D2.2 MODULAR POWERTRAIN REQUIREMENTS

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1 EXECUTIVE SUMMARY

This deliverable details the technical requirements for the modular powertrain. It is the reaction to the project objective to develop a powertrain within a consortium of 12 partners. These traction systems must be organised with multiple parts, each under the responsibility of one partner. This element is an attractive feature of the EU-LIVE development. Several requirements will be consequences of this nature. This is an innovative way of thinking a L-category powertrain design and it is a progress beyond state-of-the-art. Automotive industry already uses this development approach and this is the first transfer of know-how from automotive to 2-wheel industry in the EU-LIVE project.

Another progress is the work shoulder to shoulder between OEMs and suppliers. This deliverable is a common creation between the concerned partners (Brembo, Continental, Elaphe, IFPEN, PSA, PSCO, and SDI). Once again, a new methodology had to be created partners to write technical requirements in a way that is not usual for the partners. Usually, the OEMs send their requirements to suppliers. On the opposite, in the EU-LIVE project, the work was done together, thus it creates an optimisation of the benefits among partners and probably of the product itself.

This deliverable is divided in three sourcing of requirements.

First, the requirements are coming directly from the overall project requirements list written by the partners. The purpose was to sum up all the expected requirements, those that could be wished in an early stage of the project. They were sorted into three categories: Legal, Market & Users and Project.

Secondly, the modular part and their physical boundaries are defined and design and performances requirements are defined directly from the parts. The design requirements come from modularity, general conception, safety, usability, etc. The performance requirements come then from D2.1 [1] and vehicle performance requirements that are then converted in powertrain part requirements. It concerns only the Internal Combustion Engine (ICE), In-Wheel Motor (IWM) and the battery system.

The third and last sourcing is the interfaces needs. This part answers directly to the modular nature of the powertrains. Parts need interaction among themselves and this section helps to summarize these needs. Besides, the whole powertrain integration in vehicles is not simple and many issues will be met during development. The aim of this deliverable is to address most of those issues right away. Nevertheless, some of these issues will be dealt with during the project, as they cannot be foreseen.

Keywords: Modularity, Requirements, Interfaces

2 OBJECTIVES

2.1 Deliverable objectives and work performed

To success in any work project, it is mandatory and obvious to define clearly the technical requirements ahead of design and development. It is above all a critical need in a project gathering several partners with different experiences and expertise. Indeed, the EU-LIVE project calls for a colossal amount of technical tasks, each with their own constraints and objectives, moreover often leaded by different consortium partners. Thus, one of the work packages, the WP2, is completely dedicated to technical requirement definitions. This WP is using results from WP1, which was the market study.

This WP2 boils down to three deliverables:

- D2.1 – Overall vehicle requirements [1]
- **D2.2 – Modular powertrain requirements**
- D2.3 – Virtual demonstrator requirements [2]

The content of this deliverable D2.2 is an explanation of the methods and the process that have been used within the EU-LIVE project to define the modular powertrain requirements. Many of those are indisputably linked to the vehicle requirements included in D2.1 [1]. Nevertheless, some are stemmed from the modular nature and by the numerous interfaces existing between powertrain parts.

First, all partners established an overall list of confidential, non-mandatory technical project requirements. These project requirements are classified in three categories: Legal/Standard requirements, Market and Users requirements and Project requirements. In this document, some of these requirements are pointed out as referring directly to modular powertrain.

Then, on a more technical side, this deliverable details the different components of the modular powertrain and the boundaries between them. This primary part allows the design work to be clearer by assigning each modular powertrain subsystem to one partner and to define clearly the boundaries between each partners' design work. Thus, this section gives the general design requirements for each subsystem. For the components related to the performances (IWM, ICE, Battery system), this section also specifies some pre-dimensional technical calculations to translate the vehicle performance requirements into powertrain performance requirements. For this work, results from D2.1 [1] are the baseline.

Lastly, the modular nature of powertrains creates also its own list of requirements. This part is divided in two sections, the external powertrain interface, in which, the powertrain is considered as a black box, and the internal powertrain interfaces. For each section, the requirements are listed.

The output of such work will be a file gathering all technical requirements concerning modular powertrain that will be checked all along the EU-LIVE project as guideline.

2.2 Project Objectives

The establishment of the technical requirements is strongly linked to the objectives of the project itself. This deliverable directly answers most of them. In the Grant Agreement [3], the general objectives are listed (Annex I, Part B, Section 1.1).

This deliverable is fulfilling the objective 1.a and the baseline of objective 2, meaning it addresses globally or partially the objectives linked to the development of the modular powertrain.

It is already highlighted by the project overall requirements list. Therefore, in a first step, partners where asked to gather all requirements linked to the project in one list. So the requirements directly linked to the project objectives are listed in section 3.1.

As a technical requirements deliverable, this document also broaches several well-known ambitions of the EU-LIVE project.

The grant agreement [3] catalogues these ambitions. In fact, this has to be taken into account right away during WP2. Here is a list of the ambitions considered in this deliverable taken from the grant agreement:

- Comprehensive Modularity (1.4.2)
- Powertrain (BEV, PHEV), IWM and E/E architecture (1.4.4)
- Transmission and Coupling (1.4.5)
- Battery system – Modularity and integration (1.4.6)
- Braking system/ Regenerative braking (1.4.7)

3 DESCRIPTION OF WORK

3.1 Overall project requirements and methodology

The powertrain requirements definition results from several sources. First, as for vehicle requirements gathered in D2.1 [1], the consortium established a list of overall project requirements sorted in three categories – Legal, Market & Users, and Project. From this list, many requirements refer directly to powertrain (modularity, cooling, etc.). These requirements can directly be included in the technical requirement list for powertrains. Table 1 lists all of these requirements. They are sorted by categories (Legal, Market & Users, Project), then by rationale (regulation, comfort, competitiveness, cost efficiency, driving experience, energy efficiency, environmental impact issues, safety). This list was built by addition of every partner proposition. For each described requirement, the person who proposed it was asked to rate the priority of this requirements within these three propositions: Nice to have, Important to have, Have to be fulfilled. The RQ_ID comes from the global list of overall project requirements (confidential list).

Legal

RQ_ID	Rationale	Requirement Description	Priority
L_05	Regulations	The L5e demonstrator has to fulfil current standards and beyond [4]	Have to be fulfilled

Market & Users

RQ_ID	Rationale	Requirement Description	Priority
MU_01	Energy efficiency	The consumption of the L5e demonstrators has to show a significant consumption compare to benchmark L5e. Target : 2,26 l/100km [8]	Have to be fulfilled
MU_02	Comfort	The overall noise vehicle has to show significant decrease compare to benchmark L5e	Nice to have
MU_19	Competitiveness	Long intervals for maintenance	Have to be fulfilled
MU_23	Competitiveness	The fast-charging system (e.g. 6kW) reduces the charging time	Nice to have
MU_24	Energy efficiency	Charge/Discharge mode depending on time of day and using vehicle as buffer storage	Nice to have
MU_33	Driving Performance	Take off capability, roll-on acceleration in city, on road or on highway, hill start ability	Important to have
MU_37	Energy efficiency	ZEV Range and (ICE + electric) range	Have to be fulfilled
MU_55	Competitiveness	Battery swapping (interesting for commercial applications)	Nice to have
MU_62	Competitiveness	A modular battery system could allow an easy way to vary the range, interior space or cargo space	Nice to have

Project

RQ_ID	Rationale	Requirement Description	Priority
P_001	Competitiveness	Every part of the electrified powertrain and the bodies must be modular	Have to be fulfilled

P_003	Competitiveness	Transfer from automotive industry know-how to two wheelers industry	Have to be fulfilled
P_005	Cost efficiency	The powertrain components costs must be minimised	Have to be fulfilled
P_006	Cost efficiency	Components out of the shelf must be used as much as possible	Have to be fulfilled
P_056	Energy efficiency	All the powertrains - electric and HY - must be energy efficient	Have to be fulfilled
P_064	Driving Performance	Sufficient cooling for all relevant powertrain components has to be guaranteed in all required driving and ambient conditions	Have to be fulfilled
P_067	Comfort	The mass of the IWM must not influence the good driving behaviour (non-damped driving mode)	Important to have
P_069	Comfort	The L5e must be able to reverse. Driving dynamics have to be taken into account	Important to have

Table 1 : Powertrain requirements extracted from overall project requirements

Most of these requirements will fit in the categories detailed below in this deliverable. Those that fit in none are kept without modification in the final technical powertrain requirements list, representing the output of this deliverable.

