EASY AND SAFE BATTERY SWITCH IN AN EV

Deliverable 1.1 –

Intermediate Interfaces Requirements Specification

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EXECUTIVE SUMMARY/ABSTRACT

"The Battery is the Car". New traction battery packs make the fully electric vehicles more and more capable. Their share of the price of the car is set to become even more dominant. Factors driving this include the strident demand for better car range. Battery packs increasingly incorporate electronics for safety and power conversion. The integration of these new complex battery packs presents major challenges especially considering the current lack of standards.

EASYBAT's main mission is to address these integration challenges by defining new concepts for the smart insertion of batteries and by developing in particular generic interfaces for electric vehicles. This research aims at enabling smooth batteries integration and swap.

The EASYBAT integration system will be developed for fully electric vehicles.

The EASYBAT consortium includes a major electric vehicle services provider, one of the top global OEMs, a leading automotive supplier, research institutes covering fields of expertise such as safety & security, interfaces and communication protocols, EVs electrical architecture, and standardization within the IEC/ISO.

Together, the EASYBAT partners will offer solutions enabling cost effective, environmental friendly switchable battery packs and will contribute unleashing the EVs potential for a wider use.

This deliverable identifies existing exchangeable battery interfaces solutions (1st generation) available on the market, analyses the overall improvements and modifications required to be done on the existing interfaces solutions, for both the vehicle and the battery necessary to develop a generic interfaces solution and defines use-cases and requirements for the next generation interfaces solution and field test.

The analysis of existing solutions and the constraints we identified regarding size, weight, height, tolerance and alignment lead us to conclude that the next generation battery type must be a "flat"/"pancake" battery located in the underfloor of the vehicle, between the wheel axels.

This conclusion has a major impact on the solution and on the requirements which will be detailed in this document.

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REVISION HISTORY

Version	Author	Changes	Date)
V1.0	Dr. Chanan Gabay & Michal Shany	1st draft	2011-12-19
V1.1	Michal Shany	Integration of input from WP partners	2012-01-15
V1.2	Michal Shany	Filtering system requirements in sections 3 and 4 to suite public dissemination	2012-02-10

Table 0.1: Revision History

DEFINITIONS/ ABBREVIATIONS

Term	**Definition**
BMS	Battery Management System
BPIL	Better Place
BSS	Battery Switch Station
CAN	Controller Area Network
DTI	Danish Technological Institute
EARPA	European Automotive Research Partners Association
EASYBAT	Easy and Safe Battery Switch in an EV
ECU	Electronic Control Unit
HU	University of Haifa
HV	High Voltage
IKA	Institut für Kraftfahrzeuge
ISO	International Standardization Organisation
LV	Low Voltage
METI	Ministry of Energy, Trade and Industry
MMI	Man-Machine Interface
OEM	Original Equipment Manufacturer
On board active mechanism	A concept in which the vehicle actively releases/locks the mechanical locking mechanism.
On board passive mechanism	A concept in which the vehicle is not involved in the locking/unlocking control, but rather the BSS is active in releasing/locking the mechanical locks of the battery.
QD	Quick Drop
R&D	Research and Development
SLA	Service Level Agreement
TUM	Technische Universität München
TUV	TUV Rheinland
VDE/DKE	German Commission for Electrical, Electronic & Information Technologies of DIN and VDE
VMS	Vehicle Management System
WP	Work Package

1. INTRODUCTION

1.1 Overview

The EASYBAT project will develop (i) generic interfaces to improve interoperability between the battery system modules and the vehicle on board-systems and (ii) new components for an easy & safe location and quick integration of the battery in the vehicle.

1.2 The Objectives

The main objective of this document is to present the investigating results of the 1st generation solutions of the mechanical, cooling, energy and signal interfaces, for the definition of a new generic switchable battery interfaces model.

The result is a set of requirements for improvement related to the next generation battery interfaces.

The analysis starting point was the list of requirements, recommendations and conclusions issued from the recent developments, tests and demonstrations done by Better Place, Renault and others.

1.3 Existing Solutions

1.3.1 On board active mechanism

In this concept, the vehicle plays an active role in releasing/locking the mechanical locks of the battery, while the battery switch station is not involved in the mechanical locking mechanism, only accepts the released battery and carries it into the station storing/charging area.

Better Place demonstrates this concept on various occasions such as Japan's METI EV taxi program.

This concept is based on mechanical latches/locks located in the underbody of the vehicle (see diagram below) that are responsible for the following functions:

- securing the battery pack to vehicle body
- aligning the battery pack with vehicle body during battery installation
- preloading the battery pack against the vehicle body

1.3.2 On board passive mechanism

In this concept developed by Renault, the battery switch station plays an active role in releasing/locking the mechanical locks of the battery, while the vehicle is not involved in the locking/unlocking control.

This concept is implemented commercially in the Renault Fluence ZE, and is based a "toolbox" carried below the vehicle (by the BSS robot) which locks/unlocks the battery.

2. EASYBAT SYSTEM ANALYSIS

2.1 Main Actors

The EASYBAT system is built of 3 main actors: Vehicle, battery and the BSS (see fig 2.1)

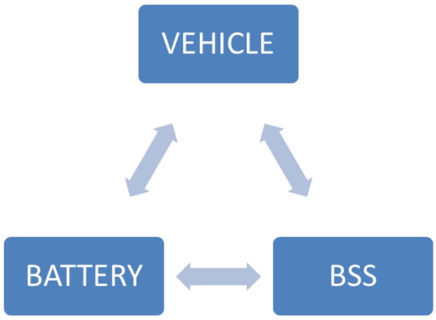

Figure 2.1: EASYBAT System Actors

Vehicle – in the EASYBAT context, 'vehicle' refers to full electric vehicle (EV), with a switchable battery (as opposed to hybrid vehicles, plug-in hybrids, range extension or fixed battery electric vehicles).

