheless meet the European Parliament's demands regarding the combination of VTP and pollutant emission measurement, it is proposed to apply PEMS testing during the VTP as a “monitoring-only” procedure on a g/kWh basis for the total trip. In the recorded PEMS data from the pilot phases the Euro VI ISC limits have been met in all cases.

  Combining the VTP test and PEMS-ISC test shall be considered further in the discussions on EURO VII in order to find a solution that the provisions on pollutant emissions in RDE conditions are kept general so that they are directly applicable to all possible variants of the VTP.

  For the VTP performed as an In Service Verification Test, it is furthermore proposed that in case the EURO VI ISC limits are exceeded by the emission values calculated by VECTO for the VTP, an additional dedicated ISV test for pollutant emissions shall be added.
- Vehicles with electrified powertrains: Verification of developed test procedures and simulation methods for vehicles with electrified powertrains (HEV and PEV, together referred to as "xEV" in the following) was the aim of pilot phase 3. In fact, the course of pilot phase 3 - as well as the entire development work for xEV - has turned out to be quite different from what was originally planned. The reasons are explained in detail in section 3.1.3 of the report. In the actual work the development of the technical methods for xEV and the related feedback loops have essentially concentrated on theoretical work in different working groups. It is not known to what extent practical component tests were included in the feedback processes. Thus updates in the

certification procedures may turn out to be needed for the third amendment when feedback from actual certification testing has been received.

Task 2.1.2: Analysis of light lorries and light and medium buses

Task 2.1.2 should analyse options for CO_2 determination for vehicle segments that fall in the current gap between VECTO and WLTP. This whole range of vehicles contains two overlapping type-approval regimes for gaseous emissions and CO_2 emissions (HD and LD). Both regimes differ significantly on the procedures to be performed. The current boundary with possibility for extensions of those regimes has created a situation, which on the one hand provides flexibilities for the manufacturers to attribute their portfolio to either of the two regimes but on the other hand results in an unclear situation with different type approval tests and type approval test results for the same vehicles.

A CO_2 test procedure close to the real world operation, is essential to stimulate the use of technologies which have high CO_2 saving potential not just in the test procedure but also in real operation. Therefore, an understanding of the typical use of these vehicle groups is the main criterion for selecting the appropriate test regime, i.e. allocating these vehicles in future to the LD regime (WLTP) or to the HD regime (VECTO) using accompanying test procedures. Unfortunately, almost no data on real world usage of these vehicles became available in the past to serve as basis for a proper decision. Therefore, the first part of the work consisted of data-mining. Unfortunately, no new data such as driving data became available. Information was gathered about the formal aspects of the usage of the vehicles such as limitations of the maximum mass, allowances for driving license and maximum speeds. These clearly differentiate the usage of vehicles at the boundary of 3.5 tons TPMLM which already gives a hint that the VECTO procedures could be more suitable for light lorries and light buses.

For the attribution of the light lorries and light buses to a test regime, three options (A, B and C) were defined and evaluated at an earlier stage. These options were further evaluated for this service request which has resulted in a list of pros and cons for each of the options. For EURO7/VII it is recommended to switch to 3.5 tons TPMLM as differentiation criterion between LD and HD regime. Based on the arguments as discussed in this report this is assumed a reasonable, simple and robust approach which would allow to smoothly align all aspects of certification of pollutant emissions and determination of CO_2 emissions without any overlaps and loopholes.

Medium buses - i.e. M3 vehicles not exceeding 7.5 tons TPMLM - were decided for a CO_2 determination based on the VECTO approach by the HDV CO_2 Editing board already in 2019. However, their implementation into the second amendment of Regulation (EU) 2017/2400 has been suspended, as the originally envisaged approach (base vehicle approach as for medium lorries) was concluded not to deliverer representative results for CO_2 emissions and fuel consumption. Any appropriate approach needs at least to a certain extend to consider the properties of the complete or completed vehicle. Taking over the complex “heavy bus approach” was found to be not appropriate, as the medium bus segment is very small in number i.e. approx. 2 600 vehicles per year and with this it is by far the smallest segment in the light/medium/heavy x lorry/bus matrix. Additionally a high number of SMEs are involved in the production of medium buses each with very low annual production numbers. Given the case that light buses will be allocated to VECTO (and not to WLTP) it is to be considered highly advisable to elaborate a single method covering both light and medium buses. Two different options seem promising:

I) Elaboration of a “light” version of the “factor method”

II) Elaboration of an extended base vehicle approach

A further item needs to be taken care in this regard: In the great majority of cases for light and medium buses the base vehicle is of category N, i.e. there is a switch to category M during the production process. For option I) this means that there needs to be a solution to update the hash in the primary vehicle CoC (or issue a new CoC) in case such a conversion is done at a later manufacturing stage without allocating the responsibility to become a primary manufacturer for any subsequent manufacturing stage.

Task 2.2: CO2 verification of heavy buses and medium lorries

Task 2.2 covered the extension of the on-road verification testing procedure (VTP) as set out in Annex Xa to Regulation (EU) 2017/2400 to the new vehicle categories (medium lorries and heavy buses) and to the “new technologies” as to be covered by task 3 of this project. The methods developed in this regard are summarised below. The methods were incorporated into the working documents in several iteration loops and were the basis for the pilot phases described above. The pilot phases also resulted in a large number of stakeholder comments on the existing provisions. These were also processed in the project and revised in consultation with the Commission.

Medium lorries: A specific set of trip provisions for the VTP was elaborated based on the cycle characteristics of the allocated VECTO mission profiles (regional delivery and urban delivery). Furthermore, the table for minimum number of vehicles to be tested by the vehicle manufacturer (Table 1 of Annex Xa) was extended to account for the lower annual production numbers in this vehicle category.

Heavy buses: Specific sets of trip provisions for the VTP have been elaborated for low floor and high floor heavy buses separately following the principle approach as for medium lorries, but considering the heavy bus specific mission profiles. Regarding the responsibilities of different kinds of heavy bus manufacturers (primary, interim, complete or completed) a version of Annex Xa was produced where performing the VTP provisions are linked to the final (i.e. complete or completed) vehicle manufacturer only. This approach raised a lot of questions and comments from stakeholders. Having to develop an alternative approach which would be agreed by all stakeholders in-time for the second amendment was deemed infeasible. The Commission decided to start developing an alternative approach, but not to include it in the current amendment. This report further analyses this subject, elaborates on an approach how to address different manufacturer levels in a VTP and lists the necessary next steps how to extend VTP for heavy buses in the future.

Dual-fuel technology: The extension of the VTP to include this engine technology required a formal change in the general scope of the VTP, i.e. to verify total CO_2 - calculated from measured fuel flow(s) – and not fuel consumption. Furthermore, a few provisions needed to be added (e.g. measurement of two fuels, calibration requirements).

With regards to the other “new technologies” (ADAS, WHR and the new gear shift algorithm in VECTO) no need to extend Annex Xa was identified.

xEV technologies: As agreed during the course of the project, the development of a VTP for xEV was not part of the final deliverables of this project. However, basic options and problems identified by the project team are included in this final report, as potential input for subsequent calls for proposals and as a collection of ideas for the general "proof-of-concept" phase on xEVs in VECTO as announced for 2022 at DG JRC.

Task 3: New technologies for CO_2 certification of heavy-duty vehicles

Task 3 is split in two sub-tasks, 3.1 for hybrid and pure electric vehicles and 3.2 for the “other new technologies”.

Task 3.1: Hybrid and pure electric vehicles

Part of this project was also to translate the technical methods developed in parallel in a DG CLIMA contract for hybrid electric vehicles (HEV) and pure electric vehicles (PEV, i.e. battery electric vehicle) into provisions in Regulation (EU) 2017/2400. To cover those the existing approach is also followed:

- The first step is the certification of all independent powertrain components of the vehicle in order to determine the input data for the simulation in standardized test procedures.
- The second step is the simulation of each specific vehicle configuration in the standardized simulation software tool VECTO.

For the following components were introduced in a dedicated new Annex Xb (“Certification of electric powertrain components”):

- Propulsion energy converters
  - Electric machine system (EMS)
  - Integrated Electric Powertrain Component (IEPC)
  - Integrated HEV Powertrain Component (IHPC)
- Rechargeable electric energy storages
  - Battery system
  - Capacitor system

For HEV and PEV a standardized set of generic powertrain architectures is foreseen to depict the specific vehicle layout in the simulation. Those are:

HEV parallel:

Five characteristic powertrain architectures that include an ICE that powers a single mechanically connected path between the engine and the wheels of the vehicle.

HEV serial:

Four characteristic powertrain architectures that include an ICE that powers one or more electrical energy conversion paths with no mechanical link between the ICE and the wheels of the vehicle.

PEV:

Four characteristic powertrain architectures for a pure electric vehicle with a single powertrain.

Task 3.2 Other new technologies for CO2 certification of heavy-duty vehicles

Table 1 gives an overview on the “other new technologies” and the related necessary technical changes in Regulation (EU) 2017/2400 covered by Task 3.2.

Table 1: Overview on "other new technologies" as covered in Task 3.2

Technology / feature covered by the simulation tool	Related component certification test procedure	Necessary technical changes in Reg. (EU) 2017/2400
Updates of generic gear shift algorithms	None	None
Advanced Driver Assistance Systems (ADAS) (2 stage implementation)	None	Phase 1 implementation already covered by Regulation (EU) 2019/318 Phase 2 implementation required technical changes in Annex III regarding system definition for ADAS for vehicles with APT transmissions.
Gas and Dual-fuel engines	Engine dyno testing	Gas engines already covered by Regulation (EU) 2019/318 Dual-fuel engines required technical changes in Annex V and in Annex Xa
Waste Heat Recovery (WHR)	Engine dyno testing	WHR required technical changes in Annex V

Necessary updates in Article 9 regarding exemptions of vehicles on the obligation to determine CO_2 emissions and fuel consumption

By including the new technologies as described above into Regulation (EU) 2017/2400, the provisions in Article 9 regarding exemption of vehicles on the obligation to determine CO_2 emissions and fuel consumption using the simulation tool also needed to be refined. Those vehicle technologies are:

- Fuel cell vehicles
- ICE operated with hydrogens
- Certain types of dual-fuel engines
- Special configurations of hybrid electric vehicles
- Special configurations of pure electric vehicle
- Vehicles with multiple permanently mechanically independent powertrains
- Vehicles with in-motion charging capabilities
- Non-electric hybrid vehicles

This report provides further information on the justifications for the individual exemptions where relevant, as well as recommendations on next steps in subsequent amendments to Regulation (EU) 2017/2400.

Task 4: CO_2 verification of lorries

Subject of task 4 was to elaborate a procedure for in-service verification (ISV) of CO_2 from lorries. For this purpose, in a first step, the project drafted an umbrella concept for the ISV process and the responsibilities of the organisations involved (Granting Approval Authorities, Accredited Labs, Manufacturers and the European Commission) in close coordination with the Commission.

The following practical validation elements are provided in the procedure:

a) Verification of input information and input data and data handling
b) Verification of vehicle mass
c) Verification of rolling resistance
d) Verification of air drag
e) Verification of the power train efficiency

These five elements were derived from the existing corresponding provisions for certification and CoP procedures in Regulation (EU) 2017/2400. For provisions that can be adopted unchanged (e.g. measurement procedures), reference is made to Regulation (EU) 2017/2400. Provisions that have to be defined separately in the case of ISV (e.g. vehicle selection, reporting, tolerances, if applicable) have been drafted accordingly.

The draft ISV provisions were discussed with stakeholders as far as possible during the course of the project and compiled into a consolidated ISV working document. This document is also an integral part of the deliverables of this project.

Task 5: Assessment of the economic feasibility of an extended scope of CO2 determination of heavy-duty vehicles

Task 5 analysed the economic feasibility of the proposed extension of Regulation (EU) 2017/2400 to heavy buses and lorries with a TPMLM in the range exceeding 5 tons and up to 7.5 tons, as well as to the inclusion of new vehicle technologies. To assess the economic feasibility, the task quantified the costs and benefits associated with the proposed extension, through the use of an online survey shared with Editing Board members and other key stakeholders. The results of the task include quantitative cost estimates associated with the proposed extension of Regulation (EU) 2017/2400, as well as a qualitative assessment of the impacts of the proposed extension on small and medium-sized enterprises (SMEs), competitiveness and innovation, employment opportunities, and international trade.

The assessment of the quantitative costs associated with the proposed extension of Regulation (EU) 2017/2400 included analysis of the **component certification costs, verification testing procedure (VTP) costs and overhead costs.**

Different component certification costs were estimated for different powertrain configurations (internal combustion engined vehicles, hybrid EVs, standalone battery EVs (BEVs) and BEVs with integrated electric powertrain components). Also, the certification costs were dependent on the extent to which "standard values" might be used as VECTO inputs. Costs were developed for three different scenarios.

VTP costs were developed for the modification of the VTP currently required for heavy lorries (according to Annex Xa of Regulation (EU) 2017/2400), and for the proposed extension of

VTP to include buses and medium lorries[2]. The estimated costs are dependent on the HDV CO_2 determination experience of the OEM, and the number of vehicles they produce per year. The costs are tabulated in the main report for three different levels of experience.

Overhead costs, like VTP costs, are dependent on the HDV CO_2 determination experience of the OEM. Generally, the overhead costs are the largest of the three components (on a per vehicle basis).

The three OEM scenarios for component certification costs, overhead costs and VTP costs are combined with vehicle categories. For conventional vehicles this gives eight vehicle category - OEM size and experience combinations. The costs / vehicle for the HDV CO_2 determination cost are tabulated in the main report, and summarised in Table 2.

Benefits and wider impacts

The proposed extension of Regulation (EU) 2017/2400 aims to elicit benefits, through supporting a reduction in tailpipe CO_2 emissions, which will benefit society as a whole, and fuel savings, which will accrue to the vehicle operators. Benefits arise from the fact that, based on the fuel consumption information being available, either the more fuel efficient vehicle can be selected, or some of the worse performing vehicles disappear from the market.

Estimates were made of the annual fuel costs for medium lorries, low- and high-floor buses, together with the financial savings from an estimated 3% reduction in fuel consumed. This is based on estimating costs on a per vehicle basis, rather than as a proportion of the CO_2 emissions for the vehicle categories involved.

For the introduction of an extended HDV CO_2 determination regulation, the one-off upfront costs are substantial; however, the ongoing benefits of CO_2 emissions reduction and fuel efficiency improvements will prevail into the future.

The direct costs and financial benefits can be compared, and a payback period, in years, for the proposed extension of Regulation (EU) 2017//2400 has been estimated. It is summarised in Table 2. It is worth noting that Table 2 presents the results for conventional vehicles. The pay-back period for HEVs, BEV standalone units and BEV IEPCs is comparable to that of conventional vehicles, given the relatively small contribution of component costs to the overall costs associated with the proposed extension.

Table 2: Summary of combined costs, benefits and pay-back period for running the CO_2 determination, on a per vehicle basis for conventional vehicles

Vehicle	Cat.	OEM size and experience	Total costs per vehicle	Annual fuel savings	Pay-back period (years)
Typical "low floor" bus	1	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 386.68	€ 1,152.00	**0.34**
	2	Medium enterprise (2500 vehicles	€ 361.16	€ 1,152.00	**0.31**

[2] As already mentioned above, the VTP for heavy buses is no longer included in the latest draft of Annex Xa. The analyses carried out for this scenario are nevertheless presented here.

Vehicle	Cat.	OEM size and experience	Total costs per vehicle	Annual fuel savings	Pay-back period (years)
		per year), not yet familiar with EU HDV CO_2 determination			
	3	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,275.88	€ 1,152.00	**3.71**
Typical "high floor" bus	4	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 806.40	**0.51**
	5	Medium enterprise (2500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 806.40	**0.48**
	6	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,304.26	€ 806.40	**5.34**
Typical medium lorry	7	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 221.76	**1.87**
	8	Medium enterprise (2500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 221.76	**1.76**

Therefore, it is seen that the proposed extension of CO_2 certification leads to significant per vehicle costs for small enterprises manufacturing either high floor or low floor buses, or medium lorries who are unfamiliar with HDV certification according to Regulation (EU) 2017/2400. This is reflected by the qualitative comments on the views of manufacturers on the distributional impact of the proposed extension on SMEs.

The Commission could tailor the requirements for SMEs, in particular small bus manufacturers only involved in manufacturing of the vehicle body, to ensure that these businesses are not faced with disproportionately high administrative costs. The dominant costs arise from overhead costs, with component certification costs and VTP costs comprising much smaller cost segments. Small manufacturers producing medium lorries were not included in the presentation of results, as it is not deemed commercially viable for a manufacturer of ~200 medium lorries a year to certify the vehicles given the relatively low return per vehicle sold.

The key benefits associated with the proposed extension of Regulation (EU) 2017/2400 include the provision of a standardised source of fuel economy information to customers, and the opportunity to engender significant fuel and CO_2 emission savings over the vehicle life-time. A short payback period was assessed for the additional costs related to the CO_2 certification. Most importantly, whole vehicle certification is the enabling methodology upon which future vehicle segment CO_2 targets, and fuel consumption reduction targets, could be set.

The proposed extension of Regulation (EU) 2017/2400 is expected to engender improvements in competition and innovation within the EU and internationally. However, the need to ensure that VECTO is capable of modelling all fuel-saving technologies was reflected by manufacturers as a key requirement for incentivising investment in the manufacture of low-emission vehicles. The proposed extension is anticipated to have only a small impact on employment and third countries.

1 Introduction

This final report gives a documentation of the work performed in the project “Technical Support for the Development of the HDV CO2 Certification (Remaining HDV)” by the consortium of TU Graz, TÜV Nord Mobilität, Ricardo and TNO Automotive.

This final report contains the deliverables as shown in Table 3.

Table 3: List of deliverables for the final report

Deliverable	Chapters + name of separate documents
Task 1: Technical support for implementation of Regulation (EU) 2017/2400	Chapter 2
Task 2.1.1: Pilot phases for CO_2 certification of buses and medium lorries	Chapter 3.1 Annex I: Approach to determine CO2 emissions and fuel consumption for heavy buses plus supporting documents with stakeholder feedback : !PilotPhase1_Comments.docx !PilotPhase2_Comments.docx !PilotPhases1and2_Comments_WD10a_beforeUpdate.docx (refer to working document 10a before the big update in December 2020) !PilotPhases1and2_Comments_WD10a_afterUpdate.docx (refer to working document 10a after the big update in December 2020)
Task 2.1.2: Analysis of light lorries and buses	Chapter 3.2
Task 2.2: CO2 verification of heavy buses and medium lorries	Chapter 3.3
Task 3.1: Certification procedure of hybrid powertrains	Chapter 4.1
Task 3.2: Certification procedure for other new technologies	Chapter 4.2
	Chapter 4.3 In addition to the information on Task 3, those vehicle technologies or vehicle configurations are described that must be exempted from Article 9 on the basis of the methodology developed for the 2nd Amendment.
Task 4.2: Verification testing procedure (VTP) of in-service lorries	Chapter 5.1 Annex ISV testing 20210826_clean-commHH_TUG.docx
Task 4.3: In-service conformity testing of air-drag, tyre rolling resistance and vehicle mass	Chapter 5.2 Annex ISV testing 20210826_clean-commHH_TUG.docx

Deliverable	Chapters + name of separate documents
used as input of the simulation tool	
Task 5: Assessment of the economic feasibility of an extended scope of CO_2 determination of heavy-duty vehicles	Chapter 6
Task 6 – Liaising with stakeholders and Commission services	Chapter 7

Furthermore, the working documents on the individual Annexes[3] of Regulation 2017/2400 represent key deliverables of this contract. The documents were sent to DG GROW between March and May 2021. Further punctual changes to the texts were made in the consolidated document submitted to the TCMV in July 2021. Since the latest version of the documents is not available to the contract holder these documents are therefore not sent again with the final report.

- Working Document 1 (CLASSIFICATION OF VEHICLES IN VEHICLE GROUPS AND METHOD TO DETERMINE CO2 EMISSIONS AND FUEL CONSUMPTION FOR HEAVY BUSES)
- Working Document 3 (INPUT INFORMATION RELATING TO THE CHARACTERISTIC OF THE VEHICLE)
- Working Document 4 (MODEL OF THE OUTPUT FILES OF THE SIMULATION TOOL)
- Working Document 5 (VERIFYING ENGINE DATA)
- Working Document 6 (VERIFYING TRANSMISSION, TORQUE CONVERTER, OTHER TORQUE TRANSFERRING COMPONENT AND ADDITIONAL DRIVELINE COMPONENT DATA)
- Working Document 7 (VERIFYING AXLE DATA)
- Working Document 8 (VERIFYING AIR DRAG DATA)
- Working Document 9 (VERIFYING LORRY AND BUS AUXILIARY DATA)
- Working Document 10 (CERTIFICATION PROCEDURE FOR PNEUMATIC TYRES)
- Working Document 10a (VERIFICATION TESTING PROCEDURE)
- Working Document 10b (CERTIFICATION OF ELECTRIC POWERTRAIN COMPONENTS)

[3] This concerns all annexes with the exception of Annex II, which was not the content of this project.

2 Task 1: Technical support for implementation of Regulation (EU) 2017/2400

Task 1 shall provide support to the Commission for all technical questions concerning the determination of the CO_2 emissions and fuel consumption of heavy-duty vehicles, including N, M, O3, O4 vehicles.

During the project, eleven requests have been received and answered by the consortium (Table 4). In total 5.1 person days have been spend in Task 1.

Due to the complexity of the subjects requests 8 and 9 had to be further investigated in the task forces after the first rely to the Commission has been provided. The allocated efforts are also included in the hours listed in Table 4.

Table 4: Processed requests in Task 1

Request #	Request received	Reply provided	Involved person(s)	Topic	person hours
1	19.06.2019	21.06.2019	Rexeis	Annex VIII: Active aero features	0.50
2	03.10.2019	03.10.2019	Quaritsch, Rexeis	Annex III: "Vocational flag" for non 4, 5, 9, 10 groups	1.00
3	10.10.2019	10.10.2019	Quaritsch	Article 11: Hashing of XMLs with standard values	1.00
4	25.10.2019	30.10.2019	Rexeis, Goschütz	Handling of FWD vehicles (e.g. 6x4)	3.50
5	05.11.2019	08.11.2019	Rexeis, Goschütz	Manufacturer definition, GVW vs TPMLM for HDV CO2	2.50
6	12.11.2019	19.11.2019	Quaritsch, Rexeis, Goschütz	Annex VII: Maximum axle input speed	8.50
7	26.11.2019	26.11.2019	Rexeis	Averaged CO2 emissions and paylaods for vocational vehicles	0.50
8	23.12.2019	07.01.2020	Goschütz, Rexeis	Retarder and start-up clutch	7.50
9	15.01.2020	20.01.2020	Goschütz, Rexeis	Default torque losses of an electrical retarder	8.50
10	19.03.2020	25.03.2020	Rexeis; Silberholz	JAMA on COP for engines	5.00
11	12.06.2020	17.06.2020	Rexeis, Goschütz	Vorgaben bezüglich des Datenhandlings für Vecto	2.50
				Total (person days)	**5.1**

3 Task 2: CO_2 determination of buses and vans

Task 2 was divided into the following thematic blocks:

- Task 2.1: Pilot phase for CO_2 certification of buses and vans
    - Task 2.1.1: Pilot phases (section 3.1)
    - Task 2.1.2: Analysis of light lorries and buses (section 3.2)
- Task 2.2: CO2 verification of new buses and vans (section 3.3)

3.1 Task 2.1.1: Pilot phases for CO_2 certification of buses and medium lorries

This section documents the work performed related to the organisation, coordination and evaluation of a stepwise sequence of three pilot phases for the CO2 determination of buses and medium lorries over the duration of the project. This contract does not cover any work to be performed in parallel on the VECTO software.[4]

Table 5 gives an overview on the pilot phases (PP 1, PP 2 and PP 3). Periods and tasks have been adapted compared to the original planning based on the actual developments in the project.

[4] The related work is covered by the DG CLIMA Service Contract Number 340201/2018/789690/SER/CLIMA.C.4. ("VECTO: Extension to hybrids and further technical support")

Table 5: Overview pilot phases

Pilot Phase	Period	Status technical annexes	Vecto software	Main Tasks	Partici-pants	Status quo
PP 1	04 2019 to 02 2020 *1)	1st draft (versions April 2019)	No new version	• Check of technical annexes • Run new component tests (medium lorries) • Elaborate data for further procedure development (VTP test, auxiliaries etc.) • Feasibility check for multistage approach	Daimler, MAN, Scania, Van Hool, Isuzu Motors Germany, CNH/Iveco, ETRMA	Completed
PP 2	01 to 09 2020 *2)	2nd draft available (versions March 2020)	Update with “Advanced Auxiliaries”, “Factor method” and Hybrids	• 2nd check of technical annexes • Run and analyse component tests for WHR and Dual fuel • Run VECTO software and give feedback • Heavy buses – validation of general approach • VTP: Analysis of tolerances and handling of pollutant emissions	Physical Testing: Volvo, Daimler, CNH Software testing: ACEA OEMs plus several CLCCR members	Completed
PP 3	04 2020 to 09 2021 *3)	Continuous updates until June 2021	Continuous updates until September 2021 (and ongoing) *4)	• 3rd check of technical annexes and give feedback • Run component tests for hybrids and battery electric vehicles*5) • Run VECTO software and give feedback *5)	ACEA, CLEPA, CLCCR	Verification of test procedures only done on theoretical basis. Tool development needs to be carried on until 2022.
	*1) The end of the pilot phase 1 has been postponed from end of Dec. 2019 to end of February 2020 *2) The end of the pilot phase 2 has been postponed from end of June 2020 to end of September 2020 *3) The ambitious original planning (completion until November 2020) could not be kept by far. Therefore, the activities were continued until the end of the project. *4) After new approaches for mapping xEV have been designed in the working groups by June 2021, the completion of the corresponding VECTO software, including testing by industry, will take until approximately the end of 2022. *5) Since the final designs for the test procedures were not fixed until June 2021, no physical have been communicated by industry to have been carried out. Further details see section 3.1.4:					

3.1.1 Overview work performed

Related to design, organisation and evaluation of the pilot phases the following work has been performed by the consortium, in agreement with the Commission:

- Organisation and holding of stakeholder meetings where outlines and tasks of the pilot phases have been discussed

- Workshops on specific new elements as proposed for the second amendment of Regulation (EU) 2017/2400 (topics: new vehicle categories “medium lorries”, “heavy buses” and the “factor method”, “multi-stage” and “individual vehicle approval”)
- Helpdesk during the test phase for the participants
- Collection and processing of feedback from stakeholders
- Holding of task force meetings related to the single working documents to discuss feedback from stakeholders and prepare next versions of the documents
- Processing of results for presentation at HDV CO_2 Editing board meetings
- Updates of all working documents and discussion of comments with the Commission.

The relevant information from the three pilot phases is documented below. The documents with the consolidated comments of the stakeholders in the pilot phases and the information of the consortium on how these comments were dealt with (adopted, not adopted, not relevant, etc., each with reasoning) are listed in Table 3 on page 18 and were also submitted with the final report. As described in more detail below, pilot phase 3 could not be carried out in the planned "conventional" form (the first complete version of Annex 10b was not available until the end of the project), so there is no such "comments" document for pilot phase 3.

3.1.2 Pilot phase 1

The activities related to pilot phase 1 have been completed until end of February 2020. Table 6 lists the physical tests that have been performed.

Table 6: Physical testing in pilot phase 1

OEM	Vehicle	Tests covered
Daimler	Heavy bus (high floor), AMT	Component tests, VTP, real world driving
MAN	Heavy bus (high floor), AMT	Component tests, VTP
Scania	Heavy bus (high floor), AMT	Component tests, VTP, (+CFD for new task force)
Van Hool	Heavy bus (high floor), AMT	Air drag, VTP
Daimler	Medium lorry (van)	Component tests, VTP, real world driving
ISUZU Motors Germany	Medium lorry (rigid)	Component tests, VTP, real world driving
IVECO	Medium lorry (van)	Component tests, VTP, real world driving

Physical testing covered all technical items as foreseen in the original planning, except the topic VTP measurements for heavy buses with transmissions with torque converters. A single OEM indicated that related vehicle tests would be caught up in pilot phase 2. But this has not taken place.

In pilot phase 1 more than 200 entries of feedback were collected. For internal documentation purposes, these were summarized in a consolidated document and the status of the processing (incorporated into working document, rejected etc.) and a justification were given. This document was provided to DG GROW as a separate deliverable to the second interim report in Q3 2020.

3.1.3 Pilot phase 2

The work to be performed in pilot phase 2 is grouped into the following topics:

- Waste heat recovery (WHR), see section 3.1.3.1
- Dual fuel, see section 3.1.3.2
- Heavy buses – General approach ("Multi-step") , see section 3.1.3.3
- Heavy buses – VTP, see section 3.1.3.4
- Medium lorries – VTP, see section 3.1.3.5
- VTP and pollutant emissions, see section 3.1.3.6

3.1.3.1 Waste heat recovery (WHR)

A basic technical introduction and detailed description of the approach developed for coverage of WHR in VECTO is given in the first interim report (pages 28 to 38). The second interim report contains a detailed description of the validation activities originally planned for pilot phase 2 (pages 14 and 15) in this regard.

In pilot phase 2 with regard to WHR, one manufacturer (CNH) finally carried out measurements. The participation announced by a second manufacturer (Volvo) was withdrawn due to the Corona crisis. The tests executed by CNH covered the engine dyno testing procedures according to working document 5 (draft version March 2020) for the use case "WHR with electrical output". For validation of the accuracy of the approach additional engine dyno cycles have been measured (engine with/without WHR), which then have been compared with the VECTO results simulated. The tests with the WHR system deactivated were carried out in order to put the observed deviations in perspective to deviations from the existing VECTO methodology for conventional engines.

The simulations with VECTO were carried out in parallel by CNH and TUG. The observed deviations in brake specific fuel consumption simulated by VECTO compared to the test results are shown in Table 7. For the conventional engine, the deviations are with +/-1% very well within the +/-2% range commonly assessed to be typical for the VECTO internal combustion engine model. For the engine with WHR, the measured fuel consumption in the cycles with "reference" payload is also very well matched. In the cycles with zero payload, however, the fuel consumption is underestimated by slightly more than 2%.

Table 7: Deviation in brake specific fuel consumption (VECTO - Meas.) / Meas.

Deviation of brake specific fuel consumption (VECTO - Meas.) / Meas.	Mission profile and payload condition			
	Long haul		Regional delivery	
	ref payload	low payload	ref payload	low payload
Engine w/o WHR	0.4%	-0.2%	-0.1%	-0.9%
Engine w/ WHR	0.3%	-2.2%	0.0%	-2.4%

The conclusions from this activity as discussed during the 19th HDV CO_2 Editing board meeting are:

- The general approach to cover WHR technology in VECTO works but the accuracy regarding differentiation of low and representative payload conditions (corresponding to different average engine power conditions) could be improved.
- However, a further improvement of accuracy would need significantly more complex methods and further testing and data analysis which was assessed to not feasible within the scope of pilot phase 2 and the second amendment of Regulation (EU) 2017/2400.[5]

One part of the validations foreseen in pilot phase 2 on the WHR topic was not carried out, namely the analysis regarding accuracies and tolerances in the VTP. This would have required VTP measurements on a vehicle equipped with WHR, which was not available. However, JRC carried out extra analyses on a data set from a preliminary study on WHR and VECTO ([4], [5]) which indicate that approximately the same accuracy of VECTO can be expected in the VTP mode as in the normal simulation mode.

As with all other topics, comments on improving the provisions in the working documents were collected for WHR during pilot phase 2 and incorporated into the text.

3.1.3.2 Dual fuel

A basic technical introduction and detailed description of the approach developed for coverage of dual fuel engines in VECTO is given in the first interim report (pages 25 to 28). The second interim report contains a detailed description of the validation activities planned for pilot phase 2 (pages 14 and 15) in this regard.

Volvo, which is currently the only known manufacturer offering such a technology to the market, participated regarding dual-fuel both with engine dyno testing and vehicle (VTP) testing. The engine test bench tests as drafted in working document 5 (version March 2020) were conducted and - analogous to WHR - four additional cycles were measured for validation purposes. Furthermore, two VTP tests have been carried out with a vehicle equipped with dual fuel technology. Results have been analysed with TUG in bilateral meetings and been presented in the 19th HDV CO2 Editing board meeting. The deviations in the VECTO simulations for the engine test bench tests were found to all be in the range of +1% to +1.2%

[5] Industry has not expressed any further concerns or aspirations in this direction. Also from the point of view of VECTO development, too, a further increase in complexity at this point is not recommended.

and thus very well within the expected range. For the VTP tests, the deviations of the VECTO VTP mode are at 1.5% and 1.7% and thus clearly within the VTP tolerance of 7.5%. Thus, the approach for dual fuel engines designed for Regulation (EU) 2017/2400 and VECTO can be considered successfully validated.

As for WHR also for dual fuel several items for improvements on the working documents were identified and implemented.

3.1.3.3 Heavy buses – General approach (“Multi-step”)

For heavy buses from the boundary conditions:

- Consideration of specifications of final bodywork and auxiliary units in the VECTO results
- Compatibility with manufacturing processes involving multiple manufacturers
- Input data confidentiality issues

A CO2 determination based on a multi-step calculation approach was developed. The general calculation approach was already drafted in an earlier project [6]. The development status of the methodology at the beginning of pilot phase 2 is described in detail in Appendix I of the second interim report of this project.

The analysis to be performed in pilot phase 2 should:

- Provide a forum for software testing in which the general operation of the VECTO multi-step tool is investigated and the methods regarding application of simulation methods, generic data etc. are analysed and discussed.
- Investigate the accuracies of the two candidate algorithms to accomplish the multi-step calculation approach (“factor method”, “delta method”). This accuracy is determined by the deviation of the results (fuel consumption and CO2 emissions) calculated using the multi-step approach compared to a simulation where all input data (for the primary and complete or completed vehicle) is available at once.

In the following, the results of pilot phase 2 are presented as they were discussed in the 19th HDV CO_2 Editing board meeting. A description of the final approach for heavy buses developed from this process is given in Annex I of this report. This description is identical to the text as also placed in point 2 of working document 1.

Software testing in pilot phase 2 was performed under active participation of Allison, CNH, Daimler, Irizar, MAN, Scania, Van Hool, VOITH, Volvo and ZF. Comprehensive feedback was collected on the general operation of VECTO for heavy buses (primary and complete or completed) in workshops and bilateral contacts with stakeholders. Items relevant for the working documents have been discussed in the task forces and implemented into the documents accordingly. Based on the feedback updated versions of the software have been compiled and distributed.[6]

[6] As already mentioned at the beginning of this chapter, in this regard this contract does not cover any work to be performed in parallel on the VECTO software.

The **accuracy of the multi-step calculation approach** was investigated on two levels:

1) An analysis of “worst case scenarios” performed by TUG, where heavy bus configurations known to lead to high-end deviations of the approaches have been simulated. This analysis is described in detail in part B of Appendix I of the second interim report. From the analysis, it was concluded that the accuracy of both approaches (Factor Method and Delta Method) is within +/-1% for most vehicles and +/-2% nearly all vehicles.

2) A data collection of simulation results from vehicle manufacturers, which analysed a proper representation of their product portfolios. Three vehicle manufacturers participated in this exercise. The collected data covers the main different conventional vehicle technologies i.e. different transmission types and both high floor and low floor vehicles. Table 8 gives the consolidated results from this analysis. The results have been presented and discussed in the 19th HDV CO_2 Editing board meeting.

Table 8: Deviations VECTO multi-step approach

Heavy bus type	Deviation	OEM average		Factor Method			Delta Method		
		Factor Method	Delta Method	OEM #1	OEM #2	OEM #3	OEM #1	OEM #2	OEM #3
Low floor (citybus)	average	0.0%	0.1%	0.0%	n.a.	0.0%	0.2%	n.a.	0.0%
	max (2σ)	0.4%	0.5%	0.4%	n.a.	0.5%	0.3%	n.a.	0.6%
High Floor (coach)	average	0.0%	-0.1%	0.0%	0.0%	0.1%	0.0%	-0.1%	-0.2%
	max (2σ)	0.6%	0.9%	0.3%	1.2%	0.3%	0.3%	1.2%	1.1%

The following conclusions have been drawn from this analysis:

- Both investigated algorithms provide very high accuracy thus successfully proving the feasibility of the proposed multi-step calculation approach
- The “Factor method” is favoured over “Delta method” as
  - The deviations are slightly lower
  - The general approach is more intuitive and transferable to other applications (e.g. to also consider the specific bodywork for rigid lorries or the the suggested “Efficiency factor” for (semi-)trailers)
- There are no particular concerns that the approach will not work for xEVs. However, a separate validation/optimisation exercise is recommended. This validation exercise will need to be done in the further course of the VECTO development in the year 2022.

The analysis shown above was based on the assumption that the input parameters for ADAS systems are only set at the "primary vehicle" level and may not be changed later. In the 20th HDV CO2 Editing board it was furthermore agreed to open those input parameters also to later vehicle manufacturing steps. For this opening of possibilities for the vehicle configuration in VECTO, it was estimated that about 0.2 percentage points of additional uncertainty on the VECTO results for the complete or completed vehicle must be taken into account.

3.1.3.4 Heavy buses – VTP

The results of pilot phase 2 on heavy buses and VTP are described below. The investigations carried out refer to the technically achievable accuracy of the VECTO VTP mode compared to the measurement, which then has to be taken into account in the tolerances written down in Annex Xa.

As detailed later in the report in section 3.3, it was finally decided not to consider heavy buses for the VTP in the second amendment of Regulation (EU) 2017/2400. If the differentiated approach for different types of manufacturers (primary, interim, complete or completed) proposed in section 3.3.4.2 is implemented in a follow-up amendment of the Regulation, the results presented here are still relevant and will apply to the "verification of powertrain-efficiency" as it would have to be carried out by primary manufacturers.

The VTP related tasks in pilot phase 2 were:

1) Analyse deviations VECTO vs. measurement for "baseline trip requirements" as established in current version of Annex Xa for lorry groups 4, 5, 9 and 10
2) Analyse influence of adapted trip requirements to elaborate a set of boundary conditions fitting better the typical mission profiles and still providing acceptable accuracy.

The baseline trip requirements as mentioned in 1) refer to a fully loaded vehicle and with most part of the trip driven at motorway speeds. Those trip requirements were introduced for lorry groups 4, 5, 9 and 10 because

- Those are quite close to real world operation of lorry groups 4, 5, 9 and 10
- The VECTO VTP mode was assumed to be most accurate, thus a small VTP tolerance could be defined

The analysis according to 1) can thus show whether there are fundamental differences in the achievable accuracies for heavy buses compared to heavy lorries groups 4, 5, 9 and 10 as mentioned above. The second step according to 2) then is needed to analyse appropriate VTP tolerances for trip conditions close to real world operation of heavy buses. The trip requirements as proposed for heavy buses and the derivation of those is described in section 3.3 of this report.

The following data were available for the analysis:

- 4 different heavy buses from 4 manufacturers have been tested
- All buses are of vehicle group "32d" (i.e. 2 axle, high floor vehicle = coach) with AMT transmission[7]
- In total 22 VTP tests are available, 14 of those tests have been performed by the DG JRC [7]

[7] As mentioned also in the conclusion section, no VTP measurements are available on low-floor buses and buses with automatic transmission. Therefore, no statement can be made for these vehicle technologies in the VTP.

Figure 1 shows the C_{VTP} ratios[8] as determined for each of the tests as a function of share of motorway on the total trip. All tests would have "passed" the VTP based on heavy lorry tolerance. There is a certain offset of C_{VTP} values to the "+" side also seen in the pilot phase for heavy lorries in 2017. No clear trend of C_{VTP} with "share motorway" can be identified.

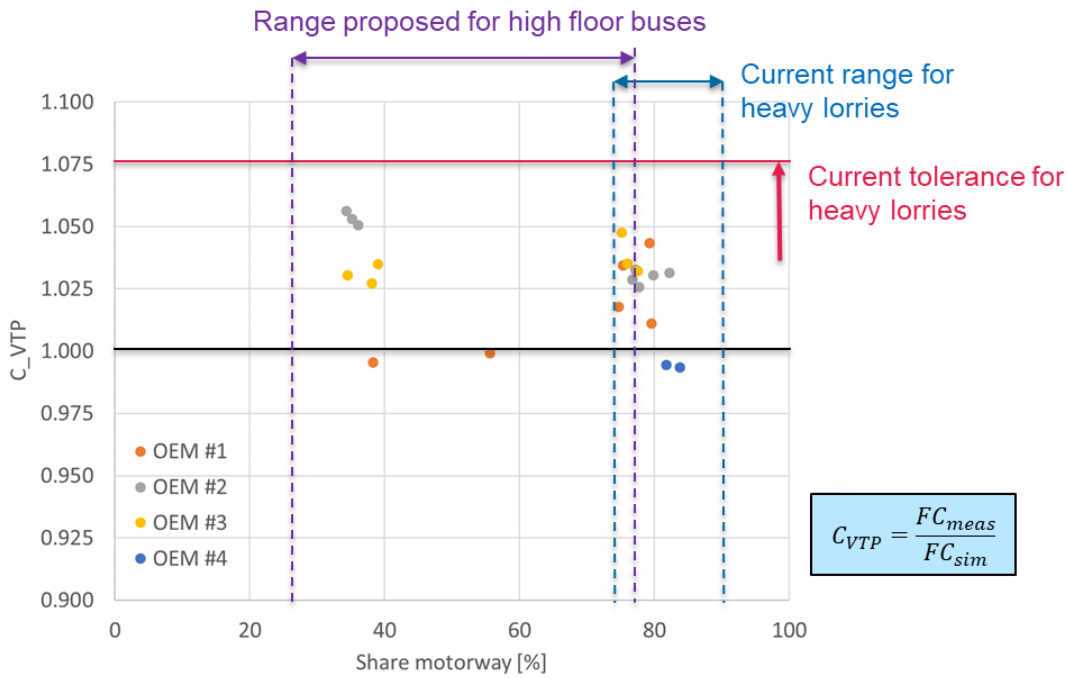

Figure 1: C_{VTP} ratio as a function of share motorway

A more in-depth analysis of the influence of trip conditions is shown in Figure 2. In this picture the C_{VTP} ratio distribution of all tests is plotted separately according to the time shares in the three trip categories (urban, rural, motorway).[9] As to be expected the "motorway parts" show lowest and most stable C_{VTP} figures. The "urban" driving parts give highest the C_{VTP} ratios. Rural parts show highest spread in C_{VTP} over the different performed parts. This high variance in C_{VTP} is probably due to the high variance in transient driving conditions for the 50 to 70 km/h speed range. Further, much deeper analysis would be needed to fully understand the causing phenomena

[8] The C_{VTP} ratio is the ratio between measured fuel consumption and fuel consumption simulated by VECTO for a particular VTP test. This value - which for formal reasons is converted to CO2 emissions, see section 3.3.2.1 - is used for the pass/fail criterion in the VTP.

