D 2.5 – Final requirement compilation and KPI's

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SUMMARY SHEET

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Abstract	*One of the project objective is to have a list of Key Performance Indicators (KPIs)*[1] *to be used as a common tool for evaluating the achievements and impacts of the use case demonstrators that will be performed during the project. In parallel, performance targets of different stakeholders involved in the project (cities, PTA/PTO, grid operators, vehicle manufacturers and charging infrastructure operators) have been defined.*

[1] The term/abbreviation KPIs is used throughout this document. It is worth mentioning however that the "Key" part of the KPI abbreviation may not applicable to all identified Performance Indicators. Which Indicators deserve the Key prefix is actually determined by the ASSURED project objectives, which focus on TCO (i.e. costs), energy efficiency, grid impact aspects, noise and environmental impacts. However, as the abbreviation KPI is much more common than the abbreviation PI, it is chosen to use the abbreviation KPI for both PIs, as well as KPIs.

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V4	03/07/18	VUB	Quality check
V5	04/07/18	RINA-C BE	Quality check
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ACRONYMS

ABS: Antilock Braking System
AC: Alternative Current
BEV: Battery Electric Vehicle
CC: Constant Current
CCS: Combined Charging System
CO2: Carbon Dioxide
CP: control pilot
CSO: Charging Station Operator
CV: Constant Voltage
DC: Direct Current
DoW: Description of Work
DSO: Distribution System Operator
EC: European Commission
EMS: Energy Management System
EU: European Union
EV: Electric Vehicle
EVSE: Electric Vehicle Supply Equipment
FIT: Failures In Time
HD: Heavy Duty
HDV: Heavy Duty Vehicle
HV: High Voltage
HVAC: Heating, Ventilation, Air Conditioning
ICE: Internal Combustion Engine
ICT: Information and Communication Technology
INEA: Innovation and Networks Executive Agency
IT: Information Technology
ITS: Information and Telecommunication System
KPI: Key Performance Indicators
kVAr: Kilovolt – Amperes reactive
kW: Kilowatt
kWh: Kilowatt hour
LA: Local Authority
LV: Low Voltage
MD: Medium Duty
MTBF: Mean Time Between Failure
MV: Medium Voltage
OCA: Oracle Certified Associate
OCP: Open Core Protocol
OCPP: Open Charge Point Protocol
OSCP: Online Certificate Status Protocol
OSI: Open Systems Interconnections
PCC: Point of Common Coupling
PE: protective earth
PPP: Public Private Partnership
PT: Public Transport
PTA: Public Transport Authority
PTO: Public Transport Operator
RESS: Rechargeable Energy Storage Systems
SCADA: Supervisory Control and Data Acquisition
SMART: Specific, Measurable, Achievable, Relevant, Time-Oriented
SOC: State Of Charge
SUMP: Sustainable Urban Mobility Plan

TCO: Total Cost of Ownership
THD: Total Harmonic Distortion
TSO: Transmission System Operator
V2G: Vehicle To Grid
WHO: World Health Organisation
WP: Work Package

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Executive Summary

ASSURED is aimed at boosting the electrification of urban commercial vehicles and their integration with high power fast charging infrastructure, evaluating several infrastructures in different cities across Europe. This implies the need to have a list of Key Performance Indicators (KPIs) as a common tool for evaluating the achievements and impacts of the use case demonstrators that will be performed during the project; in parallel to that, performance targets of different stakeholders involved in the project (cities, PTA/PTO, grid operators, vehicle manufacturers and charging infrastructure operators) are settled in line with the impacts expected in this call.

The objective of this deliverable is to identify a KPI Tree that includes all the indicators needed for the use cases outcomes assessment and the setting of the final requirements compilation analysed in the previous tasks of WP2.

Part of the evaluation of each demonstrator will be based on the KPI Tree identified in this deliverable, which represents the complete set of Performance Indicators (parameters + units of measure) needed for the evaluation, but the appropriate selection of KPIs is case specific and especially performed in T9.3.

The study starts with an explanation of the different strategies used for the KPIs' evaluation and selection, specifying how the requirements studied in the previous tasks and the general criteria of transport measurement conduct to the determination of KPIs. Furthermore, the KPI Tree is defined for what concern the general structure to facilitate the interpretation and the consequent use of it. After this, the work proceeds with the final compilation of requirements and point of view of different stakeholders and the definition of the main criteria of transport measurement involved in the determination of KPIs.

The main content of the document is represented by the list of performance indicators, representing the KPI Tree, and divided in different levels per each main criterion. A chapter is also dedicated to the relationships that exist within the various indicators also among different criteria, to understand how the KPIs are interconnected and how they could influence each other. Definitions about how to evaluate the performance indicators in terms of unit of measurement and assessing method are contained in the following chapter.

The last part of the deliverable is dedicated to the performance targets and impacts expected in this project; a particular attention is paid to the Total Cost of Ownership (TCO), which improvement is one of the most relevant target. TCO minimisation and other performance targets derived from the outcomes of use cases analysed; they are put in relation to KPIs, with the aim of better explain how KPIs can be used for the evaluation of ASSURED proposed solutions.

<u>Attainment of the objectives and explanation of deviations:</u>

The objectives related to this deliverable have been achieved in full and by the beginning of M10.