The electric car is becoming inevitable. Nearly every major automaker has an active program to develop and introduce EVs, ultimately providing the consumer a broad range of options. These electric vehicles will be distinctive in more respects than their zero tailpipe emissions. EVs inherently provide instant torque, delivering smooth, seamless acceleration. EVs also offer ultra-quiet operation. And since these cars typically have half the moving parts of their gas combustion engine counterparts, lower maintenance costs are expected.

EVs are giving automakers new freedom for innovative designs since the engine, exhaust and complex gearing systems are replaced by simple gearboxes, electric motors and solid state batteries. Flat or ‘pancake’ batteries under the floor of a car allow the cars to have a lower center of gravity, improving handling and increasing interior packaging flexibility.

In addition to the performance benefits, an easily accessible location simplifies manufacturing and will reduce maintenance costs.

All this means that in the coming decade, EVs will be at the center of mainstream personal transportation.

Electric vehicles suffer from short driving range performance. By switching the battery of the electric vehicle, its range can be virtually limitless.

Battery – the lithium-ion battery industry is dominated by the consumer electronics industry but the forthcoming wave of EVs is changing the game.

Made from nontoxic materials, today's lithium-ion batteries have unprecedented safety, high abuse tolerance, low heat dissipation, stable cathode material, and an intelligent pack design that ensure consumer safety. A lithium-ion battery can also be recycled with minimal environmental impact. More than 95% of the battery materials can be recovered and reused. Despite some concerns of availability of lithium, the industry universally accepts that lithium supplies will continue to be abundant, especially if recycling infrastructure is scaled up.

The billions of dollars invested into lithium-ion battery research and development, with a focus on automotive EV applications, will lead to further advances in battery performance (including power, range, charge time, lifetime, and cost). While new battery technologies are emerging, lithium-ion batteries are the leading chemistry for EVs today.

Older generations of EV batteries were characterized by two major problems - providing short driving range and offering limited performance. Today's lithium-ion batteries can store significantly more energy and generate twice the power per unit volume as older battery technologies. These improvements in storage capacity and power availability are critical in maximizing the range of a vehicle. Now, a 24 kWh lithium-ion battery (about 300 kg/660 lbs) in a competitively priced medium-sized sedan provides a range of about 160 kilometers (100 miles) on a single charge.

The cost of lithium-ion batteries has come down by over 75% in the past decade, creating a cost-effective, high-performance solution for EVs. The batteries are expected to perform for over 8 years and 2,000 recharges. If each charge gets 160 kilometers, the battery is projected to last 320,000 kilometers.

In most cases, normal charging from the vast majority of charge spots will be what is referred to as Level II charging, which delivers about 25 km. of driving energy per hour of charging. Given that a vehicle battery can be fully recharged in 4 - 8 hours, if a driver plugs in an EV at night or at work, he/she will wake up to a fully charged battery in the morning. Off-peak (nighttime) charging is ideal for both consumers and the grid since energy demand is lowest (and energy is cheapest), the ratio of renewable energy to non-renewables is commonly highest, and, if managed correctly, the need to invest in grid infrastructure and additional electricity generation is minimized.

Another type of charging is quick charging, providing a recharge to 80% state of charge in 30 minutes. 30-minute quick charge spots are more expensive to build and deploy and present challenges to the grid, but can be practical for certain situations. Fast charging (<10-minute full charge) is another technology under discussion about but it is currently infeasible due to cost, technology and flexibility considerations.

While it may be said that the majority of charging will be done when cars are stationary for an extended period of time, for high volume EV adoption people need a way to extend their range in less than 5 minutes - and the only way to do this is by switching batteries.

A switchable battery pack is a battery pack that can be easily installed and removed into and out of the electric vehicle.

Battery Switch Station (BSS) – In order for EVs to provide a "no compromise" solution, they need to deliver the same freedom to go anywhere that drivers of combustion engine cars enjoy today.

Long battery recharge times are a matter of physics. Even as batteries and charging infrastructure improve, using EVs for long journeys will require a way to quickly and reliably extend the range provided by a battery.

The battery switch station provides this solution using an ingenious robotic system to switch new batteries for depleted ones, cool and charge the batteries in inventory, and manage the complex logistics to ensure that each EV gets a fully-charged battery each time the vehicle arrives at a station.

At the battery switch station, drivers enter a lane and the station takes over from there. The car proceeds along a conveyor while the automated switch platform below the vehicle aligns under the battery, washes the underbody, initiates the battery release process and lowers the battery from the vehicle. The depleted battery is placed onto a storage rack for charging, monitoring and preparation for the next vehicle. A fully-charged battery is then lifted into the waiting car. The switch process takes less time than a stop at the gas station and the driver and passengers may remain in the car throughout.

One of the main goals of the EASYBAT project is to define standard interfaces which will ensure that EVs and battery switch stations are compatible.