[9] The division of the evaluation of a VTP test separately according to urban, rural and motorway shares is only carried out for reasons of analysis and is not proposed for the pass/fail criterion according to Annex Xa.

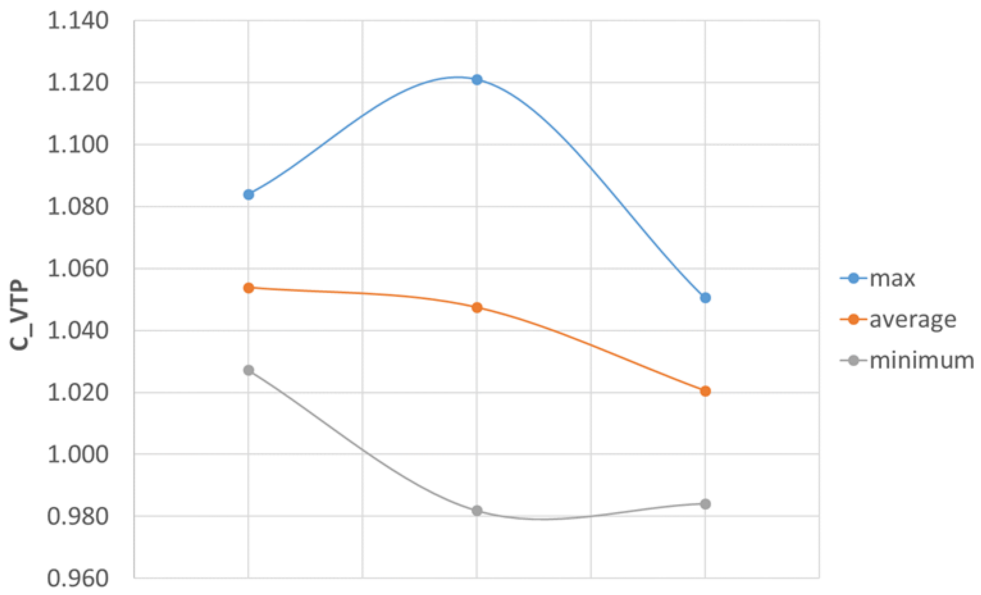

Figure 2: C_{VTP} ratio per sub-part of the trip

Based on this data the following conclusions have been drawn:

- For high floor buses the general approach for VTP is assessed to be validated as all tests including those driven according to proposed high floor bus specific trip provisions are within the 7.5% tolerance as established already for heavy lorries
- It suggested to apply the proposed "high floor buses" specific set of trip provisions and a correlated tolerance of 7.5% in Annex Xa
- For a later application of the VTP test as an in-service verification test procedure, performed by third parties it is furthermore recommended to apply a further pilot phase to find out if the assumed sensitivity of the C_{VPT} ratio with transient driving conditions does not lead to fails that are only due to the test conditions and the methodology and not to the performance of the vehicle. To avoid such cases additional limits for transient driving conditions (similar to the v x a criteria in LDV RDE testing) could possibly be introduced for third party tests.

On the application of VTP for low floor buses no conclusions can be drawn at this point. The draft trip requirements for urban buses are much more demanding in terms of accuracy for the simulation model as only urban and rural trip parts are proposed and the typical APT transmissions with torque converter are more complex to model. Thus test data will be needed, otherwise no robust decisions on suitable trip provisions and a correlated C_{VPT} tolerance can be made.

3.1.3.5 Medium lorries – VTP

In pilot phase 2 analogous investigations to the VTP were also to be carried out for medium lorries. The following data were available for the analysis:

- 2 vehicles from 2 different OEMs
- Thereof 1 rigid lorry and 1 van, both with "manual" transmission (SMT)
- In total 8 VTP tests (6 thereof measured by DG JRC [7])
- Data from a third vehicle (van) as measured at the DG JRC in 9 VTP tests was not included into the final analysis as from component testing the engine fuel consumption map and the gearbox loss map were not measured as specified in Annexes 5 and 7. There is no evidence how much of an error this introduces in the simulation results.

Figure 3 shows the C_{VTP} ratios as determined for each of the 8 analysed tests as a function of share of motorway on the total trip. The results for the vehicle of OEM #1 are very close around the "ideal" C_{VTP} ratio of 1. This vehicle was only testing in the "baseline" trip conditions and not in the alternative provisions as proposed for medium lorries. The values of the vehicle of OEM #2 are systematically below 1, i.e. the simulated value of VECTO for the measured VTP trips overestimates the measured value by up to approx. 5%. JRC has analysed this systematic overestimation of the measured consumption in more detail and found the main cause in the generic values for energy consumption of the electrical system (approx. 1 kW) defined in VECTO for medium lorries. If the generic values are corrected to the actual 400 W in the test, the C_{VTP} values increase by approx. 0.025. It is therefore proposed to change the generic values in VECTO accordingly [7].

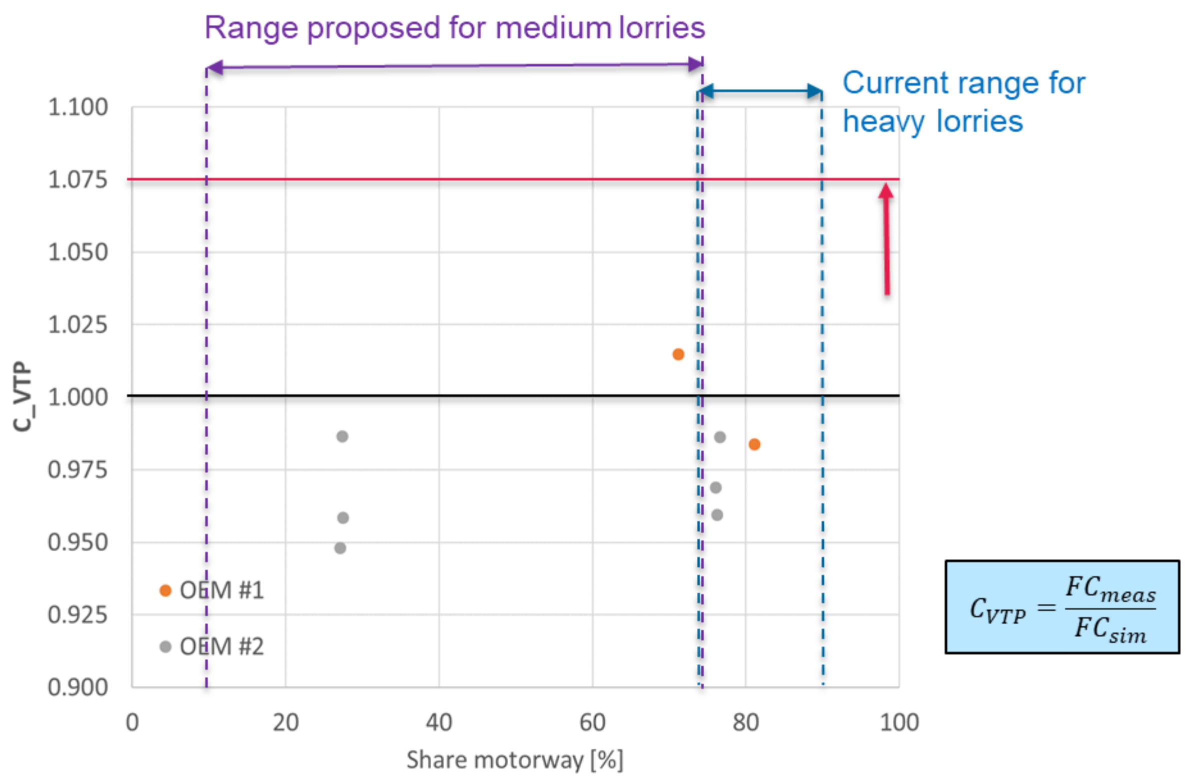

Figure 3: C_{VTP} ratio as a function of share motorway

A more in-depth analysis of the influence of trip conditions is shown in Figure 4. In this picture, the C_{VTP} ratio distribution of all tests is plotted separately according to the time shares in the three trip categories (urban, rural, motorway). As already seen for heavy buses the C_{VTP} in motorway parts is stable and close to 1. The highest variance and C_{VTP} ratios is seen here for the urban trip shares (dashed oval) with a C_{VTP} range of approx. 0.8 to 1.2. However, if only these trips are taken in which the urban driving situation also has significant shares of the total VTP (solid oval) then the C_{VTP} variance is reduced to a range of approx. 0.92 to 1.02.[10]

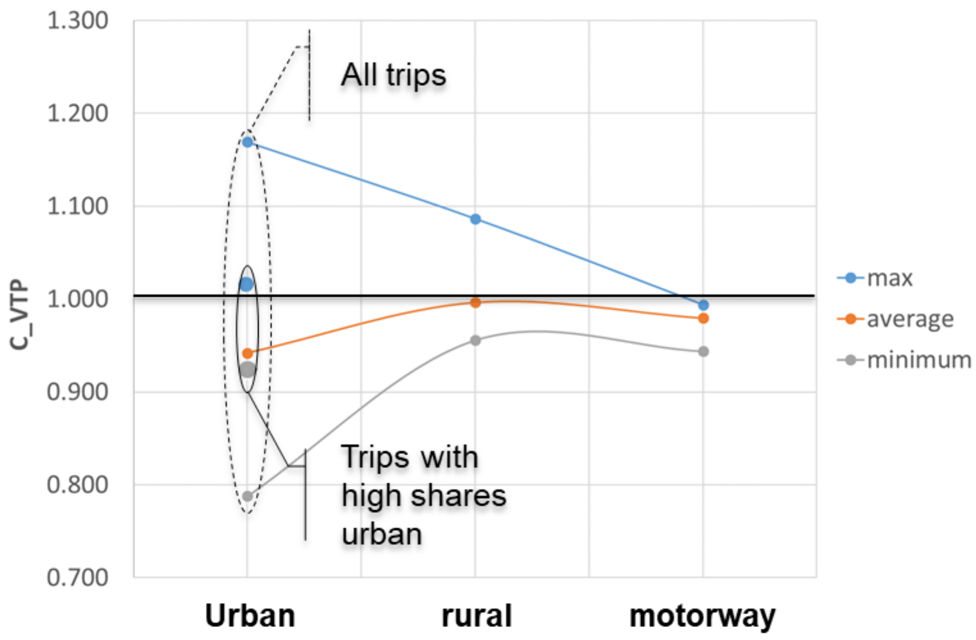

Figure 4: C_{VTP} ratio per sub-part of the trip

The analysis as shown above was discussed in the 19th HDV CO_2 Editing board meeting and the following conclusions were drawn:

- It is recommended to apply the proposed medium lorry specific trip provisions and a correlated + 7.5% tolerance as for heavy lorries
- In response to industry comments that higher payloads correlate with higher accuracies in the VTP (i.e. C_{VTP} ratios closer to 1), the payload provisions were increased to 55% to 75% load factor (original proposal from COM and Consultants was 40% to 60%).
- It is additionally proposed that the provisions on trip composition and payloads also apply to heavy lorries in groups 1s, 1, 2 and 3. These vehicle groups also tend to be used more for distribution transport than for long haul and are therefore more similar to medium lorries in terms of their operational profile than vehicle groups 4, 5, 9 and 10.

In addition, the above-mentioned medium lorry specific adjustments of the generic data in VECTO are recommended.

[10] The urban share of VTP tests in the solid oval is 50 to 60%. The urban share of the VTP tests additionally contained in the dashed oval is 6% to 15%. For these very short time intervals of only a few minutes duration generally higher differences between measurement and simulation seem reasonable.

The recommendation already made for heavy buses that an application of the VTP as an ISV test also requires a pilot phase to secure the testing provisions (especially worst-case trip conditions) also applies to medium lorries.

3.1.3.6 VTP and pollutant emissions

In this project, the feasibility of expanding the VTP to include an assessment of pollutant emissions was to be investigated. The analysis as performed in Task 4.1, which was to be delivered already with the first interim report, showed that most of the boundary conditions as set out in the Euro VI ISC pollutant type approval test, e.g. on vehicle mileage, trip requirements and data evaluation, are not compatible with the corresponding provisions in the VTP. Therefore, for EURO VI vehicles as a matter of principle, no parallel pass/fail assessment of fuel consumption and CO_2 emissions as well as pollutant emissions can be carried out in a VTP measurement without introducing additional provisions with regard to pollutant emission verification. In order to nevertheless meet the European Parliament's demands regarding the combination of VTP and pollutant emission measurement, the HDV CO_2 Editing Board decided on the following approach:

- The provisions for VTP shall be extended to include also measurement of pollutant emissions, referring to the procedures as set out in Appendices 1 to 4 to Annex II to Regulation (EU) 582/2011. The data evaluation shall provide instantaneous emission mass flows as input to the simulation tool. The additional requirements mentioned in Regulation (EU) 582/2011 on data evaluation (e.g. work based windows, moving average windows), test start and trip mentioned in Regulation (EU) 582/2011 shall not apply. Recording of pollutant emissions shall be started and stopped simultaneously with the start of the fuel measurements.
- Based on these input signals the simulation tool shall automatically calculate the total grams pollutant per total positive engine work in the VTP. These shall then be automatically written into the output of the simulation tool.
- For vehicles pollutant type approved in accordance with EURO VI these results cannot be used for a pass/fail decision. Accordingly, the data should only be used for monitoring purposes.
- Combining the VTP test and PEMS-ISC test shall be considered further in the discussions on EURO VII in order to find a solution that the provisions on pollutant emissions in RDE conditions are kept general so that they are directly applicable to all possible variants of the VTP.

For the VTP performed as an In Service Verification Test, it is furthermore proposed that in case the EURO VI ISC limits are exceeded by the emission values calculated by VECTO for the VTP, an additional dedicated ISC test for pollutant emissions shall be added. For the VTP applied during ISV this can be performed with much less efforts than for a VTP operated as a CoP, because the issue with the different mileage provisions does not apply.[11]

[11] For a valid PEMS ISC test the odometer reading shall exceed 25 000 km. For a valid VTP to be performed as CoP the odometer reading shall be below 15 000 km. Thus, to add a valid PEMS ISC test after a CoP VTP, a vehicle would need to be operated for at least 10 000 km before such a test could be accomplished. This problem does not arise for a VTP to be performed as ISV as odometer readings between 15 000 and 300 000 km are proposed to be allowed.

To substantiate the topic of VTP and measurement of pollutant emissions with experimental data, PEMS equipment was installed in most of the VTP tests carried out in the pilot phases. The results of the data evaluation, i.e. pollutants per positive engine work are shown for NOx in Figure 5. As expected, the average NOx emission level in the VTP ("total trip") is well below the ISC limit of Euro VI. This picture does not change significantly when the emissions are evaluated separately for the three trip categories for analysis purposes. The other two emission components, CO and THC, were also well below the ISC Euro VI limits in the VTP.

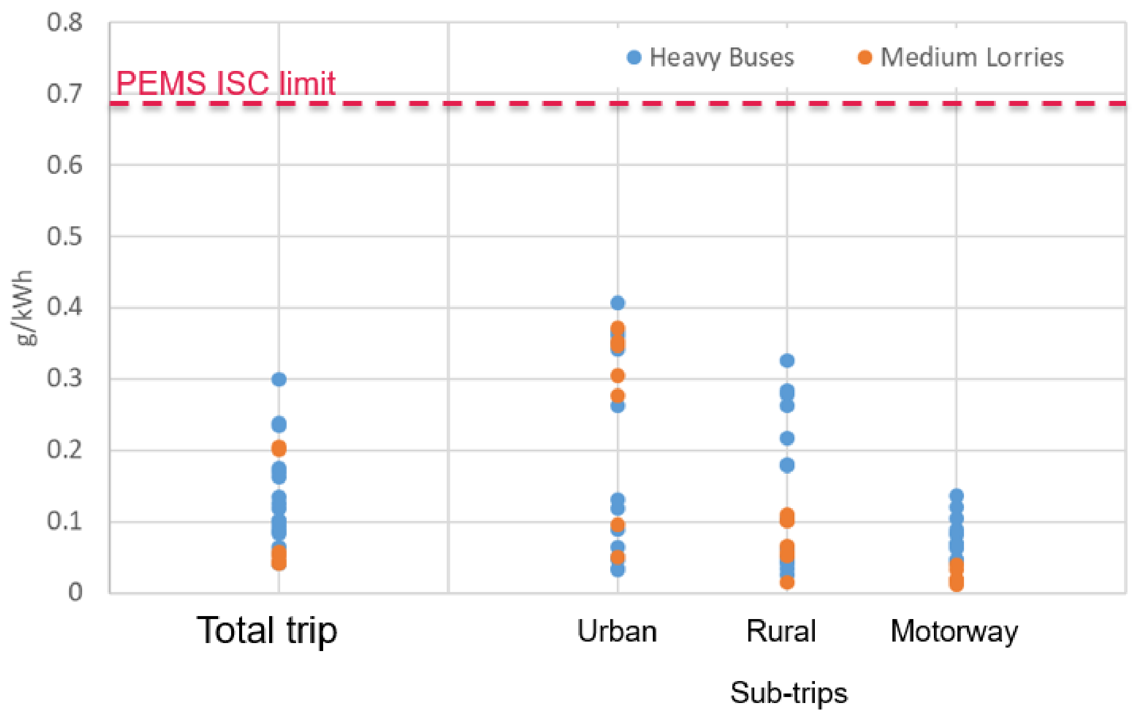

Figure 5: Results for total g NOx / kWh engine work (all VTP tests)

3.1.4 Pilot phase 3

The aim of pilot phase 3 was to verify the developed test procedures and simulation methods for vehicles with electrified powertrains (HEV and PEV, together referred to as "xEV" in the following) by means of physical testing and subsequently running the simulation tool for such vehicles.

In fact, the course of pilot phase 3 - as well as the entire development work for xEV - has turned out to be quite different from what was originally planned. In the original planning, it was envisaged that the methodology to be developed would focus on hybrid electric vehicles and - in coordination with the project on VECTO software development run by DG CLIMA (see footnote 4 on page 21) - aim at a simple and quickly implementable approach, which would be realistic to be finalised within the given time frame. A distinction should only be made between essential "archetypical" power trains (parallel hybrid, serial hybrid, possibly also third "power-split" hybrid variant). Pure electric vehicles (PEVs) should only be included "as far as possible" (quote from the tender) in order to enable an estimation of the electric range (CO_2 emissions would be zero anyway). Concerning component testing it was originally assumed that the methods, if at all necessary [12], can be based on the procedures already developed for GTR4 HILS. In this original planning, it was foreseen to develop the new technical Annex Xb at the beginning of 2020, to distribute it in May 2020, and then to validate it in practice within pilot phase 3, which would run for the rest of 2020 in close cooperation with industry.

Due to the steep learning curve regarding xEV technologies in the period since early 2019 that has taken place among all participants (industry, consultants, Commission) and also due the significantly changed political framework conditions regarding alternative powertrains ("Green Deal"), a significantly more complex path had to be taken with regard to the coverage of xEVs in VECTO. Anything else would have been negligent, as the methods developed now will certainly represent the backbone of Regulation (EU) 2017/2400 and VECTO in the next 10+ years. The following major changes in the basic concept have resulted from the developments in the project:

1) A strong simplification of hybrid powertrain architectures is assessed as not possible due to the high variance of systems realised on the market in the meantime and taking into account the high accuracy requirements established in Regulation (EU) 2017/2400. Therefore, distinction between 13 separate different powertrain architectures for HEVs have now been considered for the second amendment, with even more possible configurations considering combinations with different transmission technologies and auxiliary system configurations (the latter is only relevant for buses).
2) A detailed assessment of the electric energy consumption of PEVs has become a central element in the methodology. For PEVs, three different powertrain configurations have been foreseen which can be combined with three different transmission technologies.
3) Going beyond the above-mentioned methods and degrees of freedom the new elements "Integrated Electric Powertrain Component" (IEPC) and "Integrated HEV powertrain component" (IHPC) have been developed. Such components are characterised by an integrated functionality of several "conventional components" (electric motor, gearbox, differential) into a single unit and thus go beyond the classical component scheme in Regulation (EU) 2017/2400 and VECTO. Thus, they need to be represented in the component test as well as in VECTO with their own methods. The necessity for such methods was raised by industry very late in Q2 2020, at a time when, according to the planning, a first complete draft of Annex Xb should have been distributed and first physical tests in pilot phase 3 were to be carried out.
4) To make the above points possible, very detailed new test procedures for all electric powertrain components had to be elaborated. The new Annex Xb to be developed in this project from scratch is by now the most comprehensive of all technical annexes in Regulation (EU) 2017/2400, i.e. also more comprehensive than Annex V for the testing of internal combustion engines.

The technical details of the approach for xEV developed are described in chapter 4.1.

[12] Quote from the tender: "From today's point of view, the electric motor and the battery will be simulated by VECTO using generic efficiency data. This approach will make results from the generic hybrid control strategy more stable on one hand and will avoid costly additional component tests for hybrids". Only full load curves and rated power values from electric machines as well as battery capacity were planned to be subject of component testing.

Due to these changes in the overall scope, in connection with an only slightly extended time frame, the development of the technical methods for xEV and the related feedback loops have essentially concentrated on "theoretical" work in different working groups. For this purpose, seventeen task force Xb meetings were held between June 2020 and April 2021, in which the methods as drafted in Annex Xb for component testing were discussed with stakeholders. In addition, a much higher number of bilateral meetings were held with manufacturers and suppliers to gather feedback and elaborate the relevant methods (e.g. standard values). Similarly separate task force meetings were also held to work on the methods for configuring xEVs as set out in Annex III.

It is not known to what extent practical component tests were included in the feedback processes. In any case, the final methods cannot have been practically tested by industry, as the text was still being worked on up to the final deadline for completion of the Annexes (July 2021). The manufacturers have already announced in the course of 2020 that no practical test results can be made available for pilot phase 3 due to the short time frame in combination with the economical situation resulting from the Corona crisis. Of course, this means that there is a risk that inconsistencies or errors may only be discovered in the homologation phase, when the legal texts can no longer be changed. It is not unlikely that some technical clarifications or revisions will be necessary in this phase (e.g. via the FAQ document for the type approval authorities) and that there may be a need for some improvements of methods for the third amendment.

In this context, it should also be mentioned that due to the above mentioned change in scope the development of the VECTO software is significantly behind the original plans. Many of the above-mentioned methods for xEVs in the second amendment of Regulation (EU) 2017/2400 decided in the task forces in 2020 (e.g. IEPCs and IHPCs) have not yet (as of the beginning of September 2021) been tendered for implementation in VECTO. It can therefore be assumed that the development and testing of the software will not be completed for official application before the beginning of 2023.

3.2 Task 2.1.2: Analysis of light lorries and buses (N1, N2 ≤ 5 tons, M1, M2)

This section contains the deliverable allocated to Task 2.1.2: Analysis of light lorries and buses (N1, N2, M1 and M2 not exceeding 5 tons).

Since buses with a technically permissible maximum laden mass from 5 to 7.5 tons ("medium buses") have been suspended from the second amendment of Regulation (EU) 2017/2400, this deliverable shall also discuss how those can be added to a possible VECTO approach. This topic is discussed in section 3.2.1 below.

3.2.1 Analysis of medium buses

Medium buses - i.e. M3 vehicles not exceeding 7.5 tons TPMLM - were decided for a CO_2 determination based on the VECTO approach by the HDV CO_2 Editing board already in 2019. However, their implementation into the second amendment of Regulation (EU) 2017/2400 has been suspended, as the originally envisaged approach was concluded not to deliverer representative results for CO_2 emissions and fuel consumption. This originally envisaged approach assumed, that a similar approach as for medium lorries, i.e. a single step CO_2 determination at the base vehicle stage can be applied to medium buses. This is not the case as:

- There is a high variance of base vehicle configurations (in most cases an N1 or an N2 vehicle) which can be used to build a medium bus in a multistage process (see Figure 6)
- For buses the definition of a "standard body" as a reference for CO_2 determination at the base vehicle stage is hardly possible.

Figure 6: Possible base vehicle configurations for an identical medium bus

Based on this analysis, it can be concluded that any appropriate approach needs at least to a certain extend to consider the properties of the complete or completed vehicle. Furthermore it needs to be taken under consideration that the medium bus segment is very small in number (approx. 2 600 vehicles per year, see Table 9 on page 47; and with this it is by far the smallest segment in the light/medium/heavy x lorry/bus matrix!) and that a high number of SMEs are involved in the production each with very low annual production numbers. It is therefore not considered meaningful to apply the very complex approach as elaborated for heavy buses without any adaptions. As a further boundary condition any method to be developed for light buses needs to be considered as well. It is not considered meaningful to develop more or less different CO2 determination approaches for the three bus segments (light/medium/heavy).

From current knowledge it would be reasonable to elaborate a similar method for light and medium buses.

Based on these considerations two different options seem promising:

<u>I) Elaboration of a “light” version of the “factor method”</u>

In comparison to the approach as applied to heavy buses the following changes should be analysed:

- A significant simplification regarding auxiliaries; e.g. the HVAC power consumption to be determined just on a few input parameters like the interior volume, number of passengers and possible a very few technologies to be declared.
- For air drag it is - due to the high ratio of bus variants to production numbers – suggested to analyse the application of interim option between full air drag testing and applying standard values, e.g. a the use of standard Cd values
- Based on the above mentioned simplifications, a reduced set of input parameters compared to heavy buses for the complete or completed vehicle stage could be elaborated. It could also be examined whether the any interim manufacturers could be excluded from any responsibilities regarding VECTO.

<u>II) Elaboration of an extended base vehicle approach</u>

Such an approach could be based on a certain set of different VECTO results to be determined at the base vehicle stage, e.g. results for a baseline configuration and correction factors for change in mass, rolling resistance and change in CdxA compared to the baseline. The properties for the complete(d) vehicle would then be determined without any further application of the VECTO tool. Such an approach would in any case be less precise and individual than option I) described above. Option II) would only be justified if it would result in significant lower efforts for manufacturers at the completed stage. This approach resembles the approach used for MSV in WLTP[13]

A further item needs to be taken care of when elaborating the approach for medium buses: In the great majority of cases the base vehicle is of category N, i.e. there is a switch to category M during the production process. For option I) this means that there needs to be a solution to update the hash in the primary vehicle CoC (or issue a new CoC) in case such a conversion is done at a later manufacturing stage without allocating the responsibility to become a primary manufacturer for any subsequent manufacturing stage. This item might also be relevant (and thus to be solved) already for heavy buses in the second amendment currently under elaboration.

[13] Commission Delegated Regulation (EU) Nr. 2019/986, Commission Regulation (EU) 2017/1151

3.2.2 Analysis of light lorries and buses

In preceding projects dealing with the development of procedures for CO_2 determination of heavy duty vehicles, the future handling of light lorries and light buses was not decided. Three options have been elaborated[14] and will be presented and evaluated in this chapter.

A CO_2 test procedure close to the real world operation is essential to stimulate the use of technologies which have high CO_2 saving potential not just in the test procedure but also in real operation. Therefore, an understanding of the typical use of these vehicle groups is the main criterion for selecting the appropriate test regime, i.e. allocating these vehicles in future to WLTP or to VECTO using accompanying test procedures. Unfortunately almost no data on real world usage of these vehicles is available today to serve as basis for a proper decision. Therefore, the first part of the work consisted of data-mining. Available data should was collected and necessary data were requested from the involved parties.

3.2.2.1 Scope

For the purpose of the contract, light lorries and light buses are defined as N1, N2, M1, M2 with a technically permissible maximum laden mass not exceeding 5 tons and with a reference mass exceeding 2380 kg.

The range of light lorries and light buses contains type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles according to Regulation (EU) 595/2009 (Euro VI) and type-approval of motor vehicles with respect to emissions of light passenger and commercial vehicles (CO_2 and pollutant emissions) according (EC) 715/2007 (Euro 6).

In principle vehicles with a reference mass not exceeding 2610 kg shall be certified according the ‘LD regime’ and vehicles with a reference mass exceeding 2610 kg shall be certified according the ‘HD regime’. For both groups the type approval may be extended. For HD, extension is possible to vehicles with a RM exceeding 2380 kg and for LD extension is possible to vehicles with a RM not exceeding 2840 kg. For HD type approval may be extended to vehicles with a RM not exceeding 2610 kg if the completed vehicle with all bodywork combinations is expected to have a RM exceeding 2610 kg.

[14] The options are: a) apply WLTP up to 5 tons TPMLM, b) apply VECTO for vehicles with HDE certification and WLTP for vehicles with criterion pollutant certification according to WLTP, c) apply VECTO down to 3.5 tons TPMLM. The options are further elaborated in section 3.2.2.4.

Table 2: Vehicle categories according to Regulation (EU) 2018/858

Category	TPMLM [t] or # of seats
N1	≤ 3.5 tons
N2	3.5 tons < TPMLM ≤ 12 tons
N3	> 12 tons
M1	< 8 seats + driver
M2	≤ 5 tons with > 8 seats + driver
M3	> 5 tons with > 8 seats + driver

3.2.2.2 Data collection

For the light lorries and light buses the following information should be collected and a data request was send out to ACEA:

Fleet analysis. Most recent values of annual sales or registrations of category N1, M1, N1, N2 vehicles with EU pollutant certification according to the 'LD' or 'HD' regime and per mass class. An MS Excel was attached to the data request with a table that contains recent numbers for various groups. The MS Excel needed to be completed, checked and updated with the most recent numbers.

Usage data. This data is needed to select the appropriate test regime (WLTP or VECTO based) and to design a representative test (e.g. measured or simulated cycles for CO_2, payload definitions).

- Data on usage of the vehicles. Which types of missions can be distinguished and which are most representative per category? (e.g. parcel delivery services vs. SME company vehicle vs. school bus)
- Data of speed and altitude profiles, typical fuel consumption values, engine load profiles and typical loading.

Relevant vehicle characteristics of vehicle technologies and designs related to usage and mission profiles for all of the cells in the excel. This information is needed to understand what test regime is most appropriate based on vehicle characteristics and to assess potential needed extensions of the WLTP or VECTO.

- Per category and weight class a description of typical vehicle characteristics that are relevant for the usage and mission:
  - construction (chassis cabin, panel,…),
  - most representative superstructures, (e.g. panel, box, tipper, drop-side, ..)
  - engine power and capacity
  - masses (running order), TPMLM
  - other characteristics (e.g. max speed) that are relevant for selection of a test regime.
  - Gearbox technology (manual transmission, automated manual transmission, automatic powershift transmission)

Unfortunately, until end of June 2020 with exception of an overview presentation by ACEA showing examples of vehicles and a spreadsheet file with sales numbers of three OEMs no new data was received. Only older data is available as retrieved in previous projects. This data represents the latest, but not up to date figures of sales numbers and are the only source to base an expert estimate upon. Without new data on the distribution of the vehicles in the groups (category, regulatory regime and maximum mass) the projected distribution, the share of vehicles in each group, will not change. Only changes in total sales would affect the totals in each group. The status based on data of 2016 and 2018 is presented in paragraph 3.2.2.3.2.

This type of data collection has now been vigorously pursued for more than five years in a total of three projects. It is therefore concluded that the requested data are not available for industry either. Therefore, the decision on the method for determination of CO2 emissions and fuel consumption of light vehicles has to be made on the basis of the information available so far. From the current point of view of the consortium, such a founded decision seems quite possible.

3.2.2.3 Characterisation of the segment of light lorries and light buses

In these paragraphs the segment of light lorries and light buses is characterised by describing the technical characteristics and the usage of the vehicles.

3.2.2.3.1 Technical characterisation of light lorries and light buses

Light lorries commonly have a ladder frame with a cabin and a superstructure on top (rigid lorry). The other common form of a light lorry is the (panel) van. Some manufacturers offer platform chassis cabins (chassis of the panel van without a construction for the cargo area) or chassis paravan (ladder frame with only the lower part of the cabin) to be upfitted to motorhome (M-category) or delivery lorry for instance. A light lorry can also be constructed as a tractor for pulling a small semi-trailer.

The N category vehicles in the LD-HD ‘transition area’ can be split in two main sub-categories (Figure 7):

1. Lorries. Regulation (EU) 2018/858 ‘Lorry’: A vehicle that is designed and constructed exclusively or principally for conveying goods. It may also tow a trailer.
2. Vans. Regulation (EU) 2018/858. ‘Van’. A lorry with the compartment where the driver is located and cargo area within a single unit.

Figure 7: N2 vehicle’s as (panel) van (left) or rigid lorry (right)

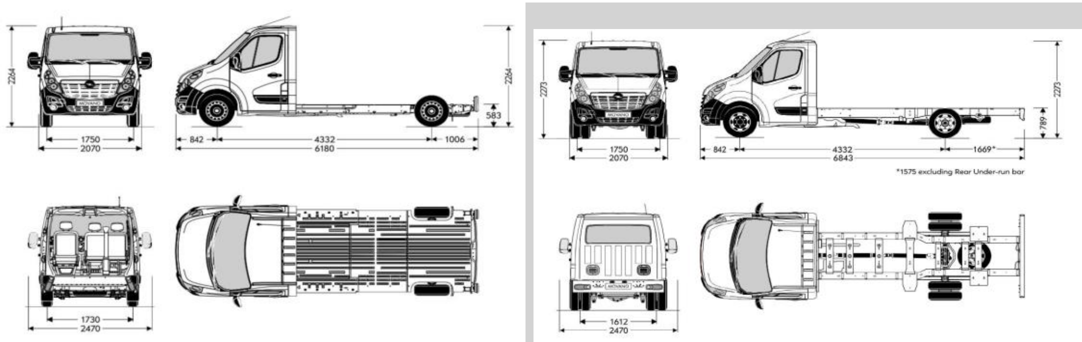

Figure 8: platform cabin (left) and chassis cabin (right).

Figure 9: tractor unit (N2, 715/2007*136/2014Y (LD)) with trailer. The drivers needs to have a BE driving license (maximum authorized mass does not exceed 7 tons).

For the transport of people, light buses are usually based on a N1 or N2 category ‘panel van’ construction that is up-fitted with extra windows, seats and a side door to a M2 light bus.

The M category vehicles concerns light buses (Figure 10).

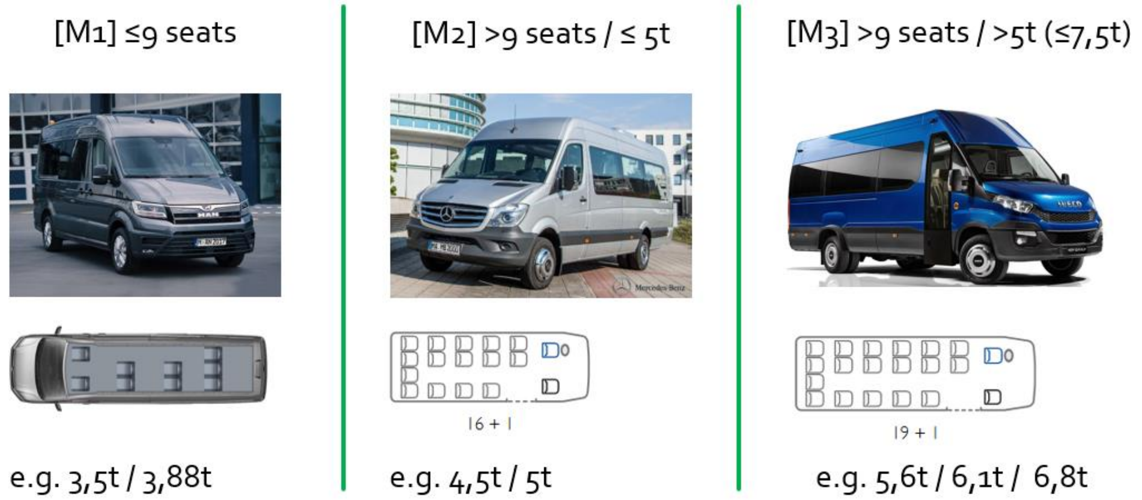

Figure 10: Example of an M1, M2 and M3 bus. ACEA presentation Consideration of large vans in VECTO. Brussels September 2019

Whole vehicles can produced by single manufacturers (as complete vehicles) but can also be upfitted from a chassis cabin, paravan (incomplete vehicle) or panel van in multiple stages by one or a few other manufacturers (bodybuilders, upfitters) to a completed vehicle (Multi Stage Vehicle or MSV). For a Multi Stage Vehicle the multi-stage type-approval process needs to be followed. Whole vehicles can be type-approved according whole vehicle type-approval, and for instance small series type-approval.

The following superstructures are typical for lorries and are specific for the use of the vehicle:

- Closed box, optionally with tail lift and/or insulation (cooling truck)
- Dropper side
- Tipper
- Flatbed
- Tractor
- Motorhome
- Special (crane, lift, …)

Most vehicle OEMS have a closed box, the dropper side and the tipper versions in their portfolio. The closed box and tipper/dropper side versions are the most common light lorries next to panel vans.

The lorries and mostly vans can be upfitted with a fit for purpose interior. A platform chassis can for instance be upfitted with a cargo area, tail lift, a fit for purpose interior to facilitate the needs of the user.

Masses of light lorries and light buses

The mass in running order and thus reference mass of light lorries and vans are mainly determined by:

- Chassis type: Chassis cabin vs. panel van
- Single cab vs. double cab
- Chassis length: all manufacturers offer different length options
- Engine and gear box: different engine sizes (capacity in cm^3) usually two, each at different power ratings
- Front Wheel Drive or Rear Wheel Drive
- Rear axle: amount of wheels; single air vs. double air
- Superstructure with doors, see above for most common options
- Auxiliaries; e.g. a cooling unit, crane, tail lift,
- Interior
    - for light lorries: cabinets, tool racks, etc.
    - light buses: seats, tables, luggage racks, etc.

Typically empty masses of light lorries range from 1.7 tons for a plain chassis cabin to 3.3 tons for a complete(d) chassis cabin with large crane or an insulated box, tail lift and cooling unit.

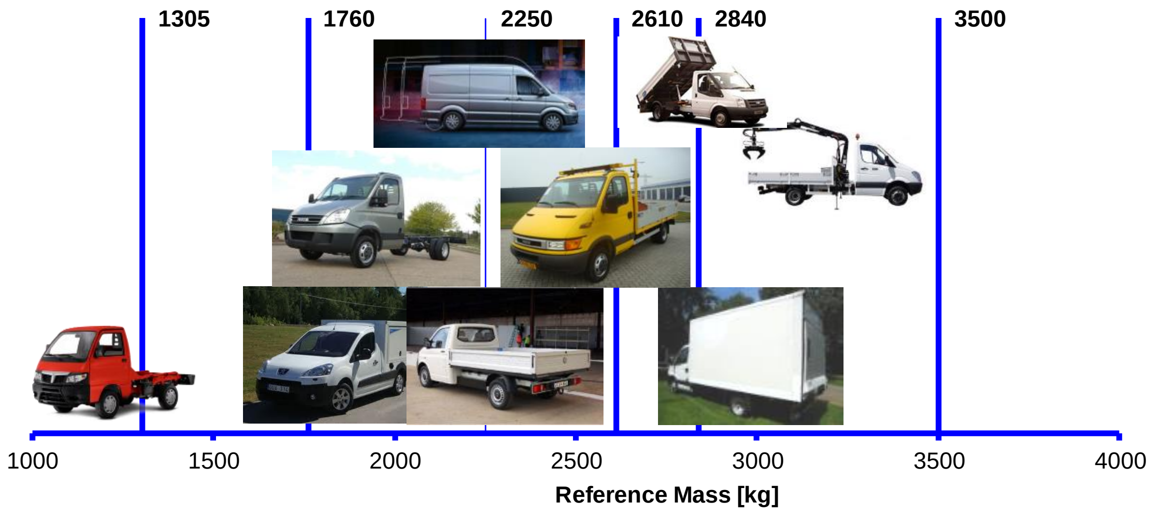

Figure 11: Examples[15] of vehicles with reference masses (RM) ranging from just above 1000 kg to around above 3000 kg. The LD-HD transition area is in the RM range from 2380 to 2840 kg. For HD certification incomplete vehicles may have RM <2610kg (even <2380 kg) provided that with all possible bodyworks RM>2610 kg.