3.2 Modular powertrain subsystem definition

In this section, powertrain components are listed and quickly described, the boundaries of each subsystem is detailed and related requirements are catalogued.

For the components linked to the performances (IWM, ICE and Battery system), the performed calculations and the induced requirements are also described. The performances of the vehicles are sorted in two modes: Full electric mode and ICE only mode. Each of these lists will help define the requirements for the electric powertrain and the engine. The full electric mode defines the minimum required torque from the IWM that defines the requested current from the battery. The ICE only mode determines the need from the engine.

ICE, IWM and battery system section will also include performance requirements.

3.2.1 Internal combustion engine – Peugeot Scooters

The ICE of the EU-LIVE L5e vehicle is one of its two propulsive systems. It allows the vehicle to achieve long distances, and high speed driving. It has to be designed in order to fulfil all the following requirements:

- To be modular and compatible with several kinds of powertrains (hybrid and pure ICE)
- To allow the whole vehicle to comply with the regulation standards (noise and pollutants)
- To allow the vehicle to achieve the performances given in D2.1 [1]

3.2.1.1 ICE design requirements

For cost-efficiency purpose, the baseline of the EU-LIVE L5e ICE is existing, and taken on PSCO shelf. Obviously, some shifts are requested to fulfil the objectives, especially regarding needed power and compactness. From these objectives, Table 2 below presents these requirements.

RQ_ID	Requirement	When?
ICE_01	ICE must fit in the vehicle environment	Pre-design & design phase
ICE_02	For exploitation and cost-efficiency purpose: ICE global architecture is kept (intake and exhaust system included, single-cylinder, one camshaft, 4-stroke, spark ignited…)	Pre-design phase
ICE_03	Component off the shelf (COTS) from automotive industry are included in the design	Design & Development phase
ICE_04	ICE is designed with an electric throttle body (torque structure)	Design Phase
ICE_05	ICE is equipped with ICEMS (ICE Management system)	Design & Development Phase
ICE_06	ECU is dealing with gasoline supply (pump, tank supply sensor)	Design & Development Phase
ICE_06	ICE work with RON 91 fuel (exportation security) [4]	Development & mapping phase
ICE_07	ICE must be liquid cooled (radiator)	Development phase
ICE_08	ICE must comply with vehicle durability – DPR_32 [7]	Development phase

Table 2 : ICE design requirements

The design of the ICE and its ICEMS is under the responsibility of Peugeot Scooters.

3.2.1.2 ICE performances requirements

The performances of the vehicles are sorted in two modes: full electric mode and ICE only mode.

For the ICE only mode, there are two kinds of performances: On the one hand, the acceleration, taking off, roll-on acceleration which mostly depends on transmission mapping and on the other hand the maximum speed with or without slope which depends on ICE maximum power and on higher gear ratio.

Therefore, before development stage, acceleration, taking-off and roll-on acceleration can be targeted but no technical requirements for the powertrain can be chosen. On the contrary, for maximum speed, the power required as well as higher ratio need to be chosen.

The calculation made concerning maximum speed is detailed below. As many of these results are confidential, however, results are kept in literal arithmetic.

Newton second's law applied to a vehicle can be sum up in automotive field by this equation (no acceleration, stabilised speed):

$$F = a + b \times v + c \times v^2$$

Where:

F is the traction force needed to get to the speed v

a, b, c are coefficient depending on vehicle characteristic, a depends on the slope

Using coast down experimentation (vehicle launch at a speed and let free for deceleration), we are able to simplify the traction force by neglecting coefficient b. Therefore, it results in the global power needed at the wheel to reach the maximum speed v_{max} :

$$P_{v_{max}} = F \times v_{max} = (a + c \times {v_{max}}^2) \times v_{max}$$

The next step is to define the different efficiencies along the powertrain – from the engine to the wheel.

Firstly, there is the transmission efficiency. Obviously, there is power loss in the gearbox, around the different shafts (free wheel loss, gears loss, oil friction loss, clutch loss etc.). Then there are the belt losses. The particularity of the EU-live project is the IWM. It is important to take into account the IWM losses (Electromagnetic and seal joint friction losses). Brembo and Elaphe supply data for losses estimation in the IWM.

It boils down on a global efficiency depending on the speed of the vehicle. Thanks to this efficiency, we can estimate the power need from the ICE.

At the same time, with the hypothesis that nominal engine speed is 7500rpm, the global higher traction ratio from ICE to the wheel can be set.

Speed (km/h)	Slope	ICE Power maximum needed (kW)	Higher ratio from ICE to Wheel
130	0%	26,4	6,74
135	0%	29,3	6,49
140	0%	32,4	6,26
90	4%	16	Not applicable
15	18%	0,30	Not applicable

Table 3 : ICE performances vs. max speed

In D2.1 [1], the objective of maximum speed is 130km/h for the L5e in pure ICE mode (DPR_24 [7]). PSCO decides to raise this speed to 138km/h, because of unexpected power losses. Below are the performances required from the ICE. As the ratio is a fuel-driven powertrain requirement, it will be included in interface requirements in 3.3.2.1.

RQ_ID	Requirement	When?
ICE_07	Maximum power of ICE needs to be 31,1kW (42,3 HP)	Development and mapping phase

Table 4 : ICE performance requirements

3.2.2 In-wheel motors – Brembo

The IWM of the EU-LIVE L5e vehicle is one of its two propulsive systems. It allows the vehicle to achieve short distance journey, taking off and inner-city driving. It has to be designed in order to fulfil all the following requirements:

> To be modular and compatible with several kinds of powertrains (hybrid and electric)

> To allow the vehicle to achieve the performances given in D2.1 [1]

> To allow electrical driving functionalities

The IWMs and the braking system constitute together the rear wheel assembly, on both the L5e and L3e vehicles. The IWMs are the second propulsive system of the L5e vehicle, and the primary one of the L3e. They aim at achieving the performances defined in D2.1 [1] – for the L5e vehicle, when the full electric mode is on, when driving in zero emission zones. It shall allow low to moderate speed driving. It includes a regenerative braking mode for deceleration phase or recharging mode.