Partners' Contribution

Company	Sections	Description of the partner contribution
POLIS	4.1	City view and requirements
UITP	4.2	PTAs and PTOs view and requirements
IBERDROLA	4.3	Power grid view and requirements
FEV	4.4	view and requirements of vehicle manufacturers
HELIOX	4.5	Charging infrastructure requirements
TNO	all	Input and review of KPI Tree
FEV	all	Review of the document
FEV	all	Input to KPI Tree with reference to vehicle
VTT	all	Review of the document and suggestions on KPI Tree
IDIADA	all	Review of the document and suggestions on KPI Tree
VUB	all	Quality assurance and check
RINA-C BE	all	Quality check

1. Introduction

1.1 Objective of the deliverable

The objective of the deliverable is to collect all the relevant KPIs related to the integration of (super) fast charging solutions for electrified HD and MD vehicles and the setting of appropriate performance targets in line with the impacts expected in this call. The final list of KPIs, that represents the KPI Tree, takes into account the typical criteria of transport measurement (such as cost, performance, quality of service etc…), following the SMART prescriptions as a selecting methodology. This is done in order to have an unmistakable tool for expressing the achievements and impacts of the use case demonstrations performed in WP8 and evaluated in WP9. The complete list is also contained in the Excel version of the KPI Tree that could be found in the Technical Annex of this deliverable. Another input for the identification of KPIs is represented by the requirements of the different stakeholders involved in the ASSURED project (cities, PTA&PTO, DSO&TSO, vehicle manufacturers and charging system operators); the previous WP2 deliverables (from D2.1 to D2.4) are used in this document as a basis for the final compilation.

Performance targets and expected impacts are set out considering the general objectives of the project (e.g minimisation of TCO) and the expected outcomes from use case demonstrators; an objective of this deliverable is also to make in relation impacts and targets with the KPIs in order to evaluate solutions proposed within the project.

1.2 Organization of the deliverable

This deliverable is divided into five main chapters, that describe the evolution of the work in task 2.5. Starting from the definition of Key Performance Indicator and the description of the selection methodology (Chapter 2), the attention is focused on the specification of the main criteria in which KPIs are divided (Chapter 3) and the requirements derived from the previous WP2 deliverables (Chapter 4).

The core part of this document is Chapter 5, in which the complete overview on the KPI Tree in all its parts and criteria is reported; the relationships among KPIs are underlined and also the role of the KPI tool for the optimization of the TCO.

The performance targets, defined to be in line with the expected impacts of this call, are argument of Chapter 6.

2. KPI Tree: definition and strategies

2.1 DEFINITION OF KEY PERFORMANCE INDICATORS AND CHARACTERISTICS

A Key Performance Indicator (well known as KPI) is a quantifier or qualifier of performance, that has the capability to express the effect of a change/measure in respect to the expected impacts and to verify against the performance targets.

KPIs are quantifiable values, either in quantitative or qualitative base; they can be indicators of an absolute performance or evaluate performance improvements, reflecting the organisation/process' goals.

In addition to the fact that KPIs have to be understandable, clearly defined, meaningful and unmistakable, they also should follow the SMART criteria. This means that they should be:

- "S"pecific: the measured values of indicators should have a specific purpose for the evaluation requested. They reflect strategic value drivers that represent activities that, when executed properly, guarantee future success;
- "M"easurable: indicators have to be measurable, in quantitative or qualitative base. To do that, they must be based on valid data and easy to understand for all people involved;
- "A"chievable: the measuring system of indicators should be achievable and feasible; in addition, KPIs should lead to positive actions;
- "R"elevant: the indicators have to be relevant to ensure that KPIs continually boost performance, verifying periodically the indicators to determine usage and relevance;
- "T"ime phased: the outcome of a measure should be related to a time period.

2.2 KPI COLLECTION FOR THE IMPLEMENTATION OF THE KPI TREE

The objective of the KPIs' collection in ASSURED is to have a common way of expressing assessment results throughout this project and more specifically to verify whether the outcomes derived from the demonstrators in WP7 are in line with the performance targets, established considering the expected impacts of this call; this kind of evaluation is the core work of WP9.

In WP2 the focus is on the selection of the relevant KPIs taking into account the needs of the different stakeholders involved in ASSURED project; given the large number of – sometimes – contradictory or duplicated requirements from the different sources interrogated, the evaluation methodology of KPIs is not the same for all of them.

In the KPI Tree there is a specific column dedicated to this kind of methodology; in this sense, KPIs can be:

- measured: the indicator can be directly evaluated with measuring instruments properly identified;
- calculated: the indicator cannot be measured directly, but there are tools of calculation or simulation of the behaviour of phenomena that we want to observe;
- estimated: if the indicator cannot be evaluated through a measurement or a calculation, it can be possible an estimation for example using historic data or survey on field. There will be an intrinsic estimation error to be considered and a confidence interval for the acceptance evaluation;

- from survey: the indicator is the result of a survey involving the knowledge and experience of the different stakeholders in ASSURED project.

2.3 KPIs' SELECTION METHODOLOGY

With regards to the selection methodology, two different approaches are used as following described: bottom – up and top – down.

An integration of both of the them has been then applied as shown in following Figure 3 to arrive to the definition of the final KPI tree compliant with all the requirements of the SMART methodology. .

2.3.1 Bottom – up approach

The first part of task 2.5 consists of the analysis of requirements of different stakeholders in order to establish a project specific assessment tool for measuring the achievements and impacts of the use case demonstrators performed in WP8 and evaluated in WP9; this activity leads to a definition of proper criteria, selected among the typical ones of transport measurements but also projected specifically for the ASSURED use cases.

This work flow, conducted with a bottom – up approach, can be schematized as following:

Figure 1 “Bottom – up” selection methodology

2.3.2 Top – down approach

A second step of the activity is to lead from general criteria to final KPIs through several levels. The number of levels increase with the aggregation level of specification, in a flow from general to particular that in the case of the present activity can be summarized with the following scheme:

Figure 2 “Top– Down” selection methodology

2.3.3 Integration of approaches

The KPI Tree is the result of an integration of bottom – up and top – down approaches. This integrated approach is illustrated in Figure 3, in which each green dot represents a level of KPI. This figure can be red in both directions, representing the two approaches described above.