Each actor has at least 4 main interfaces:

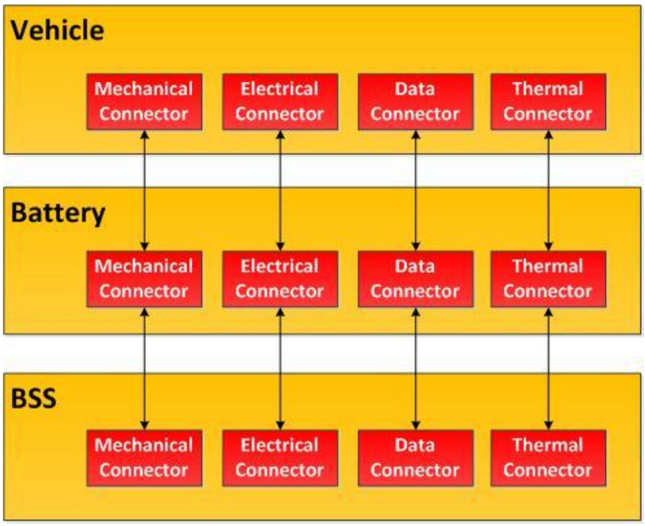

Figure 2.2: EASYBAT main interfaces

Mechanical interface:

The battery bay latching mechanism is responsible for securing the battery pack to vehicle body, aligning the battery pack with vehicle body during battery installation and preloading the battery pack against the vehicle body

The goal of the project is to achieve a mechanical interfaces that is :

- A generic solution that can be used for all EVs and all battery packs.
- Simple and cost effective for the customer.
- Not sensitive to underbody contaminations.
- Allows a fast switch process.
- A generic interface between battery switch station and any type of vehicle.

The EASYBAT project will consider developing a combined **HV (electrical) + LV (data) + Cooling** connector which will have the following benefits:

- Save cost on sealing
- Reduce the part count of the entire system
- Will not constrain the entire battery pack to vehicle alignment process
- Design for cost, safety, crash, environment, testability, usability and more

While cooling by air solutions already exist, a study regarding water cooling will be conducted within the EASYBAT project. The results of the study are expected to include a full design of the proposed solution as well as a technical and economical comparison to current air cooling solutions.

2.2 Requirements Identification

This section will describe requirements that were identified between the actors in the system.

These requirements are the result of the analysis of the current solutions, identification of advantages and disadvantages (which will be described in more detail in the following sections), and definitions of improvements for the next generation solution

2.2.1 Process requirement

For a question of simplicity of the process (of both BSS and assembly plant) the battery shall be assembled in the vehicle vertically.

2.2.2 Vehicle requirements

Battery trunk location is favourable for the vehicle height but not for the trunk capacity and functionality. EASYBAT requirement is to keep trunk capacity and functionality optimization. So the proposed battery location is under the central body of the vehicle (like in the case of Zoe architecture). In this case, the vehicle critical paths are made by the ground clearance, mechanism and/or battery vertical dimension, floor structure thickness, driver and passenger position (heel location and ergonomic requirements) and head clearance vs vehicle height.

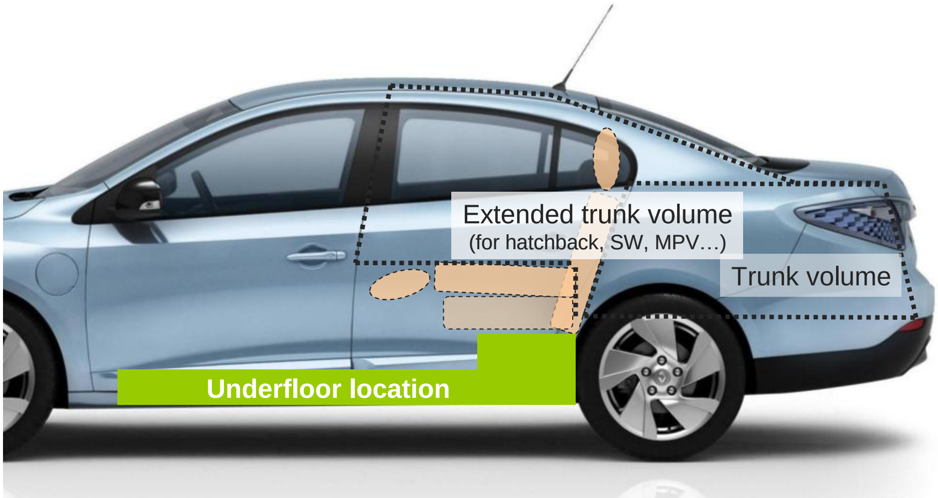

Figure 2.3: Underfloor location – trunk volume and functionality

2.2.3 Interfaces requirements

Electrical and thermal interfaces shall be dust and water proof. So sealing are needed to protect them and also to protect the battery against dust and water penetration. In order to simplify the BSS interfaces, the sealing will be located on the battery side rather than on the vehicle/BSS side.

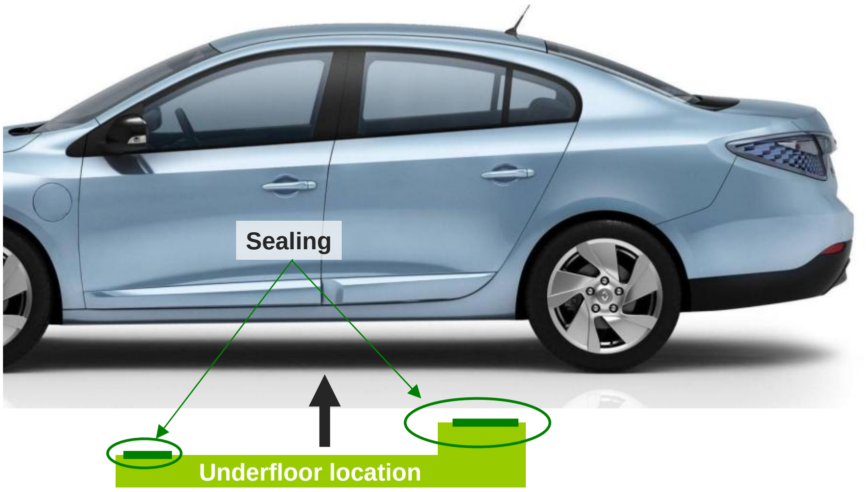

Figure 2.4: Electrical and thermal sealing requirement (dust and water proofness) and location

Mechanical interfaces dimensions shall be such as they will not impact battery modules in application of all standard crash tests (regulation and euroNCAP), and in particular all kind of lateral pole crash (same test speed as regulation).