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[15] TNO 2012, Vermeulen, R.J. et al., Development of a method for the measurement and monitoring of CO_2 emissions for N1 multi-stage vehicles, TNO-060-DTM-2011-03978 | Final report, 16 February 2012

Engines for light lorries and light buses

Most OEMs currently offer vehicles with a Euro 6d-temp (LD) certification and vehicles with a Euro VI-D (HD) certified engine. The vehicles with lower TPMLM usually have only LD certification and the heavier versions only HD certification. Also comparable versions are offered with optionally either LD or HD certification. Engines are offered in different power ratings in different engine sizes (capacity in cm^3). Generally, the larger the TPMLM the larger the engine capacity and power ratings are for the offered portfolio. For a TPMLM not exceeding 3.5 tons the engine capacity is approximately 2 200 to 3 000 cm^3, for 3.5 to 7.5 tons approximately 3 000 to 4 000 cm^3. Most engines are turbo charged diesel engines but some manufacturers also offer vehicles with CNG engines.

2.3-litre Light Duty | **2.3-litre Heavy Duty** | **3.0-litre Heavy Duty** | **3.0-litre CNG**

2.3-litre FIA engine Euro 6D Light Duty

COMMERCIAL NAME	120	140	160
POWER (hp)	116 (86 kW)	136 (101 kW)	156 (116 kW)
TORQUE (Nm)	320	350	380*
TURBO	e-VGT		
GEARBOX	HI-MATIC / MANUAL		

2.3-litre Light Duty | **2.3-litre Heavy Duty** | **3.0-litre Heavy Duty** | **3.0-litre CNG**

2.3-litre FIA engine Euro 6D Heavy Duty

COMMERCIAL NAME	140	160
POWER (hp)	136 (101 kW)	156 (116 kW)
TORQUE (Nm)	350	380
TURBO	e-VGT	
GEARBOX	HI-MATIC / MANUAL	

2.3-litre Light Duty | 2.3-litre Heavy Duty | **3.0-litre Heavy Duty** | 3.0-litre CNG

3.0-litre FIC engine Euro 6D Heavy Duty

COMMERCIAL NAME	160	180	210
POWER (hp)	160* (119 kW)	180 (134 kW)	210 (156 kW)
TORQUE (Nm)	380	430	470
TURBO	VGT	VGT	e-VGT
GEARBOX	MANUAL	HI-MATIC / MANUAL	HI-MATIC

2.3-litre Light Duty | 2.3-litre Heavy Duty | 3.0-litre Heavy Duty | **3.0-litre CNG**

3.0-litre FIC engine Euro 6D Heavy Duty CNG*

COMMERCIAL NAME	NP
POWER (hp)	136 NP (101 kW)
TORQUE (Nm)	350
TURBO	WG
GEARBOX	HI-MATIC / MANUAL

Figure 12: Example of engine portfolio of the Iveco New Daily

Other specifications that affect categorisation and usage of light lorries and light buses[16]

- Driving license, B (not exceeding 3.5 tons maximum authorised mass)), BE (B and semi-trailer not exceeding 3.5 tons maximum authorised mass) and C (exceeding 3.5 tons maximum authorized mass)
- (Road) taxation, toll
- Maximum speeds at different types of roads:
    - Lorries exceeding 3.5 tons maximum mass have a maximum allowed speed of 80 km/h on motorways in most EU countries, sometimes 90 km/h. See also speed limiter.
    - Cars and vans not exceeding 3.5 tons maximum mass; have a maximum allowed speed of 100 to140 km/h on motorways in most EU countries
- Speed limiter: the requirement to have a speed limitation device for vehicles of category N2, N3, M2 and M3.
- Maximum mass, axle load
- Change in category.

[16] A glossary of the different mass definitions is given on page 6 of this report.

- National re-categorisation of N2 to N1 (an N2 with a maximum mass exceeding 3.5 tons can change via national type-approval to N1 not exceeding 3.5 tons). The reason is that driving with a more regular B driving license is then allowed.

3.2.2.3.2 Data on new registrations

The table below shows the data of new vehicle registrations that was put together from data of 2016.

Table 9: New vehicle registrations (N+M) > 2380 kg RM and below 7500 kg TPMLM. Data refers to EU28 in year 2016, source ACEA questionnaire.

axle conf-iguration	vehicle reference mass [kg]	tech. permiss. max. laden mass [kg]	vehicle category according to 2007/46/EC	new registrations [#/a]	type approval pollutant emissions	
					Regulation (EC) 715/2007 [#/a]	Regulation 595/2009 [#/a]
all	> 2380 to ≤ 2610	≤ 3500	N1	126 109	109 995	16 114
all	> 2610 to ≤ 2840	≤ 3500	N1	35 766	28 009	7 757
all	all	> 3500 to ≤ 5000	N2	25 331	11 661	13 670
all	all	> 5000 to < 7500	N2	7 987	-	7 987
Total N < 7500 kg TPMLM				**195 193**	**149 665**	**45 528**
all	> 2380 to ≤ 2610	≤ 9 seats	M1	4 410	not counted	4 410
all	> 2610 to ≤ 2840	≤ 9 seats	M1	4 410		4 410
all	all	>9 seats, ≤ 5000	M2	8 566	-	8 566
all	all	>9 seats, > 5000 & ≤ 7500	M3	2 600	-	2 600
Total M < 7500 kg TPMLM				**19 985**	**-**	**19 985**

Newer data was received in 2018 in response to requests for data to ACEA. This data was collected by JRC. A dataset (Excel: ACEA data collection_all TNO.xls) was received on 18 July 2019 from JRC. The dataset contains registration figures of the year 2018 of ACEA's major manufacturers and according JRC is said to cover 85-90% of the total registrations. The dataset gives figures divided over EU vehicle categories, ranges of RM (e.g. 2380 kg < RM ≤ 2610 kg) and unknown RM, LD and HD certification and complete and incomplete vehicles.

The sum of all registrations is 231 334 for N1, N2 (TPMLM ≤ 7.5 tons), M1 (HD only) and M2 (TPMLM ≤ 5 tons). For 76 077 of the registrations the RM is unknown, most of these (69 681) are N1 with a LD certification.

Notes to the 2018 data set:

- For empty cells no or no complete data was provided.
- 21 960 incomplete LDV's have a reference mass <=2 380kg and it is unknown how many completed will have a reference mass >2 380 kg.
- 28749 HDV's are incomplete base vehicles with a reference mass below 2 380kg but in many cases the completed vehicle is over 2 380kg.
- For a number of N1 (71 776) and N2 (4 301) vehicles the reference mass is unknown.
- Regarding the vehicle categories, the final stage category of an incomplete vehicle is unknown to the base vehicle manufacturer. It means that the category can be changed at a later stage for instance during a national, small series or single type approval process. Eg.

- ➔ N1 to M1 and N2 to M1 (e.g. special purpose vehicles such as a motor home, ambulance
- ➔ N2 to N1 to allow driving with a B driving license

- Out of the N1/N2 incomplete vehicles around 900 M2 buses and 100 M3 buses are built by body builders

The data of 2016 and 2018 is shown in Table 10. Some differences can be observed. Total annual registrations in the segment of light commercial vehicles and light buses have increased by 7% from 2016 to 2018[17]. It is not clear why larger relative changes in numbers of registrations have occurred within certain categories between 2016 and 2018. It may be caused by inconsistencies, or a lack of information for certain segments of the dataset, such as for the multi stage vehicles and situations where re categorisation has happened. The registration of new light lorries is about 207,347 units in 2018. This constitutes 1.4% of the registered motor vehicles in the EU. The registration of new light buses in the incomplete dataset is 7443 in 2018. In 2018, newly registered vehicles certified according the HD regime for pollutant emissions, for which no CO_2 value is determined, are estimated to be between 15904 and 33491 light lorries and 7443 light buses.

Table 10: Comparison of data from 2016 and 2018. Note the notes about the 2018 dataset.

Regime pollutant emissions	Light/medium, Lorry/bus	RM	TPMLM or seats	Category	Registrations count 2016	Registrations count 2018	Applicable CO2 test (1 January 2021)
	Lorry						
LD	Light	>2380 to <=2610	<=3500	N1	109995	110251	WLTP
LD	Light	>2610 to <=2840	<=3500	N1	28009	28074	WLTP
LD	Light	all	>3500 to <= 5000	N2	11661	2493	WLTP
HD	Light	>2380 to <=2610	<=3500	N1	16114	33038	WLTP
HD	Light	>2610 to <=2840	<=3500	N1	7757	33491	none
HD	Light	all	>3500 to <= 5000	N2	13670	17587	none
HD	Medium	all	>5000 to <7500	N2	7987	8730	none, Vecto with the 2nd amendment
LD	Medium	all	>5000 to <7500	N2	0	7650*	WLTP
	Bus						
LD	Light	>2380 to <=2610	<=9 seats	M1	not counted	not counted	WLTP
LD	Light	>2610 to <=2840	<=9 seats	M1	not counted	not counted	WLTP
HD	Light	>2380 to <=2610	<=9 seats	M1			WLTP
HD	Light	>2610 to <=2840	<=9 seats	M1	4410	4137	none
HD	Light	all	>9 seats, <=5000	M2	8566	3306	none
HD	Medium	all	>9 seats, >5000 &<=7500	M3	2600	not counted	none, but Vecto later than 2nd amendment
*Incomplete vehicles							

[17] https://www.acea.be/statistics

Based on the 2018 data the excel table was checked and further filled:

Table 11: Excel table with 2016 data (ACEA to TUG) and 2018 data (ACEA to JRC).

	<= 2 380 kg RM	2 380 kg < RM <= 2 610 kg	2 610 kg < RM <= 2 840 kg	> 2 840 kg RM
<= 3.5 t TPMLM	N1 M1 M2	N1: 109 995 LDV/a, 16 114 HDV/a M1: LDV no data , 4 410 HDV/a (<= 9 seats) M2: No data: None. (assuming that > 9 seats is > 3.5 t TPMLM)	N1: 28 009 LDV/a, 7 757 HDV/a M1: LDV no data, 4 410 HDV/a (<= 9 seats) M2: LDV no data, 182 HDV/a [2018]	N1 M1 M2
3.5 t < TPMLM <= 5 t	N2 M1 M2	N2: 11 661 LDV/a, 13 670 HDV/a [2016], 2 493 LDV/a, 17 587 HDV/a [2018] M1: LDV no data, 4137 HDV/a M2: LDV none, 8 566 HDV/a (assuming that > 9 seats is > 3.5 t TPMLM), 3306 HDV/a [2018]		N2 M1 M2
5 t < TPMLM <= 7.5 t	N2	N2: LDV none, 7 987 HDV/a [2016], 7 650 LDV/a, 8 730 HDV/a [2018] M3: 2 600 HDV/a *(not covered by LDV 715/2007)		N2 M3

LDV (715/2007)
HDV (595/2009)
Overlap LDV (715/2007) and HDV (595/2009)
at the request of the manufacturer

3.2.2.3.3 Vehicle usage

Not much data is available of driving profiles of the light lorries and light buses.

The WLTP in-use database that was used for the development of the WLTC contains in-use data for 19 N1 vehicles. This data would still be available. However, it is data of mainly large N1, i.e. LDV with a TPMLM not exceeding 3.5 tons and not the light lorries. Within the development process of the WLTC it was discussed whether LDV and cars would need different cycles. But the analysis of the driving behaviour and the driving dynamics showed no significant differences between car and LDV, so that a common cycle (WLTC) was developed. The same accounts for the Handbook for emission factors were the same cycles are used for the calculation of emission factors for different traffic situations. The LDV concerned are however mainly small to large vans (class I to III) with a TPMLM not exceeding 3.5 tons.

There is very little real world driving data of light lorries. Missing is data of the various uses of light lorries (delivery, construction, haulage,…). Driving data of light buses is not available.

Existing test cycles:

- INRETS PVU cycles 2.5 and 3.5 tons
- LowCVP City Centre Delivery cycle (VECTO based but with higher Kinetic Energy density)
- Dutch LDV delivery cycles.
- NL-ART Delivery truck cycle London
- FedEx delivery truck cycle (US, FTP based)
- EU HD CO_2, TPMLM >7.5 tons: VECTO urban delivery and regional delivery

In general the above mentioned test cycles have low average speeds and represent delivery cycles for vehicles not exceeding 3.5 tons. The VECTO cycle was designed for medium and heavy lorries. Some test cycles have typical longer stops to simulate the time needed for the delivery of goods. Some also have motorway parts.

Payload statistics

This is relevant because a 4 to 7 tons TPMLM N2 category vehicle may carry much higher payload than an almost comparable N1 vehicle not exceeding 3.5 tons TPMLM. Thus any payload definition as currently applied in the WLTP for N1 vehicles cannot be transferred.

It can be investigated whether Weighing In Motion (WIM) data is suitable to determine vehicle mass distributions.

Conclusions on usage and next steps

Given the various constructions of the vehicles, the usage is widespread. Only few data is available. Certainly, there is currently not enough data to develop a separate representative test cycle. There are some indications (see LOT4 report, [1]) that the VECTO cycles do fit better real world operation than WLTP for the lorries with a TPMLM exceeding 3.5 tons.

In case light lorries and light lorries would be assigned to Regulation (EU) 2017/2400 and VECTO, there would still be time to review the existing mission profiles and adapt them if necessary. In Regulation (EU) 2017/2400 the mission profiles are not explicitly specified in the legal text so they could be modified until a very late stage before the legislation becoming applicable, like done already in case of heavy lorries. It is furthermore assumed that, as soon as the decision is made to implement a determination method for CO_2 emissions and fuel consumption for light vehicles with a certain date, industry will provide more resources for the collection of the driving behaviour. If this is not the case, the Commission could also launch a project.

3.2.2.4 Options for general approach to determine CO_2 emissions and fuel consumption for light lorries and light buses

Three options were elaborated which have different boundaries for assigning a test regime. For these options pros and cons have been collected in discussion with stakeholders. The three options are:

A) WLTP for all vehicles with TPMLM not exceeding 5 tons and VECTO for all vehicles with TPMLM exceeding 5 tons

B) WLTP for vehicles covered by Regulation (EC) No 715/2007 (LD pollutant regime) and VECTO for vehicles covered by Regulation (EC) No 595/2009 (HD pollutant regime)

C) WLTP for all vehicles with TPMLM not exceeding 3.5 tons and VECTO for all vehicles with TPMLM exceeding 3.5 tons

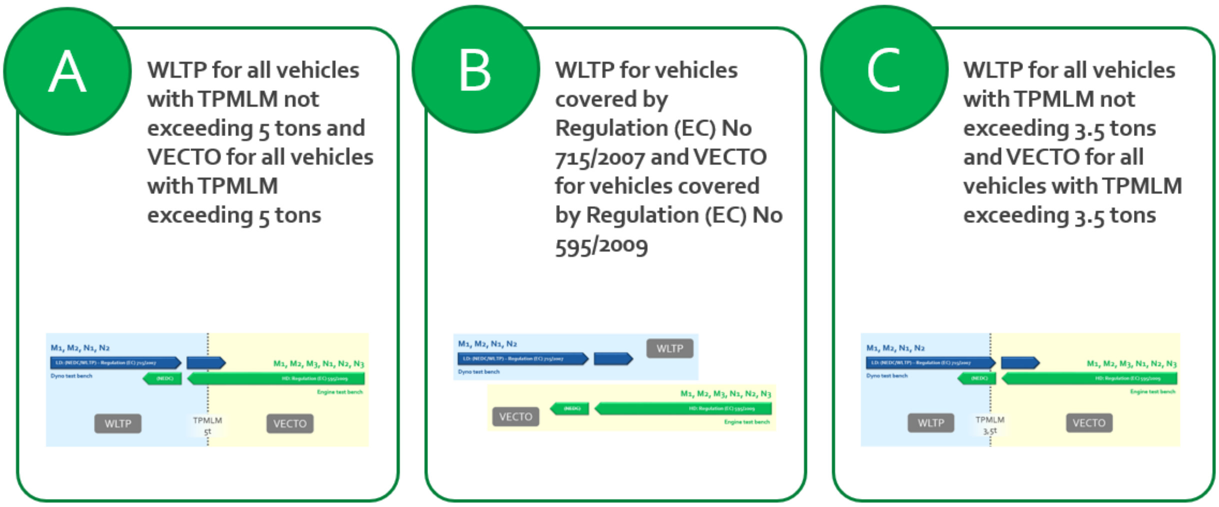
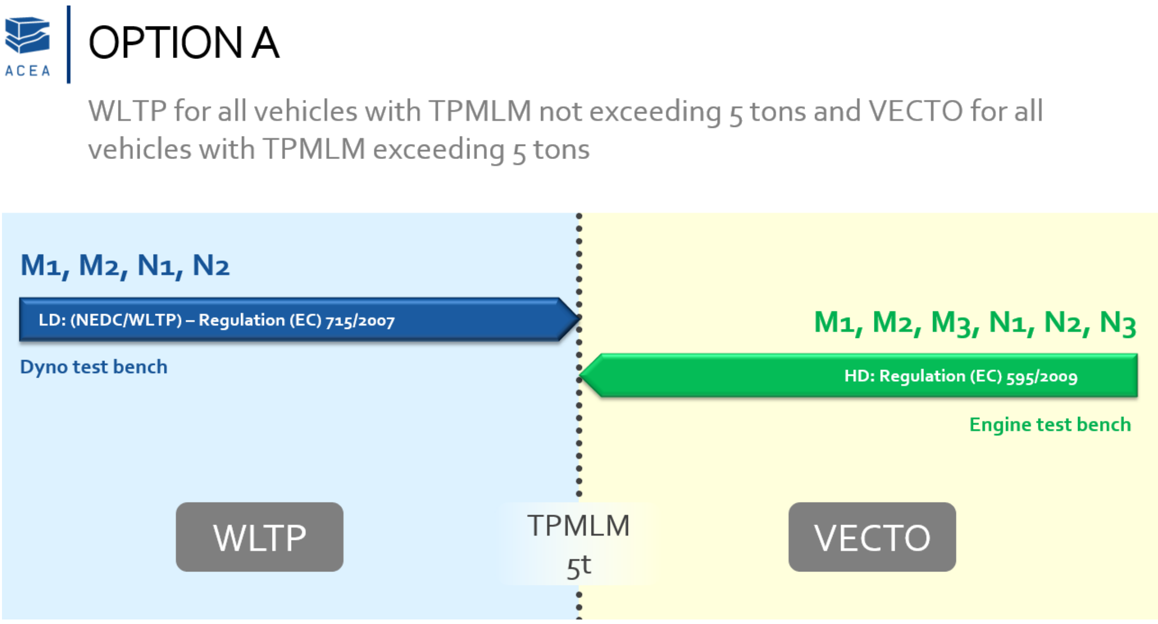


Figure 13: Overview of the three options as provided by ACEA. ACEA presentation Consideration of large vans in VECTO. Brussels September 2019



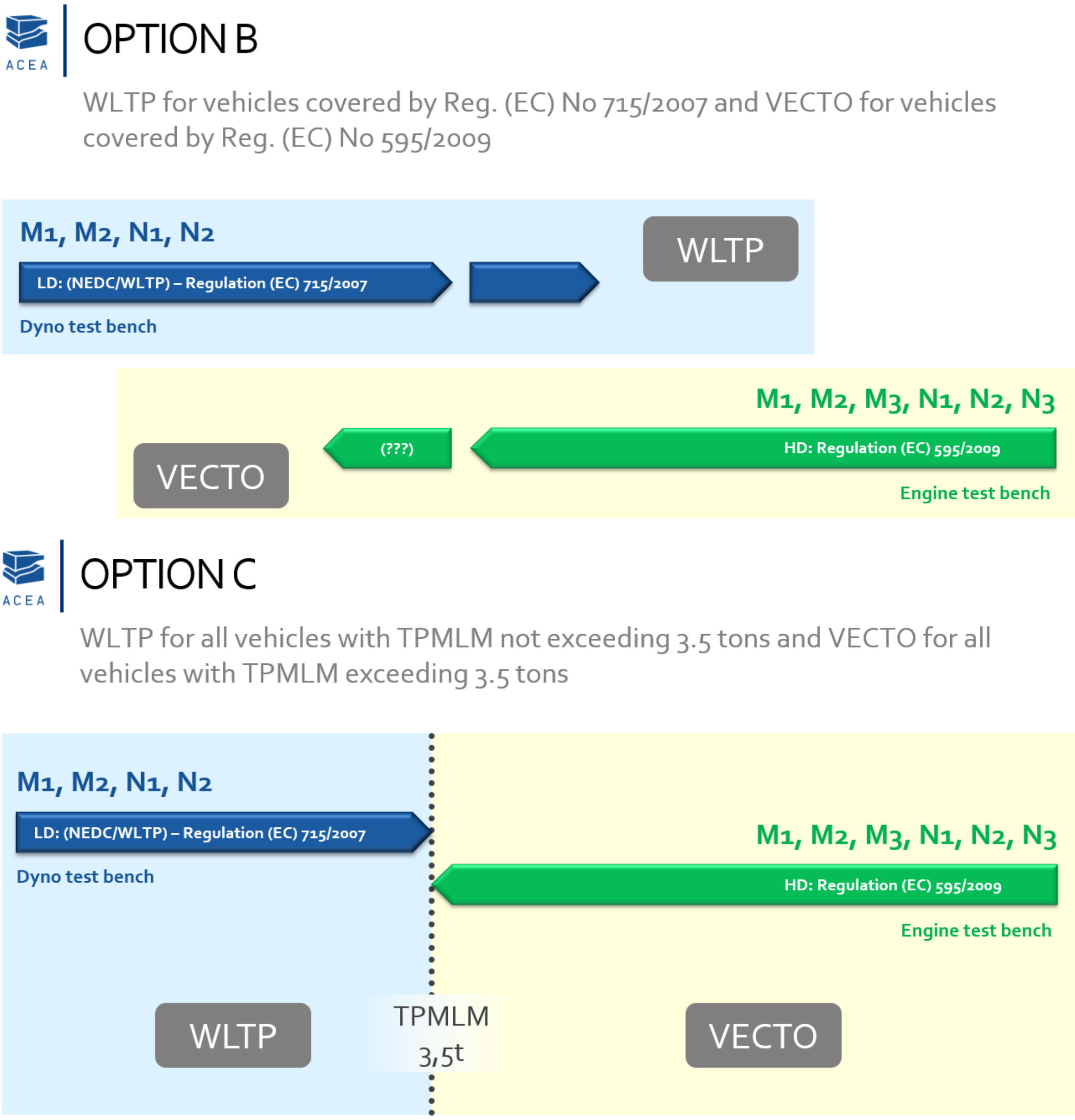


Figure 14: Figures explaining the 3 options. ACEA presentation ‘Consideration of large vans in VECTO’, Brussels, September 2019.

3.2.2.4.1 Considerations for selecting an appropriate general approach

Pros (+), cons (-) and remarks for each of the options are given hereafter:

A) WLTP for all vehicles with TPMLM not exceeding 5 tons and VECTO for all vehicles with TPMLM exceeding 5 tons

- \+ Simple solution for WLTP/VECTO differentiation without any overlaps and special cases as in the current situation for pollutant emissions
- \+ the cut point fits to the M2/M3 differentiation
- o the cut point does not fit the current N1/N2/N3 differentiation

- o Chassis dynamometers for LDVs designed for NEDC tests are typically capable of simulating maximum approx. 2400 kg vehicle weight since the maximum inertia demanded in the NEDC in Regulation No. R 83 was 2270 kg. With this limitation, the typical real world vehicle weight including payload can't be simulated on the chassis dynos which have the weight limitation for vehicles with a TPMLM close to 5 tons. This applies mainly to N2 vehicles category of Table 1 (RM = all; 3.5 tons < TPMLM ≤ 5 tons). Chassis dynamometers designed already for the actual WLTP demands according to Regulation (EC) 715/2007 shall be able to cover higher masses. Thus the issue with limited test capacities for vehicles with a TPMLM exceeding 3.5 tons is expected to decline in future. N1 vehicles of Table 1 can be simulated already without any issues.
- o The WLTC seems not to be very representative for real world operation of larger vehicles around approx. 5 tons TPMLM ([1], chapter 6.2.2). This is also because there is a different speed limit for vehicles with a maximum mass exceeding 3.5 tons (often 80 or 90 km/h in various member states) compared to vehicles with a lower mass. Using non representative cycles leads to a non-representative CO_2 test for heavier vehicles as mentioned before. Thus measured CO_2 and real world CO_2 could have larger gaps and technologies with high efficiency in the test may not have a similar efficiency in real world driving. This can increase the gap between type approval CO_2 and real world further in future, as happened for LDV with the NEDC. This is not relevant for N1 vehicles of Table 1; however, it could be an issue for the N2 category (RM = all; 3.5 tons < TPMLM ≤ 5 tons) vehicles. The use of WLTC excluding the high-phase speed could be a viable solution for N2 (RM = all; 3.5 tons < TPMLM ≤ 5 tons); however, it needs to be further analysed.
- o Option A If Option A is introduced through comitology the pollutant regulation could remain unchanged. Some vehicles would have to be tested on both WLTP and VECTO.
- – HDVs have besides a different engine application also a higher vehicle mass and might not fulfill the pollutant emission limits of WLTP. These heavy vehicles would also contribute to the CO_2 fleet value.
- – A change in the allocation of LDV and HDV in the range up to 5 t TPMLM will have also impact on other measures topics (Emission regulation, OBD requirements, requirements for PEMS, OCE, control of NOx measures, RDE…).

B) WLTP for vehicles covered by Regulation (EC) 715/2007 ("LD pollutant regime") and VECTO for vehicles covered by Regulation (EC) 595/2009 ("HD pollutant regime")

- + For manufacturers this will give the smallest change in the existing way of working for homologation with the light and heavy vehicles for emissions. Manufacturers, type-approval authorities and member states can continue on the same bases as they are used to do. Also the possibility that vehicles do not fit in WLTP or HDV CO2 or will fit both will be the smallest when option B is chosen.

+ No change of co-legislation required.
+ No change from RM to TPMLM required.
o Incentive to manufacturers not to use the overlapping area between 595/715 (“at the request of the manufacturer”).
– Vehicle models with same TPMLM can have either VECTO or WLTP test results for CO_2 or both, which may confuse consumers and requires double-testing and certification by manufacturers. A clear notification of the underlying test procedure thus seems to be necessary in COC documents and in the CO_2 monitoring data base.
– This option keeps the door open to the manufacturers to attribute vehicles with similar characteristics to different type approval regulations, thus compromising the credibility of the procedure.

C) WLTP for all vehicles with TPMLM not exceeding 3.5 tons and VECTO for all vehicles with TPMLM exceeding 3.5 tons

+ Simple solution for WLTP/VECTO differentiation without any overlaps and special cases as in the current situation for pollutant emissions
+ The proposal is in line with the preferred direction indicated by Japan in IWG WLTP.
+ Option for simplification for post Euro 6/VI.
+ When introduced for post Euro 6/VI double testing would be avoided and would give sufficient lead time to adapt the portfolios and applicable test regimes.
+ The cut point fits to the N1/N2 differentiation which uses 3.5 tons TPMLM.
+ the cut point fits to the driver’s license differentiation, based on maximum mass
+ the cut point fits to the max speed differentiation, based on maximum mass
+ It is assumed that testing vehicles with a TPMLM not exceeding 3 500 kg in the WLTP will be possible on most chassis dynamometers with an electrical brake for simulation of the inertia so no adaptations on testing infrastructure are necessary.
o Option C seems to have the effect that all vehicles will be covered. But, based on the current LD and HD pollutant regimes some vehicles will have to be double tested (WLTP for pollutants and additionally VECTO for CO_2). If in the future post Euro VI legislation the similar simple boundary. Additional component data would be needed from vehicles of a LDV platform. between LD and HD regime is set, any double testing would be avoided. Arguments for such a single and straight forward differentiation based on TPMLM applied for CO2 and pollutant emissions are given in section 3.2.2.4.2 below.
o The M category uses number of passengers as a criterion for distinction between M1 and M2. In 2018, 4037 M1 vehicles were certified as HD. It is assumed all M2 are certified as HD. When option C would be introduced for post Euro 6/VI the criterion could be reconsidered and harmonized.

3.2.2.4.2 LD/HD Segmentation: Considering arguments for TPMLM vs. RM

This section considers the consequences to switch to TPMLM as universal criterion to differentiate between LD and HD regime both for CO2 and pollutant emissions.

Boundary conditions:

- Rules based on RM currently define the border between the 'LD' and 'HD' regime. These provisions are only defined in the 'pollutant legislation' (Euro 6 / Euro VI) but not explicitly in Regulation (EU) 2018/858 (there only some references are given for explanatory reasons).
- The current version of Regulation (EU) 2017/2400 is an implementing legislation of Regulation (EU) 595/2009 (i.e. EURO VI HDV). As long as this link is not changed, any of the vehicles currently allocated to "LD" cannot be subject to any of the VECTO methods. This means that currently "Option B)" as explained above is already in place.
- Provisions based on TPMLM will be in any case needed in a future version of Regulation (EU) 2017/2400 for vehicle group classification for the vehicles as currently covered . Thus, if RM would be used for classification in the lower mass groups, undesirable overlapping cannot be avoided (e.g. resulting in double testing, loopholes and non-comparable CO_2 figures for similar vehicles). Thus, for a long term perspective it is suggested to consider that only a single criterion (TPMLM or RM) is used. Proposed candidate for the long term (post Euro 6/VI) is TPMLM.

Arguments to use TPMLM for LD/HD segmentation both for pollutants and for CO2:

1) TPMLM correlates with real world use of vehicles at the N1 / N2 border better than RM due to link to:
    a. Speed limits
    b. Driver licences
    c. Limit for maximum of a vehicle mass on the road
2) TPMLM limits the total mass of the vehicle in-use. Thus this quantity can be checked by on-road vehicle weighing. This verification is assumed to be more relevant for real world emissions than the "dry" verification of the RM which is done only when the vehicle is not in use.
3) Using TPMLM for classification purposes the vehicle curb mass of a vehicle would still be reflected in the results as the simulated mass (in VECTO) or the test mass on the chassis dyno (in the WLTP) still will be determined based on the curb mass plus payload rules.
4) When TPMLM is used tractors would fall under HDV and be tested in a representative way. Currently, tractors with a RM not exceeding 2840kg can be certified as LDV (WLTP) N1 but are used as tractors with semi-trailers up to 7 tons and can be driven with a BE license.
5) It is assumed that post-Euro 6/VI takes care that the requirements for LD and HD pollutant approval are to a large extend compatible in terms of requirements on limits, pollutants, durability, OBD/OBM and thus on engine and aftertreatment. Thus it is assumed that certifying a certain engine to both regulation should be easier than with the current regulation (but for a few engine applications this is also already done). So the boundary between the LDV / HDV world should be less sharp than in current

legislation resulting in manageable problems changing the system and the LDV/HDV world.

6) The proposal to set TPMLM as parameter for the cut-off point between LDV and HDV is in line with the preferred direction indicated by Japan in IWG WLTP

Arguments against TPMLM

- In contrast to RM TPMLM cannot directly be measured because it is a declared value. This argument is often used, especially by type approval authorities, but is not considered relevant, see argument 2) from above.

3.2.2.5 Option for a family concept

In addition to the options A and C a family concept can be applied. The family concept means that the vehicle with either the lowest TPMLM in a family, or the vehicle with the highest TPMLM in a family defines if the entire family is HDV or LDV.

The identified pros (+) and cons (-) of this additional element are:

+ Makes type approval for vehicle families simpler for OEMs. Several vehicle models have a TPMLM range from below 3.5 tons to above 3.5 tons; e.g. the Iveco Daily can be ordered with TPMLM between 3.3 tons and 7.2 tons. Without family concept vehicles with same body and engine but differently declared TPMLM will partly need to apply LDV or HDV test procedures for pollutants and for CO2
- Additional provisons and complexity required in the Regulation
- Different vehicle models a similar TPMLM range might be using either the LD or the HD method, making the official results difficult to compare for customers and other Regulation purposes.
- OEMs may use family concepts to move entire family to the “easier” regulation since TPMLM is a value declared by the OEM. If e.g. the heaviest vehicle in family shall define if HDV or LDV tests are applicable, an OEM may produce a few vehicles with TPMLM > 3.5t to shift the entire family to HDVs and vice versa. Shifting heavy vehicles to LDV tests is rather not attractive for OEMs (difficult to meet g/km limits with heavy versions), the vehicle with the lowest TPMLM in a family shall define if the family belongs to HD or LD.

3.2.2.6 Option for a new metric: frontal area

End of 2020, ACEA proposed a new metric to distinguish between ‘Light-Duty’ and ‘Heavy-Duty’. The metric is the frontal area (FA) of a vehicle expressed in square meters. The cut point for the distinction between the LD and HD regime is suggested to be 3.5 m^2. The approach is shown in the schematic below.

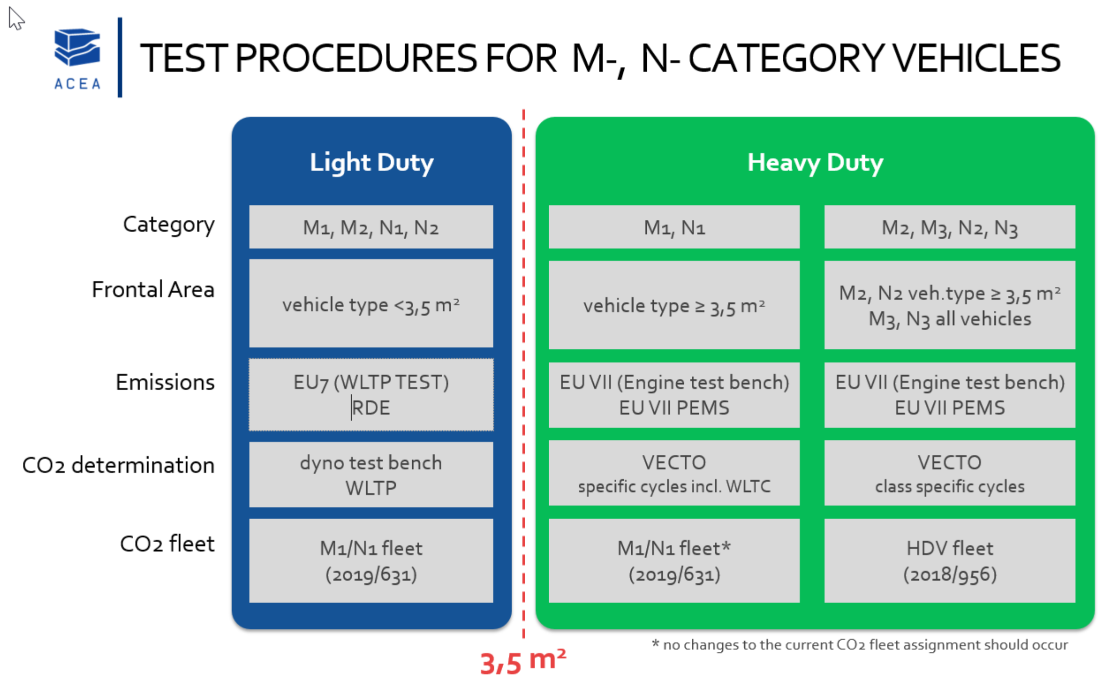


Figure 15: schematic of the frontal area approach as presented by ACEA on 16 November 2020.

+ ACEA argues, that the frontal area better differentiates the usage of vehicles. Above 3.5 m² vehicles are typically used for goods transport, below other missions are dominant. If FA should indeed separate the missions better than TPMLM, then also the test cycles would fit better (VECTO cycles represent heavy good transport or bus driving while WLTC rather represents passenger car like driving). If test cycles fit better to real world use, the best technologies for good type approval CO2 values would also be the best for real driving.
- Currently, frontal area is not used or recorded in legislation. Only in the road-load metric family FA plays a role to determine road load settings. So there is a general lack on knowledge and underpinning of this parameter.
- A new parameter needs to be introduced in the EU pollutant emission regulations. HDV CO2 certification yet uses TPMLM for classification and lorries above 5 tons TPMLM are to be introduced in the next VECTO extension. Thus all vehicles <5 tons and >3.5 m² need to be added in a later step (bit more complex than “3.5 $\leq$ TPMLM < 5 tons”)

The Frontal Area approach was proposed in the workshop on simplification in the EURO 7/VII stakeholder consulation. The proposal was not assessed in the framework of HDV CO_2 emissions regulation. It is therefore advised to further investigate the usability of the FA concept and the possible impacts on the attribution of a test regime for CO_2 emissions.

3.2.2.7 Recommendations for an approach for determination of CO_2 emissions and fuel consumption for light lorries and light buses

3.2.2.7.1 General approach

In case the determination of CO2 emissions and fuel consumption for light vehicles shall be applicable before EURO 7/VII is in force, the straight forward decision would be to follow option B) as described in section 3.2.2.4.1 above. By doing so vehicles under the LD pollutant regime would fall under WLTP CO2 and vehicles with engines certified according to the HD regime would be allocated to the VECTO method. This solution also reflects the current status of Regulation (EU) 2017/2400 as an implementing act to Regulation (EC) No 595/2009. The extensions made necessary by the inclusion of light vehicles to the methods WLTP and VECTO are described in sections 3.2.2.7.2 and 3.2.2.7.3. below.

For EURO7/VII it is recommended to switch to 3.5 tons TPMLM as differentiation criteria between LD and HD pollutant certification. Based on the arguments as discussed in section 3.2.2.4.2 this is assumed a reasonable, simple and robust approach which would allow to smoothly align all aspects of certification of pollutant emissions and determination of CO_2 emissions without any overlaps and loopholes. In this scenario option B) as discussed above would become identical with option C).

Longer term option C would fit the goal of simplification of the regulation. A form of simplification could be to bring LD, HD, pollutants and CO_2 under one regulation. Equalisation of the stringency for LD and HD under this regulation would diminish the need for differences in technologies and result in proportional costs for this technology and comparable administrative burdens for certification for pollutants. For CO_2 a distinction between LD and HD would still be necessary for the CO_2 determination (WLTP chassis dyno vs. a hybrid of component testing and modelling with VECTO). A procedure to test pollutants and CO_2 at the same time would be necessary for both LDV and HDV. RDE/ ISC, OBM and FCM requirements could be harmonized.

3.2.2.7.2 Light vehicle related development requirements for the WLTP

For vehicles to be covered by the WLTP the following items need to be taken into consideration:

- If option B is considered for the time being, some vehicles certified according the LD regime will be category N2. See Table 9 and Table 10. for the numbers of new registrations in 2016 and 2018. Because the maximum mass is >3500kg, these vehicles have a maximum speed of 80 to 90 km/h in most member states which is higher than the maximum speeds of phases of the WLTC. In these cases, the vehicle shall be driven with its maximum speed in those cycle periods where the cycle speed is higher than the maximum speed of the vehicle. Also, vehicles with power to mass ratios close to the borderlines between Class 2 and Class 3 vehicles or very low powered vehicles in Class 1 may not be able to achieve the accelerations required to maintain cycle speed. In these cases, a downscaling procedure can be applied to reduce the maximum acceleration rates to improve driveability. A consequence of this procedure is a reduction of maximum cycle speeds.

- ADAS, Advanced Driving Assist Systems, are not tested in a WLTP test. If ADAS are common on LDV and LDV and HDV CO_2 testing should be equalized in stringency and coverage, ADAS should also be considered for WLTP testing. On the other hand, CO2 values based on WLTP and VECTO will not be directly comparable anyway.
- For multi-stage vehicles to be tested with WLTP the current approach[18] using the interpolation method can be maintained.
- The assigned category and TPMLM of a base vehicle should be known from delivery by the first manufacturer and not change. Only in this case tests remain representative for the usage of the vehicle.

3.2.2.7.3 Light vehicle related development requirements for VECTO

The following necessary development work with regard to VECTO was identified:

- As VECTO offers the possibility to define underlying vehicle usage patterns (i.e. mission profiles and payload functions) in a comparably flexible way, it is recommended to trigger a further data collection either with industry or via a dedicated project. Based on the discussions lead with stakeholders so far it is expected that the commitment will increase significantly once the approach for light vehicles is fixed.[19] Mission profile development will especially be of importance for light (and medium) buses, as neither the cycles as applied for heavy buses not the ones for lorries are assumed to be representative.
- Light vehicles are in contrast to heavier vehicle categories to a high share equipped with manual transmissions (SMTs). Because of their minor importance, the VECTO gear shift model assigned to the SMT was until now never compared to real word data. It is recommend in the data collection exercise as mentioned in the point above to collect real world data which can also be used for this purpose.
- Other necessary changes would need to be analysed, i.e. the data on auxiliary technologies and generic power consumption might need to reviewed if taken over from the heavier vehicle segments.
- To determine realistic CO2 emissions and fuel consumption for light buses, further bus specific development of the VECTO approach is identified. This development should be aligned with the work to be performed for the inclusion of medium buses as described in chapter 3.2.1 of this report. These necessary developments also cover the topic of multi-stage for light lorries.
- For multi-stage light lorries, there following options are identified:

[18] Delegated Regulation (EU) 2019/986 (monitoring CO_2 emissions of MSV) and Commission Regulation (EU) 2017/1151.

[19] In the stakeholder consultations led to elaborate the approach for medium vehicles more interest was expressed in the question of what actually happens to the light vehicles. This can be explained by the significantly higher sales numbers of this segment.