3.2.2.1 IWM design requirements

The strategies will be driven by the VMCU. It will assure a regenerative braking, in the conditions defined by the Vehicle Control Unit. IWMs working conditions have to be compatible with the ICE working conditions, to allow the previously quoted modes. A specific interface section is dedicated to fuel driven powertrain and IWM (3.3.2.2). As electrical traction subsystem, it will be responsible of some of the overall vehicle needs. In the following table (Table 5), IWM design requirements are listed:

RQ_ID	Requirement	When?
IWM_01	IWM width must be kept as low as possible	Pre-design & design phase
IWM_02	IWM is responsible of reverse gear	Development phase
IWM_03	IWM is responsible for insuring synchronized torque on both wheels while not having the same speeds in electric mode – L5e	Development phase
IWM_04	Regenerative braking is available	Development phase
IWM_05	The IWM must be modular (hybrid and electric)	Development phase
IWM_06	The IWM is air cooled (rim design)	Design and Development phase
IWM_07	IWM is supplied with an inverter	Development phase
IWM_08	IWM must comply with vehicle durability – DPR_32 [7]	Development phase

Table 5 : IWM design requirements

The design of the mechanical part of the IWM and of the braking system is under the responsibility of Brembo. Nevertheless, Elaphe is in charge of the design of the electro-magnetic parts of the IWM and thus of its performances.

3.2.2.2 IWM performances requirements

The first step in calculating IWM's parameters is calculation of vehicle's requirements from basic laws of physics. Vehicle parameters such as mass, dimensions, air drag and rolling resistance coefficients have to be coupled with expected driving demands such as maximum speed, hill climbing ability and acceleration. This analysis results in the required input parameters or boundary conditions, which are a starting point of propulsion and motor design and are one of the most important aspects of designing the propulsion.

Propulsion parameters – such as power, torque, efficiency, weight, size, etc. – depend on vehicle data and expected driving performances. In order to get the right performance, Elaphe is supported by computer simulations and flexible development process, based on:

> Vehicle data (weight, air drag data, friction data, energy source characteristics, number of motors, rolling radius, frontal area etc.)

> Typical use of the vehicle (driving cycle, top speed, expected range, demanded hill-climbing abilities etc.)

From the electromagnetic aspect, the need for high power density and high efficiency is defined as minimum. Energy losses are shown in heat generation which can cause degradation in performance or can fatally influence on magnets or winding isolation, which for both cases results in EM malfunction. For this reason, a unique mathematical model is used, which is based mainly on analytical equations and advanced calculated numerical parameters which make it very robust, accurate and extremely fast compared to any FEM based calculation of motor parameters. FEM simulations with coupled electromagnetic and thermal analysis are made as the last stage in order to verify and finalise the electromagnetic design.
Based on preliminary defined vehicle requirements, search for suitable motor parameters was performed in several iterations. Several dimensional and architectural vehicle characteristics and requirements need to be known in order to extrapolate the IWM parameters. The basic ones are summarised in Table 6. Some of the data is confidential.

Parameter	L3e	L5e	L6e
Estimated rolling coefficient	Confidential	Confidential	Confidential
Estimated air drag coefficient	Confidential	Confidential	Confidential
Frontal area A [m^2]	1.2	1.2	1.2
Numbers of driven wheels	1	2	2
Type of powertrain	BEV	PHEV	BEV
Kerb mass	250kg	380kg	< 425kg
Total load capacity	150kg	180kg (2P + options + load) no additional volume or pay load for delivery vehicle, compared to personal vehicle	180kg (2P + options + load)
Tire and wheel dimensions DPR_10 [7]	front 120/70 – 14'' & rear 140/60 – 13''	Confidential motorcycle tire section	L5e

Table 6 : Preliminary vehicle main dimensional characteristics and architectural features

In addition to dimensional and architectural vehicle characteristics, required driving performance also dictates the required torque of the IWM. Basic driving performance parameters are presented in Table 8.

	L3e	L5e	L6e
Speed requirements DPR_24 [7]	110km/h (BEV, 1P) 90km/h (BEV, 2P, slope 4%)	90 km/h (BEV, 1P) > 50km/h (BEV, 2P, slope 4%)	< 45km/h
Take off capability	Distance after 2s, BEV, 1P / Confidential	Distance after 2s, BEV,1P / Confidential	Distance after 2s, BEV, 1P/ Confidential
Acceleration req. #1	Time to reach 0-100m, BEV, 1P / Confidential	Time to reach 0-100m, BEV, 1P / Confidential	Time to reach 0-50m, BEV, 1P / Confidential
Acceleration req. #2	Time to reach 20-50km/h, BEV, 1P / Confidential	Time to reach 20-50km/h, BEV, 1P / Confidential	Time to reach 0-45km/h, BEV, 1P / Confidential
hill start ability	> 5km/h during 60s, BEV, 2P, slope 18%	> 5km/h during 60s, BEV, 2P, slope 18%	> 5km/h during 60s, BEV, 2P, slope 18%

Table 7 : Vehicle requirements – driving performance (BEV/PHEV modes)

From required driving performance, vehicle dimensional characteristics and architecture features, required in-wheel motor torque and max motor speed can be calculated. Calculations are based on basic laws of physics taking into account force needed for acceleration, rolling friction and air drag.

For the analysis of air drag for the L3e and L6e, a quadratic approximation of the drag force was used:

$$F_{airdrag} = \frac{1}{2} A \cdot k_{airdrag} \cdot \rho \cdot v^2 \tag{1}$$

where:

A is the frontal surface

$k_{airdrag}$ is the air drag coefficient

ρ is the air density and

v is the vehicle speed

For the analysis of the rolling friction in case of L3e and L6e the used equation was:

$$F_{rolling} = N \cdot k_{rolling} \tag{2}$$

where:

N is the normal force and

$k_{rolling}$ is the rolling coefficient

However, for the analysis of the rolling friction and air drag of the L5e, an empirically derived equation provided from PSCO was used (cf. 3.2.1.2):

$$F_{rolling+airdrag} = \mathrm{a} + \mathrm{b} \cdot v^2 \tag{3}$$

where:

v is the vehicle speed in km/h.

When calculating the force on the slope the rolling resistance force is reduced by a factor of $\sin(\alpha)$ due to the inclination, an additional dynamic force has to be overcome:

$$F_{Dynamic} = m \cdot g \cdot \sin(\alpha) \tag{4}$$

where:

m is the vehicle mass

g is the gravitational acceleration and

α is the inclination.

In case of acceleration of the vehicle, Newton's second law results in the force needed for the acceleration:

$$F_{acceleration} = m \cdot a \tag{5}$$

where:

m is the vehicle mass and

a is the vehicle acceleration needed to satisfy the vehicle requirements.

Vehicle acceleration was calculated from motion equations using data provided in vehicle requirements (time needed to travel a certain path or to accelerate from one speed to another).

Considering all the forces calculated above it is possible to calculate the needed IWM motor torque to satisfy each of the vehicle requirement using the equation below:

$$T_{IWM} = \sum F \cdot r/n \tag{6}$$

where:

$\sum F$ is the sum of forces which has to be exceeded

r is the outer radius of the tire and

n is the number of motors.

In case of acceleration requirement, the sum of forces and thus required IWM torque increases with increasing velocity. For this reason another step is needed to calculate the constant value of IWM torque which would satisfy the given acceleration requirements. The calculation is based on assumption of equal work performed in both cases.

In Table 9, the calculated IWM requirements from vehicle requirements are presented. In this table the X stands for a confidential number

	L3e	L5e	L6e
Speed Requirements	85 Nm @ 1172 RPM 105 Nm @ 960 RPM	56Nm @ 770 RPM > 57Nm @ 428RPM	< 85Nm @ 358 RPM
Take off capability	170 Nm for 2s	150 Nm for 2s	209 Nm for 2s
Acceleration req. #1	206 Nm for X s	225 Nm for X s	156 Nm for X s
Acceleration req. #2	176 Nm for X s	225 Nm for X s	114 Nm for X s
hill start ability	192 Nm for 60s @ 53 RPM (continuous torque)	153 Nm for 60s @ 43 RPM (continuous torque)	172 Nm for 60s @ 43 RPM (continuous torque)

Table 8 : Calculated IWM requirements from vehicle requirements

Calculated IWM requirements are one of the basic inputs for analytical models used for IWM parameters calculation. Since all the vehicles will have the same motors, the worst scenarios will have to be taken into account while designing and evaluating IWM. Required parameters for the IWM design are listed in Table 9.