The electrical interface is already developed and standard. Its definition shall be carried over. However, it shall be cost reduced.

2.2.4 Battery requirements

The air cooling parameters shall respect the specified values in order to keep cooling efficiency regarding battery performance and durability in one hand, and battery internal components reliability in other hand.

2.3 Requirements Analysis Conclusion

All the above analysis of current (1st generation) solutions and the constraints we identified regarding size/weight/height lead us to conclude that the next generation battery type must be a "flat"/"pancake" battery located in the underfloor of the vehicle, between the wheel axels.

This conclusion has a major impact on the solution and on the requirements which will be detailed in the next section.

3. EXTERNAL REQUIREMENTS

This chapter describes in detail the list of requirements from the point of view of external actors (not directly involved in the system).

Each requirement is described by the following attributes:

- Requirement number – for simple reference and traceability.
- Requirement – the description of the requirement itself.
- Original constraint – external factor defining a constraint that had to be taken into consideration and which led to the definition of the requirement.
- From/To system component – defines the actors involved/affected by the requirement.

Req. #	Requirement	Originating constraint	From	To
R1	Battery location won't impact the trunk volume in coherence with market values of the vehicle segments	Cabin functionality – trunk volume	Customer	Battery
R2	Battery location won't impact the RR seats functionality compatible with hatchback, SW, MPV... concepts	Cabin functionality – RR seats functionality	Customer	Battery
R3	Battery location won't impact the vehicle length in coherence with market values of its segment	VH length	Customer	Battery
R4	Keep the vehicle height in coherence with market values of its segment	VH height	Customer	Battery
R5	The battery modules shall be protected against any part penetration by the architecture design and/or by the structure	Side pole crash	Customer	Battery
R6	The mechanism shall support 20G in Z	VH roll over	Customer	Battery mechanic connector
R7	The battery shall still be switchable after front and rear RCAR crash	Front and Rear RCAR crash	Customer	Battery mechanism electrical connector
R8	The battery shall be laid out in a such way its gravity center is close as much as possible to the vehicle gravity center (XY directions)	VH behavior	Customer	Battery
R9	The battery switch process cannot start without a command coming from the driver which takes the responsibility of launching the process	MMI (Man Machine Interface)	Customer	BSS
R10	The driver should have the possibility to stop the battery switch process at any time in case of emergency	MMI (Man Machine Interface)	Customer	BSS

Req. #	Requirement	Originating constraint	From	To
R11	Battery switching process should include communication with the vehicle in order to get reliable real time information about possible failures in car and battery (via wireless communication and BSS center control)	MMI (Man Machine Interface)	Customer	BSS
R12	Vehicle power-train should be disabled during the whole battery switch process. Driver must not be able to drive the car during the battery switch process	MMI (Man Machine Interface)	Customer	VH
R13	Driver and passengers should be allowed to stay onboard of the vehicle during battery switch process	BSS usage	Customer	BSS
R14	Driving skills required to allow the car and driver to undergo a switch process must remain minimal	BSS usage	Customer	BSS
R15	Battery switch process should be user friendly and should consist of minimum movement of the car during battery switch (distances max 100mm and speed max 10mm/s)	BSS usage	Customer	VH
R16	Battery switching should be very short, no more than 4 minutes from start to finish	BSS usage	Customer	BSS
R17	Driver shall be able to use the brake, hand brake, steering, shift gear lever and all vehicle control without stopping the system. If the system stops, possibility to restart the process after additional driver action	BSS usage	Customer	BSS
R18	The mechanism should integrate a contactor to give the driver the information of battery locking/unlocking	Safety	Battery interfaces	Customer
R19	Sealing protection level will be defined according to its layout regarding the water splash exposure	Waterproofness and cleanliness	Customer Environment	thermal & electrical connection sealing
R20	Sealing and parts geometry shall assure IPXX when the battery is assembled on the vehicle, depending on interface layout	Waterproofness and cleanliness	Customer environment	Electrical connection
R21	Electric connector shall assure prevention of finger poking inside the connector, and water/dust to penetrate into the battery	Waterproofness and cleanliness	Plant and after sales environment	Electric connector
R22	The assembled part geometry and the sealing shall assure protection against water and dust. (IPXX will be defined at a later stage, depending on interface layout design).	Waterproofness and cleanliness	Customer environment	Thermal interface
R23	Connector and HV harness shall be installed in a such way the protecting parts needed will be minimized	Waterproofness and cleanliness, gravels protection	Customer environment	Connector and HV harness