- Stick to the base vehicle approach as currently in force for heavy lorries and extended to medium lorries with the second amendment of Regulation (EU) 2017/2400.
- Consider the features of the completed vehicles. For this option there are two possible general approaches: First possible approach would be to extend the “factor method” based approach currently developed for heavy lorries also to the light and medium lorry segment. Second possible approach could be comparable to the approach used for WLTP testing: For WLTP, an interpolation method is to be used to determine the CO_2 emission of the completed vehicle using the relation between CO_2 emission and cycle energy which is defined by CO_2 measurement of a vehicle L (low) and a vehicle H (high).Since VECTO uses calculation to determine the CO_2 emission, the CO_2 emission of an L and H vehicle and the corresponding cycle energy can be determined as well. The CO_2 emission of a completed vehicle can be calculated using the calculated cycle energy of this vehicle.

3.3 Task 2.2: CO2 verification of heavy buses and medium lorries

Task 2.2 covered the extension of the on-road verification testing procedure (VTP) as set out in Annex Xa to Regulation (EU) 2017/2400 to the new vehicle categories (heavy buses and medium lorries) and the “new technologies” as to be covered by task 3 of this project. The work carried out in this regard and the resulting methodology is described in this section.

Moreover, task 2.2 should ensure that during the VTP a new vehicle is not optimised for CO_2 emissions while increasing emissions of gaseous and particulate pollutants (and vice versa). A related general analysis options for combining VTP tests and ISC tests for the conformity of a vehicle's pollutant emissions was already submitted as deliverable with the First Interim Report of this project in March 2020. The conclusions reached in Task 4.1 were discussed with stakeholders in pilot phase 2. Results and decisions taken are documented in section 3.1.3.6 of this report and have been incorporated into the draft document for Annex Xa as submitted at the end of the project.

3.3.1 Overview of the work carried out and the course of the project

The basic approaches for the above-mentioned new topics were developed by the consortium during the course of the project and presented in HDV CO_2 Editing board meetings. The incorporated extensions in Annex Xa regarding new vehicle categories were distributed in July 2019 for pilot phase 1, the extensions for the new technology dual-fuel in April 2020 for pilot phase 2. With regard to the other "new technologies" ADAS, WHR and the new gear shift algorithm in VECTO, no need to extend Annex Xa was identified.

Based on these documents, approximately 80 points of feedback were reported by industry and processed by the project consortium. The majority of the comments did not relate to the new elements in the VTP but to errors or unclear formulations in the existing provisions. These comments have been, where necessary, discussed with the Commission and addressed accordingly. This feedback process is described in the document[20] also delivered with the final report. The relevant changes were incorporated into the major update of draft Annex Xa distributed at the beginning of December 2020. With regard to the provisions for heavy buses, this version of the document was drafted based on the instructions by DG GROW in such a way that only the final manufacturer is responsible for carrying out the test and thus the same basic procedure can be applied to all vehicle categories (lorries and buses).

Approximately 100 comments from stakeholders were received on this version of Annex Xa at the beginning of 2021[21]. In addition to many other comments on technical details, the main point of criticism was that the VTP for heavy buses is not differentiated by "manufacturer level" in the multi-step process, which could cause issues in many respects. After further discussions with DG GROW and DG CLIMA, it was decided to exclude heavy buses from the VTP provisions in the second amendment due to the complexity of the matter and the short time remaining. Nevertheless, this report documents the methods developed for heavy buses so far and already provides a substantial proposal how to go ahead for the following amendments.

The development of methods for the VTP for xEV vehicles was not explicitly stated in the ToR of this project, but was mentioned in the offer to be analysed as well, in case corresponding data from pilot phase 3 would be available. A first basic analysis on possible approaches for VTP and HEV and related challenges to be solved was presented by the consortium at the VECTO HEV Workshop in Brussels in March 2020. In a follow-up meeting between DG GROW and TUG as held on the 18th of March 2020 it was agreed to exclude the topic VTP for xEVs in this contract. This decision was made as by then it was already clear that the basic methodology for CO_2 certification of these technologies would not be completed before the very end of the project, and that there would therefore be no time for further development of VTP methods and physical VTP testing. Nevertheless, this report briefly outlines basic options and challenges for a VTP both for HEV and PEV vehicles.

The following documentation of Task 2.2 is structured as follows:

- Extension of VTP to “new technologies” (section 3.3.2)
- Extension of VTP to medium lorries (section 3.3.3)
- Extension of VTP to heavy buses (section 3.3.4)

3.3.2 Extension of VTP to “new technologies”

3.3.2.1 Dual-fuel

Point 7 of the currently applicable version of Annex Xa describes that in the VTP “the simulated fuel consumption shall be compared to the measured fuel consumption using the simulation tool.” In the comparison the measured fuel consumption must be below the simulated fuel consumption multiplied by 1.075.

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[20] Document: “!PilotPhases1and2_Comments_WD10a_beforeUpdate.docx”

[21] Document “!PilotPhases1and2_Comments_WD10a_afterUpdate.docx”

If this provision were to be applied to dual-fuel engines without adaptation, this comparison would have to be carried out separately for two fuels. Such a pass/fail check on a single fuel level would be a non-robust method taking into account the small amounts of Diesel fuel applied in current dual-fuel applications.[22] The relevant figure for the verification is assessed to be the total amount of CO_2 emissions. Thus it is suggested to use this quantity for the pass/fail check based on the following approach:

- Fuel consumption is measured for the single fuels separately[23]
- The total CO_2 emissions for the measurement are then calculated by the simulation tool as follows:
  - Calculation of CO_2 emission per fuel using the generic CO_2 content as applied in the simulation tool
  - Adding CO_2 from both fuels (Natural Gas and Diesel)

For consistency reasons the general scope of section 7 („Test evaluation“) was changed from „comparison of fuel consumption“ to „comparison of CO_2 emissions“, i.e. for all vehicles the pass/fail check is suggested to be done now for CO_2 as calculated above. This results in no changes for single fuel vehicles compared to the previous version as the term with the generic CO_2 content can be cut short of the equation, i.e. the resulting C_{VTP} factor is the same than if evaluated from fuel consumption. Referring to CO_2 at this point furthermore increases the consistency of the text as the C_{VTP} factor is in the end for formal reasons multiplied with the declared CO_2 emissions.

Further minor changes in Annex Xa with regard to dual-fuel engines concern the provisions on the calibration range of the fuel measurement and, in several places, the general requirement that all fuel-related provisions apply separately to Diesel and NG.

3.3.2.2 ADAS, WHR and the new gear shift algorithm in VECTO

As already mentioned in the introduction to this task, with regards to the “new technologies” ADAS, WHR and the new gear shift algorithm in VECTO no need to extend Annex Xa was identified.

3.3.2.3 xEV

As mentioned earlier in the text, the development of a VTP for xEV was not part of the final deliverables of this project. However, basic options and problems identified by the project team are listed below, as potential input for subsequent calls for proposals and as a collection of ideas for the general "proof-of-concept" phase on xEVs in VECTO as announced for 2022 at DG JRC.

Regarding approaches for the VTP a distinction needs to be made between methods for HEVs (and for those further distinction between vehicles without and with plug-in feature) and for PEVs. Starting point of this analysis is the basic approach of the VTP for conventional vehicles

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[22] Technical details related to dual-fuel engine were provided in the first interim report.

[23] A direct measurement of CO2 emissions was not considered a meaningful option because of the greater inaccuracies involved.

as shown in Figure 16. The basic ideal here is to verify the efficiency of the powertrain components in the operation particular points as recorded during the test. By intention, all generic controls of VECTO (driver model, gear shifts) are bypassed in this approach as verification against those is not found reasonable to be under the responsibility of the manufacturer.

- **VTP verifies powertrain efficiency (g/kWh$_{wheel}$) for component operation points as recorded during the test**:
  - Axle:
    - Speed available (via vehicle speed)
    - Torque available (via wheel torque)
  - Transmission:
    - Gear available (calculated via vehicle and engine speed)
    - Speed available (calculated via vehicle speed and gear)
    - Torque available (calculated via axle torque)
  - ICE:
    - Speed available
    - Torque available (calculated via transmission torque and aux)
- Generic controls by VECTO (gear shifts, coasting etc.) are “bypassed” e.g. excluded from the comparison with real vehicle performance

Input data to VECTO:
- Vehicle speed
- Engine speed
- Wheel torques
- Wheel speeds
- Gear
- Engine cooling fan speed
- Fuel flow

Figure 16: Basic VTP approach for conventional vehicles

VTP for HEVs (without considering plug-in feature)

Starting from the basic approach of the VTP for conventional vehicles as shown above in principle there are two possible methods how the VTP for HEV could be designed. The first approach would be to take-over the input data structure from the approach for conventional vehicles (see Figure 17). To accurately determine the effective actual fuel consumption in the VTP test, in addition the SOC would have to be measured.[24] This first option poses several fundamental disadvantages or difficulties:

- It deviates from the idea that the vehicle does not have to prove its performance against the generic VECTO controls
- Thus the approach might require a significantly higher VTP tolerance, which might be also difficult to define for the different hybrid architectures
- The implementation effort for the VECTO VTP mode is estimated to be high, since firstly a new derivate of the hybrid strategy would have to be developed, which takes over the given boundary conditions from the measurement (power in the driveline, gear) and only optimises the open parameters (distribution of ICE and EMs). Secondly, this algorithm would have to be adapted and tested separately for each of the 13 possible hybrid architectures and for all the possible operation states of a xEV.

[24] In order to apply a correction on the total fuel consumption as measured during the test based on the measured delta SOC over the test

- **HEV Option 1: Input data as for conventionals (+ SOC)**
  - VECTO VTP mode would need to apply generic controls to determine load distribution between ICE and EM(s) (and gears in case of non-parallel architectures)
  - Measured REESS current would only be used for energy balance related to measured fuel consumption (only minor influence)
  - Thus vehicle would need to prove its performance against the generic VECTO controls
    - Different from approach as for conventionals
    - Generic VECTO HEV controls uses an optimization algorithm*, thus it is assumed that a real world controllers in tendency perform worse than VECTO
    - Might either need a higher pass/fail tolerance for HEVs or a "HEV factor" to be declared by the OEM
  - High implementation effort for VECTO VTP mode

Input data to VECTO:

- Vehicle speed
- Engine speed
- Wheel torques
- Wheel speeds
- Gear
- Engine cooling fan speed
- Fuel flow
- + ΔSOC REESS(s)

** Only an optimisation algorithm leads to a fair ranking between different HEV vehicles*

Figure 17: HEV Option 1 - Input data as for conventionals

The second option is to retain the basic approach that the VECTO VTP mode simulates the vehicle components at the actual operating points occurring during the VTP. For this, the speed and load point of the electric motors would also have to be measured (Figure 18). The direct recording of the EM torque (option 2a) is not considered feasible for practical reasons (i.e. accessibility and space for attachment of measurement equipment). The much more obvious option 2b would be to record the speed and electric energy consumption of the electric motor(s) (or IEPC, IHPC). In a first step, VECTO could use the related component data to calculate the mechanically delivered torque and, in a second step, assign the difference in torque to the total torque required by the drive train to the ICE. With this procedure, the torque determined for the electric motor(s) would not by fully correct (due to differences in the real component performance vs. certified performance), but this error would then be compensated for in the simulation of the fuel consumption via the power assigned to the ICE.[25] According to a first quick assessment, the implementation effort in VECTO is estimated to be lower than for option 1. In both cases, separate implementations for parallel and serial hybrids would have to be provided within the programme.

[25] Example: If an EM has a worse efficiency in the VTP than in the certification test, the VECTO VTP mode would calculate higher mechanical EM torque thus a lower ICE torque than in the measurement. This means that the simulated fuel consumption will also be lower than in the measurement. This shifts the CVTP ratio upwards.

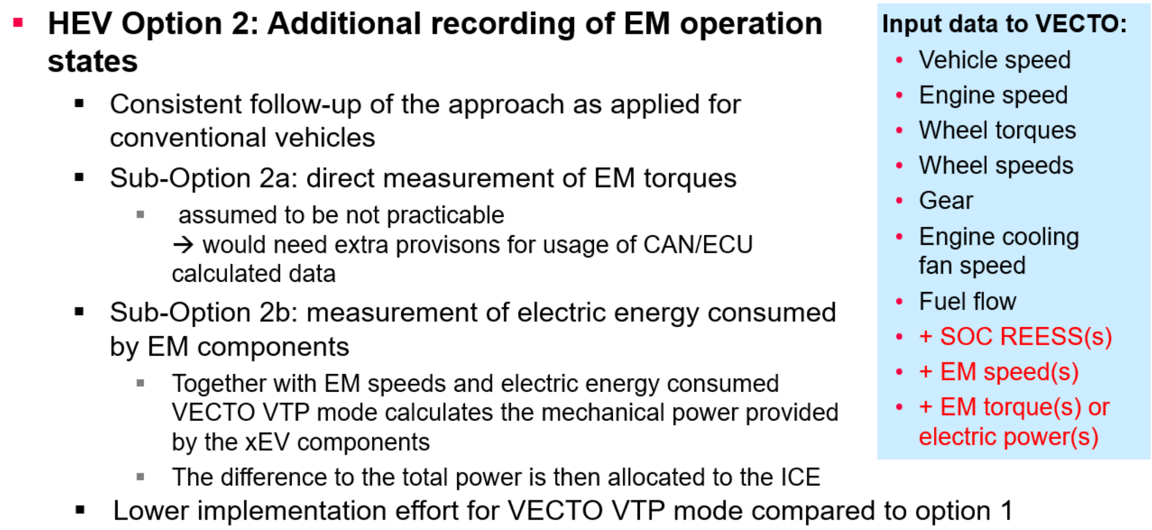


Figure 18: HEV Option 2 - Additional recording of EM operation

From the project team's point of view, option 2b is clearly the best candidate, both in terms of the consistency with the basic VTP approach and the technical feasibility.

VTP for PEVs

New approaches need to be developed for the VTP of PEVs. In a first step, the performance parameters to be verified should be defined. According to current assessment, the overall vehicle performance would have to be subdivided into individual elements:

a) The propulsion efficiency regarding electric energy consumption
b) The actual useable capacity of the REESS(s)
c) Possibly additionally a round-trip efficiency of the REESS(s)

For **all items a) to c)** the physical positions(s) at which current and voltage are to be measured need to be defined. A technical simple approach would be to define recharging after the test via the charging cable for this purpose. This would not fully correspond to the component system boundaries in the VECTO xEV approach and require to define generic charging losses in the test evaluation and thus to some extend lower the significance of the measurement result. The more precise, but technically much more complex variant would be to define the terminals of the batteries and the e-motors as measuring points. These measuring points are not accessible without a high technical effort, which would be a problem especially for the implementation of the VTP as ISV. In the end, it will probably also have to be decided politically where the balance will be found in the VTP between effort and demands for accuracy.

The actual useable battery capacity **b)** (value in Ah) is of course of central interest in a full verification test. In principle, the measurement can be done simply by driving the fully charged vehicle until the storage is empty and measuring the current at the battery terminals. For the test the driving conditions and the comparison value for a pass/fail from the VECTO data need to be defined.[26] Also boundary conditions on deterioration need to be elaborated (at least for ISV testing).

In addition, the actual battery efficiency could be estimated according to **c)** by means of a vehicle test in which the current at the battery terminals is also measured during recharging. If desired by the policymakers, the corresponding methods would have to be developed and the comparative value from the certification test would have to be defined.

VTP for HEVs with plug-in feature

For hybrids with plug-in feature, a combination of the above-mentioned methods for HEVs and PEVs could in principle be envisaged. Here, too, there is a need for specific definitions in the VTP, e.g. for determining the actual usable battery capacity when the charge depleting mode ends and the change sustaining mode begins. The respective methods could possibly be developed based on the principles defined in the legislation for the WLTP.

Concluding remarks

Finally, it should be said that from contractors view meaningful substantial work towards a VTP for xEV vehicles can only be done after first practical experiences ("proof-of-concept") with the developed VECTO xEV methods are available. For a solid development of the method, first the basic method would have to be defined, then the algorithms would have to be implemented in VECTO and measurements would have to be carried out in parallel, followed by sufficient time for analysis of results and fine-tuning.

3.3.3 Extension of VTP to medium lorries

The new elements to be developed for the extension of the VTP from currently heavy lorries to medium lorries are:

- Trip provisions
- Extension of the table for minimum number of vehicles to be tested by the vehicle manufacturer

Regarding all other provisions, no specific adaptations were found to be necessary. The background to the two topics is described below. The practical suitability of trip provisions and related pass/fail criteria for CO_2 were analysed in pilot phase 2. The results and conclusions for the VTP for medium lorries are described in section 3.1.3.5 on page 31.

3.3.3.1 Trip provisions

As already described in the section on pilot phase 2, trip provisions should be elaborated, which fit better the typical mission profiles of the new vehicle categories and which are still providing acceptable accuracy. The relevant parameters to be defined are the maximum time

[26] The component test certifies the nominal capacity of the battery. In VECTO, this range is limited by generic SOC limits.

share of idling at vehicle standstill and the minimum and maximum trip shares in the three categories "urban", "rural" and "motorway" as defined as:

- "urban driving" means the total distance driven during the fuel consumption measurement at speeds not exceeding 50 km/h;
- "rural driving" means the total distance driven during the fuel consumption measurement at speeds exceeding 50 km/h but not exceeding 70 km/h;
- "motorway driving" means the total distance driven in the fuel consumption measurement at speeds above 70 km/h;

Since no external data on typical driving behaviour was available for medium lorries, the mission profiles assigned in VECTO to medium lorries were uses as basis and have simulated with a typical distribution lorry (group 2)[27]. The driving shares in the three trip categories were then calculated analysing the modal simulation data. The same exercise was also carried out for a group 5 heavy lorry in order to have a basis for comparison when deriving the trip provisions from the VECTO simulation results in the official mission profiles. The driving shares from VECTO are shown in Table 12. The min/max values derived from this analysis as draft provisions for the VTP test are shown in Table 13 - again together with the corresponding specifications for group 5 vehicles - for comparison.

Analogous to the provisions for group 5, the min max specifications were set approximately corresponding to the range of values in the two relevant mission profiles in VECTO. The values were rounded to even numbers, and the urban portion was slightly reduced compared to VECTO, as it is known that this driving situation is subject to higher uncertainties in the simulation and is therefore unfavourable for a low pass/fail tolerance.

Table 12: Trip shares from VECTO simulations

Vehicle	Mission profile	Time share of idling at stand still	Distance based share urban driving	Distance based share rural driving	Distance based share motorway driving
Lorry - group 5	Long haul	1%	2%	3%	95%
	Regional delivery	12%	9%	18%	73%
Lorry - group 2	Regional delivery	13%	9%	18%	73%
	Urban delivery	24%	68%	21%	11%

[27] In this analysis, the specific vehicle data has a subordinate influence. A group 2 vehicle (heavy lorry in the lower weight category) was selected here, as it was already assumed that the trip provisions worked out would also be adopted for the small heayv lorries groups (1s to 3).

Table 13: Proposals for trip shares for medium lorries

Vehicle categorie / groups	Min / Max	Time share of idling at stand still	Distance based share urban driving	Distance based share rural driving	Distance based share motorway driving
Groups 4, 5, 9, 10	min	---	2%	7%	74%
	max	5%	8%	13%	--- (91%)
Other medium and heavy lorries groups	min	---	10%	15%	25%
	max	10%	50%	25%	--- (75%)

As also described in the conclusions from pilot phase 2, it was finally decided to adopt these trip provisions for all trucks smaller than group 4 (i.e. in addition to medium lorries also for groups 1s, 1, 2 and 3).

3.3.3.2 Number of vehicles to be tested by the vehicle manufacturer

Since medium lorries are produced in significantly lower numbers per manufacturer and year than heavy lorries[28], Table 1 in Annex Xa had to be supplemented with the entries for lower quantities. This table was compiled using the method also used in Annex VIII for air drag, i.e. reducing the test frequency to less than one year for very small annual production numbers. The final table was discussed by the industry and DG GROW in a dedicated meeting and agreed on in the HDV CO_2 Editing board. Table 14 shows the extended table, where the new entries are highlighted in blue.

Table 14: Updated table 1 in Annex Xa on "Determination of the minimum number of vehicles to be tested by the vehicle manufacturer"; new lines marked in blue

Number of vehicles to be tested	Schedule	Verification testing procedure relevant vehicles produced / year
0	**-**	**≤ 25**
1	**every 3 years**	**26 – 250**
1	**every 2 years**	**251 – 5 000**
1	**every year**	**5 001 – 25 000**
2	every year	25 001 – 50 000
3	every year	50 001 – 75 000
4	every year	75 001 – 100 000
5	every year	more than 100 000

[28] According to material as presented by ACEA in the HDV CO2 Editing board, in total some 9000 medium lorries are expected to undergo CO2 determination in accordance with Regulation (EU) 2017/2400. The single manufacturer, which provided expected production numbers on medium lorries in the economic survey, reported 500 vehicle per year on the bases of 2018 data.

It was additionally proposed by DG GROW that the table now applies per manufacturer across all vehicle categories. This approach will have to be checked for suitability in the case of an extension for heavy buses according to the multi-step methodology described below.

3.3.4 Extension of VTP to heavy buses

As already described in the introduction to task 2.2, the project worked on the implementation of heavy buses, but in agreement with the Commission did not include them in the final version of Annex Xa due to the lack of a mature solution agreed with stakeholder regarding the responsibilities of different manufacturers in the “multi-step” process.

Three specific heavy bus specific VTP issues are addressed below:

- the specific trip provisions developed
- a possible approach for responsibilities of different manufacturers in a multi-step process
- a summary of the issues that need to be addressed for a sound implication of heavy buses in the VTP in future amendments.

3.3.4.1 Trip provisions

In order to elaborate the trip provisions for heavy buses, the same methodology was used as described above for medium lorries. Due to the fundamentally different operating profiles of low floor buses and high floor buses, the analyses were carried out separately for these two categories. For high floor buses, the mission profiles "interurban" and "coach" were simulated in VECTO with a typical coach model. For low floor buses, the three "urban" cycles were simulated with a typical city bus model. In contrast to medium lorries, the 5 mission profiles as implemented for heavy buses in VECTO were elaborated in the during the 2010s large data set of real operational data [1], [8], and can thus be considered a very robust data set on typical real world operation.

The resulting trip shares from this analysis are shown in Table 15. The derived specifications for minimum and maximum trip shares in the VTP are listed in Table 16. This was done by applying the range of trip shares in the different mission profiles to the min/max targets considering the following points:

- Idle time shares were shortened, as these are firstly an operating condition which is not of interest in the VTP[29] and which thus reduces the VECTO accuracy in the recalculation (and thus drives up the necessary C_{VTP} tolerance)
- Urban shares where rounded off, also for reasons to keep the C_{VTP} tolerance low.
- In general, all numbers have been rounded.

[29] The fuel consumption of a vehicle at standstill is determined to a very high degree by the energy consumption of the auxiliary consumers, which is defined generically in VECTO - taking into account the specifications made by the manufacturer for installed auxiliary consumer technologies. The validity of the specified auxiliary consumer technologies is verified in the VTP by means of a technical inspection.

Table 15: Trip shares from VECTO simulations

Vehicle	Mission profile	Time share of idling at stand still	Distance based share urban driving	Distance based share rural driving	Distance based share motorway driving
Coach	Interurban	13%	45%	27%	28%
	Coach	3%	13%	12%	75%
Citybus	Heavy urban	42%	98%	2%	0%
	Urban	32%	91%	9%	0%
	Suburban	16%	81%	19%	0%

Table 16: Proposals for trip shares for heavy buses

Vehicle categorie / groups	Min / Max	Time share of idling at stand still	Distance based share urban driving	Distance based share rural driving	Distance based share motorway driving
Heavy buses - high floor	min	---	12%	10%	30%
	max	10%	40%	30%	--- (78%)
Heavy buses - low floor	min	---	75%	10%	--- (0%)
	max	10%	90%	25%	0%

A practical test of the suitability of these provisions was carried out in pilot phase 2 for high floor buses. Based on the results, the HDV CO_2 Editing Board agreed to adopt the trip requirements for high floor accordingly. A practical validation for low floor busses is pending, as no such vehicles were made available in the pilot phase.

3.3.4.2 Multistep

For heavy buses, in many cases more than a single manufacturer is involved in the obligations regarding VECTO, resulting in "multi-step" process as described in Annex I of this report. According to the definitions developed in the project, the following different “levels” of manufacturers and allocated “levels” of a vehicle exist:

- Primary
- Interim
- Complete or completed

For the implementation of the VTP according to Annex Xa, the relevant tasks and responsibilities are to be defined according those manufacturer levels.[30]

[30] A similar multi-step process is also being developed for heavy lorries with box bodies (project CLIMA.C.4/SER/2019/0003). This would mean that the provisions in the VTP would also have to be extended in a similar way for these vehicles. In any case, the procedures will differ in detail, e.g. because of the difference in the determination and responsibilities regarding CdxA, mass and PTOs.

The approach to this, which was incorporated into Annex Xa of December 2020 in consultation with GROW, stipulated that the VTP was only to be carried out by the final vehicle manufacturer (i.e. complete or completed). In the feedback process on this approach, the following serious weaknesses or problems were identified:

- The element in the VTP provisions as laid down in the currently version of Annex Xa, which causes the main costs, is the practical test-based verification of the vehicle's powertrain efficiency.[31] This element only verifies input data for which the primary manufacturer is responsible. However, according to the approach described above, this testing effort would have to be borne by the final manufacturer of the vehicle.
- In case for a vehicle different manufacturers would be responsible for the primary and the completed vehicle, the operation of the simulation tool for the VTP would need to be performed by a thrusted third party, i.e. a type approval authority, a designated Technical Service or the DG JRC in order to avoid confidentiality issues with input data and input information. Confidentiality issues exist in both “directions”, i.e. in case primary data are accessible from a manufacturer of a completed vehicle (engine maps etc., this was the reason why the factor method was invented) but also if completed vehicle data are accessible at the primary manufacturer (e.g. those manufacturers could be competitors for complete or completed vehicles on the market).
- Primary manufacturers would not directly have to carry out the VTP by themselves, but they would be involved in the process, namely for providing input data, component certificates etc. and in given cases to carry out remedial measures. The associated effort, i.e. for how many vehicles primary manufacturers would actually be involved, would, according to the selection method set out in Table 1 in Annex Xa, only depend to a small extent on how many primary vehicles a manufacturer has produced, but mainly on whether and how many subsequent manufacturers have produced completed vehicles.

Due to these identified disadvantages of this approach, it was decided by the Commission to exclude heavy buses from the VTP for the second amendment.

In order to give direction to further work on this issue, an alternative “multi-step VTP” approach is presented here. This approach is essentially following the idea as already proposed by the project team in the second interim report of this project and is also in line with the comments made by industry.

Basic principle

The basic principle of this approach is that the obligations for different manufacturer levels shall only verify those parameters for which the respective level is responsible. It shall furthermore cover all three “verification elements” as currently covered by the provisions in Annex Xa which are:

- Verification of input information, input data and data handling
- Verification of mass

[31] Other elements are the verification of input data and data handling as well of the vehicles’ mass, see next pages.

- Verification of powertrain-efficiency

Table 17 gives an overview of the allocation of the three verification elements to the three different manufacturer levels.

Table 17: Allocation of the three verification elements to the three different heavy bus manufacturer levels

"Level" in multi-step approach	Verification of input information, input data and data handling	Verification of mass	Verification of powertrain-efficiency
Primary	applicable	*not applicable*	applicable
Interim	applicable	*not applicable*	*not applicable*
Complete(d)	applicable	applicable	*not applicable*

The verifications to be carried out for the individual applicable cases are described in more detail below. It should be noted in advance, that, for a detailed elaboration of these procedures, first practical experience with the "multi-step" process in the official application of Regulation (EU) 2017/2400 needs be available. Furthermore, at the time of writing this section, the authors do not know, which licence provisions will apply to the individual manufacturer levels. This will also be an important boundary condition for the design of effective and cost efficient verification procedures.

Verification of input information, input data and data handling

As the name suggests, this part of the verification procedure aims to ensure that all data processes from the assignment of input data, the execution of simulations, the handling of result files and the creation of the CoC have been carried out correctly. With a few exceptions, no physical test procedures are required for this element. The single steps as described below generally represent a more systematic and extended methodology compared to the system described in the current Annex Xa.

<u>Primary and complete(d) level:</u>

- ✓ Verification of data integrity of input data and input information (“job-file”), MRF, VIF (for primary) and CIF (for complete(d)) using the hashing tool
- ✓ Verification of components input data by comparison of hashes in component certificates with the corresponding hashes in the job-file
- ✓ Verification of results in the MRF, VIF (for primary) and CIF (for complete(d)) by running the simulation tool with the job-file and comparing the set of results[32]

[32] The hashes of the MRF as provided by the manufacturer and the MRF from the re-calculation will differ because the hash contains the date of the simulation run. Thus, the results would need to be checked “manually”. If this suggested verification element is implemented into the legislation, however, the function of the hashing tool could be extended accordingly to automatise this process.

- ✓ Verification of MRF hash in CoC[33]
- ✓ Verification of input information by comparison of job-file with actual vehicle (VIN, auxiliary technologies, disabled gears, torque limits etc.).

  A few of the declared input information to be verified on the primary level (engine torque limitations, disabled gears) require a short test drive with the vehicle, where CAN data needs to be recorded. Since a verification of power-train efficiency (the “classic” VTP measurement) also needs to be carried out for the primary level, this part of the verification can also be carried out by then.
- ✓ Verification of components by comparison of certification numbers and model specifications on the markings of the actual vehicle with the job-file

<u>Interim level:</u>

- ✓ Verification of data integrity of input data and input information (“job-file”), VIF from previous manufacturer and output VIF using the hashing tool
- ✓ Verification of input information by comparison of job-file with the actual vehicle (VIN, auxiliary technologies, dimensions etc.).

  If this screening were to be carried out in isolation for a single interim level, only the inputs from the interim manufacturer would actually have to be checked. On the basis of an inspection of the vehicle where already all modifications have been made, however, it would presumably be not possible to distinguish externally in all cases between faults at the previous manufacturers and faults at the manufacturers under inspection.
- ✓ Verification of air drag input data by comparison of hashes in component certificate with the corresponding hash in the job-file (only applicable in case air drag component is provided)
- ✓ Verification of air drag component by comparison of certification number and model specification on the marking on the actual vehicle with the job-file (only applicable in case air drag component is provided)

For the interim level, the general point to be defined is, whether those verifications shall be carried out for all individual interim steps or rather as a single comprehensive verification on the completed level. In the latter case, the completed manufacturer would have to take legal responsibility for all inputs made after the primary level. If the verifications are to be carried out at single interim level, such formal obligations could possibly be integrated into the provisions on licensing for the simulation tool to not pose an additional burden for small manufacturers.

One final remark on the element “Verification of input information, input data and data handling” as currently defined in point 6.1.1.3 of Annex Xa (“Actions to be taken”). This provision states that in case discrepancies are detected, the procedure (i.e. the physical VTP test) shall be continued with the corrected data. The manufacturer does not have to bear any further consequences as a result of a detected error. In an update it is recommended to define separate consequences at this point - in case of a fail of this verification element.

[33] It is assumed that the CoC will contain both MRF hashes (i.e. for the primary and the complete(d) level)

Verification of mass

The verification of the mass is only to be assigned to the complete(d) level, since in the multi-step procedure as defined for heavy buses an entry of this value ("corrected actual mass") is only required at this point.

Since this mass value to be provided in the multi-step procedure refers to the final condition of the vehicle, this value is practically much easier to verify than in the current procedure for heavy lorries (here the value refers to a vehicle condition without bodywork and with corrections for individual parts that were not present on the base vehicle).

As far as the verification of mass within the framework of Annex Xa is concerned, it has often been mentioned by manufacturers that provisions regarding mass verification come from several places (requirements from Regulation (EU) 1230/2012, requirements on the process licence for VECTO, VTP as CoP according to Annex Xa, in future also mass verification as part of ISV provisions). This comment cannot be fully rejected. However, the Commission has clearly stated its intention not to remove this element from Annex Xa.

Verification of powertrain-efficiency

This element of the verification procedure involves the established physical VTP test to verify the CO_2 emissions of the vehicle[34]. In technically precise terms, this test procedure verifies the powertrain efficiency of the vehicle. All relevant vehicle properties related to this quantity are under the responsibility of the manufacturer of the primary vehicle. Accordingly, this verification element is only to be assigned to the primary level.

Physical testing requires a vehicle in a condition in which it can at least in principle be registered. Thus it needs to have reached the complete or completed stage of manufacturing. To minimise the procedural effort, it would be obvious to carry out all elements for all manufacturer levels on this complete or completed vehicle. In the case of primary manufacturers, for most vehicles the same manufacturer will also be responsible for the complete(d) vehicle. In the criteria for vehicle selection, however, a certain quota of VTP tests would have to be explicitly provided for vehicles where the primary manufacturer and the completed manufacturer are not identical. Otherwise, it would be clear for primary vehicles sold to body builders that they could never be the subject of a VTP. For these tests, it would then be necessary to define that only the levels for which the primary vehicle manufacturer is responsible (primary and possibly interim) are subject to verification.[35]

Integration of new elements into Annex Xa

If a basic agreement is reached on this approach, these elements are to be incorporated into an updated version of Annex Xa. From consultant's point of view, the current structure cannot be maintained, as the various elements are very interwoven in the current structure. For example, at the beginning of point 6 “Test procedure”, "Verification of input information and

[34] And in case xEV are added to the VTP, the electric energy consumption of the vehicle, see section 3.3.2.3.

[35] Otherwise, confidentiality issues with input data and input data from other manufacturers would arise.

input data and data handling" (point 6.1.1), "Verification of vehicle mass" (point 6.1.1.2) and “Run-in phase” (point 6.1.2) are specified in a nested manner. A first recommendation for a new structure is:

1. Introduction
2. Definitions
3. Vehicle selection (to be checked if this makes sense on a super-ordinate level)
4. Verification of input information, input data and data handling
    - 4.1. Lorries
    - 4.2. Heavy buses
        - 4.2.1. Primary
        - 4.2.2. Interim (if relevant)
        - 4.2.3. Complete and completed
5. Verification of mass
    - 5.1. Lorries
    - 5.2. Heavy buses
6. Verification of powertrain efficiency
    - 6.1. Measurement systems
    - 6.2. Vehicle configuration
        - 6.2.1. Lorries
        - 6.2.2. Heavy buses
    - 6.3. …
    - 6.4. Trip provisions
        - 6.4.1. Lorries
        - 6.4.2. Heavy buses
    - 6.5. …
    - 6.6. Test evaluation
7. Reporting procedures

Further details will have to be decided during the elaboration. It will be important to consider that all provisions which are different in the "CoP"-like procedure - as Annex Xa is currently designed according to Regulation (EU) 2017/2400 – and in the application as an ISV test, are explicitly listed in separate points (e.g. vehicle selection, run-in, mileage, vehicle configuration, pass fail tolerances).

3.3.4.3 Summary of tasks to cover heavy buses by a VTP

From the project team's point of view, solutions would have to be worked out for the following issues in order to ensure a sound application of the VTP procedure on heavy buses:

1) For low-floor buses of conventional vehicle technology, i.e. ICE both with and without “smart alternators”, the accuracy of the VECTO recalculation in VTP mode needs to be practically verified. As described in detail in section 3.1.3.4 on pilot phase 2, on this

subject no data is available yet. In this regards, the accuracy of VECTO for vehicles with APT transmissions as well as in VTP tests with vehicles mainly driven in "urban" trip conditions will have to be verified in practice to make a sound decision on trip conditions and applicable C_{VTP} ratio for a pass/fail decision.

2) As described in the previous section, a suitable approach to the responsibilities of different manufacturers in the multi-step process needs to be elaborated.
3) In order to capture a significant share of the new heavy buses to be registered in 2025+ by a VTP, methods need also be available specifically for the technology HEV, and depending on political view on relevance, also for PEVs. From the survey conducted in Task 5 it is unfortunately not possible to derive exact figures on the expected share of technology in the mid 2020ies. However, it can be clearly assumed that conventional ICE vehicles (i.e. without at least a 48V recuperation module) will have a relatively small share, especially for low floor buses.

4 Task 3 – New technologies for CO_2 certification of heavy-duty vehicles

Task 3 is split in two sub-tasks, 3.1 for hybrid and pure electric vehicles and 3.2 for the other new technologies. Those sub-tasks are described in sections 4.1 and 4.2 below.

By including these new technologies in Regulation (EU) 2017/2400 in the course of the second amendment, the provisions in Article 9 regarding exemption of vehicles on the obligation to determine CO_2 emissions and fuel consumption using the simulation tool also need to be refined. Section Necessary updates in Article 9 regarding exemptions of vehicles on the obligation to determine CO2 emissions and fuel consumption describes the proposed list of exemptions and identifies further steps that may be necessary for subsequent amendments to Regulation (EU) 2017/2400.

4.1 Task 3.1: Hybrid and pure electric vehicles

4.1.1 Approach for certification

The existing approach for the certification of CO_2 emissions and fuel consumption consisting of two separate steps is also followed for HEV and PEV: The first step is the certification of all independent powertrain components of the vehicle in order to determine the input data for the simulation in standardized test procedures. The second step is the simulation of each specific vehicle configuration in the standardized simulation software tool VECTO. For HEV and PEV a standardized set of generic powertrain architectures is foreseen to depict the specific vehicle layout in the simulation. For HEV it is required to determine the split of propulsion power either between the different propulsion energy converters for parallel HEV or between propulsion energy converter and storage for serial HEV. This function is accomplished by a generic control strategy implemented in the simulation tool.

4.1.1.1 Covered vehicle architectures to be covered

The elaborated approach covers the following powertrain configurations:

HEV parallel:

> Powertrain architectures that include an ICE that powers only a single mechanically connected path between the engine and the wheels of the vehicle.
>
> A special variant of parallel hybrid with a fully integrated powertrain component is depicted by an IHPC (explained in detail in section 4.1.2).

HEV serial:

> Powertrain architectures that include an ICE that powers one or more electrical energy conversion paths with no mechanical link between the ICE and the wheels of the vehicle.
>
> A special variant of serial hybrid with a fully integrated powertrain component is depicted by an IEPC (explained in detail in section 4.1.2).

PEV:

Pure electric vehicle (i.e. battery electric vehicle) with a single powertrain (multiple permanently mechanically independent powertrains are exempted from the current approach, see section 4.3).

A special variant of PEV with a fully integrated powertrain component is depicted by an IEPC.

The HEV/PEV powertrain configurations covered with the second amendment are described in detail in Table 19. Based on this characterisation of the vehicle's powertrain configuration on the top level, a clear set of rules was elaborated in order to define the applicable standard architecture to be used for the simulation of a specific vehicle. Based on two parameters, namely the vehicle's powertrain configuration and - for powertrains not containing an IEPC or IHPC - in addition the position of the electric machine in the vehicle's powertrain, a certain powertrain architecture ID is assigned for each specific vehicle. This powertrain architecture ID is used as input to the simulation tool in order to characterize the applicable standard architecture for the simulation.

Table 18 gives an overview of the options for the different position of the electric machine in the powertrain and Table 19 lists all valid combinations of inputs to the simulation tool where the respective architecture was implemented.

Table 18: Possible positions of EMs in the vehicle's powertrain

Position index of EM	Powertrain configuration	Transmission type	Definition / Requirements*	Further explanations
1	Parallel HEV	AMT, APT-S, APT-P	Connected to the powertrain upstream of the clutch (in case of AMT) or upstream of the torque converter input shaft (in case of APT-S or APT-P). The EM is connected to the crankshaft of the ICE directly or via a mechanical connection type (e.g. belt).	Distinction of P0: EMs which can as a matter of principle not contribute to the propulsion of the vehicle (i.e. alternators) are handled in the input to auxiliary systems (see provisions in Annex IX and table 3 for lorries, 3a for buses). Notwithstanding the previous sentence, EMs at this position which can in principle contribute to the propulsion of the vehicle but for which the declared maximum torque in accordance with Table 9 is set to zero shall be declared as "P1".

Position index of EM	Powertrain configuration	Transmission type	Definition / Requirements*	Further explanations
2	Parallel HEV	AMT	The electric machine is connected to the powertrain downstream of the clutch and upstream of the transmission input shaft.	
2	PEV, Serial HEV	AMT, APT-N, APT-S, APT-P	The electric machine is connected to the powertrain upstream of the transmission input shaft (in case of AMT or APT-N) or upstream of the torque converter input shaft (in case of APT-S, APT-P).	
2.5	Parallel HEV	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the clutch (in case of AMT) or downstream of the torque converter input shaft (in case of APT-S or APT-P) and upstream of the transmission output shaft.	The EM is connected to a specific shaft inside the transmission (e.g. layshaft). A specific transmission ratio for each mechanical gear in the transmission according to Table 8 shall be provided.
3	Parallel HEV	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the transmission output shaft and upstream of the axle.	
3	PEV, Serial HEV	n.a.	The electric machine is connected to the powertrain upstream of the axle.	
4	Parallel HEV	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the axle.	
4	PEV, Serial HEV	n.a.	The electric machine is connected to the wheel hub and the same arrangement is installed twice in symmetrical application (i.e. one on the left and one on the right side of the vehicle at	

Position index of EM	Powertrain configuration	Transmission type	Definition / Requirements*	Further explanations
			the same wheel position in logitudinal direction).	
GEN	Serial HEV	n.a.	The electric machine is mechanically connected to an ICE but under no operational circumstances mechanically connected to the wheels of the vehicle.	