RQ_ID	Requirement	When?
IWM_08	The electric motor is an inner rotor motor	Pre-design phase
IWM_09	The peak torque is 225Nm for X s	Design phase
IWM_10	The minimum continuous torque is 192Nm	Design phase
IWM_11	The peak rotation speed is 1172rpm (at 48V)	Design phase
IWM_12	No requirement clear on the higher torque (20s)	

Table 9 : IWM performances requirements

3.2.3 Gearbox or equivalent system – IFPEN

The innovative gearbox will adapt the torque and rotation speed to allow the engine to run on more efficient operating points. Moreover, its own efficiency will exceed the current two- or three-wheelers transmission, which will result in extra fuel savings. The gearbox should be able to provide the necessary torque and power, while keeping reasonable weight and dimensions. It should be also integrated into the vehicle, in terms of architecture, as well as in terms of control, with a seamless communication between the Transmission Control Unit (TCU) and the VMCU. In first line, the objective was to develop this transmission in a modular way. Eventually, the design is too strongly linked to ICE architecture to be fully modular, nevertheless, the development will be thinking to provide a transmission fulfilling its first objective, as it is a common objective for EU-LIVE and IFPEN.

RQ_ID	Requirement	When?
GB_01	The gearbox needs to fulfil compactness objectives	Design phase
GB_02	Allow the vehicle to use the best range of engine speed	Development and mapping phase
GB_03	The gear box needs its own oil system	Design and development phase
GB_04	The transition between gear is seamless	Development and mapping phase
GB_05	The transmission is equipped with its own control unit (TCU)	Design and development phase
GB_06	The gearbox is allowed to rotate in reverse mode	Design and development phase
GB_07	The gearbox higher ratio allows to reach the max speed required (cf. Intl_17 in 3.3.2.2)	Design and development phase
GB_08	Noise and vibration are taken into account during development	Development phase
GB_09	Allow to fulfil taking off and acceleration requirements	Development phase
GB_08	Gear box must comply with vehicle durability – DPR_32 [7]	Development phase

Table 10 : Gearbox requirements

The gearbox is under the responsibility of IFPEN.

3.2.4 Differential gear and wheel end transmission – Peugeot Scooters

The role of these two systems is to transmit the adapted ICE torque from the gearbox to the wheel, while allowing the functioning of the vehicle suspension, and the rear wheels to rotate at different speed in road bends. As well as the other powertrain parts, this subsystem should address durability issues, especially as it will be exposed to severe weather conditions. This component is obviously needed only on vehicles with 2 wheels on the rear end track. In fact, the output of the differential gear will be linked on both sides to the wheel by pulleys and rubber belt.

RQ_ID	Requirement	When?
DGWET_01	The differential gear allows one output shaft to stop while the other is rotating	Development phase
DGWET_02	The differential gear allows the two shafts to rotating at the same time	Development phase
DGWET_03	The differential gear allows different speed on different wheel	Development phase

DGWET_03	The differential gear box oil needs to be the same as transmission oil system	Development phase
DGWET_04	The compactness must comply with integration	Design phase
DGWET_05	The final transmission is made with a synchronic belt	Development phase
DGWET_06	The belt goes through the rear arm	Design phase
DGWET_07	The differential gear and whee-end transmission must comply with vehicle durability – DPR_32 [7]	Development phase

Table 11 : Differential gear and wheel-end transmission requirements

The differential gear and the final transmission are under the responsibility of Peugeot Scooters.

3.2.5 Battery System – Samsung SDI

Within the EU-LIVE project, 48V batteries for plug-in hybrid application (L5e) and purely electric application (L3e) with a modular concept approach will be established.

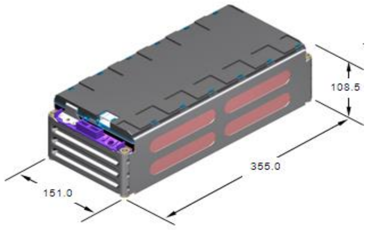

Figure 1 : Example of a 48V standard module

3.2.5.1 Battery system design requirements

Both batteries will be designed according to a “stand-alone” approach with regard to weight reduction and cost-effectiveness. Within the L5e, a single 48V battery pack is used, whereas in the BEV L3e, 3-4 battery packs (cf. Figure 2) will be integrated in alignment to the requirements of each project partner. The latter will consist of 1 battery that is considered as “master” and the other 2-3 batteries are regarded as “slave” with a parallel connection. While the system boots, an automatic system configuration takes place and – during initialising – the “master” should realise via the developed software the available performance parameters from the other batteries and deliver this information to the vehicle (e.g. available power from the overall system).

Figure 2 : Example of L3e vehicle with 4 battery modules shown in green

The design of the Battery system is under the responsibility of SDI.

RQ_ID	Requirement	When?

BS_01	The battery system voltage is 48V	Pre-design phase
BS_02	The battery system must be modular between L5e and L3e	Design phase
BS_03	The battery system is equipped with its own control unit (BMS)	Development phase
BS_04	Battery system must comply with vehicle compactness	Design and development phase
BS_05	The battery system must be kept under 60°C	Development phase
BS_06	The battery system must be a SDI COTS	Pre-design and design phase
BS_07	A 12V system is needed	Pre-design and design phase
BS_08	Battery must comply with vehicle durability – DPR_32 [7]	Development phase

Table 12 : Battery system design requirements

3.2.5.1 Battery system performances requirements

The 48V battery system needs to fulfil two kinds of performances, electric range and electric dynamic driving. For the range, the vehicle requirements from D2.1 [1] are the following:

	PHEV L5e	BEV L3e
Electric range / km	25	100
Utilisable energy at BoL / kWh	≥0.96	≥7.81

Table 13 : L5e and L3e range parameters

Regarding dynamic driving performances, the IWM performance requirements (3.2.2.2) result in required DC current from battery. By taking into account DC efficiency and battery voltage 44V, the following Table 14 summarises the resulting current needs.

	Battery current [A]		
	L3e	L5e	L6e
Speed requirements	255 263	111 > 62	< 85
Take off capability req.	Peak 93	Peak 160	Peak 302
Acceleration req. #1	Peak 430	Peak 950	Peak 388
Acceleration req. #2	Peak 225	Peak 630	Peak 255
hill start ability req.	86 (cont.)	56 (cont.)	68 (cont.)

Table 14 : Battery current needed to achieve vehicle requirements

RQ_ID	Requirement	When?
B_07	The L5e Battery system needs at least 0,96kWh for useable capacity at BOL	Design phase
B_08	The L3e Battery system needs at least 7,81 kWh for useable capacity at BOL	Design phase
B_09	Current delivery needs to meet performance requirements	Design phase

Table 15 : Battery system performances requirements

Since the battery is identified as the performance limiting component, the 48V systems will be developed according to the individual cell limitations and in accordance with state-of-the-art technology to guarantee safety and power performances over lifetime. Below, the following two tables show the achievable performances with a 12s1p battery as modular building block (12 cells in series) for the 37Ah PHEV cell (cf. Table 16) and for the 60 Ah BEV cell (cf. Table 18), respectively. For the L3e vehicle, 3-4 battery packs will be connected in parallel, so that the usable energy targets can be met.