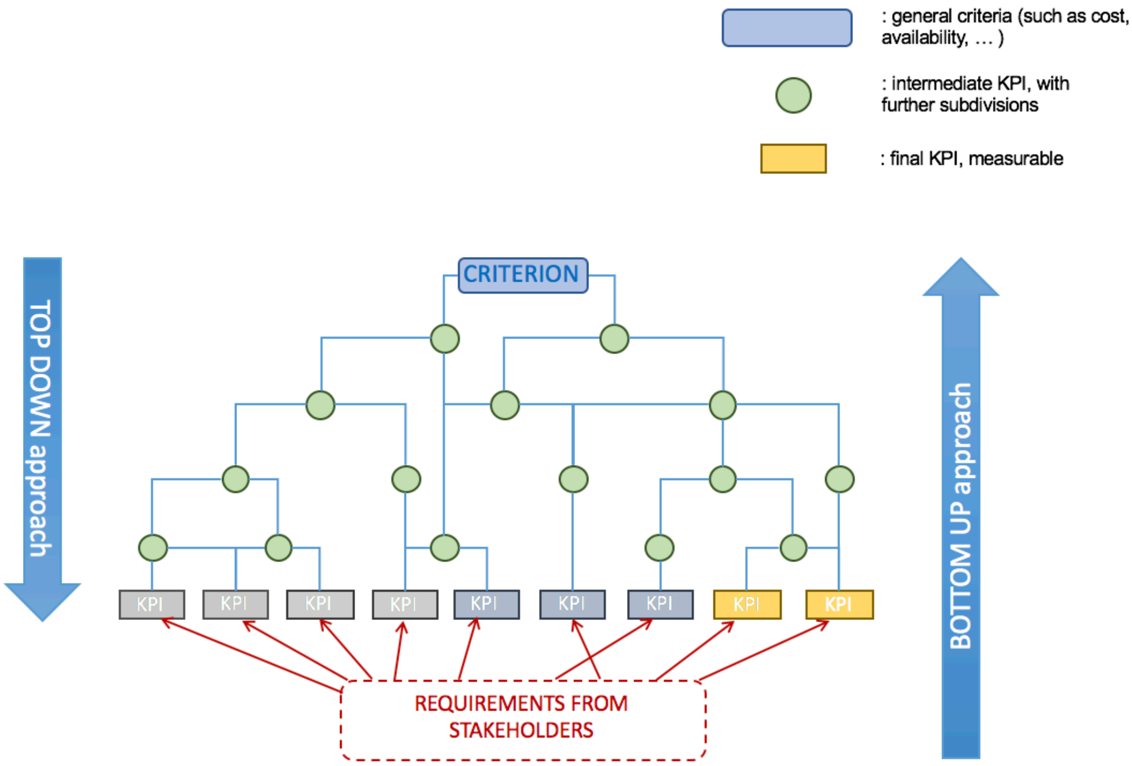

Figure 3 Integration of “bottom – up” and “top – down” selection methodologies

2.4 KPI TREE STRUCTURE

The work of collecting KPIs comprises operations of matching, grouping and ranking information taking into consideration the needs and requirements of the different stakeholders of ASSURED project.

There are a number of benefits that result from using this KPI Tree, for example:

- it sums up a complex situation with just a few indicators;
- it shows depth, coherence and clarity;
- it makes clear how KPI interact.

Particular attention has to be paid to these instructions in order to avoid problems in comprehension:

- uniqueness of definition: this is fundamental to distinguish similar indicators;
- documentation of the exact source;
- keeping a KPI record: each KPI must be identified by one unique record.

The outcome of this activity is a table in which all the levels of KPIs are divided into main criteria, selected among the most typical ones within the transport research domain; in some cases, specific criteria were used in order to support assessments of higher aggregation levels.

The main criteria are the following ones:

- Cost;
- Availability/Stability;
- Reliability;
- Environmental Impacts;
- Performance;
- Quality of Service;
- Human Factor.

The next chapter is focused on the description of these criteria.

With regard to the structure of the first version of the KPI Tree attached to this document, an example is shown below:

Criterion	KPI 1° level	KPI 2° level	KPI 3° level	KPI 4° level	Unit of measurement	KPI description	Evaluation method	Reference
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…

After a column dedicated to the main criteria of selection of KPIs, the core part of the table is dedicated to several levels of KPIs. The level increases with the specificity of the KPI, and the maximum level is equal to four, for the most articulate criteria.

For each KPI there are three columns that particularly identify each indicator: the unit of measurement, the description and the evaluation methodology (see Paragraph 2.2). These three columns respond to the SMART criteria prescriptions and to the need to have an unmistakeable tool for measuring the achievements and impacts of the ASSURED project.

The last column is dedicated to the references; in some cases no reference is available due to the fact that some KPIs are originated from experience of the author.

3. Definition of main criteria

This chapter is dedicated to the definition of the main criteria, in order to make clear how the KPIs are selected and divided.

Indicators related to the selected criteria are relevant for the analysis of demonstrators' outcomes and for making a comparison with the opportune baseline.

Most of criteria are subdivided in the main components of the system: vehicle (and battery), power grid and infrastructure.

3.1 Cost

Cost is the main criterion to consider, taking into account that one of the most important goals of ASSURED is the optimization of the TCO (Total Cost of Ownership) of the fast charging infrastructure, combined with the electrified fleet of urban commercial and public transport vehicles. The cost related KPIs that are considered as most relevant are:

- Capex: capital costs due to the purchasing of necessary infrastructure and technology;
- Opex: operational costs due to vehicle operation, transmission of electricity and maintenance operations of all the components involved;
- End of life: costs due to dismantling and selling of components to second life;
- Revenues: due to the passenger payload.