* The term EM as used here includes an additional ADC component, if present.

Table 19: Valid inputs of powertrain architecture into the simulation tool

Powertrain type	Powertrain configuration	Architecture ID for VECTO input	Powertrain component present in vehicle								Comments
			ICE	EM position GEN	EM position 1	EM position 2	Transmission	EM position 3	Axle	EM position 4	
PEV	E	E2	no	no	no	yes	yes	no	yes	no	
		E3	no	no	no	no	no	yes	yes	no	
		E4	no	no	no	no	no	no	no	yes	
	IEPC	E-IEPC	no	no	no	no	no	no	*1)	no	
HEV	P	P1	yes	no	yes	no	yes	no	yes	no	
		P2	yes	no	no	yes	yes	no	yes	no	*2)
		P2.5	yes	no	no	yes	yes	no	yes	no	*3)
		P3	yes	no	no	no	yes	yes	yes	no	*4)
		P4	yes	no	no	no	yes	no	yes	yes	
	S	S2	yes	yes	no	yes	yes	no	yes	no	
		S3	yes	yes	no	no	no	yes	yes	no	
		S4	yes	yes	no	no	no	no	no	yes	
		S-IEPC	yes	yes	no	no	no	no	*1)	no	

**1) "Yes" (i.e. axle component present) only in case both parameters "DifferentialIncluded" and "DesignTypeWheelMotor" are set to "false"*

**2) Not applicable for transmission types APT-S and APT-P. A vehicle with an IHPC type 1 is configured in VECTO as a special version of a P2.*

**3) In case the EM is connected to a specific shaft inside the transmission (e.g. layshaft) in accordance with the definition in Table 8*

**4) Not applicable for front wheel driven vehicles*

In case the powertrain configuration being an IHPC the powertrain architecture ID “P2” shall be declared and the EM in the vehicle’s powertrain shall be located at position 2.

The following figures illustrate the possible HEV and PEV architectures in VECTO for each of the different “classical” powertrain configurations except for IHPC or IEPC.

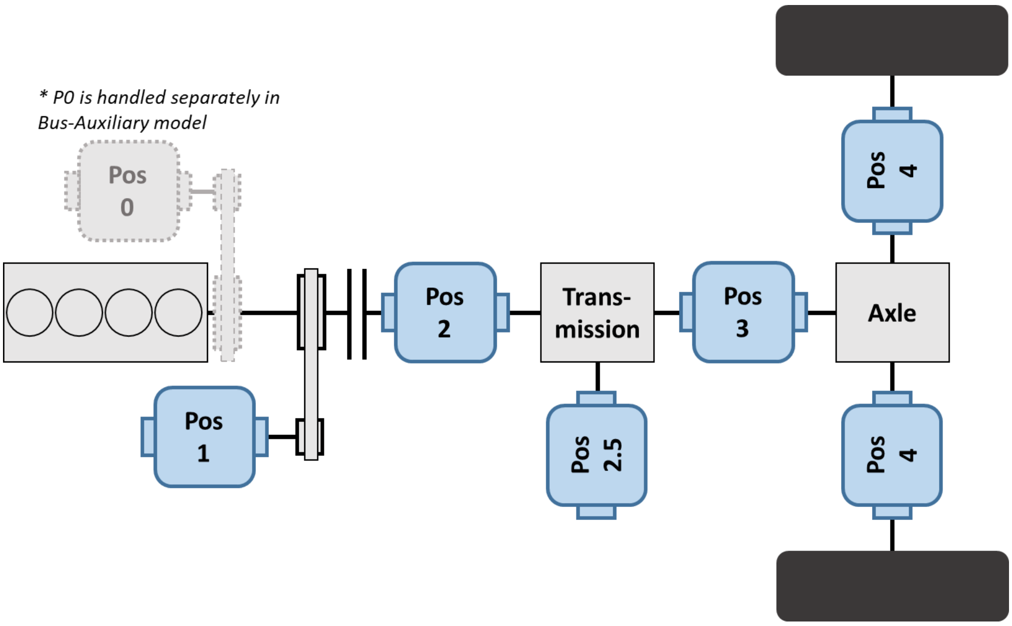


Figure 19: Powertrain architecture and position of EMs for a HEV parallel configuration

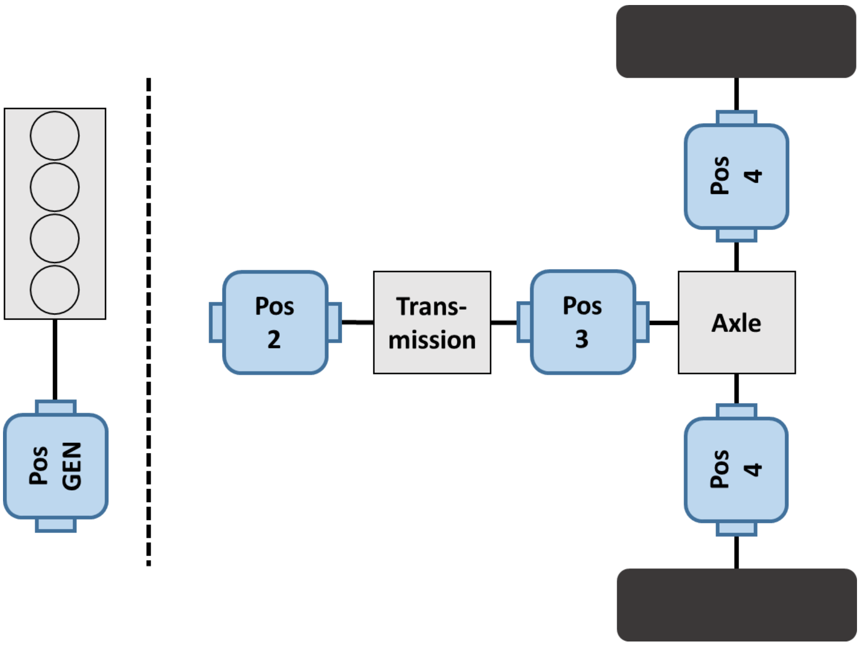


Figure 20: Powertrain architecture and position of EMs for a HEV serial configuration

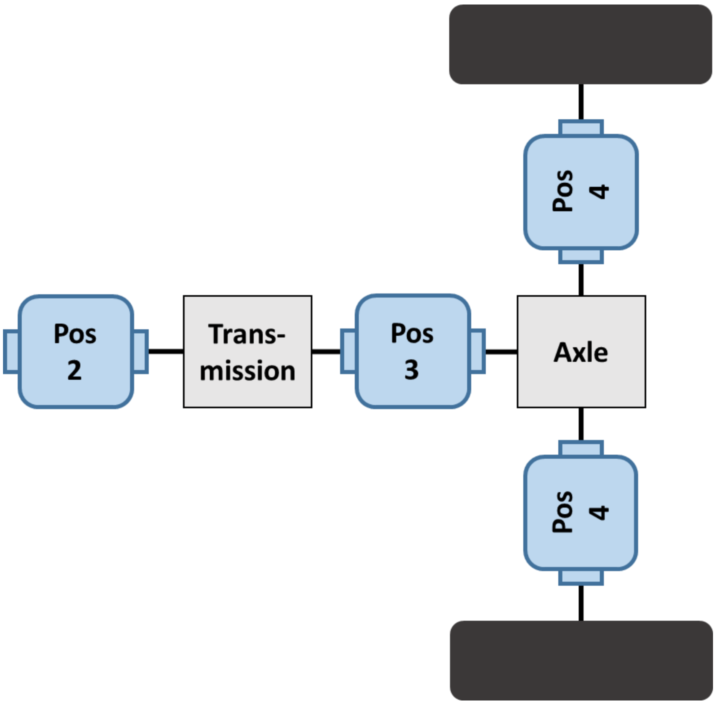


Figure 21: Powertrain architecture and position of EMs for a PEV configuration

As opposed to the original planning and initial status quo, two major changes occurred over the course of the project regarding more complex powertrain systems as explained in chapter 3.1.4:

1. The focus shifted more towards PEV and specifically depicting different variants of highly "Integrated Electric Powertrain Components" (IEPC)
2. The demand to cover several different complex hybrid systems identified at the very beginning of the project was no longer given and in the end there was only one specific complex integrated HEV powertrain component (IHPC) left to be covered.

Thus, for both cases above specific simulation methods as well as the respective component tests were developed which should be able to depict the general mode of operation and resulting energy saving potential of such components realistically.

The concept developed for IEPCs is universally applicable. For the specific IHPC, a concept tailor-made for one OEM-specific system design was elaborated. The approach was discussed extensively with Commission services (GROW, CLIMA; JRC). The Commission in this case agreed to implement an OEM-specific concept, because due to the focus shift towards fully electric powertrains the number of additional newly-introduced OEM-specific complex hybrid EV concepts to be expected in future was deemed to be very low.

4.1.1.2 Component certification

For the following components relevant for HEV and PEV new test procedures were introduced in a dedicated new working document 10b ("Certification of electric powertrain components"):

- Propulsion energy converters
    - Electric machine system

 - IEPC
 - IHPC
- Rechargeable electric energy storages
  - Battery system
  - Capacitor system

The following tables give an overview on the approaches chosen for testing the different components as well as the input data required for the vehicle simulation that is derived from the specific test procedures:

Table 20: Overview on component testing for electric machines systems / IEPC / IHPC

Test name	Purpose	Description of testrun	Reference in working doc. 10b	Input data for vehicle simulation
Torque limits	Derive power limitations for the EM/IEPC/IHPC for propulsion and also for braking	Unit is run at full positive (i.e. driving) setting of the power controller and in a second run at full negative (i.e. braking) power setting of the power controller. The torque limitations are measured at several different rotational speeds (≥10) to define correctly the torque limitations between zero and the highest motor speed. Defined preconditioning is performed before each run. To be measured at two voltage levels.	Par. 4.2.2	Maximum and minimum torque as function of the rotational speed
Drag curve (Testrun not relevant for IHPC)	Derive drag losses (i.e. the torque necessary to spin the EM/IEPC at a certain speed with zero power delivered by the machine)	The unit is driven at a certain rotational speed and torque and electric power are measured. Defined preconditioning is performed before the actual test.	Par. 4.2.3	Drag torque as function of the rotational speed (applied if EM/IEPC power is zero in VECTO)
Maximum 30 minutes continuous torque	Derive torque that can be constantly delivered by EM/IEPC/IHPC	Operating point declared by manufacturer upfront must be kept for 30 minutes, Otherwise test needs to be repeated with lower power. Defined preconditioning is performed before the actual test.	Par. 4.2.4	Continuous maximum torque required for simplified thermal derating model (i.e. reduction of maximum power depending on EM/IEPC/IHPC load profile over time)

Test name	Purpose	Description of testrun	Reference in working doc. 10b	Input data for vehicle simulation
Overload characteristics	Derive torque that can be delivered by EM/IEPC/IHPC for a defined short period	Operating point declared by manufacturer upfront must be kept for a declared period of time, Otherwise test needs to be repeated with lower power. Defined preconditioning is performed before the actual test.	Par. 4.2.5	Energy buffer is derived from short-period maximum torque and respective duration required for simplified thermal derating model (i.e. reduction of maximum power depending on EM/IEPC/IHPC load profile over time)
EPMC	Derive power losses of EM/IEPC/IHPC	Electric power to or from the inverter is measured for different steady-state operating points of the EM/IEPC/IHPC (≥100 theoretically) with a dedicated sequence of testing to define thermal boundary conditions. Defined preconditioning is performed before the actual test. To be measured at two voltage levels.	Par. 4.2.6	Power losses of EM/IEPC/IHPC as function of the operating point (rotational speed and torque)

Table 21: Overview on component testing for batteries

Test name	Purpose	Description of testrun	Reference in working doc. 10b	Input data for vehicle simulation
Rated capacity	Derive total energy content of the battery	Battery is preconditioned, fully charged and rested for a defined period. Then the actual measurement is performed by discharging with a defined current. Integration of current over time gives the energy content of the battery.	Par. 5.4.1	Energy content of battery (actual usable energy restricted by SOC limits – either generic as function of cell technology or declared and verified in VTP)
Open circuit voltage	Derive battery voltage for different levels of energy content	Battery voltage is measured at different SOC levels after discharging with a defined current and a defined resting time.	Par. 5.4.2	Battery voltage as function of the level of energy content (SOC)
Internal resistance	Derive parameter that defines internal losses of battery	Battery is operated in a specific cycle of discharging and charging current pulses. This is done	Par. 5.4.2	Internal resistance for battery model as function of SOC and current pulse duration

Test name	Purpose	Description of testrun	Reference in working doc. 10b	Input data for vehicle simulation
		for different currents at several SOC levels. Defined preconditioning is performed before each testrun.		(internal losses in the simulation are calculated as a function of this parameter and actual battery current)
Current limits	Derive power limitations for the battery for charging and discharging	Declared values by battery manufacturer are verified in test for internal resistance	Par. 5.4.2	Maximum and minimum allowed current of the battery

Table 22: Overview on component testing for capacitors

Test name	Purpose	Description of testrun	Reference in working doc. 10b	Input data for vehicle simulation
Capacitance	Derive parameter that defines correlation of integrated capacitor current to energy stored	Single testrun consisting of a charging and discharging cycle with defined resting periods in between.	Par. 6.3	Capacitance for capacitor model (integration of ratio of current divided by capacitance gives delta energy from/to capacitor)
Internal resistance	Derive parameter that defines internal losses of capacitor	Combined single testrun with capacitance	Par. 6.3	Internal resistance for capacitor model (internal losses in the simulation are calculated as a function of this parameter and actual capacitor current)

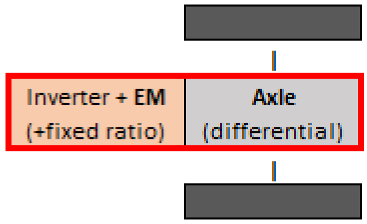
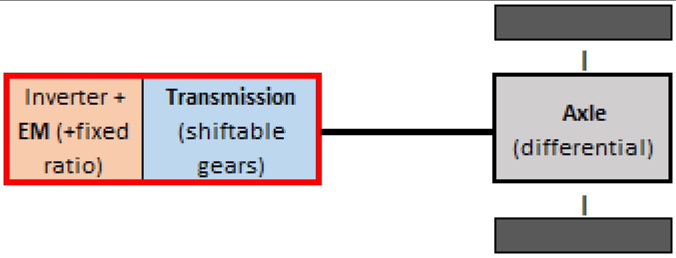
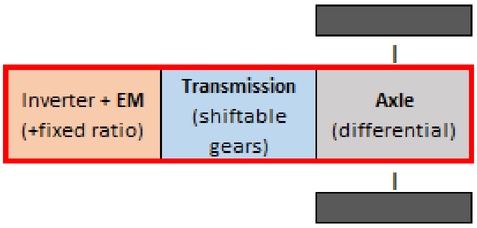
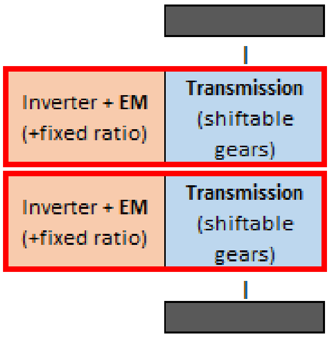
4.1.2 Integrated powertrain components

As explained in the introduction the need to develop two completely new types of powertrain components for xEV vehicles was identified over the course of the project. Thus, the two new component types IEPC and IHPC were defined and related methods for simulation as well as component testing were developed. Such components are characterised by an integrated functionality of several "conventional components" (electric motor, gearbox, differential) into a single unit. Separate testing of these “classic” VECTO components is on the one hand hardly possible (as it would require demounting of the single parts and setting up special housings for testing of each single part) and would on the other hand not give representative component data due to decomposing the integrated system into several individual sub-systems with tailor-made amendments. Further details regarding handling of these components in the certification framework are explained in the following sections.

4.1.2.1 IEPC

Table 23 gives an overview on all archetypical configurations of IEPC identified in task force meetings with industry experts.

Table 23: Archetypical configurations of integrated components identified

ID	Symbolic picture
"1" **EM plus axle**	
"2" **EM plus transmission, axle as separate component**	
"3" **EM plus transmission plus axle**	
"4" **EM plus transmission per wheel (no axle)**	

For component testing, the same basic principles as for EM apply, but depending on the specific system configuration the test setup or the test runs are partly carried out differently.

For an IEPC with shiftable forward gears all testruns listed in Table 20 above except the EPMC are only performed in one specific gear. For the EPMC to be measured on all forward gears, the grid of target setpoints determined based on the maximum and minimum torque limits determined in a single gear needs to be converted to the respective equivalent target setpoints for all other gears by following a dedicated set of defined provisions.

Based on the respective parameters in the component data describing the layout specific system configuration, the correct powertrain architecture and position of the system in the vehicle’s powertrain is allocated by the simulation tool automatically.

4.1.2.2 IHPC

An IHPC is more complex than an IEPC since it includes an input for feeding torque provided by an externally located ICE into the system besides two EM and a shiftable transmission. Thus, opposed to the IEPC the gearbox functionality needs to be decoupled from the EM functionality from a methodological point of view in order to be able to assign gearbox losses correctly, independent of the source of propulsion torque.

For component testing, the same basic principles as for IEPC with multispeed gearboxes apply and thus the EPMC is measured separately for each single forward gear. In addition to the test runs defined for IEPCs, the losses in the gearbox parts are determined by separate test runs based on the existing provisions for “regular” transmissions. Out of these two sets of measurements – one for the entire system including the gearbox and one for the gearbox parts only by deactivating the EM parts – two separate data sets are generated by following the dedicated provisions developed for IHPC. The resulting separate data sets are then used for certifying two different types of regular components, one EM and one transmission. Since these separate data sets define the IHPC the can only be used combined together in the vehicle in order to give meaningful results. This is ensured by separate parameters in the respective component data marking the regular component as part of an IHPC and also by the same certification number to be used for both regular components.

Since the methods invented were designed for one OEM-specific component, the definition of the IHPC was developed in a very specific way in order to not allow potential components (which are not existing as of today, but could in theory be introduced in future) with a different structure or functional principle to make use of these specifically designed methods. For this reason, the provisions on IHPC were additionally marked as "Type 1" in the Annex. If further systems come onto the market in the future, these would have to be analysed and, if necessary, the provisions would have to be supplemented by further "types".

Due to the complexity of the methodology and the fact that the IHPC Type 1 represents the technology of a specific manufacturer, it is considered particularly important that the approach is practically tested before the official CO_2 determination is launched. The project team, in close cooperation with DG JRC, has already worked out the scheme of such a test programme. The manufacturer concerned has also already agreed to provide a vehicle for these measurements.

4.2 Task 3.2 Other new technologies for CO_2 certification of heavy-duty vehicles

Table 24 gives an overview on the "other new technologies" and the related necessary technical changes in Regulation (EU) 2017/2400 to be covered by Task 3.2.

Table 24: Overview on "other new technologies" as to be covered in Task 3.2

Technology / feature covered by the simulation tool	Related component certification test procedure	Necessary technical changes in Reg. (EU) 2017/2400
Updates of generic gear shift algorithms	None	None
Advanced Driver Assistance Systems (ADAS) (2 stage implementation)	None	Phase 1 implementation already covered by Regulation (EU) 2019/318 Phase 2 implementation required technical changes in Annex III regarding system definition for ADAS for vehicles with APT transmissions.
Gas and Dual-fuel engines	Engine dyno testing	Gas engines already covered by Regulation (EU) 2019/318 Dual-fuel engines required technical changes in Annex V and in Annex Xa
Waste Heat Recovery (WHR)	Engine dyno testing	WHR required technical changes in Annex V

A description of the technical background, relevant boundary conditions from other pieces of legislation as well as on approaches for component testing and simulation was provided with the first interim report of this contract.

To integrate these new technologies into the HDV CO_2 certification, the potential changes to Regulation (EU) 2017/2400 have been drafted in Task 3.2. The related working documents (3, 5 and 10a) have been uploaded to HDV CO2 CIRCABC in March 2020 and were the basis for pilot phase 2. As described in detail in section 3.1.3 the methods for dual-fuel engines and WHR have been successfully validated in this pilot phase. The methods for "Updates of generic gear shift algorithms" and "ADAS Implementation Phase 2" concern only the software (no component tests) and were already developed in project [2] for DG CLIMA.

4.3 Necessary updates in Article 9 regarding exemptions of vehicles on the obligation to determine CO2 emissions and fuel consumption

By including the new technologies as described in sections 4.1 and 4.2 above into Regulation (EU) 2017/2400, the provisions in Article 9 regarding exemption of vehicles on the obligation to determine CO_2 emissions and fuel consumption using the simulation tool also need to be refined. Table 25 shows the list of technologies as proposed for Appendix 1 of Annex III. The technologies are divided into categories, for each of which criteria for an exemption to apply have been defined. The right column in Table 25 contains the proposed identifier to be entered as input parameter for such vehicles in VECTO.[36] This identifier makes it possible later in the monitoring process to assign the exempted vehicles to individual technologies.

Table 25: Vehicle technologies exempted from obligations according to Article 9

Vehicle technology category	***Criteria for exemption***	***Input parameter value in accordance with Table 5 of this Annex***
Fuel cell vehicle	The vehicle is either a fuel cell vehicle or a fuel cell hybrid vehicle in accordance with point 2 (12) or (13) of Annex III.	"FCV Article 9 exempted"
ICE operated with hydrogen	The vehicle is equipped with an ICE that is capable of running on hydrogen fuel.	"H2 ICE Article 9 exempted"
Dual-fuel	Dual-fuel vehicles of types of types 1B, 2B and 3B as defined in Article 2(53), 2(55) and 2(56) of Regulation (EU) No 582/2011	"Dual-fuel vehicle Article 9 exempted"
Hybrid electric vehicle	An exception applies if at least one of the following criteria is met: • The vehicle is equipped with multiple EMs which are not placed at the same connection point in the driveline in accordance with point 10.1.2 of this Annex. • The vehicle is equipped with multiple EMs which are placed at the same connection point in the driveline in accordance with point 10.1.2 of this Annex but do not have exactly identical specifications (i.e. the same component certificate). This criterion shall not apply in case the vehicle is equipped with an IHPC Type 1. • The vehicle has a powertrain architecture other than P1 to P4, S2 to S4, S-IEPC in accordance with point 10.1.3 of this Annex or other than IHPC Type 1.	"HEV Article 9 exempted"

[36] Vehicles exempted under Article 9 shall also run through the simulation tool, but without simulation of energy consumption and CO2 emissions and with a reduced set of input parameters according to Table 5 in Annex III.

Vehicle technology category	***Criteria for exemption***	***Input parameter value in accordance with Table 5 of this Annex***
Pure electric vehicle	An exception applies if at least one of the following criteria is met: • The vehicle is equipped with multiple EMs which are not placed at the same connection point in the driveline in accordance with point 10.1.2 of this Annex. • The vehicle is equipped with multiple EMs which are placed at the same connection point in the driveline in accordance with point 10.1.2 of this Annex but do not have exactly identical specifications (i.e. the same component certificate). This criterion shall not apply in case the vehicle is equipped with an IEPC. • The vehicle has a powertrain architecture other than E2 to E4 or E-IEPC in accordance with point 10.1.3 of this Annex.	“PEV Article 9 exempted”
Multiple permanently mechanically independent powertrains	The vehicle is equipped with more than one powertrain where each powertrain is propelling different wheel axle(s) of the vehicle and where different powertrains can under no circumstances be mechanically connected. In this regard hydraulically driven axles shall in accordance with point 5(a) of this Annex be treated as non-driven axles and shall thus not be counted as an independent powertrain.	“Multiple powertrains Article 9 exempted”
In-motion charging	The vehicle is equipped with means for conductive or inductive supply of electric energy to the vehicle in motion which is at least partly directly used for vehicle propulsion and optionally for charging a REESS	“In-motion charging Article 9 exempted”
Non-electric hybrid vehicles	The vehicle is a HV but not a HEV in accordance with point 2 (26) and (27) of this Annex.	“HV Article 9 exempted”

In the following, further information on the justifications for the individual exemptions is provided where relevant, as well as recommendations on next steps in subsequent amendments to Regulation (EU) 2017/2400:

Fuel cell vehicles

Methods need to be developed for the component certification of fuel cells and the configuration of fuel cell vehicles in VECTO. The corresponding work is already underway[37] and is planned to be completed in time for the third amendment of Regulation (EU) 2017/2400.

ICE operated with hydrogen

The first key framework condition for enabling vehicles with hydrogen-fuelled engines is the inclusion of this engine technology in the Regulation for emissions type approval. Building on

[37] Task 2.2 in Service Contract Number 340201/2020/835254/SER/CLIMA.C.4.

this framework, the provisions in Regulation (EU) 2017/2400 Annex V need to be extended for H2 (e.g. in regards accuracy provisions for H2 mass flow measurement, reference fuel etc.). Also on this topic the corresponding work is already underway[38] and is planned to be completed in time for the third amendment of Regulation (EU) 2017/2400.

Dual-fuel

The implementation of dual-fuel engines in Regulation (EU) 2017/2400, as carried out in this project in task 3.2, fully covers the technology currently available on the market ("type 1A" according to the classification in UN/ECE Regulation 49 Rev.06). The elaborated methodology could furthermore be applied to all "type A" engines. Formal exemptions are needed for "type B" engines – i.e. engines which have both a "Dual-fuel mode" and a "Diesel mode". To date, no OEM has announced to come up with type B dual-fuel engines and it is seen as very unlikely for this to happen in the future.

Covering "type B" engines would require additional provisions for engine certification as well as extended methods in the VECTO simulation, i.e. weighting of CO_2 emissions from "Diesel mode" and "Dual-fuel mode" to a consolidated CO_2 figure in VECTO).

Hybrid electric vehicles

Exemptions are formulated for complex powertrain architectures that cannot be specified and simulated with the configurations described in Annex III.

In theory, the number such hybrid powertrain architectures is almost unlimited. However, as a result of the ambitious extension of the scope of this project (see also the related statements in section 3.1.4), as far as the project team is aware, all hybrid electric architectures currently coming onto the market in any significant number should be covered by the current methods.[39] [40] The market situation must of course continue to be monitored. Anyhow, due to the strong development of the market towards fully electric vehicles, it currently seems unlikely that completely new hybrid electric powertrain concepts will be developed to market introduction.

Pure electric vehicles

As for hybrid electric vehicles exemptions are formulated for complex powertrain architectures that cannot be specified and simulated with the configurations described in Annex III. The clear difference to hybrid electric vehicles is that due to the general formulation of the definition of IEPCs, the very largest proportion of systems under development for PEVs can probably be covered by VECTO and will thus not fall into this exemption.

For how many systems the methodology planned for the second amendment will actually work will have to be investigated based on the homologation phase in 2022 and an associated

[38] Task 2.3 in Service Contract Number 340201/2020/835254/SER/CLIMA.C.4.

[39] Two architectures that have been presented by the industry during the development phase 2019 to 2020 would not have been covered by the current methods. Those are - according to the latest information - no longer relevant for the market (i.e. either stuck in pre-development or only released for small series vehicles).

[40] For the specific product for which the component type "IHPC Type 1" was defined, a simplified modelling in VECTO was developed with significantly fewer degrees of operation than in the real vehicle application. The modelling of this technology in VECTO in long haul application should be relatively accurate. The application of the system in distribution trucks and buses, which has also been announced by the manufacturer, is in all likelihood depicted by VECTO with the current with fewer advantages over a conventional driveline and thus less fuel efficient than in the real vehicle application.

VECTO test phase. It is unclear, for example, whether the approach will work reasonably for IEPCs with several EMs that can be switched off/on in the operation strategy. In any case, it is already clear that powertrains that work without discrete transmission ratios cannot be depicted with the current approach. Such are not expected for the first generation of HDV PEV but are announced by industry to be likely for follow-up generations. It is therefore recommended that after a phase of gathering in-depth experience with the current methodology in 2022 (and the resulting required revisions to the current provisions as to do for the third amendment, see section 3.1.4), a possible further need for substantial work on PEVs is investigated for a fourth amendment.

Multiple permanently mechanically independent powertrains

The issue of multiple permanently mechanically independent powertrains becomes relevant through electrified vehicles. For those, additional driven axles can be realised in a flexible way through applying additional e-components (“e-axles”). Such vehicle configurations are in particular known to be of relevance for electrified articulated buses (for both HEV, PEV and FCEV).

With the current methods in Regulation (EU) 2017/2400 and in VECTO, such vehicles cannot be represented and modelled. To cover those in a future amendment the following tasks would need to be accomplished:

- Definition which combinations of powertrain architectures are relevant (i.e. any combination of E2, E3, E4, IEPC1, IEPC2, IEPC3, IEPC4, ICE?; more than 2 powertrains needed?)
- Extensions in Annexes, XMLs schemas, the MRF CIF: Provide component information by powertrain ID
- VECTO simulations: Apply a generic traction force distribution between different axles, apply special rules for gearshift, provide simulation results (e.g. power losses) per component and powertrain ID

In-motion charging

With the methods currently developed, the energy consumption and if relevant fuel consumption and CO2 emissions of vehicles with in-motion charging systems[41] can only be inadequately be determined. Reasons for this are:

- Electric energy efficiency of such systems would be underestimated as electricity can be directly used for propulsion without being stored in the battery and having to be discharged from the battery again.
- In addition, for vehicle configurations with very small batteries, battery losses would be significantly overestimated.
- In the case of hybrid electric vehicles (i.e. vehicles with combustion engines as currently used for catenary systems), separate definitions must be made for the utility factor (ratio of mileage with purely electric driving to mileage in charge depleting or charge sustaining mode).

[41] In-motion charging: means for conductive or inductive supply of electric energy to the vehicle in motion which is at least partly directly used for vehicle propulsion and optionally for charging a REESS. Examples are catenary systems for lorries or trolley buses.

The corresponding work on implementation has already been started [42] and is planned to be completed in time for the third amendment of Regulation (EU) 2017/2400.

Non-electric hybrid vehicles

In principle, a variety of non-electric hybrid drive trains are also feasible, e.g. a vehicle with an internal combustion engine and pneumatic pressure accumulator or flywheel set as energy storage for recuperation purposes. However, it is considered very unlikely that such systems will come onto the market in significant numbers in the future.

5 Task 4: CO2 verification of lorries

Task 4 is split in three sub-tasks, 4.1 covering the analysis of options, 4.2 extending the VTP to verification of in-service lorries and 4.3 drafting of procedures for in-service conformity testing of air-drag, tyre rolling resistance and vehicle mass.

Task 4.1 was already finalised as planned with a final deliverable in the First Interim Report of this project in March 2020. Part of Task 4.1 was also to analyse options for combining VTP tests and ISC tests for the conformity of a vehicle's pollutant emissions. The conclusions reached in Task 4.1 were discussed with stakeholders in pilot phase 2. Results and decisions taken are documented in section 3.1.3.6 of this report.

This chapter summarises the work and results of Task 4.2 and 4.3. The workflow in the project was as follows:

- Q1 and Q2 2020: Development of basic concepts for technical procedures and coordination meetings with the Commission
- 10 July 2020: Stakeholder meeting with all relevant participants of the HDV CO2 Editing board where the basic technical concepts were presented and feedback was requested
- 18 September 2020: ACEA submitted a detailed feedback document
- 24 September 2020: Meeting with ETRMA on tyre related topics in the ISV
- 9 October 2020: Submission of a first overall draft for the ISV document to the Commission
- 2 February 2021: Coordination meeting TUG, LAT and Commission
- 11 March 2021: Meeting with ACEA on VTP for in-use lorries
- 5 May 2021: Submission of a revised ISV document to the Commission.
- 8 July 2021: Coordination meeting with COM and decision to revise the structure of the document.
- 26 August 2021: Submission of a revised ISV document to the Commission
- 13 October 2021: Submission of a revised ISV document to the Commission after a final feedback loop

[42] Task 3 in Service Contract Number 340201/2020/835254/SER/CLIMA.C.4.

5.1 Structure of the ISV working document

An overview of the structure of the ISV document is given below. Based on this structure, the important points in the elaboration of the different parts are then discussed.

General provisions on ISV

Annex I: In-service verification elements

- Verification of input information, input data and data handling
- Verification of vehicle mass
- Verification of rolling resistance
- Verification of air drag
- Verification of the powertrain efficiency

Annex II: Reporting format

5.2 General provisions on ISV

5.2.1 Abbreviations

AL .... Technical Service or other accredited laboratory for performing ISV checks

CCA .... Component Compliance Assessment

GAA .... Granting Approval Authority, i.e. the approval authority that provides the licence to operate the simulation tool in the CO2 determination

ISV .... In Service Verification

ISF .... In-Service-Verification Reporting File

5.2.2 Overview[43]

GAAs and other Type Approval Authorities are authorised to initiate the In-Service Verification (ISV) checks and may act, where appropriate, with the support of a designated Technical Service, inspection body or other accredited laboratory.

The GAA shall insure that the tests performed as part of the in-service verification are documented and that the test reports are made available to the Commission, and on request by other Type Approval Authorities, market surveillance authorities and recognized third parties. All ISV check results shall be reported using the forms defined in Annex II in electronic form as input for the Electronic Platform for ISV results (to be established by the Commission).

The GAA shall analyse the reports on ISV checks of vehicles and its components or technical units and shall inform the manufacturer of the vehicles concerned of the results of the in-service verification by providing the test reports from the in-service tests.

[43] All references in this section to sub-items or Annexes refer to the ISV working document as submitted on the 13.10.2021.

If the results of the in-service verification show that there is no deviation in the CO_2 emission values, the GTAA shall take a decision to that effect.

In case of components or vehicles, failing ISV checks, the GAA shall set actions:

1) The GAA shall inform the manufacturer of the vehicle and component(s) concerned and give the manufacturer the opportunity to perform an analysis of the reasons for failing the ISV checks and demonstrate the validity of the CO_2 emission values recorded in the customer information file, certificates of conformity or individual approval certificates of the vehicles concerned.

2) The GAA shall analyse the ISV check report and the response of the manufacturer to possibly identify the reason for non-compliance without further test activities.

3) If the reason for non-compliance of a verification of the powertrain efficiency cannot be identified by such an analysis , the GAA may[44] perform one or more further repetitions of the total or of single elements of the ISV check where the results failed. If the ISV check repetition(s) is/are failing the pass/fail criteria defined in the following paragraph 4, the vehicle model is considered to have failed the ISV check.

4) If one or more components and technical units are identified after point 2) and 3) as possible reason for failing single elements of the ISV check, these components or technical units shall be tested in “Component Compliance Assessment (CCA) tests”, either by the GAA itself, or it may entrust this to a technical service other than the technical service that performed the approval test, in which case the technical service shall be acting on behalf of the GAA.

    - For tyres according to the procedure defined in point 1.3 of Annex I,
    - For air drag according to the procedure defined in point 1.4 of Annex I
    - For all other components and technical units which were identified possibly contribute to the fail of the verification of the powertrain efficiency (engine, gear box, axle,…) the test procedure defined in the corresponding CoP procedures defined in Regulation (EU) 2017/2400 shall be applied.

5) The components and technical units have failed the ISV test, if:

    - For tyres the pass/fail criteria according to the procedure defined in point 1.3 of Annex I are failed
    - For air drag the pass/fail criteria according to the procedure defined in point 1.4 of Annex I are failed
    - For all other components and technical units if the CoP tolerances are failed according to the corresponding CoP procedures defined in Regulation (EU) 2017/2400.

[44] If the component(s) concerned are available at the OEM for easy and cheap CoP like checks, component tests according to 4) may be performed without such further ISV check tests.

6) In case of failure(s) at the verification of input information, input data and data handling (point 1.1 of Annex I) and/or at one or more component and technical unit tests, remedial measures shall be elaborated by the manufacturer.

7) The GAA shall initiate and approve the plan of remedial measures, presented by the manufacturer.

8) The GAA shall take a final decision on the ISV check accordingly. Where the GAA establishes a lack of correspondence between the CO2 emissions of the vehicles in-service and those recorded in the customer information file, certificates of conformity or individual approval certificates, it shall specify the vehicles concerned, the size of the deviation and the corrections to be made in said documents.

The GTAA shall transmit its decision to the manufacturer concerned and to the Commission.

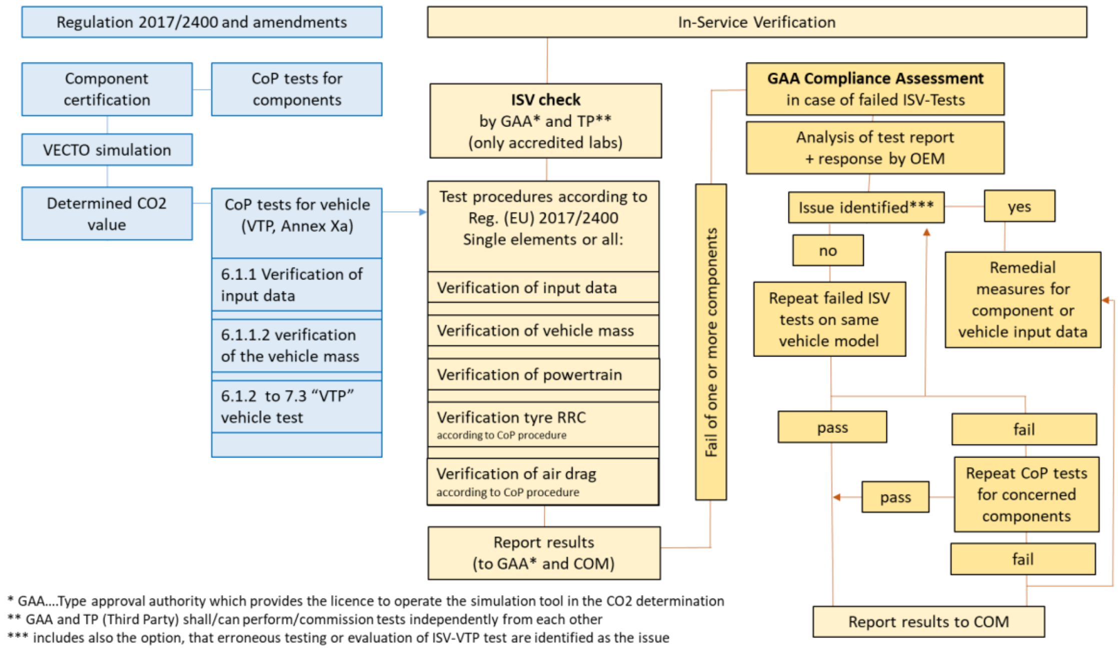


Figure 22: Schema of the ISV procedure

5.2.3 General vehicle provisions and requirements

Subject to in-service verification procedures are any kind of vehicles where official results for CO_2 emissions and fuel consumption in accordance with Regulation (EU) 2017/2400 have been determined.

If the vehicle has undergone any modifications with relevance to CO_2 emissions and fuel consumption as determined by Regulation (EU) 2017/2400 (e.g. mounting of an additional power take off, change in auxiliary components or in axle configuration) in any subsequent manufacturing stage after the base vehicle , the original vehicle configuration has either to be restored or the vehicle is excluded from the verification test procedure.

For the given elements for verification procedures according to chapter 5.3 additional vehicle provisions and requirements criteria do apply. Verification of rolling resistance can be carried out independently of the selection of a specific vehicle.

5.2.4 Requirements for documents to be provided

The following shall be made available by the manufacturer of the vehicle concerned to the Commission (JRC):

- Input information und input data
- Manufacturers records file
- Customer information file
- The certificates for all components for which measurements were carried out in the certification

In case the in-service verification is only performed for tyres (without connection to a specific vehicle), only the tyre certificate has to be provided by the tyre manufacturer.

5.2.5 Data handling

The verification of input information and input data and the VECTO simulations needed for verification of powertrain efficiency shall be performed by the Commission (DG JRC). The input data from the vehicle and/or component tests performed during the VTP shall be provided by the AL to the Commission.

The results from the VECTO simulation and from the verification of input information and input data shall be provided by the Commission to the AL within 30 working days after all needed input data was provided by the AL and by the vehicle manufacturer. The AL is responsible for the further evaluation steps in the VTP procedure and for the reporting to the GAA.

5.3 In-service verification elements

The ISV checks are proposed to consist of one or more of the following verification elements:

a) Verification of input information and input data and data handling
b) Verification of vehicle mass
c) Verification of rolling resistance
d) Verification of air drag
e) Verification of the power train efficiency

Draft provisions for the individual elements have been developed and are given in Annex I, points 1.1 to 1.6 of the submitted ISV document. Relevant considerations in deriving the provisions from Regulation (EU) 2017/2400 are described and any open points identified are noted.

5.3.1 Verification of input information, input data and data handling

This element was taken over unchanged from Annex Xa as revised for the second amendment of Regulation (EU) 2017/2400. The only minor proposed change is that „a verification as described in point 6.1.1.1 item (c) is only applicable in case the vehicle undergoes also a verification of the powertrain efficiency." This provision is related to a verification of declared maximum torque values, which requires a physical test with large parts of the measurement equipment for the powertrain efficiency test. Thus, it is suggested to skip this minor item if such a physical test is not scheduled anyway.

5.3.2 Verification of vehicle mass

Subject to verification in the proposed ISV procedure is the value for "corrected actual mass", which is the relevant input parameter for VECTO. Before weighing, superstructures and any additional optional equipment shall be removed.