		SDI 37Ah cell	
Basic cell data		**BoL**	**EoL**
minimum Capacity	Ah	37	29,6
System basic data			
Module Configuration		12s1p	
Pack Configuration		12s1p	
Overall system energy	kWh	1,6	1,3
Useable system energy	kWh	1,0	0,8
SOC Range	%	60%	60%
Max. System Voltage Pulse U_{max}	V	50,4	50,4
Nominal System Voltage U_{nom}	V	44,2	44,2
Min. System Voltage U_{min}	V	36,0	36,0

Table 16 : Example for performance parameters for the L5e vehicle

		SDI BEV 62 Ah	
Basic cell data		**BoL**	**EoL**
minimum Capacity	Ah	60	48
System basic data			
Module Configuration		12s1p	
Pack Configuration		12s1p	
Overall system energy	kWh	2,8	2,2
Useable system energy	kWh	2,2	1,8
SOC Range	%	80%	80%
Max. System Voltage Pulse U_{max}	V	51,0	51,0
Nominal System Voltage U_{nom}	V	44,4	44,4
Min. System Voltage U_{min}	V	25,2	25,2
Possible Operating Temperature Usage	°C	-25 to 60°C	
recommended Storage Temperature	°C	20 to 35°C	

Table 17 : Example for performance parameters for 1 module for the L3e vehicle

3.2.6 Electric and electronic management – Continental

The EU-LIVE concept vehicles need a complex EE interface. Here is a detailed view of the L5e and L3e electric and electronic grid.

In principle, the driver request has to end up in a longitudinal and lateral acceleration. To fulfil the approach of being modular the Vehicle Management Control Unit acts as computational unit (on which e.g. Torque Split Software is implemented) for doing this. Depending on vehicle class and powertrain concept (purely e-driven, purely combustion driven, hybrid driven) other control units are connected via CAN (on which the correlated functional software is running) to the VMCU.

This approach allows each vehicle class and powertrain concept to fulfil its specific needs based on modular light vehicle EE architecture.

Below the EE Architecture of a L3e (purely electric driven scooter, Figure 3) and of a L5 hybrid (plug in hybrid driven 3 wheeler, Figure 4) is described including the general interface