3.2 Availability/Stability

The KPIs related to availability and stability are important for assuring the continuity of service and operations.

Time for charging, both for opportunity and overnight system, is considered as an unavailability time and is therefore included in the availability criterion; the same for the maintenance of vehicle, battery and charging system.

An important aspect is related to stability, in terms of power and current quality: here are considered the harmonic distortions, in-rush current and other factors that can affect the quality and stability of grid.

KPIs related to interoperability are also included in the availability criterion, because these are considered as a performance indicator associated with the development of interoperable (and scalable) high power charging solutions as provided by different key European charging solution providers.

3.3 Reliability

The development of next generation modular high–power charging solutions of electrified HD and MD vehicles needs innovative charging management strategies that could suffer from teething problems, taking also into consideration the large amount of components and technologies involved.

For this reason, in the reliability criteria there are indicators of number of failures of vehicle, battery, infrastructure and power grid in specified unit of time, coming from the use cases demonstrations.

3.4 Environmental Impacts

The improvement of environmental impacts is one of the most important objectives of ASSURED project: specific KPIs are dedicated to the evaluation of pollutant emissions, greenhouse gas and noise impacts from the city point of view.

3.5 Performance

ASSURED solutions consider innovative strategies for charging solutions that don't affect the actual performance of vehicles and batteries: for this reason in this criterion are listed all the relevant KPIs to measure the performance, especially of vehicle and battery.

The indicators refer to specific characteristics of vehicle and battery such as physical and design features and performance related to energy efficiency, driving range, expected lifetime of components and operation time of service.

3.6 Quality of service

Beyond a large number of indicators related to technical aspects, an entire criterion is dedicated to KPIs to measure the satisfaction of people as end-users of the service; passengers and driver points of view are taken into consideration.

The concept of "comfort" is considered from the point of view of noise and as thermal comfort due to HVAC system for both passengers and driver; service speed is instead intended to be a performance indicator only for passengers, defined as the average commercial speed of buses, including operational stops.

3.7 Human factor

Not only technical issues are to be considered to achieve the objectives of ASSURED: also the human factor, as an interaction of man using the operational instruments and following procedures, plays an important role.

1) The behaviour of the driver in respect to the opportunity charging system; in this case, it can have an impact on the good functioning of the system.
2) The behaviour of the driver in respect to the capability to harvest regenerative energy.

These aspects are particularly relevant in the first stages of application of ASSURED solutions, taking into account the technological shift that operators on the field have to deal with. For this reason training plays a fundamental role for a safe and efficient application.

Nevertheless, considering the human factor as a performance indicator is not easy and calculable, so it will be not included in the KPI Tree. The only, but crucial aspect that can be relevant is the training of drivers, that can affect the optimization of the Total Cost of Ownership; in this sense, it can reduce battery ageing by lowering acceleration peaks, and in general lower the wear and tear of tires, brakes and cooling system by optimizing the (regenerative) braking of the electric vehicle.

A better management of the acceleration could also have a positive impact on passenger safety, consider the high torque of electric buses, that could provoke brusque accelerations weakening the stability of standing people.

4. Final requirements compilation

One of the aims of the tasks from 2.1 to 2.4 of WP2 is the determination of the needs of cities and stakeholders within WP7/WP8 with reference to electric buses, trucks and vans and the identification of boundary conditions and constraints for the fast charging infrastructure implementation. The study on the feasibility of ASSURED fast charging solutions determine the list of main topics of interest for the different stakeholders involved. The following paragraphs include the point of view of each stakeholder involved in the project (included cities) and a list of main topics with explanations of the needs or requirements of the stakeholder.

4.1 View and requirements of cities

The World Health Organization (WHO) links many transport-related emissions (i.e. nitrogen oxides, particle matter, etc.) to diseases reducing life expectancy and quality of living, including lung and bladder cancer, chronic bronchitis, asthma and cardiovascular diseases[2].

Compared to conventional vehicles powered by an Internal Combustion Engine (ICE), the electrification of vehicles in urban areas has direct benefits on the (local) quality of air, and consequently generates positive impacts from a social, economic and environmental point of view for the community. The emissions of vehicles are significantly reduced, generating a reduction in the external costs of transport for public health: having fewer sick citizens, means having a healthier society, but also lower costs regarding public spending on health. Furthermore, when combined with the use of renewable energies, vehicle electrification brings benefits to the urban and non-urban environment, which could reduce global emissions and greenhouse gases from the production of fuel for traditional-powered vehicles.

Electrification of vehicles is emerging as a leading technology to achieve the urban-related objectives defined by the EC in the 2011 White Paper on Transport[3]: reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050; halve the use of ‘conventionally fuelled’ cars in urban transport by 2030; phase them out in cities by 2050; and achieve essentially CO_2-free city logistics in major urban centres by 2030.

Cities play a key role in supporting vehicle electrification policies. Through their planning schemes, local authorities (LAs) can define long-term visions and roadmaps, adopt strategies and implement measures that are essential to influence the uptake of Electric Vehicles (EVs) in urban environments. Electromobility strategies can contribute to reaching local goals that reflect EU objectives. For being effective, those interventions must be included in existing plans, such as Sustainable Urban Mobility Plans (SUMP).