For in-use rigid lorries, this quantity can be determined only with an high level of effort, as it refers to a vehicle without bodywork. Therefore, for verification, the superstructure has to be removed. Thus, for the ISV mass verification of rigids lorries - which in contrast to the procedure in Annex Xa of Regulation (EU) 2017/2400[45] can be carried out independently of a whole vehicle test - it is proposed to carry out the check directly on vehicles in the condition of a base vehicle. Whether this approach works out reasonably in practice will have to be derived from stakeholder feedback.

5.3.3 Verification of rolling resistance

For the verification of the rolling resistance of tyres, it is proposed to use the same methodology as required for CoPs under Regulation (EU) 2017/2400. This approach consists of a test in a reference laboratory while applying all provisions from the original certification of the tyre according to Regulation (EU) 2017/2400. It is also proposed that the tolerances prescribed for CoP shall be taken over unchanged from the Regulation. ETRMA has confirmed that they support this approach and that a sufficient number of HDV tyre test rigs, which can also be used by third parties, are available.

As far as tyre selection for ISV is concerned, it is necessary to use new tyres as available on the market, since the rolling resistance changes considerably in the course of the service life (approx. 20% reduction until the lower limit of the tread depth). This means that a robust comparison with the certified values would not be possible for used tyres.

With this approach, it seems plausible to conduct ISV for tyres independently of ISV tests on a particular vehicle, i.e. solely on the basis of the number of certified tyres in the market or per tyre manufacturer. As tyres do not have a marking containing the certification numbers like

[45] Due to these fundamental difficulties, it is formulated in Annex Xa that verification of mass is only to be carried out at the request of the type approval authority and in this case only the relatively easy-to-verify mass data for the final vehicle are to be verified. Only if this verification fails, the verification of the "corrected actual mass" is required.

the other components defined in Regulation (EU) 2017/2400, a link between a tyre at hand and the correct certificate needs to be established. This process is proposed as follows:

- Option 1: The tyre model is selected first. The tyre manufacturer is contacted based on tyre model information and shall provide the related tyre certificate. The information in certificate section 4 and 5 shall be used to verify whether the certificate really matches with the selected tyre.
- Option 2: The selection is started having a certificate number (e.g. from type approval data or the EEA database). The tyre OEM shall be contacted based on the certificate number. From the information in section 4 and 5 then the tyre can be identified and taken from the market.

In order to establish the approach described above in legislation, details regarding the availability of tyres certified in accordance with Regulation (EU) 2017/2400 still need to be clarified. In this regard ETRMA states that such Original Equipment (OE) tyres are available in the market as replacement tyres “in most cases”. ETRMA further states, that “if a customer want to be sure to fit as replacement exactly the same tyre type as the OE tyre, he should always ask confirmation to the tyre manufacturer through the dealer”. Asking the manufacturer is however problematic in the context of ISV, as OEM then may always have control over which specific tyres are selected.

5.3.4 Verification of air drag

Also for the verification of the air drag value it is suggested to use the procedure foreseen for CoP in Regulation (EU) 2017/2400 as far as possible. However, for air drag there are some fundamental challenges as far as ISVs are concerned:

- As for CoP, the vehicle selection is limited to vehicles that are "testable" (i.e. mainly relevant for rigid lorries: vehicles on which the standard body fits), for which no standard values have been applied and for which no genetic derivations (“transfer”) of the CdxA value from other vehicle groups have been made. For the latter category, a verification element could be added, to check whether the provisions as laid to in Annex VIII Appendix 5 (Family concept) have been applied correctly. This would only be a desktop exercise.
- The main challenge in ISV is to bring the vehicle as taken from in-use into a condition that corresponds to the aerodynamic configuration for which the manufacturer is responsible. For this purpose the following reviews are proposed:
    - Visual inspection of:
        - No dents or damaged parts
        - Aftermarket parts, like sun visors, horns, additional head lights, signal lights, bull bars or ski-boxes shall be removed from the vehicle
        - Chassis condition, mudguards, bumpers, tanks etc.
    - Measured inspection of:
        - Chassis to ensure no frame deformations
        - Cab and component positions
        - Axle alignment

    - Any deviations identified in the checks listed above shall be corrected or repaired to restore the original condition.

  In order to verify the practical feasibility of these provisions, a pilot phase is strongly recommended. As the authors do not have access to any air drag certificates, it is not possible to check whether all the information required to produce the original condition is available.

- For rigid lorries, it furthermore also necessary to remove the vehicle body, if present, and install the standard body.

As far as the measurement procedure is concerned, the provisions for CoP in Regulation (EU) 2017/2400 are adopted unchanged. The proposal also contains the pass/fail criteria in unchanged form. The Commission has suggested that the tolerances (+7.5%) should be reviewed, possibly with a widening of provisons for ambient conditions. For this purpose JRC has requested and received the test reports from the manufacturers on the CoP measurements carried out so far. The results of this evaluation is still pending. When evaluating the data from the manufacturer CoP, it should also be kept in mind that these were carried out by the same operators and with knowledge of the original measurement. Compared to this, operators, conditions and motivation at ISV tests are fundamentally different. Because of this point, it is again recommended to run a pilot phase for ISV .

5.3.5 Verification of the powertrain efficiency

The verification of powertrain efficiency is performed with the VTP on-road measurement as described in Annex Xa of Regulation (EU) 2017/2400. Here, too, reference can be made to this document to a large extent.

The criteria for the selection and condition of the vehicle are formulated separately for the ISV, as not all the provisions from the Annex Xa make sense and there needs to be an additional provision for the mileage of the vehicle. On this point, it is proposed to limit the mileage of vehicles to be tested in a ISV test within a range of 15 000 km up to 300 000 km because of its influence on the powertrain efficiency. The results determined by VECTO refer to a new vehicle in run-in condition. For VTP testing, this condition is already defined to be after 15 000 km. From this point on, it can be assumed that the fuel consumption level will slowly increase again. In its document presented in March 2021, ACEA indicates a range of 2% to approx. 10% percent increase of fuel consumption over lifetime, but also emphasises the high influence of the maintenance condition and an unknown influence of different operation profiles, which is included in these indicated range. A 2% increase of fuel consumption over 300.000 km was also obtained from other TUG sources[46] as a very reasonable number. The main reason for this effect is a decrease of turbo-charger efficiency.

This influence was also incorporated into the pass/fail criterion for the ISV. The formula does not change the tolerance at 15,000 km and takes into account a 2% additional margin at 300,000 km.

JRC also proposes to use a tolerance margin of 7,5% in the negative range (C_{VTP} <0 .925, i.e. too low fuel consumption in the measurement compared to the VECTO simulation) for a fail

[46] For reasons of confidentiality, these sources cannot be quoted here.

for both the VTP and the corresponding test as ISV. The motivation is to possibly detect errors in the component data or other issues in the data handling process as occurred during the pilot phases. From the point of view of the authors, however, there is the difficulty of an overlap of the influence of using standard values (e.g. for transmissions and axles) and also with auxiliaries which might in the tested vehicle perform better than reflected in the generic VECTO data. All those influences, which cannot be a reason for a fail, can result in a systematic shift of the C_{VTP} ratio to the lower than 1 range. Thus a straight “fail” seems not to be justified. From the authors' point of view, the solution could be to use the proposed ISV database for such analyses, in which all "pass" tests are stored as well. The tests for which the C_{VTP} ratios are below 0.925 could be analysed in more detail. If decided, it would have to be stipulated in the ISV provisions that manufacturers are also obliged to support the analyses with data or cooperation in this case.

6 Task 5: Assessment of the economic feasibility of an extended scope of CO_2 determination of heavy-duty vehicles

6.1 Introduction

This task analysed the economic feasibility of the extension of Regulation (EU) 2017/2400, through an assessment of the expected costs and benefits associated with the inclusion of lorries with a Technical Permissible Maximum Laden Mass (TPMLM) in the range greater than 5 tonnes and up to 7.5 tonnes, and heavy buses (M3 vehicles greater than 7.5 tonnes TPMLM), as well as the inclusion of new vehicle technologies, including waste heat recovery (WHR) systems, advanced driver assistance systems (ADAS), dual-fuel engines, battery electric vehicles (BEVs)[47] and hybrid electric vehicles (HEVs). This task also assesses the economic feasibility of the conformity of production (CoP) verification testing procedure (VTP) for heavy lorries, heavy buses and medium lorries with internal combustion engines (ICEs), as detailed in the working documents to amend Regulation (EU) 2017/2400.

This task builds upon the technical outputs of the following tasks:

- **Tasks 2.2:** The extension of Annex Xa to Regulation (EU) 2017/2400, to include heavy buses[48] and medium lorries, "Conformity of simulation tool operation and of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems: verification testing procedure";
- **Task 3:** "Certification procedures for new technologies", which include BEVs, HEVs, and vehicles with WHR, ADAS, and dual fuel engines;
- **Task 4:** "CO_2 verification" comprising an analysis of the potential scope of extended CO_2 verification of lorries, the VTP of in-service lorries and using VTP as in-service conformity (ISC).

This task aims to quantify the costs and benefits associated with the extension of Regulation (EU) 2017/2400, through gathering inputs from relevant stakeholders through the use of an online survey. Qualitative inputs from the survey are used to complement the quantitative findings, particularly in relation to the expected impacts of the proposed extension on small and medium-sized enterprises (SMEs), competitiveness and innovation, employment opportunities, and international trade. The analysis also draws upon the findings from an earlier study, which assessed the economic feasibility of the previous proposed extension of Regulation (EU) 2017/2400, to include N2 and M3 ICE vehicles.

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[47] In the description of vehicle technologies in the draft technical Annexes, it was decided in autumn 2020 to use the term "pure electric vehicle" (PEV), instead of battery electric vehicle (BEV). In this chapter, the term BEV is still used, as in the survey which was sent out.

[48] In the final draft of Annex Xa, heavy buses were removed. Since it is assumed that the VTP will be introduced for this vehicle category in the 3rd Amendment of Regulation (EU) 2017/2400, the analyses carried out are maintained in the report.

6.2 Scope and methodology

To assess the costs and benefits associated with the proposed extension, a survey was developed to gather inputs from vehicle and component manufacturers, type-approval authorities and NGOs. Although vehicle and component manufacturers are the key obligated parties (as specified in Regulation (EU) 2017/2400), it is important to account for the potential costs incurred by other stakeholders, such as type-approval authorities and the Commission. In addition, it is important to determine the potential benefits (e.g. CO_2 emissions reductions and fuel savings) and wider impacts associated with the proposed extension. As such, the survey sought to gain information from stakeholders on the topic areas presented in Table 26.

Table 26: Topics covered in survey to manufacturers, type-approval authorities and NGOs

Survey segment	Vehicle and component manufacturers	Type-approval authorities	NGOs
Background information	• Vehicle categories and technologies manufactured[49], and future projections; • Vehicle axle configuration criteria; • Vehicle components manufactured.	• Involvement in verification, granting licences for operating the simulation tool and certification of components/separate technical units (STUs)/ systems; • Type-approval of vehicles.	N/A
Component certification costs	• Component certification costs associated with the proposed extension; • Additional certification costs for new vehicle technologies.	• Costs for witnessing certification of components/STUs/systems; • Additional certification costs for new vehicle technologies.	
VTP costs	• Costs associated with the proposed VTP.	N/A	
Overhead costs	• Costs associated with keeping abreast of legislation; • Costs for providing/amending data management systems; • Costs for providing staff training; • Costs for covering audits/consulting in relation to verification.	• Costs associated with keeping abreast of legislation; • Costs for data management/exchange; • Costs for providing staff training.	
Wider impacts	• Expected impact on fuel cost savings; • Expected impact on innovation, job growth and competiveness in the vehicle manufacturing industry; • Expected impact on SMEs and third countries.		

The survey was shared with key stakeholders, including Editing Board members, to provide the opportunity for these stakeholders to estimate the expected impact of the proposed extension on their organisation, and the sector more broadly. The survey remained open for responses between October 2020 and December 2020, and gathered a total of 16 responses in total. At this point, it should be noted that, at the time that the survey was conducted, many

[49] "Manufactured" is used as shorthand for the terminology to 'sell, register or put into service', as in Regulation (EU) 2017/2400.

of the methods were still under development. In particular, the test procedures for electric powertrain components (Annex 10b) as well as the powertrain architectures covered (Annex 3) were still being decisively developed after the survey was completed. Accordingly, the survey responses may not be fully compatible with the latest status of the Annexes for the 2nd Amendment. Similarly, it was decided in spring 2021 that heavy buses should not yet be included in Annex 10a (VTP).

The response rate for this survey is comparable to the survey conducted under the earlier study. However, the level of detail provided by each stakeholder varied, due to the comprehensive nature of the survey questions and the specific expertise of each stakeholder, and for a number of questions, minimal quantitative estimates were provided by the respondents. Due to the COVID-19 pandemic, a number of respondents indicated that they were unable to provide information relating to future projections. Furthermore, some stakeholders declined to respond to the survey due to the constraints facing their organisation, as a result of the COVID-19 pandemic. Table 27 displays the number of survey responses received, split by stakeholder group.

Table 27: Overview of survey responses

Organisation type	Survey responses
Vehicle and component manufacturers	9
Type-approval authorities and technical services	5
NGOs	2

The analysis presented in this task also draws upon the findings from an earlier study[50], which assessed the economic feasibility of the previous proposed extension of Regulation (EU) 2017/2400, to include N2 and M3 ICE vehicles. The earlier study similarly involved the collection of data from key stakeholders in the vehicle manufacturing industry through the use of a survey, and drew upon expert judgement from the study team to complement survey findings.

The following subsections present the results of the analysis, through initially outlining the coverage of vehicle technologies by the survey respondents (Section 6.3), presenting the direct costs associated with the proposed extension (Section 6.4), the benefits (Section 6.5) and the wider impacts (Section 6.6). The conclusion brings this analysis together, to present a summary of the combined costs, benefits and pay-back periods associated with the proposed extension (Section 6.7).

6.3 Overview of survey respondents

6.3.1 Vehicle and component manufacturers

The vehicle manufacturers which responded to the survey manufacture a variety of vehicle categories and technologies. In addition to ICE vehicles, the majority of manufacturers also manufacture HEVs and BEVs (see Figure 23), and therefore, will need to align with Technical Annex 10b.

[50] Final Report: Technical support for the development of the CO_2 HDV (buses and vans) certification procedure. For specific Contract N. SI2.767363, **DG GROW of the European Commission.** TUG Report No. I-04/19/Rex EM-I-14/06 SR15/679, Issued 19.06.2019.

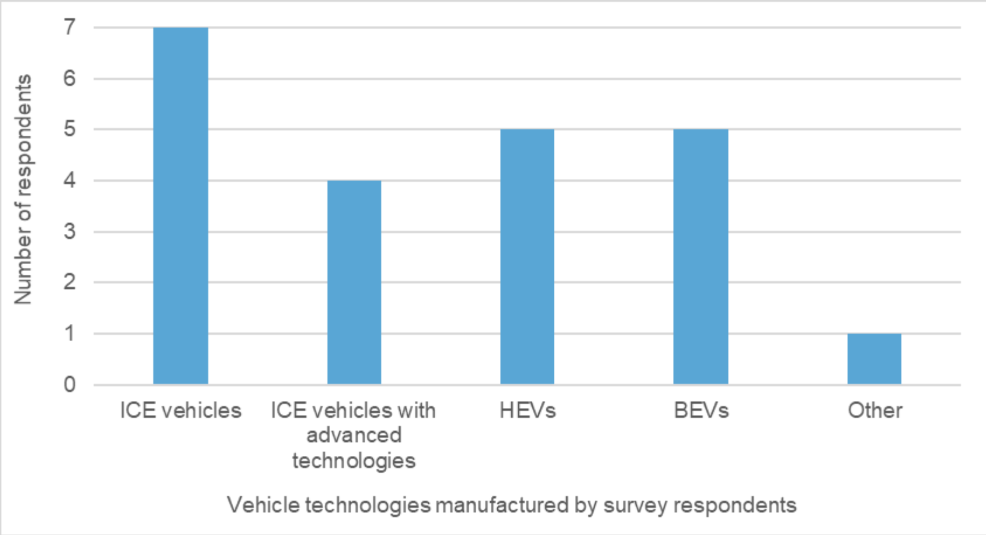

Figure 23: Vehicle technologies manufactured by survey respondents

The vehicle manufacturers were asked to provide the latest data available on their annual manufacturing volumes[51], split by vehicle category (see Table 28). It is important to note that a relatively low level of quantitative data was provided by the survey respondents, with only six manufacturers providing vehicle manufacturing data.

The vehicle manufacturers indicated that they manufactured 119,010 heavy lorries in total in 2019. Currently, BEVs comprise a negligible proportion of the total number of heavy lorries manufactured (0.01%). One manufacturer that responded to the survey indicated that they produce medium lorries, manufacturing a total of 500 in 2018 (all of which were ICE vehicles).

For high floor heavy buses, where the total number of vehicles manufactured is much lower than for heavy lorries in 2019 (3,615 high floor buses manufactured by the respondents), none of the manufacturers that responded to the survey currently manufacture high floor heavy bus BEVs, and HEVs only comprise 0.7% of total high floor heavy buses manufactured. For low floor heavy buses, the total number of vehicles manufactured by the respondents in 2019 was approximately 2,000. Of these, 61% were conventional ICE vehicles, 19% were HEVs and 20% were BEVs. One manufacturer also indicated that a further 33 buses, which were fuel cell and trolley buses, were manufactured in 2019.

Table 28: Total number of vehicles manufactured per year by the survey respondents

Vehicle technology	Medium lorries	Heavy lorries	Low floor heavy buses	High floor heavy buses
ICE vehicles	500[52]	83,000	1,195	2,090
ICE vehicles with advanced technologies (ADAS, WHR and/or dual-fuel)	0	36,000	0	1,500
HEVs	0	0	374	25
BEVs	0	10	400	0

[51] The majority of manufacturers provided annual data for 2019, with the exception of a medium lorry manufacturer, which provided 2018 data.

[52] Only 2018 data were provided by the manufacturer. The remaining values in the table represent 2019 data.

Total	**500**	**119,010**	**1,969**	**3,615**

The vehicle manufacturers also provided forward-looking estimates of manufacturing volumes, indicating expected coverage by the proposed extension of Regulation (EU) 2017/2400. As the survey was released during the COVID-19 pandemic, a number of respondents indicated that their organisations were unable to provide accurate estimates for future manufacturing volumes, and hence, did not provide any data.

Although the proposed extension of Regulation (EU) 2017/2400 includes plans to extend VECTO to cover additional powertrain technologies, some innovative technologies are being retrospectively modelled. As a result, some vehicle technologies are not included in the latest proposed extension of VECTO. Vehicle manufacturers were asked to provide their views on the proposed coverage of technologies in VECTO.

Figure 24 displays the expected coverage of heavy lorries by the proposed extension, as indicated by survey respondents. A total of 118,000 vehicles were projected to fall under the amended Regulation by the survey respondents in 2025. In contrast, manufacturers estimated that 11,100 of their heavy lorries would not fall under the proposed extended scope of Regulation (EU) 2017/2400. Therefore, 91% of heavy lorries manufactured by the survey respondents were expected to be covered by the proposed extension. Of the heavy lorries which were not expected to fall under the proposed scope, the majority (86%) were 'complex' HEVs[53].

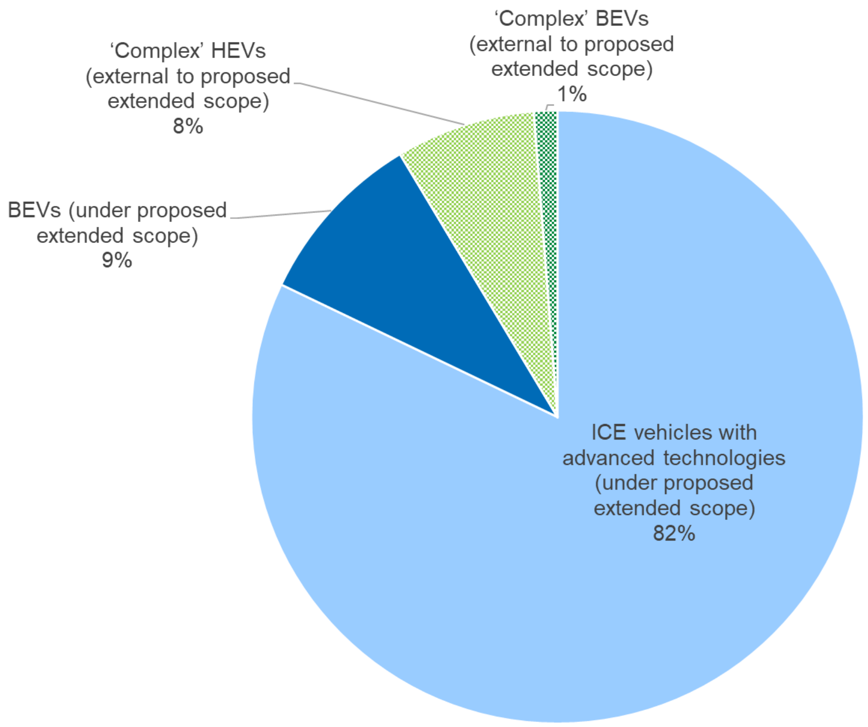

Figure 24: Coverage of heavy lorries by proposed extension to Regulation (EU) 2017/2400 as estimated by survey respondents (for consortiums assessment see Footnote 53 on page 106)

[53] According to the latest status of the Annexes, the consortium estimates that all of these vehicles can now be covered by VECTO in the 2nd Amendment of Regulation (EU) 2017/2400 (however, by a simplified approach which might not fully cover the fuel consumption reduction potential in a different vehicle applications).

One manufacturer produces medium lorries, and projected that 2,000 will be manufactured in 2023, all of which are expected to be ICE vehicles which fall under the proposed extended scope of Regulation (EU) 2017/2400.

Figure 25 displays the expected coverage of low floor heavy buses by the proposed extension, as indicated by survey respondents. In total, 2,080 (54%) vehicles manufactured per year were projected to fall under the proposed extended scope of Regulation (EU) 2017/2400, whilst 1,750 (46%) would not fall under the proposed extension. Of the low floor heavy buses which were not expected to fall under the proposed scope, the majority (57%) were 'complex' BEVs, followed closely by BEVs with 'integrated components' (43%)[54].

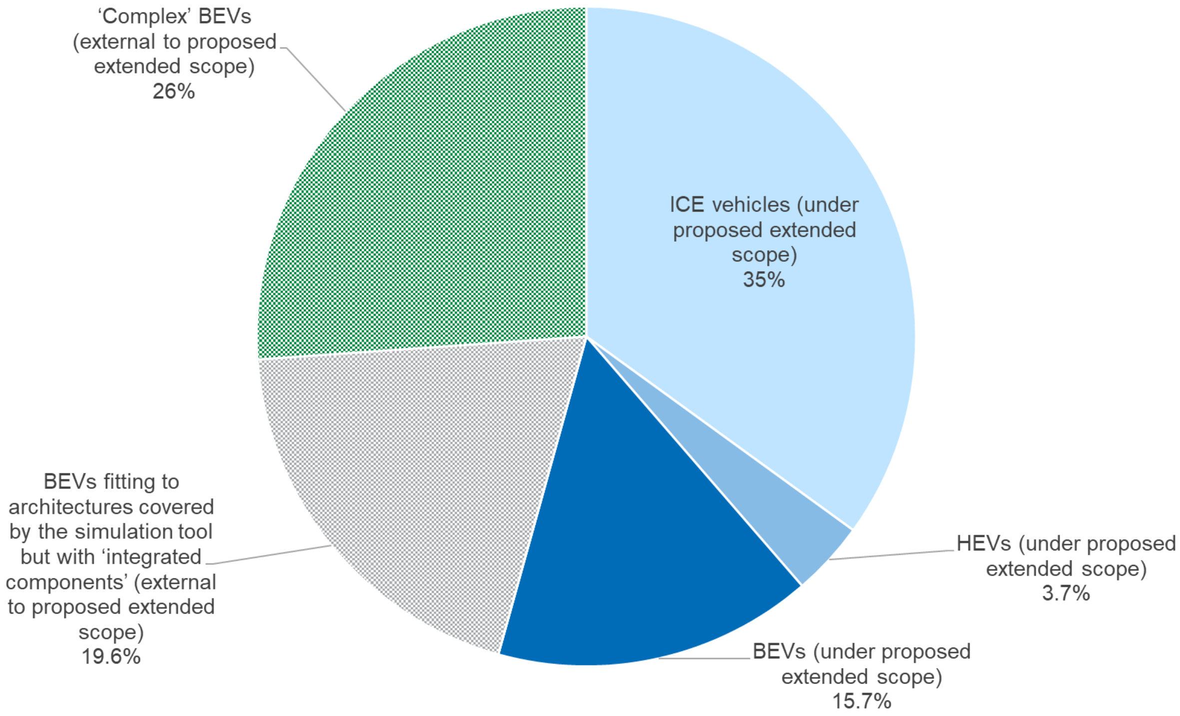

Figure 25: Coverage of low floor heavy buses by proposed extension to Regulation (EU) 2017/2400 as estimated by survey respondents (for consortiums assessment see Footnote 54)

Figure 26 displays the expected coverage of high floor heavy buses by the proposed extension, as indicated by survey respondents. Manufacturers estimate that 2,230 (82%) vehicles manufactured per year would fall under the proposed extended scope of Regulation (EU) 2017/2400, whilst 475 (18%) high floor heavy buses were expected to fall outside of the proposed extension. Of the high floor heavy buses which were not expected to fall under the

[54] As above, it is assessed that any of the BEVs with 'integrated components' and 'complex' architectures are now covered by the 2nd amendment. However, vehicles with more than a single powertrain are not covered. In practice, this will apply for some configurations of HEV or BEV articulated buses.

proposed scope, 'complex' HEVs comprised the majority of vehicles, with a small segment of BEVs with 'integrated components'.[55]

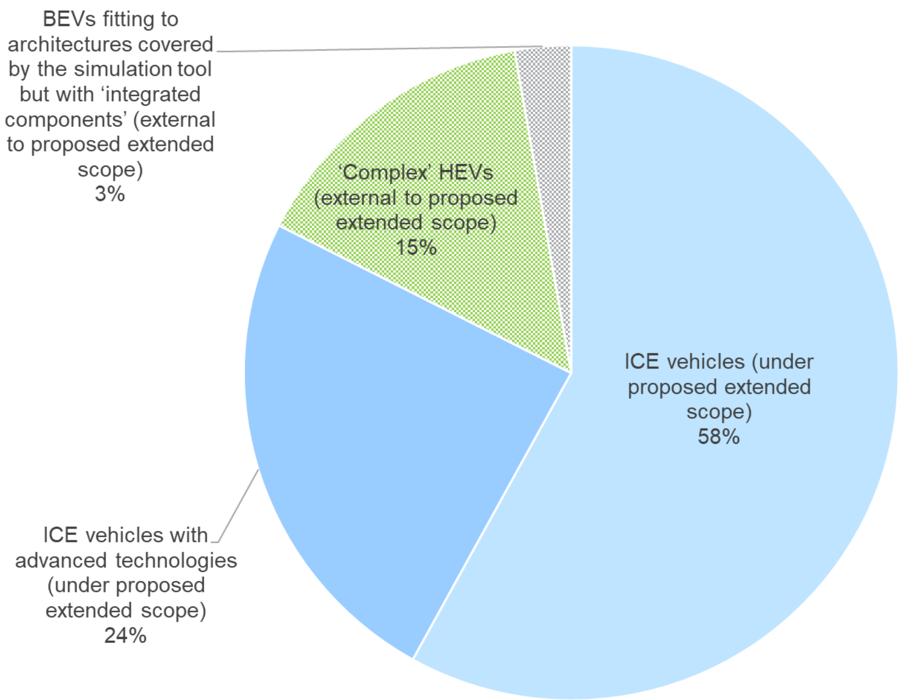

Figure 26: Coverage of high floor heavy buses by proposed extension to Regulation (EU) 2017/2400 as estimated by survey respondents (for consortiums assessment see Footnote 55)

From the perspective of one manufacturer, 'complex' HEVs (e.g. power-split[56]) cannot be simulated in VECTO to deliver an accurate representation of performance, relative to other technologies. From their view, it also remains uncertain as to whether future 'complex' BEVs can be simulated. Therefore, the manufacturer considered these vehicle technologies to fall outside of the proposed extended scope of Regulation (EU) 2017/2400. The manufacturer indicates their view that there should be greater clarity regarding the capacity for VECTO to simulate HEV and BEV performance in a technology-neutral manner. As already mentioned above, from the consortium's point of view, this assessment no longer corresponds to the latest status of the Annexes. Table 29 and Table 30 display the total expected vehicle manufacturing volumes, split by vehicle category.

[55] As for heavy lorries above, the consortium estimates that according to the latest status of the Annexes, all of these vehicles can now be covered by VECTO in the 2nd Amendment of Regulation (EU) 2017/2400.

[56] Vehicles which include power-split devices, enabling power paths from an ICE which can be mechanical or electrical.

Table 29: Total number of expected vehicles manufactured per year, which would fall under the proposed extended scope of Regulation (EU) 2017/2400

Vehicle technology	Medium lorries	Heavy lorries	Low floor heavy buses	High floor heavy buses
ICE vehicles	2,000	0	1,340	1,570
ICE vehicles with advanced technologies (ADAS, WHR and/or dual-fuel)	0	106,000	0	660
HEVs	0	0	140	0
BEVs	0	12,000	600	0
Total	**2,000**	**118,000**	**2,080**	**2,230**

Table 30: Total number of expected vehicles manufactured per year, which would not fall under the proposed extended scope of Regulation (EU) 2017/2400[57]

Vehicle technology	Medium lorries	Heavy lorries	Low floor heavy buses	High floor heavy buses
ICE vehicles (e.g. H_2 engines)	0	0	0	0
'Complex' HEVs (e.g. power-split)	0	9,500	0	400
BEVs fitting to architectures covered by the simulation tool but with 'integrated components' (e.g. e-motor and gearbox in single unit)	0	0	750	75
'Complex' BEVs	0	1,600	1,000	0
Total	**0**	**11,100**	**1,750**	**475**

Vehicle manufacturers were also asked to provide the share of manufactured vehicles according to axle configuration criteria, for medium lorries and heavy buses. The majority of manufacturers indicated that all of their produced vehicles were rear-wheel drive (RWD), with none of the manufacturers suggesting that their vehicles were solely front-wheel drive (FWD). For medium lorries, the single manufacturer involved in their production stated that 20% are all-wheel drive (AWD), and the remaining 80% are RWD. For heavy buses, one manufacturer stated that 78% are AWD, and the remaining 22% are RWD, whilst the remaining manufacturers indicated that 100% are RWD. Table 31 presents the proportion of vehicles manufactured by the survey respondents, according to axle configuration.

Table 31: Driven axle arrangements for vehicles manufactured by survey respondents

Axle arrangements	**Medium lorries**		**Heavy buses**					
	ICE vehicles		ICE vehicles		HEVs		BEVs	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
FWD	0	0%	0	0%	0	0%	0	0%
RWD	400	80%	4,785	100%	327	82%	400	100%
AWD	100	20%	0	0%	72	18%	0	0%

6.3.2 Type-approval authorities

The type-approval authorities that responded to the survey are involved in granting simulation tool operating licences, verifying vehicles and certifying components/STUs/systems (see Figure 27). Of the three type-approval authorities that provided information on the vehicle categories for which their organisation offers services relating to CO_2 determination, all three indicated that their organisation will provide services for heavy buses (when Regulation (EU)

[57] In cases where manufacturers provided a range of values, midpoints have been used.

2017/2400 is amended as such), whilst two indicated that they already provide services for heavy lorries, and will provide services for medium lorries buses (when Regulation (EU) 2017/2400 is amended).

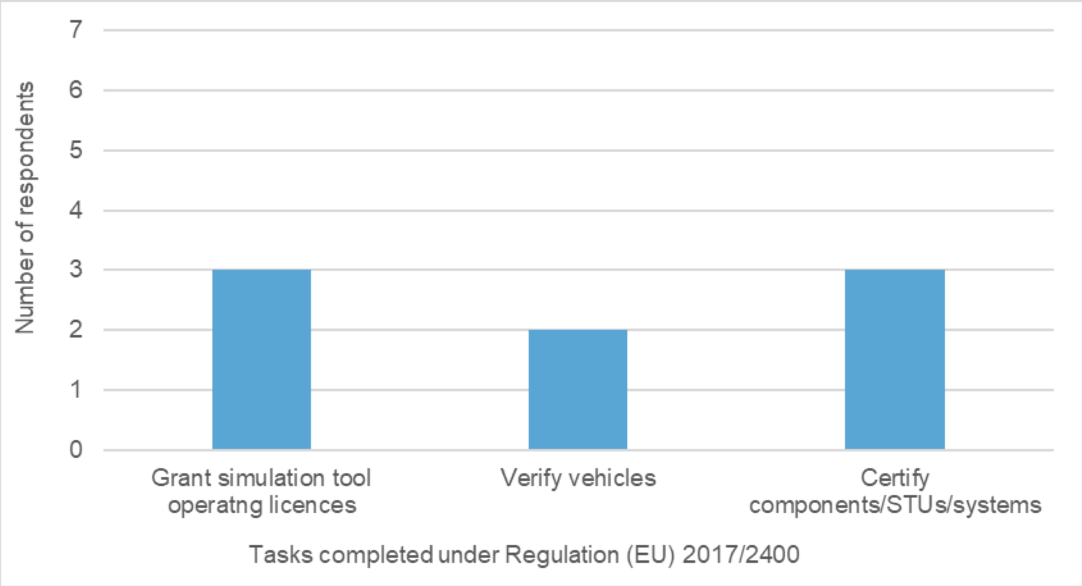

Figure 27: Tasks performed by survey respondents

6.4 Direct costs

This subsection presents an assessment of the direct costs associated with the extension of Regulation (EU) 2017/2400, namely component certification costs, VTP costs and overhead costs.

6.4.1 Component certification costs

There are several Annexes to Regulation (EU) 2017/2400, which outline the HDV certification procedures to follow for N2 vehicles greater than 7.5 tonnes, and for all N3 vehicles. It is proposed to extend the scope of component certification to cover new vehicle categories and technologies, such as electric energy converters and rechargeable energy storage systems. Table 32 presents the relevant Annexes to Regulation (EU) 2017/2400, their associated vehicle components, and the potential to use “standard values” (as opposed to undertaking a full certification cycle).

The performance of the components listed in Table 32 can be practically determined to provide input data for VECTO, using the procedures described in the appropriate technical Annex to Regulation (EU) 2017/2400. However, this is not the only route for defining input data. For the majority of the components, “standard values” for input data are available. A “standard value” is component input data which can be used for the VECTO simulation tool, where the certification of input data is required, yet the component has not been measured. “Standard values” reflect performance of a “worst-case” component, plus a certain tolerance margin, which estimate a higher fuel consumption level, relative to a result associated with the use of bespoke certification input data. However, the use of “standard values” removes the cost of undertaking the regulatory component certification procedure.

As specified in Annex VIII on verifying air drag data, for low floor heavy buses, “generic values” should be used. A “generic value” is data used in the simulation tool for components or vehicle parameters where no component testing or declaration of specific values is foreseen. “Generic values” reflect performance of average component technology or typical vehicle specifications.

Table 32: Annexes in Regulation (EU) 2017/2400 which refer to the certification of components

Annexes in Regulation (EU) 2017/2400	Annex description	Potential use of standard values
Annex V	Verifying engine data	Standard values are not applicable[58]
Annex VI	Verifying transmission, torque converter, other torque transferring component and additional driveline component data	Standard values may be used
Annex VII	Verifying axle data	Standard values may be used
Annex VIII and its Appendices	Verifying air drag data	Air drag certification is not required for low floor buses, where generic values are used. For other vehicles, standard values may be used but it is assumed unlikely, especially for high floor buses (“coaches”) due to the large disadvantage on fuel consumption.
Annex IX	Verifying truck auxiliary data	Currently auxiliaries are represented only by a combination of generic and declared values
Annex X	Certification procedure for pneumatic tyres	Standard values may be used
Annex Xb[59]	Certification of electric powertrain components	Standard values may be used

To provide stakeholder evidence on the potential costs of certification, the survey requested the following key pieces of information from vehicle and component manufacturers:

a) The number of vehicles and/or components manufactured in 2019, which would fall under the proposed extended scope of Regulation (EU) 2017/2400;

b) The cost per certification associated with the proposed extended scope of Regulation (EU) 2017/2400.

The number of vehicles and components manufactured in 2019 are reported in Table 33 (heavy lorries), Table 34 (low floor heavy buses) and Table 35 (high floor heavy buses). The single medium lorry manufacturer that responded to the survey did not provide any information on components manufactured.

It is important to note that the data presented below are only partial, as the manufacturers which responded to the survey do not comprise the entire European market, and therefore, it can be assumed that retarders are being produced by other manufacturers which did not respond to the survey.

[58] All engines used in HDVs must be certified.

[59] This is a proposed Annex to cover new vehicle technologies, and is not an existing Annex to Regulation (EU) 2017/2400.

Table 33: Numbers of heavy lorries and their key components, manufactured per year by survey respondents

Product manufactured	Median	Total
Primary vehicles	70,000	70,000
Engines	59,600	119,200
Transmission and angle drive	58,950	117,900
Retarders	0	0
Axle gears	100,000	100,000
Air drag	59,600	119,200
Tyres	4,000,000	4,000,000
Electric energy converters (e-motors)	10	10
Rechargeable energy storage system (RESS)	10	10

Table 34: Numbers of low floor heavy buses and their key components, manufactured per year by survey respondents

Product manufactured	Median	Total
Primary vehicles	110	1,800
Engines	685	1,370
Transmission and angle drive	413	825
Retarders	0	0
Axle gears	2,600	2,600
Air drag	230	1,230
Tyres	261,000	261,000
Electric energy converters (e-motors)	50	285
RESS	100	335

Table 35: Numbers of high floor heavy buses and their key components, manufactured per year by survey respondents

Product manufactured	Median	Total
Primary vehicles	450	2,550
Engines	700	1,400
Transmission and angle drive	438	875
Retarders	0	0
Axle gears	2,600	2,600
Air drag	380	2,240
Tyres[60]	479,000	479,000
Electric energy converters (e-motors)	25	25
RESS	25	25

The cost of component certification is important to consider in order to assess the economic feasibility of the proposed extension to Regulation (EU) 2017/2400. Therefore, the survey respondents were asked to provide the minimum and maximum cost per certification for each component manufactured (see Table 36).

For the single manufacturer that provided estimates for the certification of e-motors, the manufacturer indicated that uncertainty surrounding the methods for certification limits the

[60] The European Tyre & Rubber Manufacturers Association (ETRMA) does not have the data on manufactured OE tyres. The data reported (740,000 for buses) are approximate values for the sold OE tyres. In addition, the data cannot split by vehicle category, as ETRMA does not know which vehicle the tyres are mounted on. Therefore, in line with the split of vehicle categories manufactured by the survey respondents, 65% of the tyres manufactured have been allocated to high floor heavy buses (and the remaining 35% to low floor heavy buses).

accuracy of the estimates provided. No estimates were provided for RESS, with one manufacturer noting that these estimates are not yet available[61].

Table 36: Current component costs for vehicle and component manufacturers

Component	Minimum cost per certification (€)	Maximum cost per certification (€)	Average cost per certification (€)	Average number of sold components per certificate	Percentage of components which do not use certified values (%)
Engine	15,000	114,000	64,500	1,500 – 8,750	
Transmission and angle drive	25,200	50,000	37,600	1,000 – 5,830	
Retarder	25,000	25,000	25,000		
Axle gear	3,080	25,000	14,040	1,000 – 2,500	
Air drag	15,000	80,000	47,500	115 – 1,000	0 – 25
Tyres	1,500	1,500	1,500		4
Electric energy converters (e-motors)	50,000	100,000	75,000		

These results were compared against the feedback received from manufacturers under the earlier study on the previous proposed revision of Regulation (EU) 2017/2400. In addition to the survey responses received from manufacturers, component certification costs were also independently assessed by the consortium team under the previous study (as summarised in Table 37). These values are based on a combination of the assessment of the survey responses under the earlier SR15 study, and expert knowledge obtained from other projects and experience. The key variations from the survey median data include the costs of certifying engines and air drag, where it was determined that the median estimates from the respondents was relatively high.

Table 37: SR15 estimates of component certification costs from the consortium team

	Cost for certification of a single component (€/component)			Comments
	Standard price	Range lower value	Range upper value	
Engines	75,000	50,000	100,000	Note 1
Gear boxes	35,000	30,000	70,000	
Axles	30,000	30,000	40,000	Note 2
Air drag	60,000	40,000	80,000	Note 3
Tyres	750	750	750	

Note 1: For an engine certification, the figure of € 75,000 ± € 25,000 was seen as reasonable. It was noted that this was the highest cost for any individual component. These estimates consider the fact, that for lower ratings inside an engine family only a reduced set of tests has to be performed in the certification according to Annex V of Regulation (EU) 2017/2400.

Note 2: Certification requires axles to be run for 10 hours or 100 hours – this is the principal source of the range given.

[61] These statements on the uncertainties in the certification costs for electrical components are understandable, as the test procedures in Annex Xb were only roughly defined at the time of the survey, and in particular, important framework conditions, such as family concepts or scalability, had not yet been defined.