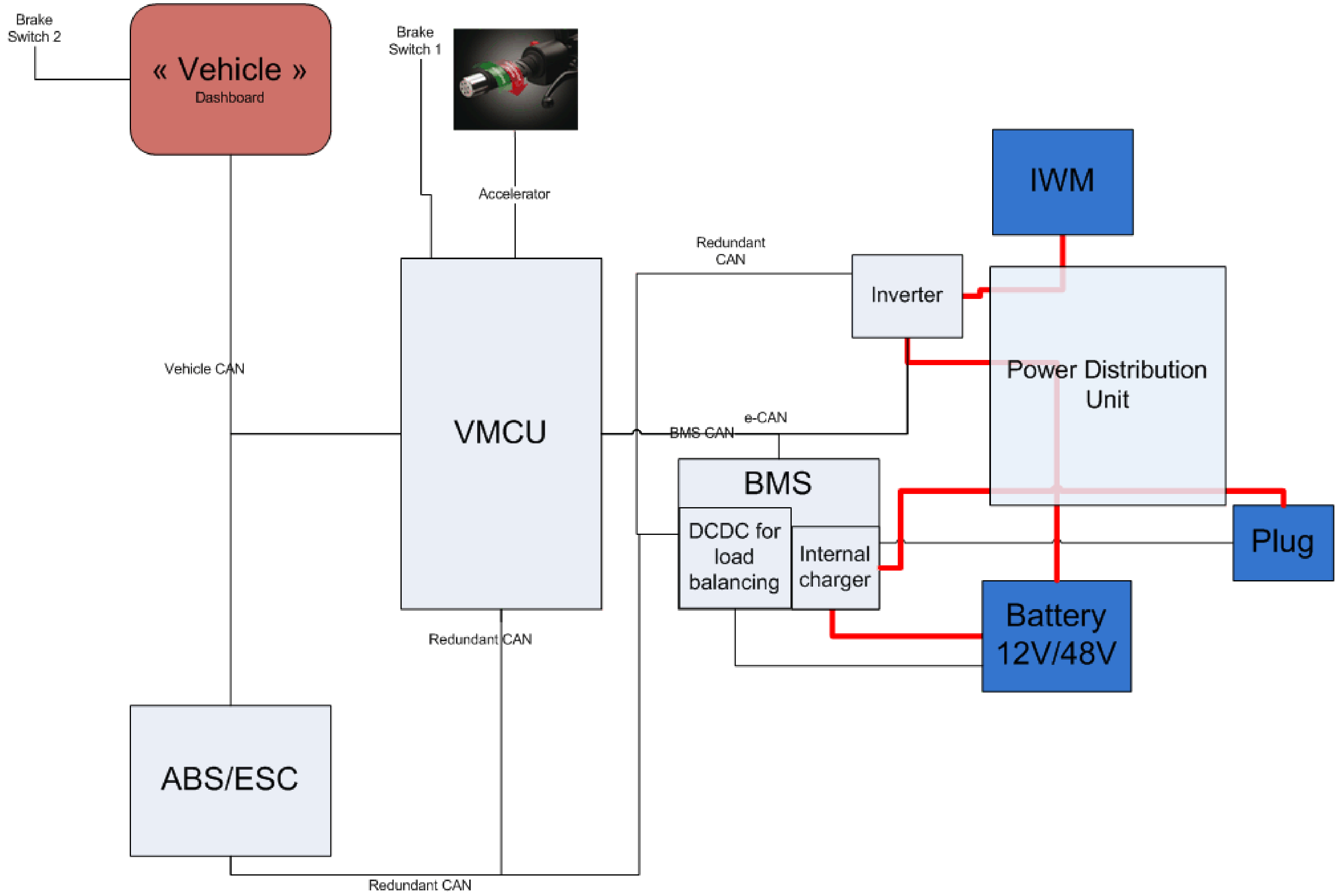

Figure 3 : L3e BEV E/E architecture overview

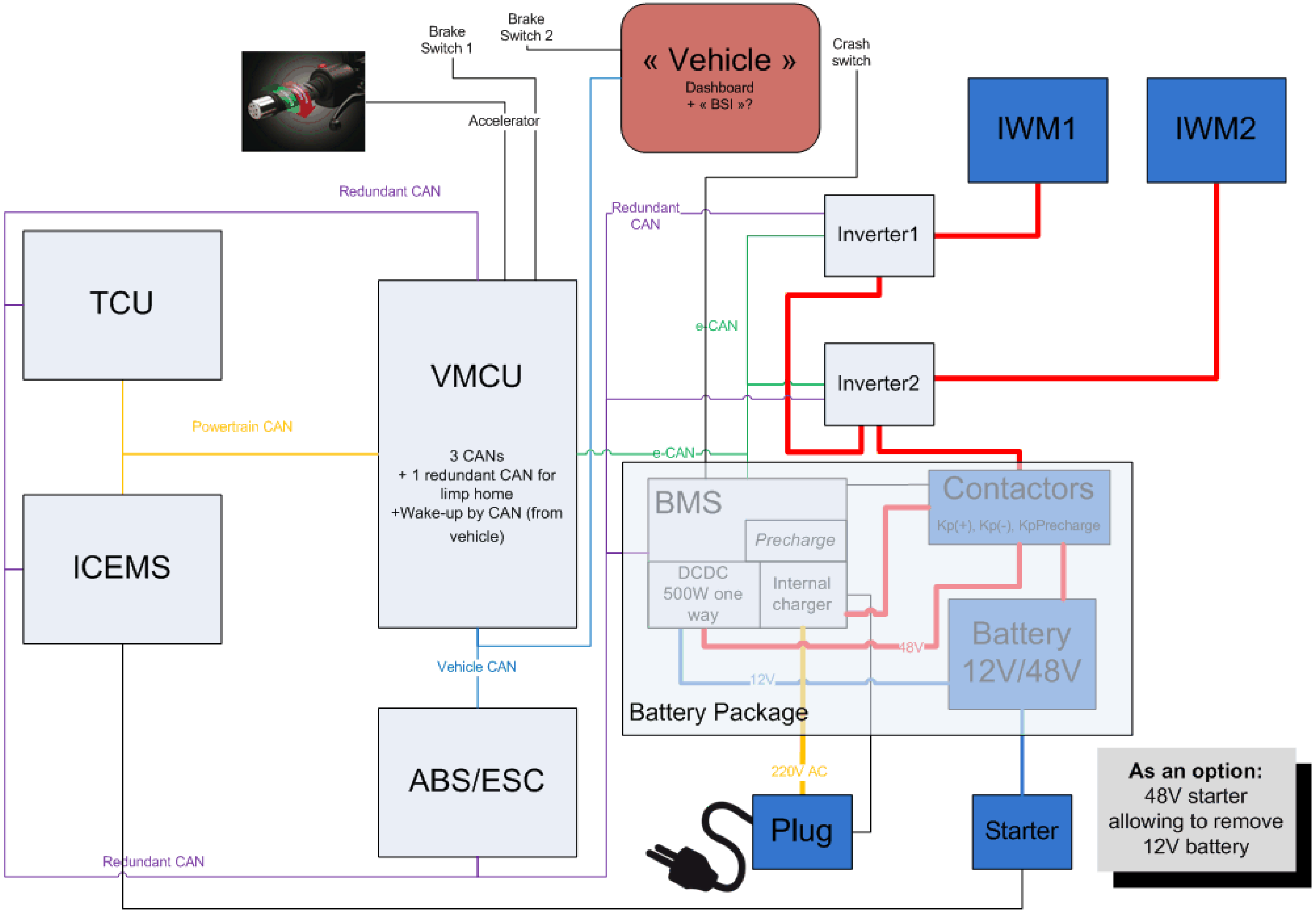

Figure 4 : L5e PHEV E/E architecture overview

3.3 Interface Requirements

A modular powertrain is very complex to integrate into a vehicle, especially in the EU-LIVE project, because each partner provides the powertrain with a component as seen in 3.3.1 The only way to get it done relevantly and efficiently is to detail every interface needs – first, by picturing the whole powertrain as a black box that interferes with the exterior (vehicle, electric grid, driver…) and secondly, within the powertrain itself, by showing connections between components.

3.3.1 Powertrain externals interfaces

This section details first requirements between powertrain and vehicle – vehicle is referring here to driver, dashboard and mechanical integration. Then, as a direct interface between powertrain and the outside environment, battery charging system requirements are developed.

3.3.1.1 Vehicle and powertrain interface

As a first direct issue that every automotive product development meets, requirements of the powertrain mechanical integration need to be set up. Out of clarity, those need a sorting by vehicle.

3.3.1.1.1 L3e electric powertrain mechanical integration

Along the design phase, electric components of the electric powertrain will be integrated in an already developed frame. This frame has first been developed by PSCO for integrating a classic ICE (mono-cylinder, 125cc-200cc, 12V battery system, CVT, suspended in the frame, rear wheel end integrated within the ICE). The EU-LIVE powertrain features a suspended rear wheel end (IWM and rear arm), a 48V/8kWh battery system and a VMCU. The latter has to feature an electronic throttle handle, and a regenerative brake switch (cf. 3.2.1.2). The repartition of the volume will be discussed and arbitrated during design phase. The requirements for the integration are listed below in Table 18.

RQ_ID	Requirement description	When?
MI_01	The centre of gravity needs to be kept as it was on the ICE PSCO version – L3e	Design phase
MI_02	The weight of the powertrain (IWM, rear arm, battery system and control units) must not exceed the ICE weight on PSCO version	Design phase
MI_03	The suspension of the rear arm must follow current rules of suspension – L3e	Development phase & prototyping phase

Table 18 : L3e Electric powertrain mechanical integration

3.3.1.1.2 L5e plug-in hybrid powertrain mechanical integration

Actually, the L5e EU-LIVE concept brings itself innovative issues concerning this point. It first concerns a category of vehicle never developed by one of the partners: 4-wheel 2-seats (in tandem) tilting closed cabin product. PSCO closest product is the Peugeot Metropolis – a 400cc Tricycle tilting – but adding a fourth wheel and a closed cabin is out of their primary field of knowledge. PSA is used to develop closed cabin for conventional vehicles, but the tilting nature is innovative. The integration of a complex powertrain in such a vehicle brings many issues, which have to be listed. Unexpected issues may be found out along development and the EU-LIVE partners will have to deal with those in a timely manner.

RQ_ID	Requirement description	When?
MI_04	Centre of gravity : The centre of gravity needs to respect the driving dynamics of the vehicle (WP4 lightweight design)	Development phase
MI_05	The weight of the powertrain (2 IWMs, 2 Rear arms, ICE, gearbox, differentia, battery system and control units) must be kept low	Design phase
MI_06	The engine must be mounted fixed in the chassis with a filtration system. (but not free as currently on scooters)	Development phase & prototyping phase
MI_07	The swinging rear arms must rotate around the same axe as output of the differential gear	Design phase
MI_08	The rear arms must be mounted stiff on the gearbox case but keep a freedom of rotation	Design and development phase
MI_09	The rear arms must be mounted on the outside of the vehicle	Design and development phase
MI_10	The ICE vibration must be kept acceptable	Development and prototyping phase
MI_11	Rear arm suspension has to allow acceptable driveability	Development and prototyping phase
MI_12	ICE suspension has to filter vibrations from the powertrain	Development and prototyping phase

Table 19 : L5e Hybrid powertrain mechanical integration

3.3.1.1.3 Powertrain Electric and Electronic integration in the Vehicle

In this section, the requirements linked to the E/E integration of the powertrain (as a black box) in the vehicle are listed. It has been established between several partners (PSA, Continental, PSCO, and Elaphe). The following requirements address the need for the serial vehicle. Therefore, during design and development phase (WP4-5) some choice will be made to ensure TRL6 [5] functional demonstrators and in that way, the EU-LIVE objectives.

One of the following requirements, concerning the regenerative braking request, it deserves a previous clarification. The consortium proposed a new and innovative way to drive the vehicle, which allows the driver to trigger the generative braking on purpose. For that purpose, the throttle control can be used in both ways – one for positive torque request and the other for negative torque request (i.e. regenerative braking). However, this proposition gives rise to a safety issue. Indeed, this regenerative brake can work only when the battery is not in its maximum SoC. As a result, you could imagine a situation where the maximum SoC is reached and the customer tries to engage the regenerative braking. The consequence would be no braking answer from the throttle control that can destabilize the driver.

Thus, this innovative system needs also an electrical safety system, which makes up for the lack of regenerative braking by an electrically piloted dissipative braking. Such a system is not simple to develop within the EU-LIVE project (lack of time and resources). For the demonstrator, the objective is to include this reverse throttle mode for regenerative braking, even if there is no safe solution for the braking issue for the moment.