Req. #	Requirement	Originating constraint	From	To
R24	The battery connection mechanism shall be protected against the consequences of water and mud splash, of dust and gravels projections	Waterproofness and cleanliness, gravels protection	Customer environment	Mechanism
R25	The mechanical, electrical and thermal interfaces shall resist snow and ice effects	Ice protection	Customer environment	Mechanism connector cooling sealing
R26	The battery shall still be switchable after corrosion tests including salts of snow clearing ($MgCl_2$, $CaCl_2$)	Anticorrosion	Customer environment	Battery mechanic connector
R27	The battery shall be protected against curbstones, obstacle and road debris impacts (enough ground clearance and/or additional protecting parts) ; its layout should minimize the additional protecting parts	Curbstones & obstacles impacts	Customer environment	Battery
R28	The battery connection mechanism shall be protected against curbstones, obstacle and road debris impacts (enough ground clearance and/or additional protectors) ; its layout should minimize the additional protectors	Curbstones & obstacles impacts	Customer environment	Battery connection mechanism
R29	The electric connector shall be protected against curbstones, obstacle and road debris impacts (enough ground clearance and/or additional protectors) ; its layout should minimize the additional protectors	Curbstones & obstacles impacts	Customer environment	Electric Connector
R30	Mechanisms shall be protected or shall resist against jack misusage (of both mechanical onboard type and hydraulic workshop type)	Jack misusage impact	Customer Environment /after sales operator	Mechanism
R31	If battery release or engagement is operated by an electro - mechanical device, manual bypass must be allowed with special tool to enable battery installation or removal when electric power is not available or in case of or mechanical problem.	Switchability availability	BSS / VH environment	BSS or VH Switch actuator
R32	The humidity of the storage/charge area shall not affect safety and functionality of the interfaces	Ambient humidity	BSS environment	BSS
R33	The BSS interior temperature shall be included between 10°C and 25°C max	Ambient temperature	BSS environment	BSS
R34	The air inside the BSS shall be in overpressure of 20 Pa	Dust protection	BSS environment	BSS
R35	The BSS shall integrate a connector cleaning equipment, to be used just before charging and just before reconnecting on the VH	Dust protection	BSS environment	Connector

Req. #	Requirement	Originating constraint	From	To
R36	No objects will be able to penetrate into the battery during all switching operation, charging and storage	Protection against objects penetration into the battery	BSS environment	BSS
R37	The battery shall be removed quickly	Operating time	After sales operator	Battery Mechanism
R38	The battery shall be assembled vertically on the vehicle	Operating time and ergonomics	Plant operator	Battery
R39	The battery connection mechanism shall be assembled vertically on the vehicle	Operating time and ergonomics	Plant operator	Battery connection mechanism
R40	The thermal and the electrical connection shall be compatible with vertical assembly	Operating time and ergonomics	Plant operator	Thermal interface
R41	The number of additional parts compared with non switchable battery versions shall be limited	Number of part references	Logistics	All
R42	Electric connector should be designed to cost	Cost	Product/ market environment	Electric Connector
R43	Cost of the complete EV user’s package (vehicle cost + mobility services costs) should be kept to minimum, lower than the costs of using comparable size ICE vehicle.	Cost	Product/ market environment	BSS/VH
R44	BSS cost must be low so it will not impose high usage cost for customers and high deployment cost for network operator	Cost	Product/ market environment	BSS/VH

4. INTERNAL (VEHICLE/BATTERY/BSS) FUNCTIONS

This chapter describes in detail the list of internal functional requirements.
Each requirement is described by the following attributes:

- Requirement number – for simple reference and traceability.
- Requirement – the description of the requirement itself.
- Original constraint – external factor defining a constraint that had to be taken into consideration and which led to the definition of the requirement.
- From/To system component – defines the actors involved/affected by the requirement.

Req. #	Requirement	Originating constraint	From	To
F1	BSS requirement : European B-C-LCV1 segment size: 1. Length: min = 3700, max = 4600 mm 2. Width : min = 1600, max = 1850 mm 3. Height : min = 1400, max = 1850 mm	Size Compatibility	VH	BSS
F2	BSS requirement : European B-C-LCV1 segments weight range : maxi = 2500 kg	Weight compatibility	VH	BSS
F3	BSS requirement : European B - C - LCV1 segments car wheel width range: Ext : mini = 1550 mm, maxi = 1850 mm Int : mini = 1150 mm, maxi 1400 mm	VH positioning: Car wheel width range	VH	BSS / alignment post
F4	BSS requirement : European B - C - LCV1 segments wheel base : mini = 2400 mm, maxi = 3100 mm	VH positioning : wheel base size	VH	BSS / alignment post
F5	Wheel size : mini = 500 mm, maxi = 750 mm	VH positioning : wheel size	VH	BSS / alignment post
F6	System needs to be able to interface VH and batteries with different altitude due to different weight distribution in the VH	VH positioning : altitude	BSS / alignment post	VH
F7	Battery and vehicle cleaning requirements, prior to switching a battery, should be kept to minimum. Cleaning device should be generic, capable of cleaning all cars and batteries, no specific devices per specific cars	Washing	BSS / Washing & drying post	VH
F8	Standard washing fluids usage Standard washing temperature < 45 °C Standard washing pressure : 70 bars No glycol use for winter	Washing	BSS / Washing & drying post	VH
F9	The vehicle underbody shall be dried after washing	Drying	BSS / Washing & drying post	VH