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[1] http://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[2] https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

Main Topics	Topic explanation/Requirements
Vehicle data collection/ sharing	Many cities stressed the need for a vehicles pan-European register log and the importance of strengthening data communication between national and local level.
Charging infrastructure data collection/ sharing	Compared to fully public facilities, privatization may reduce the amount of data available for the municipality, that is very useful for planning and land use management. EU non-binding guidelines could be prepared to address this challenge.
Data collection/sharing on e-fleets facilities	Cities need to exchange even more at the EU level on e-bus depots, maintenance and storage facilities related to e-fleets, as well as interoperability of charging plugs and on-route recharging systems' standards.
Identification of governance level(s) in charge	Depending on the country, but also on the region, it may be that strategies, funds, data, jurisdiction, etc. are attributed to different bodies, so for each aspect, it is important to understand who has the power to make decisions
Positioning of charging points	In general, the tendency is to encourage normal charging in off-street parking and residential areas, and to assign on-street infrastructure to fast chargers. This vision also influences the positioning of fast chargers, in particular those that must also be used by taxi drivers and freight operators. They need fast-charging infrastructure to be placed especially at points of interest and service centres, especially where stopovers will last 10-15 minutes, in order to have a high number of charging processes.
Identification of most appropriate business model for charging infrastructure	As for financing, being an open market system, operators must see the existence of a market that generates profits for them. Infrastructure needs to be packaged up as an attractive commercial long-term investment proposition with a strong return on investment. There are three models for developing a long-term proposition: 1) public sector owned and developed, 2) private sector owned and developed, or a 3) Public/Private Partnership (PPP).
More efficient and expensive energy connections	When the deployment is systematic and on large-scale, there will be challenges with the energy grid, which will no longer be adequate to drive the amount of electricity needed. The company that manages and maintains the electricity grid will have to discuss with the municipality and other stakeholders to find the most appropriate solutions that guarantee a smooth deployment of the EV charging infrastructure.
Upscale of the fleet	When it comes to the further deployment of e-bus systems, the main concern of PTAs and PTOs is how to upscale the fleet meeting the economical, operational and environmental requirements. It is thus important to underline that the identified needs and requirements are aligned with this need.

Main Topics	Topic explanation/Requirements
Environmental issues	Electrification of vehicles in urban areas has direct benefits on the quality of air, and consequently generates positive impacts from a social, economic and environmental point of view for the community.
Economic and operation issues	The fact that provision of charge points and methods of access and payment are inconsistent between authorities can discourage people and in particular freight operators to shift to EVs.
Urban development and quality of life	Cities where the number of EVs has started to increase are trying to change the perception of users, since the electricity has a cost and recharging of EVs at charging points is often interpreted as a parking stop, implying an excessive occupancy of parking areas. For this reason, cities have begun to introduce a per-minute charge, to minimize the occupancy of the charging stations and to set time limits for the use of fast-chargers.
Sharing of fast charging infrastructure between public and freight transport	To overcome the limited battery range issues and to allow additional charging during operational hours, cities need to install fast-charging stations in strategic points of the city that can be used by public and freight operators for opportunity charging. The choice of location of the fast charging stations is important to attract high usage. Once available, drivers of commercial electric vehicles are more frequent users of fast chargers than citizens.

Table 1 Requirements of cities

4.2 View and Requirements of PTA and PTO

Noise and air pollution from urban transport are posing a threat to citizens' health and the liveability of cities. Environmental noise levels can cause stress, sleep disturbances and cardiovascular diseases. Likewise, air pollution can cause cardiovascular and respiratory diseases as well as cancer, and is the leading environmental cause of premature death in the EU[4].

Local administrations are developing policies and regulations to balance the need of ensuring healthy urban environments with the need of preserving mobility as a driver of city life and the economy.

Many cities have introduced measures to mitigate the environmental impact of urban traffic, e.g. pedestrian zones, traffic calming, restricted traffic zones, subsidies for cleaner vehicles (e.g. electric powertrains), etc. Some cities have announced plans to ban conventional cars (internal combustion engines) in the next future and even become car-free[5].

Against this background, PTAs and PTOs are ready to play their role to keep cities moving while improving quality of life with cleaner air and reduced noise levels. In this sense, bus fleet renewal is a priority, especially considering the pivotal role of the bus in the provision of affordable and efficient PT services.

[4] http://www.europarl.europa.eu/ftu/pdf/en/FTU_2.5.5.pdf

[5] EC White Paper on Transport (2011) includes measures such as the phase out of conventional cars by 2050.

In 2013, only 1.2 % of the European bus fleet was fuelled with electricity. However, the interest of PT actors in cleaner technologies was already high, with over 40 % of the PTAs and PTOs aiming to shift to electric powertrains (UITP, 3iBS Project). Today, the purchase orders of electric buses are growing fast (orders in 2017 increased about 60 % with respect to 2016). The evolution of the bus market share projections shows a progressive exchange of roles among clean diesel and electric technology, which will reach over 45 % of the market share by 2030 (ZeEUS, UITP VEI).

Projects such as ZeEUS have paved the way to a wider electrification of PT, creating a solid knowledge and experience base on electric bus fleets deployment, and providing decision-makers with means and tools to understand If, When and How to deploy electric bus fleets. The next step is supporting and ensuring a successful fleet upscale. To achieve this, PTAs and PTOs need interoperable charging infrastructure and smart charging solutions. This will be facilitated by ASSURED.

Area	Needs for the deployment of large fleets of electric buses	Description
SERVICE PERFORMANCE	Monitoring on-road charging infra	On-road infrastructure availability is essential in order to ensure the correct operations of e-buses, when opportunity charging strategy is adopted.
		A part grid status, in case of energy storage (e.g. to get cheaper fares) need also to be checked the SOC of local storage system.
		This need is of course dependant on the charging station ownership. In case the authority own it, then the status need to be communication to the operator and the consequences of unavailability on the service contract considered.
SERVICE PERFORMANCE	Management of on-road charging access	This need refer to the best use of the charging station.
		It linked to the dynamic monitoring of the fleets by the operator, who is then optimising the access to the charging station based on the status of the fleet e-buses.
		In case the charging station is shared between different PT operators or road users, then the management of the access to the station will need to be carefully managed also in relation to its contractual implications
ECONOMIC AND OPERATION ISSUES	Flexibility for the introduction of alternative	Prior to decision, to define the best approach to alternative energies implementation. Local factors to be considered.