Note 3: For a large manufacturer, an air drag certification was estimated to cost around € 40,000, whereas for a small manufacturer, an air drag certification was estimated to cost around € 80,000. This reflects the fact that usually, more than a single constant speed test is performed for certification of a specific CdxA value. Large original equipment manufacturers (OEMs) might test several vehicles in parallel, so the cost for the test track infrastructure is reduced.

The results from the survey under the current study are comparable to the estimates from the SR15 study, indicating that these estimates align with the expert knowledge adopted by the consortium team under the previous study.

Under the previous study, estimates for the average certification cost per produced component were developed, through use of the following equation:

$$\frac{\text{Cost for each certification}}{(\text{Number of components produced per year} \times \text{Average lifespan per certification})}$$

This gives the vehicle component certification costs for the component cost scenario where certified VECTO input data are the key input data (Case A). An alternative approach uses standard values as VECTO input, where possible (Case B). Other VECTO input data were estimated to require no significant direct cost, or in the case of the transmission and axle, a small fee may be charged. The consortium's expert judgement is that a consultancy fee of €500 applying to 100 components is an appropriate estimate for these two components, as displayed in Table 39. Table 39 draws upon the average values provided by survey respondents under the existing study.

From these two VECTO input data scenarios, using certified or standard values input data, the component costs of certification were estimated for three separate scenarios. These scenarios draw upon standard values and certified data to varying extents. For each scenario, the percentage shares of the "certified" and "standard" data are given with the resulting cost for each component, and the resulting "total cost per vehicle certification". These scenarios are outlined in Table 38**.**

Table 38: Scenarios considered to estimate component costs

Scenario	Description
Scenario 1	For vehicle body only, the lowest certification cost of all three scenarios, using principally "standard data" VECTO inputs.
Scenario 2	A more realistic scenario for city buses (where air drag certification is not required) or for medium lorries using default air drag data.
Scenario 3	A more realistic scenario for coaches (where standard air drag certification is not acceptable) or for medium lorries using bespoke air drag data.

Table 39 contains the certification costs for the individual components as determined in the current study. Table 40 presents the cost per certification per vehicle for each component, under the SR15 contract for each of the scenarios considered. Table 41 to Table 44 display the cost per certification per vehicle drawing upon survey data from this study, for conventional vehicles, HEVs, BEVs with standalone units and BEV IEPCs respectively.

Table 39: Component certification costs

	Case A. Component cost scenario where VECTO input data is certified				Case B: Component cost scenario where VECTO input data is based on standard values		
Component	**€ / set of VECTO input data**	**Average number of produced components per year per set of VECTO input data**	**Number of years before new set of VECTO data is needed**	**Certification costs per produced component**	**€ / set of VECTO input data**	**Average number of produced components per set of VECTO input data**	**Certification costs per produced component**
Engine	€ 64,500	5,125	2.5	€ 5.03	Not available	Not relevant	€ 0
Transmission	€ 37,600	3,415	3.0	€ 3.67	€ 500	100	€ 5
Retarder	€ 25,000	1,000[62]	3.0	€ 8.33	€ 0	Not relevant	€ 0
Axle gear	€ 14,040	1,750	3.0	€ 2.67	€ 500	100	€ 5
Air drag	€ 47,500	558	3.0	€ 28.38	€ 0	Not relevant	€ 0
Tyres	€ 1,500	100,000[63]	Not relevant	€ 0.02	€ 0	Not relevant	€ 0
Auxiliaries	Not relevant	Not relevant	Not relevant	€ 0	€ 0	Not relevant	€ 0
E-motors	€ 75,000	1,000[64]	3.0[65]	€ 25	€ 500	100[66]	€ 5
IEPCs	€ 150,000[67]	2,500[68]	3.0	€ 20	€ 1,500[69]	100	€ 15
RESS	€ 10,000[70]	10,000[71]	1.5[72]	€ 0.67	€ 50	100	€ 0.50

[62] Value from the SR15 study is used, due to lack of inputs received from survey respondents.
[63] Value from the SR15 study is used, due to lack of inputs received from survey respondents.
[64] Consortium estimate, considered to be very uncertain.
[65] Consortium estimate (as for transmissions).
[66] Consortium estimate (as for transmissions). Family size will be smaller than for certified e-motors, which is one of the arguments not to go for certification.
[67] Consortium estimate. Builds up on e-motor test but to be measured for several gears and with high torque ranges for dyno.
[68] Consortium estimate. Assumed to be in the middle between ICEs and transmissions.
[69] Consortium estimate. Standard values for IEPCs consist of standard values per e-motor plus standard values for transmissions plus standard values for axles plus conversion. Rules from different powertrain reference points.
[70] Consortium estimate. No moving parts, no torque measurement units. However, testing duration in a range of a few days.
[71] Consortium estimate. Battery submodules which are tested, so the numbers here are multiples to equipped vehicles.
[72] Consortium estimate. A rapid development of batteries is assumed in the next 5 years.

Table 40: Cost of certification per vehicle for each component under the SR15 contract[73]

		Scenario 1: Chassis only standard values (minimal cost scenario)			Scenario 2: More realistic scenario (city buses, CdxA not relevant) or medium lorry if standard CdxA value is used			Scenario 3: More realistic scenario (coaches, standard CdxA value not acceptable) or medium lorry if a measured CdxA value is used		
	Number of components per vehicle	% "Certified data"	% "Standard data"	Cost per average component(s)	% "Certified data"	% "Standard data"	Cost per average component(s)	% "Certified data"	% "Standard data"	Cost per average component(s)
Engine	1	100%	0%	€ 9.60	100%	0%	€ 9.60	100%	0%	€ 9.60
Transmission	1	0%	100%	€ 5	67%	33%	€ 9.44	67%	33%	€ 9.44
Retarder	1	0%	100%	€ 0	67%	33%	€ 4.44	67%	33%	€ 4.44
Axle gear	1	0%	100%	€ 5	67%	33%	€ 8.33	67%	33%	€ 8.33
Air drag	1	0%	100%	€ 0	0%	100%	€ 0	100%	0%	€ 100
Tyres	6	0%	100%	€ 0	100%	0%	€ 0.05	100%	0%	€ 0.05
Auxiliaries	Not relevant	0%	100%	€ 0	0%	100%	€ 0	0%	100%	€ 0
		Total cost per vehicle		**€19.60**	**Total cost per vehicle**		**€31.87**	**Total cost per vehicle**		**€131.87**

[73] Only conventionally-fuelled vehicles were assessed under the SR15 contract.

Table 41: Cost of certification per vehicle for each component under existing contract – conventional vehicles

		Scenario 1: Chassis only standard values (minimal cost scenario)			Scenario 2: More realistic scenario (city buses, CdxA not relevant) or medium lorry if standard CdxA value is used			Scenario 3: More realistic scenario (coaches, standard CdxA value not acceptable) or medium lorry if a measured CdxA value is used		
	Number of components per vehicle	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**
Engine	1	100%	0%	€ 5.03	100%	0%	€ 5.03	100%	0%	€ 5.03
Transmission	1	0%	100%	€ 5	67%	33%	€ 4.11	67%	33%	€ 4.11
Retarder	1	0%	100%	€ 0	67%	33%	€ 5.56	67%	33%	€ 5.56
Axle gear	1	0%	100%	€ 5	67%	33%	€ 3.45	67%	33%	€ 3.45
Air drag	1	0%	100%	€ 0	0%	100%	€ 0	100%	0%	€ 28.38
Tyres	6	0%	100%	€ 0	100%	0%	€ 0.09	100%	0%	€ 0.09
Auxiliaries	Not relevant	0%	100%	€ 0	0%	100%	€ 0	0%	100%	€ 0
		Total cost per vehicle		**€ 15.03**	**Total cost per vehicle**		**€ 18.24**	**Total cost per vehicle**		**€ 46.62**

Table 42: Cost of certification per vehicle for each component under existing contract – HEVs

		Scenario 1: Chassis only standard values (minimal cost scenario)			Scenario 2: More realistic scenario (city buses, CdxA not relevant) or medium lorry if standard CdxA value is used			Scenario 3: More realistic scenario (coaches, standard CdxA value not acceptable) or medium lorry if a measured CdxA value is used		
	Number of components per vehicle	% "Certified data"	% "Standard data"	Cost per average component(s)	% "Certified data"	% "Standard data"	Cost per average component(s)	% "Certified data"	% "Standard data"	Cost per average component(s)
Engine	1	100%	0%	€ 5.03	100%	0%	€ 5.03	100%	0%	€ 5.03
Transmission	1	0%	100%	€ 5	67%	33%	€ 4.11	67%	33%	€ 4.11
Retarder	1	0%	100%	€ 0	67%	33%	€ 5.56	67%	33%	€ 5.56
Axle gear	1	0%	100%	€ 5	67%	33%	€ 3.45	67%	33%	€ 3.45
Air drag	1	0%	100%	€ 0	0%	100%	€ 0	100%	0%	€ 28.38
Tyres	6	0%	100%	€ 0	100%	0%	€ 0.09	100%	0%	€ 0.09
Auxiliaries	Not relevant	0%	100%	€ 0	0%	100%	€ 0	0%	100%	€ 0
E-motors	1	0%	100%	€ 5	67%	33%	€ 18.40	67%	33%	€ 18.40
RESS	2	0%	100%	€ 1	67%	33%	€ 1.22	67%	33%	€ 1.22
		Total cost per vehicle		**€ 21.03**	**Total cost per vehicle**		**€ 37.87**	**Total cost per vehicle**		**€ 66.24**

Table 43: Cost of certification per vehicle for each component under existing contract – BEV standalone units

		Scenario 1: Chassis only standard values (minimal cost scenario)			Scenario 2: More realistic scenario (city buses, CdxA not relevant) or medium lorry if standard CdxA value is used			Scenario 3: More realistic scenario (coaches, standard CdxA value not acceptable) or medium lorry if a measured CdxA value is used		
	Number of components per vehicle	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**
Engine	0	100%	0%	€ 0	100%	0%	€ 0	100%	0%	€ 0
Transmission	1	0%	100%	€ 5	67%	33%	€ 4.11	67%	33%	€ 4.11
Retarder	1	0%	100%	€ 0	67%	33%	€ 5.56	67%	33%	€ 5.56
Axle gear	1	0%	100%	€ 5	67%	33%	€ 3.45	67%	33%	€ 3.45
Air drag	1	0%	100%	€ 0	0%	100%	€ 0	100%	0%	€ 28.38
Tyres	6	0%	100%	€ 0	100%	0%	€ 0.09	100%	0%	€ 0.09
Auxiliaries	Not relevant	0%	100%	€ 0	0%	100%	€ 0	0%	100%	€ 0
E-motors	1.5	0%	100%	€ 7.50	67%	33%	€ 27.60	67%	33%	€ 27.60
RESS	4	0%	100%	€ 2.00	67%	33%	€ 2.45	67%	33%	€ 2.45
		Total cost per vehicle		**€ 19.50**	**Total cost per vehicle**		**€ 43.26**	**Total cost per vehicle**		**€ 71.63**

Table 44: Cost of certification per vehicle for each component under existing contract – BEV IEPCs

		Scenario 1: Chassis only standard values (minimal cost scenario)			Scenario 2: More realistic scenario (city buses, CdxA not relevant) or medium lorry if standard CdxA value is used			Scenario 3: More realistic scenario (coaches, standard CdxA value not acceptable) or medium lorry if a measured CdxA value is used		
	Number of components per vehicle	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**	**% "Certified data"**	**% "Standard data"**	**Cost per average component(s)**
Engine	0	100%	0%	€ 0	100%	0%	€ 0	100%	0%	€ 0
Transmission	0	0%	100%	€ 0	67%	33%	€ 0	67%	33%	€ 0
Retarder	0	0%	100%	€ 0	67%	33%	€ 0	67%	33%	€ 0
Axle gear	0	0%	100%	€ 0	67%	33%	€ 0	67%	33%	€ 0
Air drag	1	0%	100%	€ 0	0%	100%	€ 0	100%	0%	€ 28.38
Tyres	6	0%	100%	€ 0	100%	0%	€ 0.09	100%	0%	€ 0.09
Auxiliaries	Not relevant	0%	100%	€ 0	0%	100%	€ 0	0%	100%	€ 0
E-motors	0	0%	100%	€ 0	67%	33%	€ 0	67%	33%	€ 0
IEPCs	1	0%	100%	€ 15	67%	33%	€ 18.35	67%	33%	€ 18.35
RESS	4	0%	100%	€ 2	67%	33%	€ 2.45	67%	33%	€ 2.45
		Total cost per vehicle		**€ 17**	**Total cost per vehicle**		**€ 20.89**	**Total cost per vehicle**		**€ 49.26**

Under the context of the existing study, type-approval authorities were also asked to provide data relating to the number of components certified in 2019 (see Table 45). For future certification, type-approval authorities indicated that no forecasts were available, with the exception of one authority. This authority indicated that they expected their organisation to certify two air drag and two tyre components for medium lorries, and one air drag and one tyre component for low floor heavy buses per year, when the planned amendment of Regulation (EU) 2017/2400 becomes applicable.

It is important to note that the data presented below are only partial, as the type-approval authorities which responded to the survey do not comprise the entire European market, and therefore, it can be assumed that transmission and axle gear components are being certified by other type-approval authorities which did not respond to the survey.

Table 45: Components/STUs/systems certified under Regulation (EU) 2017/2400 in 2019

Component	Median	Total
Engine	3	6
Transmission and angle drive	0	0
Retarder	2	2
Axle gear	0	0
Air drag	22.5	45
Tyres	39	39

The costs faced by type-approval authorities and technical services as a result of the certification process include the cost of granting the certification, as well as the costs associated with witnessing the certification and developing the test reports.

Two type-approval authorities provided estimates for the costs per certification associated with granting a certification (see Table 46). These estimates do not include the costs associated with travel to and from, attendance at, and reporting of the certification. Therefore, they cannot be deemed to be representative of the full costs to type-approval authorities and their technical services.

As such, it can be expected that the cost per certification is likely to range from € 1,500 – € 3,500 for the majority of components (e.g. engine, transmission, axle gear, air drag). This accounts for the basic fee for certification (€ 550), as well as costs associated with witnessing the certification measurement, travel, accommodation and daily allowance costs, post processing and creating the report.

In regard to the costs associated with witnessing the certification and developing test reports for e-motors and RESS components, one type-approval authority indicated that the cost per certification for e-motors was € 3,000 – € 5,000, whilst the cost per certification for RESS was estimated at € 3,000 – € 4,000.

Table 46: Current component costs for type-approval authorities

Component	Minimum cost per certification (€): Granting a certification	Maximum cost per certification (€): Granting a certification
Engine	300	500
Transmission and angle drive	300	500
Retarder	300	500
Axle gear	300	500
Air drag	300	500
Tyres	300	500
Electric energy converters (e-motors)	300	5,000[74]
RESS	300	2,000[75]

Working document 3[76] outlines the additional information which manufacturers are required to store from the simulation tool in relation to ADAS. The costs associated with the proposed extended scope of HDV CO_2 determination are expected to be negligible for vehicles with ADAS, a statement which two out of four type-approval authorities supported (with the remaining two indicating that they 'do not know'). However, in regard to WHR and dual-fuel engines, two of the type-approval authorities indicated that costs will be incurred as a result of the tests needed for these new technologies. Neither of the authorities provided quantification for these test costs[77]. Two out of the four type-approval authorities indicated that 100% of the costs associated with component/STU/system certification will be borne by the vehicle and component manufacturers, whilst the remaining two authorities indicated that they 'do not know'.

6.4.2 VTP costs

The VTP is an on-road test to verify CO_2 emissions of new vehicles following production, to be carried out by vehicle manufacturers. Annex Xa of Regulation (EU) 2017/2400 specifies the VTP currently required for heavy lorries. A modification of the VTP for heavy lorries has been proposed, to augment the existing test procedure by including portable emissions measurement systems (PEMS). It was also proposed to extend the VTP to

[74] The higher maximum cost is due to an uneven distribution of responses from type-approval authorities, as one stakeholder only provided responses for e-motors and RESS, and therefore, the higher range of costs provided by this stakeholder for the two components distort the component costs. It can be assumed that these two components would not result in significantly higher costs than the remaining components.

[75] As above.

[76] Working document 3 (Annex 3): Input information relating to the characteristics of the vehicle.

[77] The consortiums estimate regarding certification costs for dual-fuel and WHR engine is, that those will be only slightly higher than for conventional engines when assuming similar production numbers per certified unit. Additional costs affect only from a few additional measurement systems, but the general certification test remains the same.

include buses and medium lorries[78]. This will involve requiring manufacturers of these vehicle categories to test a certain number of vehicles. The final proposal is summarised in Table 48.

In the proposed extension to Regulation (EU) 2017/2400, the VTP will not apply to hybrid or battery electric vehicles of any of the above-mentioned vehicle categories.

The survey aimed to determine the costs associated with modification from the existing VTP for heavy lorries to the proposed new VTP, as well as the costs associated with the extension of the proposed new VTP to medium lorries and heavy buses.

It is assumed that there are no vehicle availability costs or additional administrative costs for type-approval authorities, or their technical services witnessing the amended VTP, as VTP testing is already required. This assumption was not challenged by any of the survey respondents, and one type-approval authority stated their view that any potential costs relating to necessary discussions between type-approval authorities and OEMs will be borne by the OEM. In addition, it is assumed that there are no additional costs for manufacturers associated with running the VECTO tool, under the proposed amended VTP, as this is already required under Regulation (EU) 2017/2400.

In regard to the additional costs for heavy lorries, the total costs were estimated to be approximately € 8,750 per vehicle by the survey respondents. One vehicle manufacturer noted that the costs for preparing a vehicle for testing according to the modified VTP at an external lab would cost approximately € 20,000 per vehicle (relative to their estimated € 3,000 – € 4,000 per vehicle).

Table 47: Direct costs associated with the proposed VTP for heavy lorries

VTP component	Average cost estimated (€) per vehicle
Additional costs of preparing a single vehicle for testing according to the modified VTP procedure, principally involved with fitting the PEMS to the vehicle	2,750
Additional costs of testing a single vehicle according to the proposed modified VTP (i.e. principally the additional costs of using a PEMS)	4,000
Additional costs, per vehicle tested, for evaluating the PEMS data, and reporting it	2,000
Total	**8,750**

In regard to the costs for heavy buses, estimates ranged from € 9,000 to € 20,000 per vehicle. However, this does not include the costs for making a vehicle available. These estimates varied widely from € 7,000 to € 25,000, bringing the total range of the cost per vehicle to € 16,000 to € 45,000.

Annex 10a outlines the testing requirements, which vary depending on vehicles produced per year (see Table 48).

[78] As already mentioned above, the VTP for heavy buses is no longer included in the latest draft of Annex 10a. The analyses carried out for this scenario are nevertheless presented here.

Table 48: Determination of the minimum number of vehicles to be tested by the vehicle manufacturer

Number of vehicles to be tested	Schedule	Verification testing procedure relevant vehicles produced per year
0	-	≤ 25
1	Every 3 years	26 – 250
1	Every 2 years	251 – 5,000
1	Every year	5,001 – 25,000
2	Every year	25,001 – 50,000
3	Every year	50,001 – 75,000
4	Every year	75,001 – 100,000
5	Every year	> 100 000

For a large volume bus manufacturer making approximately 2,000 vehicles a year, it would be necessary to test one vehicle every two years (i.e. VTP costs would accrue over 4,000 vehicles manufactured, and would be € 4 – € 11 per vehicle (i.e. negligible)). However, for a small volume manufacturer making 260 vehicles per year, the manufacturer would similarly need to test one vehicle every two years (i.e. VTP costs would accrue over 520 vehicles, and would be € 31 – € 87 per vehicle). This is a small fraction of the price of a heavy bus, which tend to cost several hundred thousand Euros.

The medium lorry manufacturer that responded to the survey did not provide estimates for the costs associated with the proposed VTP. The costs associated with VTP were not assessed under the earlier study, and therefore, a comparison to earlier findings cannot be made.

Table 49: Direct costs associated with the proposed VTP for heavy buses

VTP component	Estimated cost (€) per vehicle		
	Minimum	Maximum	Average
Administrative costs per vehicle tested associated with the proposed VTP (i.e. costs for TAA or their technical service witnessing)	1,000	11,500	5,167
Costs associated with validating input data of the vehicle according to the provisions in points 6.1.1.1 (Verification of components, separate technical units or systems and input data and information) and 6.1.1.2 (Verification of the vehicle mass) of working document 10a	1,000	1,000	1,000
Costs associated with making each vehicle available for the proposed VTP (i.e. value lost from selling a used vehicle after some run-in from testing), on a per vehicle basis	7,000	25,000	16,000

VTP component	Estimated cost (€) per vehicle		
	Minimum	**Maximum**	**Average**
Cost of preparing a single vehicle for testing according to the proposed VTP procedure (including measurement equipment costs, mounting the sensors and PEMS system to the vehicle, i.e. all preparation costs)	2,000	10,000	6,000
Costs of testing a single vehicle according to the proposed VTP (except points 6.1.1.1 and 6.1.1.2 as listed above)	2,000	3,000	2,500
Costs per vehicle tested for data evaluation, reporting and running the VECTO tool, under the proposed VTP	2,000	5,750	3,917
Total	**15,000**	**56,250**	**34,584**

6.4.3 Overhead costs

Annex II of Regulation (EU) 2017/2400 outlines the current requirements and procedures related to the operation of the simulation tool for the calculation of CO_2 emissions and fuel consumption of specific HDVs. The proposed extension of the HDV CO_2 determination is expected to lead to overhead costs for vehicle manufacturers, as processes will need to be set up or amended, with a view to the operation of the simulation tool.

For example, to ensure the necessary data and systems are in place to enable manufacturers to utilise VECTO, it is expected that developments in data management systems will need to take place to facilitate the handling and storage of data, as well as the retrieving of input information and calculations. In addition, keeping abreast of the legislative amendments and allocating staff training time for operating the simulation tool are also expected to incur overhead costs.

Vehicle and component manufacturers were asked to provide estimates of the annual overhead costs for the four aspects listed in Section 1.1 of Annex II (covering sourcing, handling and retrieving input information and data), and of keeping abreast of the amendments to the Regulations. These estimates were within the same range, regardless of whether the organisation currently manufacturers heavy lorries and their components certified under Regulation (EU) 2017/2400. One manufacturer, which does not currently manufacture vehicles under Regulation (EU) 2017/2400, estimated that the total overhead costs would equate to € 840,000. For the organisations which already manufacture vehicles under the scope of the Regulation, annual overhead costs were estimated at € 640,000 – € 1,000,000.

As heavy bus production numbers range between 527 and 2,212 between manufacturers, annual costs per vehicle are estimated at € 452 – € 1,594 per vehicle (with the smaller manufacturers bearing the larger costs). In addition to this, the manufacturers also incur the one-off costs of setting up new processes for buses/coaches and extending the process for trucks to cover electric powertrain technologies. One manufacturer estimated this cost to be € 1.7 million. In addition, one manufacturer indicated that additional overhead efforts are required, as a result of the need to introduce Product Lifecycle Management (PLM) systems to facilitate a more efficient (and less manual) process for the management of data. The manufacturer does not currently produce vehicles certified under Regulation (EU) 2017/2400, and estimated that the associated annual cost for the PLM system would be € 400,000.

Under the previous SR15 contract, cost estimates of approximately € 500 per vehicle for a small enterprise manufacturing 200 buses a year, and a cost of around € 110 per vehicle for a medium enterprise manufacturing 2,500 buses a year were presented. The estimates obtained from this more detailed survey are considerably higher, yet within a factor of five of the estimates from the earlier survey.

Table 50: Estimated overhead costs for organisations that do not currently manufacture vehicles/components certified under Regulation (EU) 2017/2400

Cost type	Annual costs
Annual costs associated with keeping abreast of the amendments to legislative and strategic affairs (i.e. annual cost of staff employed to oversee legislative and strategic affairs)	65,000
Annual costs associated with providing a data management system (as per Section 1.1.1 of Annex II) covering sourcing, handling and retrieving input information and data	200,000
Annual costs associated with providing a data management system (as per Section 1.1.2 of Annex II) covering retrieving of the input information and calculations	100,000
Annual costs associated with providing a process for consulting (as per Section 1.1.3 of Annex II) the dedicated electronic distribution platform	50,000
Annual costs associated with providing staff training (as per Section 1.1.4 of Annex II) for working with the simulation tool	15,000
Annual costs associated with the fees paid to technical services /type-approval authorities for audits and consulting in relation to the verification of processes above (as per Section 2.1 of Annex II) assuming that 4 audits per year will take place	10,000
Additional costs	400,000
Total	**840,000**

Table 51: Estimated overhead costs for organisations that do currently manufacture vehicles/components certified under Regulation (EU) 2017/2400

Cost type	Minimum (€)	Maximum (€)	Average (€)
Annual costs associated with keeping abreast of the amendments to legislative and strategic affairs (i.e. annual cost of staff employed to oversee legislative and strategic affairs)	170,000	200,000	185,000
	100,000	420,000	260,000
Annual costs associated with amending a data management system (as per Section 1.1.2 of Annex II) covering retrieving of the input information and calculations	100,000	100,000	100,000
Annual costs associated with amending a process for consulting (as per Section 1.1.3 of Annex II) the dedicated electronic distribution platform	100,000	170,000	135,000
Annual costs associated with providing staff training (as per Section 1.1.4 of Annex II) for working with the simulation tool	100,000	100,000	100,000
Annual costs associated with the fees paid to technical services/type-approval authorities for audits and consulting in relation to the verification of processes above (as per Section 2.1 of Annex II) assuming that 4 audits per year will take place	40,000	240,000	140,000
Additional costs	0	0	0
Total	**610,000**	**1,230,000**	**920,000**

The considerations made here on overhead costs are based on the provisions on process license as defined in the current Annex II of Regulation (EC) 2017/2400. For the extension to heavy buses, it is discussed to define less strict requirements for the process license, especially for smaller manufacturers who are only involved in manufacturing the vehicles body (interim or completed manufacturers). Depending on the new set of provisions regarding Annex II points 1.1.2 to 1.1.4, Table 50 could be used to estimate approximately how much the overhead costs would be reduced by a "light license".

Regarding overhead costs related to type-approval authorities only a single institution attempted to quantify the overhead costs which would face their organisation. They indicated that annual costs associated with keeping abreast of the amendments to legislative and strategic affairs were likely to equate to € 5,000, annual costs associated with data exchange and management were estimated at € 10,000 and annual costs associated with providing staff training to cover the increase in demand for witnessed certifications were estimated at € 5,000, resulting in a sum of € 20,000 on an annual basis. Another type-approval authority noted that they expect to engender costs related to keeping abreast of amendments to legislative and strategic affairs, and with providing staff training. However, the authority did not quantify the costs.

6.4.4 Summary of costs

Sections 6.4.1 to 6.4.3 have provided a summary of the survey results and further analysis with regard to the direct costs associated with the proposed extension to Regulation (EU) 2017/2400. The variation in responses reflects the varying remit of each manufacturer, type-approval authority or NGO. This section provides a summary of these costs, and indicates the relative contribution of the different cost components to the overall costs.

Upon questioning the vehicle and component manufacturers and type-approval authorities on their perception of the most significant costs to their company, responses varied. Multiple respondents referred to the cost of developing or amending a data management system, as per Section 1.1.1 of Annex II. The cost of component certification was another prominent response from a number of manufacturers. On a per vehicle basis, the costs associated with the proposed extension to the VTP were also expected to be significant.

The quantitative costs have been discussed in the preceding subsections. Figure 28 provides an overall view of the cost estimates provided by vehicle and component manufacturers for heavy lorries, buses and medium lorries, and the consultant team's view.

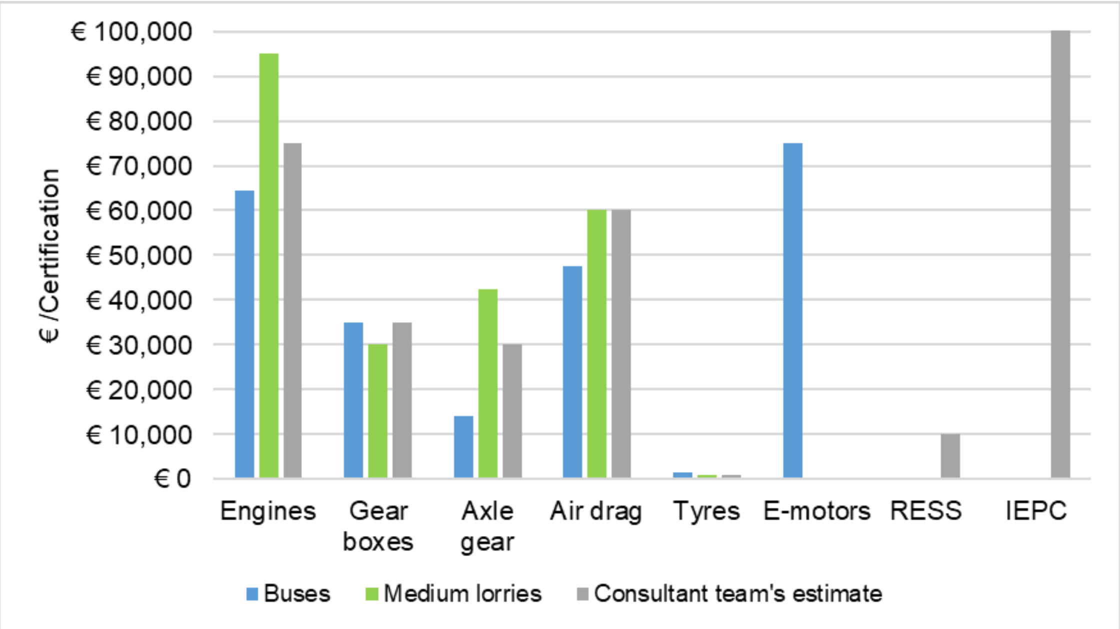

Figure 28: Relative costs per vehicle model of certifying components for buses and medium lorries

Figure 29 also provides, for comparison, the costs of certifying all the components on a whole vehicle basis for the three scenarios, drawing upon the data presented in Table 41.

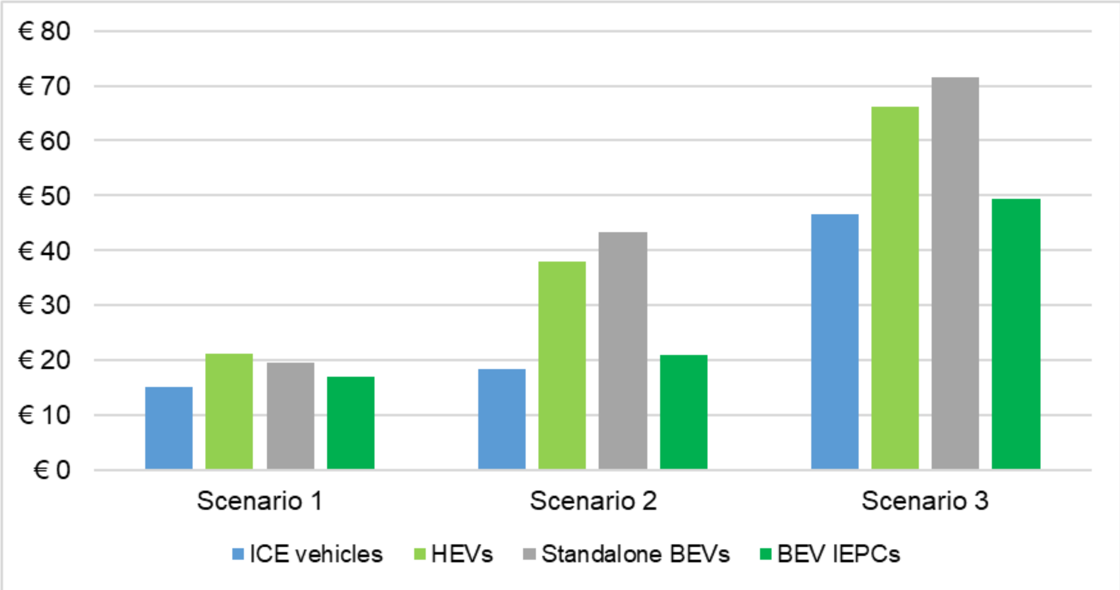

Figure 29: Average certification costs for each scenario

A summary of the overall cost of certifying the components within a vehicle for the three vehicle category scenarios, the overhead costs of running the CO_2 certification according to the potential extension of Regulation (EU) 2017/2400, and the cost estimates for the proposed extension to the VTP, are provided in Table 52, Table 53 and Table 54 respectively.

Table 52: Summary of component certification costs for running the CO_2 determination, on a per vehicle basis

Vehicle scenario	Costs per vehicle				Comments
	ICE vehicle	HEV	BEV standalone	BEV IEPC	
Scenario 1: Vehicle using standard values as far as possible	€ 15.03	€ 21.03	€ 19.50	€ 17.00	N/A
Scenario 2: Typical "low floor" bus (city bus) using standard value for Cd x A	€ 18.24	€ 37.87	€ 43.26	€ 20.89	N/A
Scenario 3: Typical "high floor" bus (coach) using certified value for Cd x A	€ 46.62	€ 66.24	€ 71.63	€ 49.26	N/A
Scenario 2: Medium lorry using standard value for Cd x A	€ 18.24	€ 37.87	€ 43.26	€ 20.89	Same as for "low floor" bus
Scenario 3: Medium lorry using certified value for Cd x A	€ 46.62	€ 66.24	€ 71.63	€ 49.26	Same as for "high floor" bus

About Table 53 it is important to note that the cost per vehicle facing small enterprises could fall considerably should the manufacturer produce a slightly higher number of vehicles than the 200 vehicles in the scenario presented. For example, one of the vehicle manufacturers which responded to the survey manufactures 527 high floor and low floor buses a year, and as such, the overhead cost per vehicle would equate to roughly € 1,600 for this manufacturer. As already state above, overhead costs for small manufacturer could furthermore be reduced by a "license light" to operate the simulation tool to be defined in Annex II of the Regulation.

Table 53: Summary of overhead costs for running the CO_2 determination, on a per vehicle basis

OEM scenario	Costs per vehicle	Comments
OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 368	Based on survey results
Medium enterprise (2,500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 336	Based on survey results
Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,200	Based on survey results

Table 54: Summary of VTP costs for running the CO_2 determination, on a per vehicle basis

OEM scenario	Costs per vehicle	Comments
OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 0.44	Assuming 60,000 vehicles are manufactured a year
Medium enterprise (2,500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 6.92	Assuming 5,000 vehicles are manufactured over 2 years
Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 57.64	Assuming 600 vehicles are manufactured over 3 years

The component certification costs, overhead costs and VTP costs are combined to give eight vehicle category combinations based on OEM size and experience for the certification cost per vehicle; these are shown in Table 55 below. This is displayed for ICEs, HEVs, standalone BEVs and BEV IEPCs. As can be expected already from the figures derived above in the report, the costs are largely determined by the overhead costs, and in this context decisively by the number of vehicles produced per year. As also already mentioned above, the high costs for small bus manufacturers, if they are only involved in the production of the vehicle body, could be significantly reduced by a "process licence light".

Table 55: Summary of combined costs of certification for running the CO_2 determination, on a per vehicle basis

Vehicle	Cat.	OEM size and experience	Total costs per vehicle			
			ICE vehicle	HEV	BEV standalone	BEV IEPC
Typical "low floor" bus (citybus)	1	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 386.68	€ 405.87	€ 411.26	€ 388.89
	2	Medium enterprise (2,500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 361.16	€ 373.87	€ 379.26	€ 356.89
	3	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,275.88	€ 4,237.87	€ 4,243.26	€ 4,220.89
Typical "high floor" bus (coach)	4	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 434.24	€ 439.63	€ 417.26
	5	Medium enterprise (2,500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 402.24	€ 407.63	€ 385.26
	6	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,304.26	€ 4,266.24	€ 4,271.63	€ 4,249.26
Typical medium lorry	7	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 434.24	€ 439.63	€ 417.26
	8	Medium enterprise (2,500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 402.24	€ 407.63	€ 385.26

6.5 Benefits from impact on greenhouse gas emissions and fuel costs

The proposed extension of Regulation (EU) 2017/2400 aims to elicit benefits, through supporting a reduction in tailpipe CO_2 emissions, which will benefit society as a whole, and fuel savings, which will accrue to the vehicle operators. Fuel savings may be estimated as a proportion of the CO_2 emissions for the vehicle categories involved, or on a per vehicle basis using average mileages and fuel consumption per vehicle category.

Under the European Green Deal, the Commission outlined a GHG emission reduction target for the transport sector of 90% by 2050, relative to 1990 levels. Lorries, buses and coaches are responsible for about a quarter of CO_2 emissions from road transport in the EU and for some 6% of total EU GHG emissions. Therefore, it is essential that transport-related CO_2 emissions are addressed.

The first EU-wide CO_2 emission standards for HDVs were adopted in 2019, which set targets for reducing the average emissions from new lorries, for 2025 and 2030. Expected benefits include around 54 million tonnes of CO_2 reduced in the period 2020 to 2030. From 2025 onwards, manufacturers will have to meet the targets set for the fleet-wide average CO_2 emissions of their new lorries registered in a given calendar year. Stricter targets will start applying from 2030 onwards. The targets are expressed as a percentage reduction of emissions compared to EU average levels in a given reference period (1 July 2019 – 30 June 2020): from 2025, a 15% reduction target applies, and from 2030 onwards, a 30% reduction target comes into force.

As a first step, the CO_2 emission standards will cover large lorries, which account for 65% to 70% of all CO_2 emissions from HDVs. As part of the 2022 review, the Commission will assess the extension of the scope to other vehicle types. Regulation (EU) 2017/2400 allows for the implementation of the emission standards, through providing the mechanism for the determination of the CO_2 emissions and fuel consumption of new lorries. Therefore, Regulation (EU) 2017/2400 has an important role to play, and its benefits are best understood through a consideration of its role in facilitating the CO_2 emission standards, rather than assessing its benefits in isolation.

This was noted by one NGO that completed the survey, in which they explicitly stated that the proposed extended scope of Regulation (EU) 2017/2400 to medium lorries, heavy buses and advanced technologies is a prerequisite to ensure wider adoption of CO_2 emission reduction technologies. The NGO suggested that the expected benefits will only arise if further complementary policy interventions are implemented, especially the extension of the CO_2 standards to other HDV segments.

A mixed level of response was received in regard to the expected benefits associated with extending CO_2 determination for HDVs. From the vehicle and component manufacturers which responded to the survey, 3 out of 9 indicated their expectation that the extension would result in fuel savings, 3 out of 9 indicated that they did not believe this would occur and three either indicated that they did not know, or did not provide a response. The survey respondents provided minimal quantification regarding the CO_2 reduction that would result from the proposed extension of Regulation (EU) 2017/2400 to buses and medium lorries. Of those that indicated that fuel savings would occur, one vehicle manufacturer indicated that fuel savings of between 1% and 4% (relative to business-as-usual), could be expected from providing customers with a higher level of information as a result of extending CO_2

determination for HDVs. One association indicated that it is difficult to quantify the expected fuel savings, as the consumer will not necessarily base their choice of replacement tyres on the fuel efficiency class of the tyres.

Table 56 provides estimates of the annual fuel costs for the different vehicle categories, together with the financial savings from an estimated 3% reduction in fuel consumed. This is based on estimating costs on a per vehicle basis, rather than as a proportion of the CO_2 emissions for the vehicle categories involved.

Table 56: Assumed characteristics of key vehicle segments and resulting potential fuel and economic benefits

Parameter	Medium lorry	Low floor heavy bus	High floor heavy bus
Annual distance travelled (km/year)	35,000	60,000	70,000
Average fuel economy (l/100km)	16.5	50.0	30.0
Average fuel price (€/litre)	1.28	1.28	1.28
Annual fuel costs (€/year)	€ 7,392.00	€ 38,400.00	€ 26,880.00
Savings from 3% improvement in fuel economy (€/year)	€ 221.76	€ 1,152.00	€ 806.40

These fuel cost savings benefit vehicle operators, rather than vehicle manufacturers. As such, fuel efficiency tends to play a significant role in purchase decisions made by vehicle operators, and these savings are likely to bring benefits to society as a whole through associated reductions in CO_2 emissions. For the three types of vehicle presented in Table 56, reductions in annual fuel consumption are estimated in Table 57. Using a standard emission factor of 1 litre of diesel being equivalent to 2.67 kg of CO_2 emissions, CO_2 emission reductions per vehicle per year have been estimated in Table 57.

Table 57: Potential benefits expressed as reductions in CO_2 emissions per vehicle

Parameter	Medium lorry	Low floor heavy bus	High floor heavy bus
Annual fuel consumption per year (litres)	5,775	30,000	21,000
3% saving (litres /year)	173.3	900.0	630.0
Reduction in CO_2 emissions (tonnes per vehicle per year)	0.5	2.4	1.7
Lifetime reduction in CO_2 emissions (tonnes per vehicle)	5.6	36.0	25.2

Note: Assuming a typical lifetime of 12 years for medium lorries and 15 years for buses.

The final manufacturer that expected fuel cost savings stated that including a common method to determine energy consumption for xEV[79] lorries is expected to, directly or indirectly, encourage further development of fuel- and energy-efficient customer offerings. The manufacturer also expressed that, for lorries, the direct effect on fuel costs of

[79] xEV is a term used to refer to all electric vehicle categories (e.g. PHEVs, BEVs).

additional information to customers is not expected to be very significant. However, the manufacturer stated that the indirect effect on the customer total cost of ownership (TCO), due to the impact of the CO_2 declaration on future taxation and road tolls, is expected be considerable, especially for HEVs. For buses, the manufacturer suggested that a higher level of information with regard to CO_2 declaration could have a direct effect on public procurement, supporting the use of the most fuel-efficient buses.