Req. #	Requirement	Originating constraint	From	To
F10	The VH is equipped with a single switchable battery located between the axles of the car. Battery shall be installed and removed from the vehicle, to and from the underbody of the car in vertical (along the Z axis) motion.	Battery switch	Battery	BSS
F11	Battery dimensions shall be Height ≤ 370 mm Length ≤ 1900 mm Width ≤ 1400 mm	Integration : Battery size	Battery	BSS
F12	400 kg maxi	Integration : Battery weight	Battery	BSS
F13	BSS shall be able to accept from 4 to 8 different types of batteries	Integration : Battery pack types	Battery	BSS / Battery storage
F14	The service disconnect shall be always accessible in the BSS	Integration : Service disconnect Accessibility	Battery	BSS
F15	The battery interfaces shall be designed for a battery which is installed and removed vertically	Mechanical/ electrical/thermal interface : battery exchange	Battery	BSS
F16	Battery pack design shall include reference points and hoist points and BSS will use only these points to interface the battery	Mechanical interface: battery pack geometrical reference	Battery pack	BSS
F17	The battery contactors shall be controlled and diagnosed by the charger ECU, in the same way as in the VH.	Electrical interface: battery contactor control	BSS / Charger	Battery
F18	Charger LV interface shall be compliant with Vehicle LV interface: it shall integrate the power supply and the interlock circuit.	Electrical interface: LV	BSS / Charger	Battery /BMS
F19	The connector shall absorb parts dispersion (XYZ/RxRyRz relative parts position dispersion)	Electrical interface: geometry	Battery / connector	VH / BSS connector
F20	The LV connector shall be compatible with voltage of 12V under 8A for a 1.5 mm² wire (same as current Fluence connector)	Electrical interface: LV	BSS / Charger	Battery
F21	The BSS charger shall be able to charge battery at voltage of 240 to 500V, 155 to 240A	Electrical interface: HV	BSS / Charger	Battery
F22	Equipotentiality between the battery pack and the charger body structure shall be insured by the connector	Electrical interface: LV	BSS / Charger	Battery
F23	The battery shall use the same thermal interface by fluid as in the car	Thermal interface	Battery	BSS / VH / thermal management
F24	The BSS shall use the same communication and CAN interfaces as those used by the vehicle (for both functional data and diagnostic services)	Data interface: Data exchanges and LV CAN interface	Battery / BMS	BSS / Charger / ECU

Req. #	Requirement	Originating constraint	From	To
F25	The minimum number of connection points between battery and VH is to be 4	Mechanical interface	Battery	VH
F26	The mechanism shall be able to withstand 20G in Z direction without battery mechanical disconnection	Mechanical interface: static and dynamic Z load transfer	Battery	VH
F27	The mechanism shall allow simple and quick assembly to car body without high precision adjustment	Mechanical interface: VH geometry	Battery	VH
F28	The mechanism shall be assembled directly to the VH body without additional part. If reinforcement is needed it shall be integrated to the VH structure	Mechanical interface: battery / VH	Battery	VH
F29	Locking/unlocking the battery system shall be cost and safe designed from both VH and BSS global point of view	Mechanical interface: locking/unlocking	Battery	VH
F30	Mechanical interface between battery switching station and car must remain as generic as possible, allowing multiple types of cars (and batteries) to use the same mechanical interface. Vehicle interface must not require equipment which is specific to only one type of vehicle and cannot be used on other type of cars	Mechanical interface integration	Mechanism	VH / BSS
F31	The mechanisms design and materials shall be able to manage a battery weight up to 400 kg	Mechanical interface: battery weight range Capability	Battery	VH
F32	The electrical connector shall be standard	Electrical interface	Battery	VH
F33	Power supply to BMS will be provided by the LV VH system	Electrical interface: BMS and battery contactors feeding	VH / connector (LV system)	Battery / connector (BMS/ contactors)
F34	VH system (EVC) shall control and diagnose the battery contactors	Electrical interface: BMS and EVC	Battery / contactors	VH
F35	The connector shall include the electric equipotentiality function between the battery pack and the VH body structure	Electrical interface: battery energy transfer	Battery pack	VH (body)
F36	The battery shall use the same thermal interfaces as in the BSS	Thermal interface	Battery	VH
F37	Sealing of the thermal connector has to be installed on the battery	Thermal interface: Sealing	Battery	VH
F38	Data exchanges shall respect CAN protocol and the EV CAN matrix definition. Diagnosis services shall be available.	Data interface: Data exchanges and CAN interface	Battery / BMS	VH / EVC
F39	The connector shall be able to deliver power at Voltage of 240 to 500V, 155A min., 240A max.	Electrical interface: battery energy transfer	Battery	VH

Req. #	Requirement	Originating constraint	From	To
F40	Locking/unlocking the battery system shall be cost and safe designed from both the VH and BSS global point of view	Locking/unlocking	BSS/locking - unlocking system	VH mechanical connector
F41	Battery pack and interface shall be compatible with the VH and assembly process tools environment.	Product/process integration	Battery	VH/ assembly process tools

5. CONNECTIONS OF DATA SETS

5.1 Battery switching process steps

Switching the battery is a quick and easy way to extend driving range without having to wait for the battery to recharge.

The switching process is quick, intuitive, does not require any special technical or driving skills – as easy as driving through a car-wash and takes less time than filling up a gas tank.

During the switching process, user-friendly messages displayed both in the vehicle's on-board system and on monitors in the BSS (Battery Switch Station) inform the driver of each step of the process.

The switching process includes the following steps:

- The driver and vehicle are identified at the front gate
- According to driver's SLA (service level agreement) and vehicle properties, a matching battery is allocated from the BSS storage.
- Entry gate opens and the driver drives towards the switching pit, stopping above the washing area.
- The underside of the battery is washed and dried
- The vehicle is then driven or pulled to the switching pit
- The wheels of the car are locked in place
- Battery is unlocked from the vehicle
- The depleted battery is removed and lowered into the switching pit. The battery will now be recharged and stored, ready to be used by another vehicle.
- A new, fully charged battery is inserted and locked into the vehicle.
- A full systems check verifies the new battery was properly placed and safely locked.
- The car is released, exit gate opens and the driver can safely drive away.