RQ_ID	Interface	Requirement description	When?

EEI_01	Driver/Throttle control	Torque request by wire directly to VMCU	Development phase
EEI_02	Driver/Throttle control	Possibility to reverse the torque request sensor (throttle control) (for regenerative braking request)	Design and development phase
EEI_03	Drive/Braking handles	Position sensor by wire to VMCU (and to Dashboard at the same time)	Development phase
EEI_04	Dashboard	CAN connexion between VMCU and Dashboard (all information pass through VMCU)	Development phase
EEI_05	Dashboard	List of data needed from the VMCU by the Dashboard (non-exhaustive): • Vehicle Speed • Fuel tank supply • Battery State of charge • MIL (Malfunction Indicator Light) • Regenerative braking • …	Development phase
EEI_06	System Ignition	Smart Key [6], authorizing ignition via en antenna system	Design and development phase
EEI_07	System Ignition	The antenna communicates by CAN with VMCU	Development phase
EEI_08	System Ignition	An indicator is needed to inform that the vehicle is on (either on the dashboard or on the vehicle itself)	Development phase
EEI_09	System Ignition	For the demonstrator, antenna connect by wire is accepted	Development phase
EEI_10	System Ignition	For the demonstrator, the connexion by wire must be powerful enough to wake all ECUs up.	Development phase
EEI_11	Overall	Energy management (relay triggering, etc.) is driven by VMCU	Development phase

Table 20 : Powertrain E/E integration requirements

3.3.1.1 Battery Charging system requirements

L3e and L5e have to be equipped with on-board unidirectional galvanic isolated battery charging system. The on-board battery charging system refers to a charger implemented inside the vehicle. The user only has access to the input of the charging system, which is connected to the AC electrical grid voltage. The link is made on a conductive way through a physical contact between the vehicle and the power grid. The interaction between the vehicle and the power grid should comply with regulatory standards, as the International Electro- technical Commission (IEC) norms (IEC 62196 and IEC 61851).

The charging system has to be an AC-DC power circuit that must be controlled in order to respect the vehicles batteries nominal characteristics to preserve their lifespan. It converts alternating current from AC 110-220V/max.16A (50/60Hz) outlet to DC current, with characteristics depending on the battery pack. For L5e vehicle, it converts to DC 50.4V/max. 47A (continuous) for charging at 25°C (configuration 12s1p) by controlling voltage and current flow to the battery. For charging the L3e (pack configuration 12s1p, 3-4 packs in parallel), a conversion to DC 51V/max. 300-400A or 260-350A (continuous) is needed. Two options for the current are mentioned since the final charging current is highly dependent on the final cell decision within the EU-LIVE project for the battery pack. The charger has to be designed to provide the interfaces of global charging standards on the input power side and thus being adapted to the given charging infrastructure. The unit must be controlled by CAN messages from the battery management system sending back its live data like battery voltage, current, available power etc. through the embedded micro-controller based control unit. The galvanic isolation between AC input and battery side is crucial for personal safety. Protective features must be built-in like monitoring overvoltage, overcurrent, temperature and short/open circuit to prevent damage to charger or battery. Currently, there is no partner responsible for this part.
It should be compact, lightweight designed and robust working within a wide ambient temperature range with high conversion efficiency on low electromagnetic induction.

RQ_ID	Requirement description	When?
EEI_12	The charging system has to be unidirectional	Design & Development Phase
EEI_13	The charging system has to be galvanic isolated	Development phase
EEI_14	The physical contact between on board charging system and electrical grid must comply with regulations (IEC 62196 and IEC 61851)	Development phase
EEI_15	The charging system is an AC-DC power circuit. converting from alternating current 110-220V/max.16A (50/60Hz)	Development phase
EEI_16	L5e – The charging system is an AC-DC power circuit converting to DC 50.4V/max. 47A(continuous)	Development phase
EEI_17	L3e – The charging system is an AC-DC power circuit converting to DC 51V/max. 300-400A or 260-350A (continuous) (still not fixed)	Development phase
EEI_18	CAN communication between the charger and the BMS is needed: • Battery voltage • Current • Available power • …	Development phase

EEI_19	Monitoring of temperature, overvoltage, overcurrent, short/open circuit	Development phase
EEI_20	The charger has to stay on low electromagnetic induction	Development and prototyping phase

Table 21 : Powertrain E/E integration requirements 2

3.3.2 Powertrain internal interfaces

The success in gathering modular powertrain parts lies in the following sections. They detail for each powertrain internal interfaces, the mechanical, informational, energy requirements. For the sake of modularity and efficient management, almost all of the informational data will transfer via VMCU even if it concerns parts mechanically linked.

3.3.2.1 Fuel-driven powertrain internal interfaces i.e. ICE – transmission – differential gear

This section relevancy relies on the fact that neither PSCO nor IFPEN is used to develop directly this kind of powertrain.

First issue is that PSCO vehicle range are all equipped with a CVT, which transmits power with a rubber belt. Although, this rubber belt is mandatory for the transmission ratio to vary continuously, it brings another advantage, the engine acyclism are filtered upstream from the gear shafts, which would never accept such acyclism. The latter, which are emphasized with a mono-cylinder engine compare to 4-cylinder has to be damped upstream from the IFPEN transmission (no rubber belt anymore). Second issue is that the IFPEN transmission is using free wheels. In addition, pre-dimensioning has shown that, these free wheels would not accept the high torque from the ICE. The solution is to increase the rotation speed upstream of the input shaft of the transmission, the minimum ratio between crankshaft and transmission is set at:

$$\frac{\omega_{Shaft_1}}{\omega_{Cranckshaft}} = 1{,}5$$

During pre-design phase, it appears that the fuel-driven powertrain has to be one block cased together. On one hand, the compactness of the powertrain is critical. The volume left in the vehicle is not extendable. On the other hand, the differential gear and transmission use the same oil system in order to be cost-efficient. Therefore, transmission is not as modular as it would be in first line. The concept stays modular, but the interactivity with the ICE imposes to adapt it every time.

The following table (Table 22) summarises the requirements for this interface.

RQ_ID	Requirement description	When?
Intl_01	ICE acyclism has to be damped upstream of the transmission	Design & Development Phase
Intl_02	ICE speed must be raised upstream of the transmission, the ratio must at least be 1,5	Design Phase
Intl_03	Oil system between ICE and transmission has to be separated	Design Phase
Intl_04	Oil system of transmission and differential gear must be shared	Design Phase
Intl_05	Odd number of inversion (Crankshaft rotates in the same way as wheels)	Design Phase

Table 22 : Fuel driven powertrain internal interfaces requirements

3.3.2.2 IWM – Fuel-driven powertrain interface

There are two categories of hybrid powertrain – series hybrid and parallel hybrid. On series hybrid, the ICE is not connected to the wheel directly. Fuel power obtained in the ICE is turned into electric power, stored in the battery. Then, when needed, the electric motor drives the wheel while using the battery power. On the L5e EU-LIVE concept, the hybrid powertrain is a parallel hybrid, which means that both kinds of power are simultaneously available at the wheel. Parallel hybrids mandatory need a productive energy management, but also a well-oiled mechanical coupling between those two sources of energy. In this section, the requirements for the interface between the IWM and the fuel-driven powertrain are listed and it obviously considers these coupling critical issues.