Area	Needs for the deployment of large fleets of electric buses	Description
	propulsion system (availability of fuel selection tools)	A feasibility study, involving all the actors, and considering risks, operational scenario and economical aspects is greatly encouraged
ECONOMIC AND OPERATION ISSUES	Financial trade-offs for e-buses and related infra procurement	One of the key barrier for the deployment of e-buses in service is the high investment required due to the increase cost of the vehicle and/or the infrastructure.
		For these reasons, the right financial means that can help the procurement should be identified and correctly applied by operators or authorities according to the organisational model.
ECONOMIC AND OPERATION ISSUES & URBAN DEVELOPMENT AND QUALITY OF LIFE	Planning of charging infrastructure	This is in relation to several different aspects beyond the technological ones linked to the operational needs of e-bus service to be planned.
		Factors that should not be underestimated are relative to the public works planning and execution, in terms of: choice of the place (linked to city image); permissions (that can a quite long process); existing regulation (that could require to modify the project); unforeseen events (unexpected pipelines).
		An important optimisation can come by having joint collaboration between all the involved actors, and comparing operator service planning with grid map. In fact, it could happen that it is possible to move the charging station of some meters in a place where high power is already available, and at the same time is still suitable for charging operation.
ENVIRONMENTAL ISSUES	Reduction of greenhouse gas emissions and pollutants (SO_2, NOx, PM_x, etc.)	Related not only to local policies and decisions from all the stakeholders but also to state level commitments such as Climate international agreements.
ENVIRONMENTAL ISSUES	Renewal of the fleet with vehicles eco-sustainable	Even if often politically driven, financial requirements have to be strongly considered versus service contracts obligations and service operational requirements.

Area	Needs for the deployment of large fleets of electric buses	Description
		Priority (supported by political decisions and adequate financial means) shall be the improvement of environmental performances, not just putting new technologies.
		In addition should never be forgotten that the main objective of bus is to bring passengers in an efficient way, so technology shift shall not impact the quality of the service (in number of buses on a line, for example).
MAINTENANCE	Control of recharging time	Crucial for charging time both at depot and on-road. Monitoring systems and smart charging are right enablers for this.
		PTOs start looking to fully automatic depots as a natural next step with the automation of the vehicle itself: automatic charging without plugs and manpower.
MAINTENANCE	Storage of enough power to perform the entire daily service	This particular issue is linked to very harsh trade-offs between service quality, vehicle weight, operating range, heating/HVAC needs, on-road charging possibilities, investment, ownership schemes, etc.
		This issue require the joint work of all the involved partners, industry, authorities, operators and energy suppliers, as it combines vehicle performances, grid capacity, depot and city infrastructure.
MAINTENANCE	Maintenance of on-road charging access	It is linked not only to the technical maintenance of the charging point, but also to the contractual responsibility for such activity. Ownership of the charging access will have of course a big impact.
		Probably the most suitable scenario would see the operator taking care of the maintenance of on-road charging access, as it can keep control on the impact on the passenger service.
		Scenarios where the charging point is shared between operators or users would probably require the direct intervention of the authority as ideal owner of the charging station in this scenario.

Area	Needs for the deployment of large fleets of electric buses	Description
MODAL INTEGRATION AND ADDITIONAL/FLEXIBLE SERVICES	Interoperability & adoption of standard protocols in the adopted charging technologies	Standardisation of charging systems and protocols is a key topic in the current phase of market up-take and variety of technical proposals.
		It concerns on the way to cope with the various charging technologies and their impact on tendering regularity, reselling value, cost optimisation.
SAFETY AND SECURITY	Safety and security provisions for charging operation	New requirements due to new type of equipment in the garage, both on board and in depot and garage.
		The use of electric buses bring changes in the operations, by adding the charging phase, in depot or during the service. Standards exist on safety during HV operations and those standard are under update in order to be applicable also for charging operation. Of course it needs to be ensured that such rules are strictly respected.
		Charging points need to be equipped with all the features necessary for the safety of drivers, passengers and maintenance staff: training is necessary for operating staff.
		Automation can greatly increase the safety of the operation, especially when charging has to be completed under time-pressure due to the late arrival of the bus at the charging station.
		From the point of view of security, modern systems are characterised by a heavy use of IT both in local that in remote. Cybersecurity would be a new aspect to be considered.

Table 2 Requirements of PTA and PTO

4.3 View and Requirements of TSO and DSO

The impact of EV charging will mostly affect the LV distribution networks, as drivers will mostly rely on domestic or semi-public charging environments to charge their cars. In terms of the additional electricity demand from EVs measured in total consumption (kWh) will not represent a critical factor for the network. However, in terms of peak demand (kW) the additional loads can cause a significant higher peak load i.e. in case of charging resulting in simultaneous power demand on distribution networks. As these networks were designed without predicting the arrival of the new EV loads, conventional grid reinforcements might be needed in the future if no load management is considered. This is why DSOs should be involved in the deployment of infrastructures and should have information on future demand. Indeed, they can monitor the actual demand through measurement systems installed in the charging station and guarantee a certain control of the assets for grid reliability purposes.

In the case of buses, the most extreme charging speeds are expected during opportunity charging, in which a bus will be given a quick boost of energy at a bus stop. Nevertheless, these chargers should be preferably connected directly to the MV grid instead of LV levels.