Throughout the switching process, the vehicle's on board systems (such as navigation, a/c, radio, etc.) remain active for driver's and passengers' comfort.

After the battery switching process is completed, a message appears confirming that the process has safely ended (both in the vehicle's on-board system and on monitors in the BSS) and informing the driver he may now drive safely out of the BSS.

5.2 Communication hardware and protocol

There are four actors in the switching process: the BSS, the vehicle (i.e. the VMS), the battery (i.e. the BMS) and the driver. The communications connections are as follows:

From/to	To/from	Connection type	Protocol
Vehicle	Driver	Mechanical (steer, pedals)	
Vehicle/VMS	Driver	MMI via infotainment system	CAN
BSS	Driver	MMI at switching post (button(s) and screen(s))	
Battery/BMS	Driver	N.A.	N.A.
Vehicle/VMS	BSS	Wireless	CAN
Battery/BMS	BSS	N.A.	N.A.
Vehicle/VMS	Battery/BMS	Hard wired ('LV connector')	CAN

Table 5.1: Communication connections BSS during the switching process

When the battery is locked inside the vehicle, the BMS only communicates to the VMS through the LV connector between battery and vehicle. If necessary, data from/to the BMS for the other actors will be handled through the VMS.

When the battery is inside the BSS for storage and recharging the battery/BMS will communicate with the BSS via the hardwired connection interface. The BSS will connect to the battery with a connector similar to the vehicle connector. The protocol between BSS and BMS (when inside the BSS) will be the same as the protocol between VMS and BMS (when inside the vehicle).

The wireless connection is used to build a connection between the BSS and the car that will change its battery. The BSS is the master of the communication. While a car enters the station, the connection sets up and the VMS of the car can communicate with the BSS. The connection should not be interrupted during the whole switching process. It is necessary, that the wireless connection is internationally approved and admitted, such as Wi-Fi or Bluetooth. The vehicle might have a separate ECU that is part of the VMS. The ECU should communicate with the BSS. The main ECU data consists of information about the battery locking state.

6. DEFINITION OF USAGE SCENARIOS

The goal of task 1.4 is to identify and define representative usage scenarios for the improved next generation switchable battery packs. Therefore a comprehensive concept was developed. The concept is based on two pillars, a consideration of car classes, as well as a consideration of climatic scenarios, both illustrated in the next sections.

6.1 Definition on Car classes

6.1.1 B&C class cars

Passenger cars can be classified in different classes as shown in Table 6.2.

<table>
<tr><th>Euro Car Segment</th><th>American English</th><th>EURO NCAP 1997-2009 (New Car Assessment Programme)</th></tr>
<tr><td rowspan="2">A</td><td>Microcar</td><td rowspan="3">Supermini</td></tr>
<tr><td rowspan="2">Subcompact car</td></tr>
<tr><td>B</td></tr>
<tr><td>C</td><td>Compact car</td><td>Small Family car</td></tr>
<tr><td rowspan="2">D</td><td>Mid-Size car</td><td rowspan="2">Large Family car</td></tr>
<tr><td>Entry-level luxury</td></tr>
<tr><td rowspan="2">E</td><td>Full-size car</td><td rowspan="3">Executive car</td></tr>
<tr><td>Mid-size luxury car</td></tr>
<tr><td>F</td><td>Full-size luxury car</td></tr>
</table>

Table 6.1: Car classification.

After a technical as well as a market analysis, the partners decided B&C class cars to be the fundamental classes to consider. Because of similar technical properties within these classes, B&C class cars will be considered as one car class for this project. Two crucial arguments are shown in Table 6.2 and Table 6.3. A consideration of the mechanical design shows a very small range of differences between B&C class cars (Table 6.2). For the mechanical interface, these minor differences are a conclusive technical factor to consider B&C class cars as one class. For other car classes this mechanical range is much larger.

Table 6.3 shows an overview of the vehicle platforms. B&C class cars sometimes even have the same vehicle platform on which they are built. Additionally a more detailed review on the vehicle platforms shows, that new B class cars are often built on an older C class platform (e.g. PQ25 <=> PQ3X, X<5).

		B	C
length (m)	hatchback	3.75-4.1	4.1-4.45
	convertible	4.0-4.4	4.4-4.75
	station wagons	4.0-4.4	4.4-4.75
	sedan	4.0-4.4	4.4-4.75
combined passenger and cargo volume		2.4-2.8	2.8-3.1
wheelbase (m)		< 2.554	2.554-2.667

Table 6.2: Minor differences in mechanical design.

Subcompact	Platform	Compact	Platform
B	**B**	**C**	**C**
Alfa Romeo MiTo	ZFA182/ Fiat/GM SCCS	Alfa Romeo 147	ZFA182
Audi A2	PQ24	Audi A3	PQ35
Audi A1	PQ25	BMW 1-Series	E87
Citroen C3	PF1	Citroen C4	PF2
Fiat Punto	Fiat/GM SCCS	Fiat Bravo	ZFA182
		Fiat Stilo	Fiat C
Ford Fiesta	Ford B	Ford Focus	Ford C1
Mazda2	Ford B	Mazda3	Ford C1
Opel Corsa	Fiat/GM SCCS	Opel Astra	
Opel Meriva	Fiat/GM SCCS		
Peugeot 207	PF1	Peugeot 307	PF2
		Peugeot 308	PF2
Renault Clio	Renault Nissan B	Renault Megane/Fluence	Renault Nissan C
SEAT Ibiza	PQ25	Seat leon	PQ35
Škoda Fabia	PQ24		
Toyota Yaris	C	Toyota Auris	E
Volkswagen Polo	PQ25	Volkswagen EOS	PQ35
		Volkswagen Golf	PQ35
		Volvo C30	Ford C1

Table 6.3: Overview on B&C class passenger cars and their platforms.