RQ_ID	Requirement description	When?
Intl_06	Differential gear output has to be on the same axes than the rear arm pivot	Design Phase
Intl_07	The Fuel-driven powertrain can drive the wheel when IWM is on	Design Phase
Intl_08	The Fuel-driven powertrain can drive the wheel when IWM is off	Design Phase
Intl_09	The IWM can drive the wheel when Fuel-driven powertrain is on	Design Phase
Intl_10	The IWM can drive the wheel when Fuel-driven powertrain is off	Design Phase
Intl_11	When the inertia clutch is open, the IWM cannot clutch it	Design Phase
Intl_12	The reverse mode is driven by IWM	Design Phase
Intl_13	The reverse mode cannot clutch the ICE	Design Phase
Intl_14	The output shaft of the differential has to go through the rear arm to reach the driving pulley	Design Phase
Intl_15	The differential authorized two different speeds on different output shafts	Design Phase
Intl_16	All bearings must accept maximum rotating speed and torque (it will depends on the transmission mapping)	Development phase
Intl_17	The higher ratio of global fuel driven powertrain is around 6,5 (from crankshaft to the driven pulley of final transmission)	Development and mapping phase

Table 23 : Fuel driven powertrain and IWM interface requirements

3.3.2.3 IWM – Battery interface

The interfaces between battery and IWM have to be partitioned on power interface and logical communication. The EU-LIVE products are totally or partially battery-operated vehicles, and therefore, include electrical energy storage systems that have high-energy content and high power density. Such vehicles must be equipped with protection devices, such as fuses, circuit breakers or main contactors, in case of overcurrent, which would overheat the rechargeable energy storage systems (in accordance with European Regulations).
The power interface connects the battery via the power distribution unit to the Inverter of the IWM fulfilling the aspects of safety (those could be included directly in the battery system):

- Ensure full galvanic isolation when vehicle is turned off
- Pre-charge relay (pre-charging inverter capacitors) to avoid damage of main contactor and inverter capacitors
- Fuse and main contactor must securely separate the battery system from the motor in case of over currents, e.g. in the event of a crash

Logical communication in between battery and IWM is connected via CAN communication from the battery management system to the IWM inverter, via the VMCU.

RQ_ID	Requirement description	When?
Intl_18	Power connexion between IWM inverter and battery system	Design and development phase
Intl_19	Information connexion in CAN between BMS and IWM inverter, mandatory via the VMCU	Design and development phase
Intl_20	Galvanic isolation between those two components when vehicle is off	Design and development phase
Intl_21	Pre-charge relay to avoid damage of main contactor and inverter capacitors	Design and development phase
Intl_22	Fuse between Battery systems and IWM inverters (overcurrent protection)	Design and development phase

Table 24 : Battery system and IWM interface requirements

4 DISSEMINATION, EXPLOITATION AND STANDARDISATION

This deliverable will be published on EU-LIVE's website.

This deliverable sets the baseline for development and design phase for EU-LIVE project. However, its content is not adapted for dissemination. In fact, some of the technical content is cut off because this deliverable is public. Thus, the readers will see the technical requirements building methodology and the modularity impact on such deliverable.

Regarding exploitation, again, it will probably exclusively for EU-LIVE use. WP5 and, to a lesser extent, WP4 are based on D2.2 results.

The work done on this deliverable is a good example of design and development among numerous partners' experts in their field.

5 INTEROPERABILITY

The objective of modularity is especially the interoperability. In this deliverable, all requirements linked to modularity are mandatory to integrate the powertrain components in other vehicle categories.

Obviously, the content concerns only L3e, L5e, and in a less extent, L6e. The powertrain concept should be adaptable at least in other L-category vehicles but maybe also other categories that could be foreseen later (automotive, go-karting, other concept vehicle etc.).

6 CONCLUSION

The first point of WP2 (T2.1 and T2.2) was to find a method to gather all different inputs coming from each partner. This obviously means to benefit the most from having experts in each field. Especially for this deliverable D2.2, this methodology was mandatory. An OEM with its own priorities usually does a new product development phase on its own. This OEM works in collaboration with suppliers. Those suppliers answer to technical requirements written by the OEM. In the EU-LIVE project, this is no longer the case. OEM and suppliers work equally regarding the objectives. Each partners' objectives are considered, nevertheless, global project objectives are first in line. With this method, the requirements are built in an innovative way. Thus, OEM and suppliers can take into consideration the goals of their partner. In comparison with the usual procedure, this is a beneficial shift and it should be considered to optimise the output of such deliverable.

The establishment of the modular powertrain requirements is a long-term job. First, the clear definitions of the boundaries of subsystems are done, and especially the partner in charge of each component is assigned. It was mandatory to decide this as early as possible. At the same time, global design vehicle are specified for each component. Some requirements can be added furthermore in the project, issues that are not known today.

In this deliverable, it was chosen to define the performance requirements as they were in D2.1 [1]. Partners have already pointed out dimensioning issues (especially regarding the battery system) and a compromise will be found later on in the project, i.e. during the design and the development phases. These vehicles requirements are converted in IWM and ICE requirements, using the dynamic laws. The IWM requirements are then converted in current needs linked to the battery system.

Obviously, the modularity implies its own category of requirements, especially regarding the interfaces. On the one hand, there are external boundaries. The powertrain (BEV or PHEV) is considered as a whole and the requirements regarding its integration in the vehicle and on the environment are itemised. In this section, it is important to mention that the partner responsible of the charging system is not currently established. On the other hand, there are the internal interfaces. Among parts, the modularity creates other issues. It has also been discovered that modularity for some components will not be feasible on our demonstrators. For example, the fuel-driven powertrain compactness needs an adaptation of the transmission to the engine. As a result, the ICE, the transmission and the differential gear are one block and thus cannot be fully modular by themselves.

This deliverable is an introduction for design, development and designing phases (WP4 and WP5).

7 REFERENCES

[1] EU-LIVE Deliverable D2.1 “Vehicle requirements”, (not available yet, due in M9)

[2] EU-LIVE Deliverable D2.3 “Virtual vehicle requirements”, v1.0, 2016-01-29

[3] EU-LIVE Grant Agreement N°653203 : “Efficient Urban Light Vehicles”, 2015-03-19

[4] It refers to the European legislation for L-Category vehicle: UE Regulation 168/2013

[5] TRL6: technology demonstrated in relevant environment (industrially relevant environment in the case technologies) Source : https://en.wikipedia.org/wiki/Technology_readiness_level#European_Commission_definition (last accessed 2016-02-26)

[6] Smart Key: Electronic access and authorization of system Source: https://en.wikipedia.org/wiki/Smart_key (last accessed 2016-02-26)

[7] DPR_32, DPR_24, DPR_10, DPR_26 – Requirement taken from Deliverable D2.1 “Vehicle requirements”

A. ABBREVIATIONS AND DEFINITIONS

Term	Definition
1P/2P	One/Two person
ABS	Anti-Blocking System
BEV	Battery Electric Vehicle
BMS	Battery Management System
BOL	Beginning Of Life
BSI	Boitier de servitude intelligent
CAN	Controller Area Network
COTS	Components Off The Shelf
DC	Direct Current
DCDC	Direct Current Tension Converter
DPR	Design and performance requirements
E/E	Electric and Electronics
ECU	Electronic Control Unit
EMI	Electro Magnetic Induction
EOL	End Of Life
ESC	Electronic Safety Control
FEM	Finite Element Method
ICE	Internal Combustion Engine
ICEMS	Internal Combustion Engine Management System
IFPEN	IFP Energies Nouvelles
IWM	In-Wheel Motor
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
PSA	Peugeot
PSCO	Peugeot Scooters
SDI	Samsung SDI
SoC	State of Charge
VMCU	Vehicle Management Control Unit
WP	Work package