As with other electronic devices, EVs can present power quality issues for distribution system assets which need to be minimised by using advanced technology and the right standards. Power quality issues include harmonics distortion and voltage deviations that can overload distribution system components if not properly designed to mitigate these problems. Their effects will nevertheless strongly depend on several factors such as the charging location and transformers and lines' capacity. In addition, when connecting charging stations to the distribution grid, aspects regarding grid operation requirements should be considered to ensure the integrity and quality of supply of the network, as potential impact on grid overloads, grid voltage variations, consumption peaks, N-1 needs, reactive power or voltage unbalance.

Main Topics	Topic explanation/Requirements
Frequency stability	Frequency stability is a TSO responsibility. When the demand is higher than the supply the frequency goes down. The simultaneous connection of a number of EVs, or HDV could require fast power ramps of generators that may exceed current capabilities. Response times vary depending on whether a primary level, secondary level or third level frequency regulation is executed. This is not a local issue, but a system level one.
LV grid reinforcement	In general LV grid reinforcement is needed when accumulation of EVs are expected to be charged by the same LV feeder because of a potential and non-manageable load congestion. It may affect voltage levels, especially in rural grids or semi-urban with some degree of congestion. Grid solutions are usually new LV cables, upgrading of small capacity cables or in some cases even new distribution transformers (MV/LV) or new secondary substations (MV/LV).
Smartening of LV grid	To reduce peak load one solution is "smartening the LV grid" which could be an alternative way to increase the capacity of the grids to manage the new scenario, avoiding/reducing the costs of generalized reinforcements and being compatible with them. This could be done by introducing of ICT (Information Communication Technology) to dynamically balance the power and supply in LV grid, thus avoiding risks of overloads and under voltages. Active demand technologies are needed as well as monitoring and control capabilities.
Use of transformer (for transforming MV to LV connections)	Charging elements should be connected directly to MV grid instead of to LV grid to ensure a lower impact on the system and a higher control of assets operation. This means that a compact solution to integrate a transformer in the charging point must be found and even a switcher with remote control capacity. Avoiding the installation of a new Secondary

Main Topics	Topic explanation/Requirements
	Substation for the charger will make easier and faster the implementation of new points.
Measurement system	Measurement system should be installed in the charging station. In general, these measurement systems are divided into two parts: the DC measurement system and the AC measurement system. The AC and DC measurement devices are placed at connection point between the grid and the charging station and between the charging station and the vehicles, respectively. This paragraph is focused on the AC grid measurement system only. The 3-phase AC measurement device must therefore be connected to the secondary of the transformer, which connects the high voltage grid to the charging station. This equipment is used to measure the currents and voltages of the three phases. These measurements should be able to provide AC currents, AC Voltages, Total Harmonic Distortions (THD), active power (kW), reactive power (kVAr), power factor and energy (kWh).
Smart charging	Smart charging is considered as an effective way of mitigating the effect of charging stations on the grid. It is particularly the case for overnight charging where the load is more likely to be flexible and could thus be reallocated. Power consumption coming from fast charging points will most likely be less flexible. This would be a totally different strategy than the traditional “fit and forget” which consists in adapting the distribution network to the peak load. To include customers in the grid management, the DSOs will have to formalize their needs in terms of products. Smart charging can be used to increase the maximum EV penetration without grid reinforcement. This is done with a centralized control that shifts the EVs charging to ensure there is no voltage or congestion problem.
Power quality	The power quality requirement must ensure the compatibility between the grid and the load (i.e. charging stations). The European Standard EN 50160 has been adopted by the European Committee for Electrotechnical Standardization (CENELEC). Power quality has several indicators and parameters such as continuity of service and voltage wave quality. Regarding the voltage magnitude and according to the proposal, ASSURED solutions should not cause more than 5% ripple on the voltage amplitude of the grid. Nevertheless, other disturbances may occur due to the ASSURED solutions or other consumers on the grid. The main standardized disturbances are voltage sag, voltage swell, over voltage, under voltage, flicker, etc. The reduction of these disturbances improves the power quality, the lifetime of the equipment, and the service quality.
Grid operation need	Traditional problems on the grid raise as grid overloads, grid voltage drops at the end of the lines, high peaks of consumption, power not granted in case of failure of one component (N-1 operation), etc.

Table 3 Requirements of TSO and DSO

4.4 VIEW AND REQUIREMENTS OF VEHICLE MANUFACTURERS

The public transport as a promising sector for full electric vehicles leads to a high amount of cycles and predictable workload. Understanding the requirements to the vehicles and their battery systems requires knowledge of the performance targets, which are requested by working every day on the route and the existing constraints from the topography and charging infrastructure. These performance targets can be derived from the driving power, the climbing capabilities, the maximum and average speed and electric driving range. In general, the operational requirements for vehicles can be derived from the specifications of the environment and their impacts:

Fleet management: the impact of the operations like the number of buses and available drivers, the number of charging stations (available charging spots) and the number of stop/start procedures at the bus route.

- Operational impacts: traffic density regarding timetables and traffic flow, commercial speed, accelerations (restricted by passenger comfort and environmental requirements (eco-driving), drive cycle and vehicle load (number of passengers).
- Environmental: the topography (length, slope) and climate (heating or air-conditioning needs).
- Charging system: the location of charging stations (distance between them), the power capacity (opportunity or overnight) and the possible charging time (opportunity or overnight).

There are many battery concepts ranging from large systems, designed for a full day of operation without charging, to fast-charging systems with charging power up to a few hundred kilowatts. In the field of electrified commercial vehicles in Europe, the battery capacities range from 30 to 450 kWh per vehicle. To fulfil all the required operational features, different solutions of RESS, will be required, involving many different combinations of battery cells and capacitors arranged in an optimal design. In this way the balance of acceleration, range, durability, lifetime, charging, discharging and cost effectiveness can be estimated and the RESS can be optimized for its business.