6.1.2 Light commercial vehicles

A light commercial vehicle (LCV) is a commercial carrier vehicle with a gross vehicle weight of up to 3.5 tons (Figure 6.1). For the EASYBAT project, LCV's will be considered as the second car class because they make up a significant amount of vehicles on the roads (e.g. in Germany there are over 1 million LCV's). Table 6.4 shows an extract of an LCV overview with technical details. The technical details listed in Table 6.4 are similar to those in Table 6.2.

LCV	Platform	Lenght	Wheelbase
Citroen Berlingo	PF2	4.38	2.728
Citroen Nemo	Fiat/GM SCCS platform	3.864	2.513
Peugeot Bipper	Fiat/GM SCCS platform	3.864-3.97	2.513
Peugeot Partner	PF2	4.38	2.728
Fiat Fiorino	Fiat/GM SCCS platform	3.864	2.513
Renault Kangoo	Renault Nissan C	3.829–4.213	2.313–2.697
VW Caddy	PQ 35	4.2	2.68
Opel Combo	Fiat/GM SCCS platform	4.332	2.716
Ford Connect	Ford C1	4.275	2.664

Table 6.4: LCV`s technical details.

Although, at first sight, some technical properties are similar, a more detailed analysis of the LCV's results in a contrast for LCV's and B&C class cars. Table 6.5 shows the major differences between the two car classes.

Due to the fact that the gross vehicle weight of a LCV is much higher than of a B or C class car, the ground clearance and pitch angle will be much more diverging for a LCV (fully loaded vs. fully unloaded), so the requirements for the BSS will be different.

Figure 6.1: LCV's with a gross vehicle weight of up to 3.5 tons.

Parameter	LCV	B&C
Ground clearance and pitch angle	↑	↓
Gross weight	↑	↓
Mileage per day	↑	↓
Market share	↓	↑
Commercial usage	↑	↓
Space for battery switch mechanism	↑	↓

Table 6.5: Major differences between B&C class cars and LCV's.

Over 70% of all LCV's are used commercial, thus the geographic allocation of LCV's is much more centralized, so there could be some possibilities to make costumer specific solutions.

German research results (Kraftfahr-Bundesamt, KBA) show that the average KM per day for LCV's reaches double the value (up to an average of 250 km a day) as for B&C class cars. Consequences:

=> Most B&C Class cars will have to recharge only once a day!

=> LCV will have to recharge at least twice a day!

After the detailed research on the vehicle classes, the comparison of B&C class cars versus LCV's arises for all partners as a successful basis.

6.2 Climate scenarios

For the climate scenarios IKA, TUV and Renault worked in a close cooperation. The climate scenarios are defined for testing complete electric Ch20913vehicles and BSS and are generated out of different standards. For following specifications are not intended for the testing on component level.

6.2.1 Boundary Conditions (hot/cold) Intermediate scenario

Definition of cold temperature scenario: - 25°C (e.g. Denmark)
Definition of hot temperature scenario: 50°C (e.g. Israel)
Additionally a decision was made to consider an additional intermediate climate scenario (e.g. France, Germany) which is specified at 12°C.

7. SUMMARY & CONCLUSIONS

The aim of this document was to identify the existing exchangeable battery interfaces solutions (1st generation) available on the market, analyse the overall improvement and modification required to be done on the existing interfaces solutions, for both the vehicle and the battery necessary to develop a generic interfaces solution and define use-cases for the next generation interfaces solution and field test.

Section one gives a brief introduction to the objectives of the EASYBAT project and a short overview of two of the currently existing solutions.

In section two, a quick overview is given of the system's main actors – Vehicle, Battery and Battery Switch Station, their role in the EASYBAT project, and also within the general context of the EV market, as well as a brief description of the 4 interfaces between each of the actors – mechanical, electrical, data and thermal.

This section also describes the process by which the requirements were identified as a result of the analysis of the current solution, identification of advantages and disadvantages and definition of improvements for the next generation solution.

A system functional diagram and a mapping of external requirements conclude section two and act as an introduction to the detailed requirements specified in sections 3 and 4.

It is important to note that the analysis of current (1st generation) solutions and the constraints we identified regarding size/weight/height lead to the conclusion that the next generation battery type must be a "flat"/"pancake" battery located in the underfloor of the vehicle, between the wheel axels.

This conclusion has had a major impact on the solution and on the requirements.

Section 3 details requirements from the point of view of external actors, not directly involved in the system.

Section 4 details internal functional requirements.

Section 5 describes in detail the 16 steps in the battery switching process, describing each step both graphically and by a sequence diagram showing the interaction between the BSS, the CAR and the DRIVER.

Last, but definitely not least, section 6 identifies and defines representative usage scenarios for the improved next generation switchable battery packs, basing the concept on a consideration of car classes – chosen specifically for the EV market as we see it evolving in the near future, as well as a consideration of climatic scenarios.

The requirements and use case scenarios defined in this document are the baseline to the work that will be achieved in subsequent work packages in order to achieve a generic, cost effective and environmentally friendly solution.