The manufacturer indicated that '*a precondition for the above effects is that the most energy- and fuel-efficient technology can be fully recognised and rewarded by VECTO'*. If a less efficient technology would appear to be a preferable choice, as a result of a lack of coverage by VECTO, the result would be counterproductive to cost and CO_2 emission reductions.

A similar split was visible for type-approval authorities, with 2 out of 4 indicating that they expected some fuel cost savings, one indicating that they did not expect savings and one stating that they did not know. None of these respondents provided quantification of fuel cost savings.

One NGO noted that greater transparency of the market (e.g. through certified CO_2 emissions) is likely to lead to increased fuel cost savings. However, the NGO noted the difficulty of quantifying emission reduction benefits without undertaking a comprehensive modelling study. The other NGO which responded to the survey stated that they did not know if fuel cost savings would be achieved.

6.6 Wider impacts

This subsection presents an assessment of the wider impacts associated with the extension of Regulation (EU) 2017/2400, namely the impact on third countries, SMEs, and competitiveness, innovation and employment in the sector.

6.6.1 Impact on competition and innovation

As fuel costs are a key consideration for operators when purchasing HDVs, it is important to assess the impact of the proposed extension on fuel savings. ACEA (2020) estimates that fuel costs comprise approximately 30% of running costs for trucks and buses, which is comparable to the labour costs associated with employing drivers. However, it is important to note that there are market barriers to the uptake of CO_2 savings, which the extension of the Regulation aims to overcome.

The potential extension of Regulation (EU) 2017/2400 will enable a more accurate comparison between vehicle types, through the use of a common assessment procedure. A more transparent HDV market is expected to encourage greater competition between manufacturers, stimulating innovation and therefore, enhancing the efficiency of HDVs in the market.

Vehicle and component manufacturers, type-approval authorities and NGOs provided their views on the expected impact of the proposed extension on competition and innovation through their responses to the survey. Of those that responded, the majority of manufacturers (4 out of 6) suggested that the proposed extension of Regulation (EU) 2017/2400 would not drive innovation, and two manufacturers stated that they did believe it would encourage growth in innovation.

Of the manufacturers that responded “no”, one manufacturer stated their view that regulatory changes tend to follow innovation (rather than vice versa). Another vehicle manufacturer noted that innovation in the HDV market is driven by customer preferences and the need to maintain low costs. They stated that a level playing field is a prerequisite to innovation, noting that if VECTO cannot model fuel-saving technologies, there is little incentive to innovate. The manufacturer suggested that a disparity in the treatment of existing technologies by Regulation (EU) 2017/2400, in a way that impacts consumer costs and society’s perceptions, is likely to hinder innovation by promoting less energy-efficient technologies. The manufacturer stated that this would be the case if the calculations of integrated and complex hybrids are not included in VECTO, but instead declared as “exempt”, while less energy-efficient hybrid solutions can be declared and benefit from tax incentives and lower road tolls.

Of those that responded “yes”, one manufacturer noted that improvements in competitiveness associated with Regulation (EU) 2017/2400 would lead to an increase in innovation, whilst another noted that the technologies accounted for in the proposed extension are expected to lead to reductions in vehicle CO_2 emissions, encouraging innovation.

From the perspective of type-approval authorities and their technical services, 3 out of 4 respondents stated that they believed extending Regulation (EU) 2017/2400 would drive innovation. The single respondent that stated that the proposed extension would not lead to innovation noted that it is important to consider NO_x emissions reduction, as well as CO_2 emissions reduction, when considering the potential impact of legislative change on innovation.

Both of the NGOs that responded to the survey indicated their view that the proposed extension would increase innovation in the HDV market. One NGO stated that greater transparency of the market, through certified CO_2 emissions, would lead to increased competition among manufacturers. The other NGO stated that the extension of Regulation (EU) 2017/2400 itself would be insufficient to drive the adoption of zero-emission technologies and other CO_2 emission reduction technologies, despite leading to greater levels of customer information. However, the NGO noted that the proposed extension is a prerequisite for further policy interventions, such as the extension of CO_2 standards, which are expected to drive innovation through incentivising the early adoption of zero- and low-emission technologies. In addition, the NGO also suggested that the proposed extension could lead to the introduction of monetary incentives for low-emission vehicles, such as the revised Eurovignette Directive which aims to adapt toll fees to HDV-specific emissions.

These findings largely reflect the conclusions from the earlier SR15 study. Similarly, under the earlier study, the vehicle and component manufacturers displayed a lower level of support relative to type-approval authorities, for the capacity of the proposed extension to drive innovation in the HDV market. The role of CO_2 standards, in driving innovation, was noted. In addition, the potential for regulatory change to stall innovation was also reflected.

6.6.2 Impact on employment

In the short-term, the impact on employment is expected to be minimal. In regard to policy-making, the Commission estimated that two additional full-time employees would be required in the European Environment Agency and one part-time employee in the

Commission to manage the initial implementation of Regulation (EU) 2017/2400 (European Commission, 2017). Therefore, although the proposed extension of Regulation (EU) 2017/2400 has the potential to require additional staff members, it is likely that this will come at negligible cost. In regard to the impact on employment in the HDV market more broadly, vehicle and component manufacturers, type-approval authorities and NGOs provided their views through the survey.

The majority of manufacturers merely indicated their anticipation that the proposed regulatory change would lead to 'no impact' on job growth in the sector (4 out of 7), without further comment. However, one vehicle manufacturer indicated that a 'significant negative impact' was likely to arise, suggesting that the proposed extension could prove to be a serious risk for SMEs. The remaining manufacturers stated that they 'do not know' what the impact on employment would be.

From the perspective of type-approval authorities, 2 out of 4 stated that a 'slight positive impact' could be expected. However, one type-approval authority stated that it is difficult to predict the expected impact on employment, noting that additional technologies result in the requirement for other type of jobs. This type-approval authority suggested that new specialisms often emerge in place of others (e.g. combustion engineers).

One NGO expressed that it is difficult to determine the expected impact on employment, yet suggests that increased competition between vehicle manufacturers will not lead to a change in production levels overall, and therefore it is unlikely to impact employment relating to production. However, another NGO stated that the extension of Regulation (EU) 2017/2040 to BEVs and HEVs could boost the uptake of zero-emission trucks in the EU, and in turn, could have a positive impact on job growth in the vehicle manufacturing industry. This is supported by a study completed by Cambridge Econometrics. The study found that the transition to low-carbon lorries in Europe could help to create over 120,000 jobs by 2030, depending on the balance achieved between different powertrain technologies and the degree to which they are imported or produced in Europe (Cambridge Econometrics, 2018).

These findings largely reflect the conclusions reached under the previous study, whereby the majority of respondents indicated their view that the earlier proposed extension would have a 'low effect (<0.1% change of employees)'. Under the previous study, some concern was raised around the potential for the proposed extension to reduce competitiveness through requiring an increase in employment to complete the same tasks, without resulting in a corresponding increase in market share.

6.6.3 Impact on third countries

There is potential that the extension of Regulation (EU) 2017/2400 will have an impact on third countries[80], through encouraging the adoption of similar certification procedures. Currently, a number of countries have implemented CO_2 standards and certification procedures for HDVs, including Japan, the US, Canada and China (ICCT, 2015).

[80] A country that is not a member of the European Union, as well as a country or territory whose citizens do not enjoy the European Union right to free movement.

Policymakers in India, Brazil and Argentina expressed an interest in exploring the feasibility of modifying VECTO for use in their HDV markets (ICCT, 2019).

The majority of countries with a similar level of market development to the EU already have a CO_2 HDV certification in place. However, many of the countries with existing HDV CO_2 certification have less sophisticated component certification procedures than are being proposed by the EU. Therefore, the EU could encourage international harmonisation of component CO_2 certification. In addition, the UK is now a third country, and the UK Government has indicated its intention to ensure that UK legislation is at least as ambitious as the regulatory regime in the EU, noting that simulation of CO_2 emissions and fuel consumption by VECTO will continue in a UK-only context (UK Department for Transport, 2020).

Vehicle and component manufacturers, type-approval authorities and NGOs provided their views on the impact on third countries, through the survey. The majority of manufacturers (5 out of 6) stated that they ‘did not know’ if the proposed extension would impact the competitiveness of the market in third countries. However, one manufacturer association noted that any additional administrative burden and negative impacts facing third countries could be minimised if the international harmonisation of CO_2 determination methodologies is ensured. The association stated that the use of VECTO input/output values could be used in respective regulatory measures in third countries, to facilitate harmonisation.

From the view of type-approval authorities, 2 out of 4 respondents indicated their view that the proposed extension would have a ‘slight positive impact’ on the competitiveness of the market in third countries. However, none of the type-approval authorities elaborated upon their response. Both of the NGOs that responded to the survey indicated that the proposed extension is likely to have a ‘significant positive impact’ on the competitiveness of third countries. One of the NGOs stated the international leadership of European lorry manufacturers will help to ensure that legislative measures aiming to boost innovation in the European vehicle manufacturing industry will enhance the competitiveness of third countries, as it is likely that CO_2 emission reduction technologies will be transferred to regions outside the EU.

These findings reflect the views expressed under the earlier study, where the need to facilitate international harmonisation of certification legislation was referenced. It was also noted that the proposed extension would have a particularly significant impact on third countries which adopt Regulation (EC) 595/2009 on the type-approval of motor vehicles and engines with respect to emissions from HDVs (e.g. Turkey, Switzerland). It was also suggested that there would be minimal to no impact on markets, such as the US, where certification legislation has been in place longer than in the EU.

6.6.4 Impact on international competitiveness of the EU industry

Drawing upon the expected impact of the proposed extension of Regulation (EU) 2017/2400 on competition and innovation in the HDV market, it is also likely that the competitiveness of EU exports will be affected by the proposed extension. The magnitude of this impact will be linked to the certification systems currently in place in the EU’s largest market competitors (e.g. US, Japan and China).

As noted in Section 6.6.2, the impact on innovation in the HDV sector could be influenced by the potential inclusion of all potentially upcoming fuel-saving technologies in VECTO. The inclusion of such fuel-saving technologies in VECTO could offer a greater incentive for manufacturers to invest in technological innovations, and in turn, enhance the international competitiveness of the EU HDV market.

Vehicle and component manufacturers, type-approval authorities and NGOs provided their views on the expected impact on international competitiveness through the survey. The responses were varied, with 3 out of 7 manufacturers suggesting that there would be 'no impact' on the international competitiveness of EU industry, two manufacturers stating that there would be a 'negative impact', and one manufacturer expecting a 'slight positive impact'. The manufacturer expecting a positive impact noted that the majority of European vehicle manufacturers operate internationally, and therefore, the proposed extension would be unlikely to have a negative impact on international competitiveness. One manufacturer association noted that particular attention should be paid to ensure international harmonisation of CO_2 determination methodologies, with the aim of aligning EU legislation with South Korea, China, Japan and other major markets. The association noted that the application of the methodologies adopted by EU legislation in third countries could help to avoid double testing and additional regulatory burden for manufacturers operating across international borders.

Of the type-approval authorities, 3 out of 4 respondents stated that a positive impact could be expected. However, none of the type-approval authorities elaborated upon their response. Both of the NGOs that responded to the survey stated that a 'significant positive impact' on the international competitiveness of the EU HDV market could be expected. One of the NGOs stated that improved fuel efficiency would enhance the competitiveness of European OEMs, and benefit the component manufacturers in the supply chain through facilitating a potential increase in production output.

Another NGO stated that the proposed extension of Regulation (EU) 2017/2400 is an essential step for ensuring that the HDV sector meets its CO_2 emissions reduction targets, as it plays a key role in enabling the implementation of the CO_2 standards. In addition, the NGO noted that, despite the leadership of European OEMs in manufacturing, China's market for zero-emission vehicles is very competitive. The NGO stated that there is potential to make greater use of financial incentives to support European OEMs in the transition towards the production of zero-emission lorries. In line with this, a report released by Cambridge Econometrics concluded that the transition to low-carbon lorries in Europe would lead to a consistent increase in GDP between 2030 and 2050 (Cambridge Econometrics, 2018).

The Commission's SWD(2017) 188 details the competitiveness challenges facing the EU HDV market, despite technical leadership in regard to fuel efficiency (European Commission, 2017). It is noted that European manufacturers face increasing competitive pressure, as the CO_2 emission standards implemented in markets such as the US, Canada, Japan and China have stimulated innovation in vehicle efficiency technologies. As the Commission moves towards alignment with the European Green Deal, and encourages the implementation of measures which facilitate the manufacture of low-emission vehicles, the potential for non-EU manufacturers to market less-efficient HDVs in Europe appears less likely.

These findings largely reflect the conclusions reached under the earlier study, with a similar variation in the potential impact on international competitiveness reached under the SR15 study. Manufacturers indicated the potential for component certification and overhead costs to accrue as a result on the proposed extension. However, it was expected that, in the long-term, as similar measures are implemented in third countries, the proposed extension will help to stimulate innovation and competitiveness.

It was expressed that the proposed extension was likely to drive a continuous improvement in vehicle energy efficiency and encourage the uptake of zero- and low-emission vehicles, allowing the EU to remain competitive with other international vehicle markets which have already introduced legislative measures relating to HDV CO_2 determination.

6.6.5 Potential disproportionate impact on SMEs

It is also essential to consider the impact of the proposed extension on SMEs. From the perspective of vehicle and component manufacturers, as expressed through the survey, 4 out of 7 respondents stated that they believed the extension was likely to disproportionately affect SMEs, with the remaining three stating that they ‘did not know’ if it would disproportionately affect SMEs.

One manufacturer association noted that SMEs, especially those involved in multi-stage production processes for buses, need to be adequately reflected in the proposed extension. One manufacturer suggested that VECTO could be adapted to the needs of SMEs, through simplifying the tool for their use and avoiding any unnecessary additional administrative costs. The manufacturer also suggested that the provision outlining the requirements for quarterly audits should be reviewed with respect to cost-effectiveness. Another manufacturer noted that the proposed extension would increase the requirements facing SME manufacturers, whilst another manufacturer stated that, as SMEs are not represented by an association, their views are not reflected in the proposed extension. It is important to note that none of the manufacturers responding to the survey are considered SMEs, as their staff headcounts exceed 250 employees.

From the perspective of type-approval authorities and their technical services, views were more disparate, with one respondent indicating their view that the proposed extension would disproportionately impact SMEs, one respondent indicating that this would not occur, and one respondent stating that they ‘did not know’. One type-approval authority stated that the burden associated with certification for SME manufacturers may be high, suggesting that exemptions should be considered for these manufacturers, based on annual production.

Both of the NGOs that responded to the survey suggested that SMEs would not be disproportionately impacted. One NGO stated that the proposed extension must include the necessary provisions to ensure that the costs incurred by SMEs are proportional to their size. In particular, the NGO suggested that the number of vehicles required to undergo the VTP must be adapted to the size of the fleet and the financial means of manufacturers. The NGO also stated that alternative means for certifying the performance of components and STUs should be considered, such as allowing SMEs to make use of computational fluid dynamics (CFD) to certify the aerodynamic performance of their components.

These varied findings reflect the conclusions of the earlier study. Similarly, the majority of manufacturers indicated their view that the extension was likely to disproportionately affect SMEs. Under the previous study, the general consensus was that the proposed extension was expected to generate a disproportionate impact on SMEs, many of which are involved in the multistage building of vehicles.

It was also noted that the magnitude of the impact on SMEs would depend on how the CO_2 declaration procedure is implemented, with one manufacturer suggesting that there is a trade-off between the potentially high volumes of VECTO input data (which could prove unmanageable for SMEs) and the alternative use of "standard values" which report systematically higher levels of CO_2 (which could damage their competitiveness). The magnitude of the impact was also considered to vary depending on whether the manufacturers already manufacture vehicles which require certification, as the additional requirement would be less burdensome.

6.6.6 Summary of wider impacts

Table 58 provides a summary of the benefits described in the preceding subsections, providing an overall view of the anticipated benefits.

Table 58: Summary of wider impacts

Impact	Description	Summary of expected impact
Impact on competition and innovation	Impact of proposed extension on competition and innovation within the sector	The proposed extension is expected to engender a positive impact on competition and innovation, through enhancing the transparency of HDV determination. However, it was noted that there is a need for VECTO to model all fuel-saving technologies, to incentivise innovation.
Impact on job growth	Additional jobs relating technical services, such as certification and job creation deriving from growth in innovation/competition	The proposed extension is expected to have minimal impact on employment in the sector. However, the potential inclusion of additional vehicle technologies could result in new types of specialisms being required, and the broader EU-level shift towards the uptake of low-emission vehicles is expected to create over 120,000 jobs by 2030.
Impact on third countries	Impact on third countries from adopting similar certification procedures (accounting for difference in vehicle types and the potential for regulation to already be in place)	Several third countries are ahead of the EU in terms of adopting HDV certification procedures. However, policymakers in India, Brazil and Argentina have expressed an interest in the feasibility of adopting a VECTO-like model. It will be necessary to encourage international harmonisation of certification procedures, to minimise any potential negative impacts facing third countries.
Impact on international competitiveness	International competitiveness of EU exports and the EU bus & medium lorry industry more broadly	There is potential for the proposed extension to enhance the international competitiveness of the EU, due to the increasing competitiveness of fuel-efficient technologies. This could allow the EU to address some of the competitive pressure which has arisen from key markets, such as the US, Canada, Japan and China, which have benefited

Impact	Description	Summary of expected impact
		from increasing levels of innovation and competitiveness due to the rise in vehicle efficiency technologies as a result of their emission standards.
Impact on SMEs	Distributional impact of the regulatory costs across SMEs (OEMs, body builders and component manufacturers)	The proposed extension is likely to disproportionately impact SMEs, through high levels of administrative burden, should the required procedures remain untailored to the needs of SMEs.

6.7 Conclusion

The potential extension of Regulation (EU) 2017/2400, to include lorries with a TPMLM in the range greater than 5 tonnes and up to 7.5 tonnes and heavy buses (M3 vehicles greater than 7.5 tonnes TPMLM), and new vehicle technologies, will engender a range of benefits and costs to OEMs, operators and policy-makers. As noted in the analysis, it is likely that the costs which accrue to type-approval authorities will be accrued to manufacturers. Therefore, it is likely that manufacturers will pass through a proportion of the costs faced to their consumers to facilitate compliance with the proposed extension, through higher prices.

The one-off upfront costs are substantial; however, the ongoing benefits of CO_2 emissions reduction and fuel efficiency improvements will prevail into the future. The pay-back period, in years, for the proposed extension of Regulation (EU) 2017//2400 has been estimated in Table 59**.** It is worth noting that Table 59 presents the results for conventional vehicles. The pay-back period for HEVs, BEV standalone units and BEV IEPCs is comparable to that of conventional vehicles, given the relatively small contribution of component costs to the overall costs associated with the proposed extension.

The pay-back periods range from under 1 year, to a maximum of 5 years. In typical investment appraisals investments are often categorised according to pay-back periods into:

- Pay-back period < 3 years: short pay-back period, attractive investment;
- Pay-back period > 3 and <5 years: moderate pay-back period;
- Pay-back period > 5 years: long pay-back period.

Therefore, it is seen that the proposed extension of CO_2 certification leads to significant per vehicle costs for small enterprises manufacturing either high floor or low floor buses, or medium lorries who are unfamiliar with HDV certification according to Regulation (EU) 2017/2400. This is reflected by the qualitative comments summarised in 6.6.5, on the views of manufacturers on the distributional impact of the proposed extension on SMEs. As outlined in this section, the Commission could tailor the requirements for SMEs, in particular small bus manufacturers only involved in manufacturing of the vehicle body, to ensure that these businesses are not faced with disproportionately high administrative costs. The dominant costs arise from overhead costs, with component certification costs and VTP costs comprising much smaller cost segments. Small manufacturers producing medium lorries were not included in the presentation of results, as it is not deemed commercially viable for a manufacturer of ~200 medium lorries a year to certify the vehicles given the relatively low return per vehicle sold.

The key benefits associated with the proposed extension of Regulation (EU) 2017/2400 include the provision of a standardised source of fuel economy information to customers, and the opportunity to engender significant fuel and CO_2 emission savings over the vehicle life-time. A short payback period was assessed for the additional costs related to the CO_2 certification. Most importantly, whole vehicle certification is the enabling methodology upon which future vehicle segment CO_2 targets, and fuel consumption reduction targets, could be set.

As outlined in Section 6.6, the proposed extension of Regulation (EU) 2017/2400 is expected to engender improvements in competition and innovation within the EU and internationally. However, the need to ensure that VECTO is capable of modelling all fuel-saving technologies was reflected by manufacturers as a key requirement for incentivising investment in the manufacture of low-emission vehicles. The proposed extension is anticipated to have only a small impact on employment and third countries.

Table 59: Summary of combined costs, benefits and pay-back period for running the CO2 determination, on a per vehicle basis for conventional vehicles

Vehicle	Cat.	OEM size and experience	Total costs per vehicle	Annual fuel savings	Pay-back period (years)
Typical "low floor" bus	1	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 386.68	€ 1,152.00	**0.34**
	2	Medium enterprise (2500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 361.16	€ 1,152.00	**0.31**
	3	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,275.88	€ 1,152.00	**3.71**
Typical "high floor" bus	4	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 806.40	**0.51**
	5	Medium enterprise (2500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 806.40	**0.48**
	6	Small enterprise (200 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 4,304.26	€ 806.40	**5.34**
Typical medium lorry	7	OEM already involved in CO_2 determination for heavy lorries; New vehicle categories only "add on"	€ 415.06	€ 221.76	**1.87**
	8	Medium enterprise (2500 vehicles per year), not yet familiar with EU HDV CO_2 determination	€ 389.53	€ 221.76	**1.76**

7 Task 6 – Liasing with stakeholders and Commission services

The work performed in this task includes all the communication held between the members of the consortium, the Commission services and the relevant stakeholders.

The communication preformed throughout the project consisted of:

- Regular audioconferences between the consortium and the Commission to discuss the status of the project and prepare HDV CO2 Editing board meetings
- Technical meetings with stakeholders to elaborate technical details
- Task force meetings with stakeholders to elaborate and discuss details of the draft Working Documents
- HDV CO2 Editing board meetings

Table 60 gives an overview on meetings throughout the contract. Due to the large number of meetings, some of which were arranged spontaneously, the list does not claim to be complete.

Table 60: List of contract meetings

Date	Location	Meeting / Topic	Participants
23.04.2019	Audio web	Kick-off meeting Pilot Phase 1	DG GROW, DG CLIMA, DG JRC, TUG, ACEA, CLCCR, CLEPA, VOITH, RDW
13.06.2019	Brussels	Kick-Off Meeting for the contract	DG GROW, DG CLIMA, DG JRC, TUG, TNM, LAT, Ricardo, TNO
09.07.2019	Audio web	Status Quo meeting Pilot Phase 1	DG GROW, DG CLIMA, DG JRC, TUG, ACEA, CLCCR, CLEPA, VOITH, RDW
27.08.2019	Munich	ACEA Aero group (Annex VIII)	ACEA, TUG
04.09.2019	Brussels	HDV CO2 Editing board	Members of the HDV CO_2 Editing board
24.09.2019	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
02.12.2019	Brussels	HDV CO2 Editing board	Members of the HDV CO_2 Editing board
09.12.2019	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
16.12.2019	Audio web	Project internal meeting	DG GROW, TUG

Date	Location	Meeting / Topic	Participants
19.12.2019	Audio web	Multistage and Process licence	ACEA, DG GROW, TUG
08.01.2020	Audio web	WHR	DG CLIMA, DG JRC, TUG, ACEA, CLEPA, ICCT, IAV
09.01.2020	Audio web	Finalisation Pilot Phase 1 and Planning Pilot Phase 2	DG GROW, DG CLIMA, DG JRC, TUG, ACEA, CLCCR, CLEPA, VOITH, RDW
09.01.2020	Audio web	Dual fuel	VOLVO, TUG
10.02.2020	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
12.02.2020	Audio web	Task Force Annex I	DG GROW, DG CLIMA, ACEA, CLCCR, TUG, TNM
25.02.2020	Audio web	Light vehicles	ACEA, TNO, TUG
03.03.2020	Brussels	Stakeholder meeting VECTO HEV	DG GROW, DG CLIMA, DG JRC, ACEA, CLCCR, TUG,
18.03.2020	Audio web	Project internal meeting	DG GROW, TUG
24.03.2020	Audio web	Task Force Annex I	DG GROW, DG CLIMA, ACEA, CLCCR, TUG, TNM
21.04.2020	Audio web	Kick-Off Task 4 (ISC)	DG CLIMA, TUG, LAT
29.04.2020	Audio web	Project internal meeting	DG GROW, TUG
26.05.2020	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
09.06.2020	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
09.06.2020	Audio web	WHR / Pilot phases	CNH, TUG
15.06.2020	Audio web	ACEA Aero group (Annex VIII)	ACEA, TUG
15.06.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, VOITH, TUG
16.06.2020	Audio web	Project internal meeting	DG GROW, DG CLIMA, TUG
22.06.2020	Audio web	Project internal meeting	DG GROW, DG CLIMA, DG JRC, TUG
30.06.2020	Audio web	Task Force Annex VIII	ACEA, CLCCR, TUG
02.07.2020	Audio web	HDV CO2 Editing board	Members of the HDV CO_2 Editing board
07.07.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, VOITH. TUG
09.07.2020	Audio web	Task Force Annex IX	ACEA; DG JRC, CLEPA, CLCCR, TUG

Date	Location	Meeting / Topic	Participants
10.07.2020	Audio web	Task 4 ISV Stakeholder Meeting	DG CLIMA, ACEA; TUG, LAT, ETRMA, Swedish Transport Agency, BMVI, DG JRC, VDA, UTAC, PZPM
14.07.2020	Audio web	Task Force Annex Xb meets and Task Force Annex VI	ACEA, CLCCR, TUG
17.07.2020	Audio web	Task Force Annex IV	ACEA, CLCCR, TUG
17.07.2020	Audio web	Project internal (ISV)	DG CLIMA, DG JRC, TUG
18.07.2020	Audio web	Annex Xb	CLEPA, TUG
18.08.2020	Audio web	Task Force Annex Xb meets and Task Force Annex VI	ACEA, CLCCR, TUG
11.09.2020	Audio web	WHR / Pilot phases	CNH, TUG
23.09.2020	Audio web	Project internal (Integrated components)	DG GROW, DG CLIMA, TUG
24.09.2020	Audio web	ISV	ETRMA, TUG
29.09.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, TUG
01.10.2020	Audio web	Battery durability	DG GROW, DG CLIMA, DG JRC, TUG
05.10.2020	Audio web	Task Force Annex I and III	ACEA, CLCCR, TUG
12.10.2020	Audio web	ACEA Aero group (Annex VIII + ISV)	ACEA, TUG
14.10.2020	Audio web	HDV CO2 Editing board	Members of the HDV CO_2 Editing board
16.10.2020	Audio web	Annex Xb	CLEPA, TUG
20.10.2020	Audio web	Annex X	ETRMA, TUG
21.10.2020	Audio web	Task Force Annex IX	ACEA, DG CLIMA; TUG
23.10.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; TUG
29.10.2020	Audio web	Wheel bearings	Schaeffler, DG JRC, DG CLIMA, TUG
29.10.2020	Audio web	Task Force Annex IX	ACEA, CLEPA, DG JRC, DG CLIMA; TUG
03.11.2020	Audio web	Micro and mild HEV	Daimler, TUG
06.11.2020	Audio web	Annex VIII – CoP Numbers	DG GROW; ACEA; TUG
11.11.2020	Audio web	Micro and mild HEV	ACEA, TUG
17.11.2020	Audio web	Annex Xb	CLEPA, TUG
20.11.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
24.11.2020	Audio web	Task Force Annex I and III	ACEA, CLCCR, TUG
01.12.2020	Audio web	Annex X	ETRMA, TUG

Date	Location	Meeting / Topic	Participants
09.12.2020	Audio web	HDV CO2 Editing board	Members of the HDV CO_2 Editing board
14.12.2020	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
15.12.2020	Audio web	Task Force Annex IX	ACEA, DG CLIMA; DG JRC, TUG
18.01.2021	Audio web	Task Force Annex IX	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
19.01.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
28.01.2021	Audio web	Task Force Annex IX / PTO	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
02.02.2021	Audio web	Task Force Annex IX / PTO	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
03.02.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
04.02.2021	Audio web	In Service Verification	DG CLIMA; DG GROW, TUG, LAT
11.02.2021	Audio web	Project coordination	DG GROW, TUG
12.02.2021	Audio web	Tyres and ISV	DG GROW, DG CLIMA, ETRMA, TUG
16.02.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
17.02.2021	Audio web	Multistage Heavy buses	ACEA, CLCCR, CLEPA, DG CLIMA; DG JRC, TUG
09.03.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
11.03.2021	Audio web	ACEA ISV	ACEA, DG CLIMA; DG JRC, TUG
16.03.2021	Audio web	ACEA Status Quo Annexes	ACEA, DG GROW, DG CLIMA; DG JRC, TUG
17.03.2021	Audio web	Workshop Individual vehicle approvals	ACEA, CLCCR, CLEPA, DG CLIMA; DG JRC, TUG
24.03.2021	Audio web	Workshop Individual vehicle approvals	ACEA, CLCCR, CLEPA, DG CLIMA; DG JRC, TUG
01.04.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
08.04.2021	Audio web	Task Force Annex III – open xEV topics	ACEA, CLEPA, DG JRC, TUG
09.04.2021	Audio web	Scania GEM Hybrid	Scania, TUG
16.04.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG

Date	Location	Meeting / Topic	Participants
16.04.2021	Audio web	Scania GEM Hybrid	DG GROW, DG CLIMA; DG JRC, TUG
23.04.2021	Audio web	Scania GEM Hybrid	Scania, TUG
28.04.2021	Audio web	Task Force Annex Xb	ACEA, CLEPA, DG CLIMA; DG JRC, TUG
07.06.2021	Audio web	Task Force Annex IX – final adjustments bus auxiliaries	ACEA, TUG
May to June 2021	Audio web	Review of Articles	DG GROW; TUG

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Annex I: Method to determine CO2 emissions and fuel consumption for heavy buses

The text in this section is identical to the description of the procedure as also proposed as point 2 of Annex I for the second amendment of Regulation (EU) 2017/2400. Furthermore the relevant definitions are provided at the beginning.

• 'Primary vehicle': 'primary vehicle' means a heavy bus with input data and input information as defined in Annex III;

• 'primary vehicle manufacturer': 'primary vehicle manufacturer' means a manufacturer responsible for the primary vehicle;

• 'interim vehicle': 'interim vehicle' means any further completion of a primary vehicle where a sub-set of input data and input information as defined for the completed vehicle according to Table 1 and Table 3a of Annex III is added and/or modified;

• 'interim manufacturer': 'interim manufacturer' means a manufacturer responsible for an interim vehicle;

2. Method to determine CO_2 emissions and fuel consumption for heavy buses

2.1. For heavy buses the vehicle specifications of the complete or completed vehicle including properties of the final bodywork and auxiliary units shall be reflected in the results for CO_2 emissions and fuel consumption. In case of heavy buses built in steps, more than a single manufacturer may be involved in the process of generation of input data and input information and the operation of the simulation tool. For heavy buses the CO_2 emissions and fuel consumption shall be based on two different simulations:

(a) for the primary vehicle as defined in Article 3 (24) of this Regulation;

(b) for the complete or completed vehicle as defined in Article 3(27) and 3(26) of Regulation (EU) 2018/858 accordingly.

2.2. If a heavy bus is approved by a manufacturer as a complete vehicle, the simulations shall be performed for both the primary vehicle and the complete vehicle.

2.3. For the primary vehicle the input to the simulation tool covers input data regarding the engine, transmission, tyres and input information for a subset of auxiliary units(3). The classification into vehicle groups is performed according to Table 3 based on the number of axles and the information whether the heavy bus is articulated or not. In the simulations for the primary vehicle the simulation tool allocates a set of four different generic bodies (high floor and low floor, single deck and double deck bodywork) and simulates the 11 mission profiles as listed in Table 3 for each vehicle group for two different loading conditions. This leads to a set of 22 results for CO_2 emissions and fuel consumption for a primary heavy bus. The simulation tool produces the vehicle information file for the initial step (VIF_1), which contains all necessary data to be handed over to the subsequent manufacturing step. The VIF_1 comprises all non-confidential input data, the results for energy consumption(4) in [MJ/km], information on the primary manufacturer and the relevant hashes(5).

(3) Input information and input data as defined in Annex III of this Regulation for primary vehicles.

(4) The results for CO_2 emissions and fuel consumption do not need to be submitted via the VIF, as this information can be calculated from results for energy consumption and the known fuel type.

(5) The content of the VIF is specified in detail in Part III of Annex IV.

2.4. The manufacturer of the primary vehicle shall make the VIF_1 available to the manufacturer responsible for the subsequent step. In case a manufacturer of a primary vehicle provides data going beyond the primary vehicle requirements as set out in Annex III, this data does not influence the simulation results for the primary vehicle but is written into the VIF_1 to be considered in later steps. For a primary vehicle the simulation tool furthermore produces a manufacturer's records file.

2.5. In case of an interim vehicle the interim manufacturer is responsible for a sub-set of relevant input data and input information for the final bodywork(6). An interim manufacturer does not apply for certification of the completed vehicle. An interim manufacturer shall add or update information relevant for the completed vehicle and operate the simulation tool to produce an updated and hashed version of the vehicle information file (VIF_i)(7). The VIF_i shall be handed over to the manufacturer responsible for the subsequent manufacturing step. For interim vehicles the VIF_i also covers the task of documentation towards approval authorities. No simulations of CO_2 emissions or/and fuel consumption are performed on interim vehicles.

(6) Subset for input information and input data as defined in Annex III of this Regulation for complete and completed vehicles

(7) 'i' represents the number of manufacturing steps involved in the process so far.

2.6. If a manufacturer performs modifications to an interim or completed vehicle which would require updates to the input data or the input information allocated to the primary vehicle (e.g. a change of an axle or of tyres), the manufacturer performing the modification acts as a primary vehicle manufacturer with the corresponding responsibilities.

2.7. For a complete or completed vehicle the manufacturer shall complement and update (if necessary) the input data and input information for the final bodywork as transmitted in the VIF_i from the previous manufacturing step and shall operate the simulation tool to calculate the CO_2 emissions and fuel consumption. For the simulations at this stage, heavy buses are classified based on six criteria (number of axles and five specifications of the final bodywork) into the vehicle groups as listed in Table 4 to 6 of this Annex. To determine CO_2 emissions and fuel consumption of complete or completed heavy buses the simulation tool performs the following calculation steps:

2.7.1. Selection of the primary vehicle sub-group which matches the bodywork of the complete or completed vehicle (e.g. “P34 DD” for “34f”) and making available the corresponding results for energy consumption from the primary vehicle simulation.

2.7.2. Performing simulations to quantify the influence of the bodywork and auxiliaries of the complete or completed vehicle compared to the generic bodywork and auxiliaries, as considered in the simulations for the primary vehicle regarding energy consumption. In these simulations, generic data are used for the set of primary vehicle data, which are not part of the information transfer between different manufacturing steps as provided by the VIF([8]).

([8]) See point 1.1. of PART III of Annex IV.

2.7.3. Combining energy consumption results from the primary vehicle simulation as made available by step 1 with the results from step 2 provides the energy consumption results of the complete or completed vehicle. The details of this calculation step are documented in the user manual of the simulation tool.

2.7.4. Results for CO_2 emissions and fuel consumption of the vehicle are calculated based on the results of step 3 and the generic fuel specifications as stored in the simulation tool. Step 2 to 4 are performed separately for each combination of mission profile as listed in the Tables 4 to 6 for the vehicle groups in both low and representative loading condition.

2.7.5. For a complete or completed vehicle the simulation tool produces a manufacturer’s records file, a customer information file as well as a VIF_i. The VIF_i shall be forwarded to the subsequent manufacturer in case the vehicle undergoes a further step to be completed.

Figure 30 shows the data flow based on the example of a vehicle produced in five manufacturing steps with relevance to Regulation (EU) 2017/2400.

Figure 30: Example of data flow in case of a heavy bus manufactured in five steps

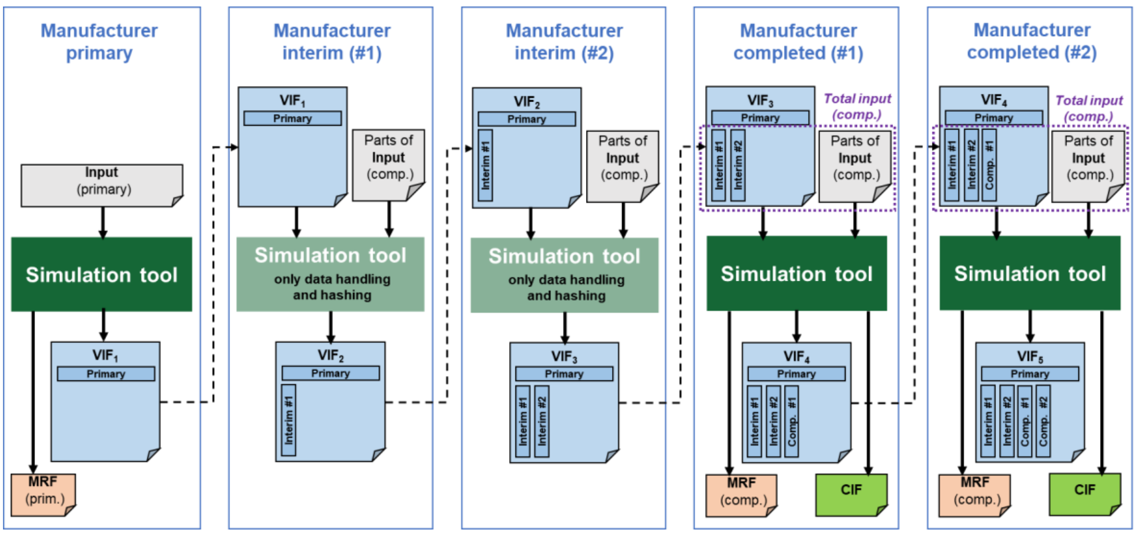


Figure 31 and Figure 32 give a graphical representation of the special cases "primary vehicle manufacturer is also an interim manufacturer" and "Complete vehicle". These illustrations were not included in the draft Annex I for the second amendment of Regulation (EU) 2017/2400.

Figure 31: Special case 1: Primary vehicle manufacturer is also an interim manufacturer

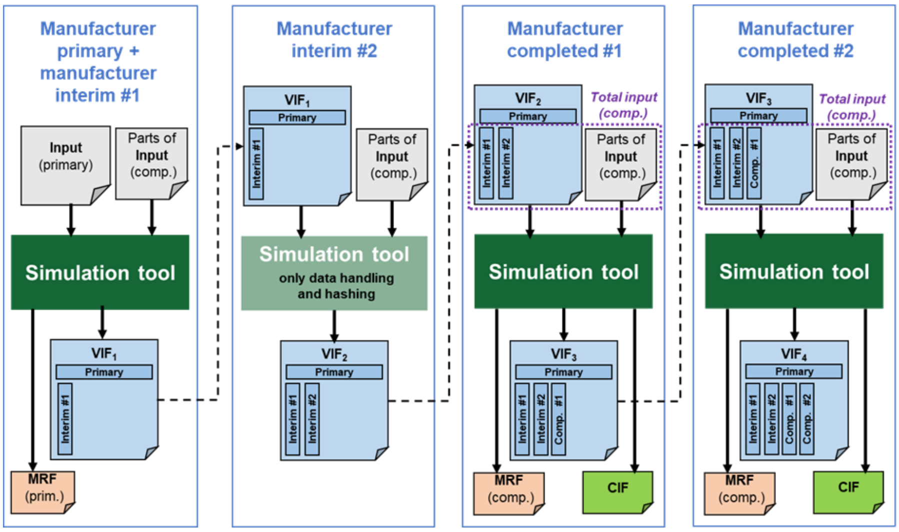
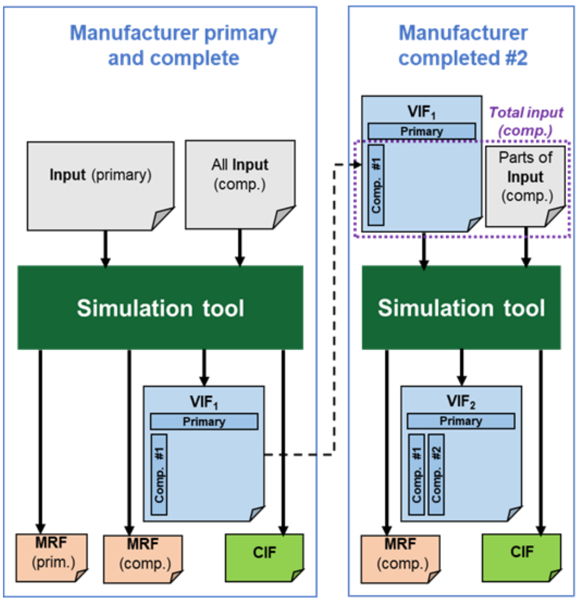


Figure 32: Special case 2: "Complete" vehicle



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