Different points for requirements are also coming from the safety perspective; the same safety specifications for electric vehicles like in case of combustion engines are given, but the understanding of working with high voltage components is essential. In this context the drivers have to be trained in an appropriate behaviour towards electrical drivetrains, and maintenance employees have to be taught in working with battery systems and wiring harnesses. Crash safety and the protection against electric shock are the demands which have to be covered by the manufacturers.

Area	Needs for the deployment of large fleets of electric buses	Description
TECHNICAL & OPERATIONAL	Optimal charging performance	• Compliance with the chose/required charging strategy (generally CC/CV - constant current / constant voltage is used

Area	Needs for the deployment of large fleets of electric buses	Description
		but different cell types will use different charging strategies in the future). • Depends on the battery performance, the optimal cooling and heating of the packs and cells (constraint is the cooling of the packages). • Constraints from the vehicles HV-components are secondary. The mayor power losses and thermal issues occur at the charging station.
TECHNICAL & OPERATIONAL	V2G charging capability	V2G is the approach to balance the grid load. In general, vehicles that are not in use can provide their battery energy to the grid via connection to the charging station. Concerning the slow and continuous discharge processes, the batteries are capable for smart charging without aging effects. For the reverse energy flow from the vehicle to the grid, bi-directional charging stations are necessary. The battery system at the vehicle has to manage the demand from the grid and the possible discharge power.
TECHNICAL & OPERATIONAL	Smart charging capabilities	Smart charging strategies for depot/fleet operators help to balance the grid load and V2G opportunities.
TECHNICAL & OPERATIONAL	Charging power for electric buses and trucks	• 190 – 500 kW for opportunity charging (future 600 kW) • 50 – 150 kW for depot charging
TECHNICAL & OPERATIONAL	Charging power for freight transportation vehicles	• 50 – 300 kW for opportunity charging (20 – 45 minutes) • 10 – 43 kW for overnight charging (8 – 9 hours)
TECHNICAL & OPERATIONAL	Charging power for vans	• 50 – 150 kW for opportunity charging • 6,6 – 22 kW for overnight charging
TECHNICAL & OPERATIONAL	Battery energy shall fit the needed range and charging infrastructure	Required energy storage strongly depends on charging strategy, range demands, vehicles weight and load, topography HVAC performance and field of activity. • Buses: 60 – 250 kWh (in some cases up to 450 kWh) • Freight vehicles: 100 – 200 kWh • Vans: 30 – 60 kWh
TECHNICAL & OPERATIONAL	Modular drivetrain for buses	Depending on route length and topography, a modular propulsion system can be configured for the needed specification like torque, gear ratio, climbing power,

Area	Needs for the deployment of large fleets of electric buses	Description
		acceleration and speed. This could also include the recuperation system specification.
TECHNICAL & OPERATIONAL	Modular batteries	The modular and stackable battery system helps to provide the proper sizing of the storable energy for each demand of the buses, trucks and vans. Modules of 5 – 50 kWh are typically available. Therefore, the cooling system aggregates could be scalable too.
TECHNICAL & OPERATIONAL	Hybridisation of the battery system	The battery system shall have the capability for combination of different cell types, supercaps and DC/DC topology for the optimal performance/duration composition
TECHNICAL & OPERATIONAL	Operation day length of the bus	In normal operation, BEV's achieve the same daily ranges like ICE vehicles. Under extreme conditions of hot and cold climate, the HVAC has to compensate the thermal issues for an optimal working temperature of the batteries.
ECONOMIC & EFFICIENCY	Leasing batteries to PTO / PTA / cities	Financing models are moving to "buying the bus and leasing the battery system" to reduce TCO. The models could provide a complete battery management. Maintenance, scheduled services and dismantling could be released from the operational costs.
ECONOMIC & EFFICIENCY	Minimize the energy consumption	Train the driver in driving style in different aspects: • high accelerations reduces range • lower energy consumption decreases charging time and demand from the grid • understanding of HVAC's and auxiliaries consumption Optimized balance between battery weight and capacity
ECONOMIC & EFFICIENCY	Driver training regarding service and maintenance	• lower the wear and tear of tires, brakes, auxiliaries and cooling systems • reduce battery aging by lowering acceleration peaks
ECONOMIC & EFFICIENCY	Logistic centres for freight transport	• Freight operators concentrate charging at logistic depot or provide their own charging points / make cooperation with charging providers
ECONOMIC & EFFICIENCY	Analysing systems for energy consumption	• Workload efficiency measurement • Energy demand measurement

Area	Needs for the deployment of large fleets of electric buses	Description
		• Balance between HVAC and internal/external climate • Forecasting and smoothening software to reduce the impact of aggressive driving
ECONOMIC & EFFICIENCY	Vehicle weight / load	Vehicle weight is the key factor for acceleration and braking/recuperation – efficiency decreases by increasing the passenger load or vehicle weight. Vehicle weight also causes the maintenance costs for brakes, damper and tires. Abuse of tires at BEV's is much higher than Diesel buses.
ECONOMIC & EFFICIENCY	Use the same plug type for depot charging	Two types of communication and interaction for DC-charging are used regarding ISO 15118. Reduction to one of the standardized plug systems, decreases costs for material and software, for the charging station and the vehicle. European and international market shares show, that the CCS Type 2 standard is common. CHAdeMO – standard will very likely disappear from the EC-market.
SAFETY	Safety - warning system at the station	Bus operators indicate that the silence of electric buses may pose a safety issue for people walking in their vicinity. They do not hear them coming.
SAFETY	Battery cooling in crash safe areas	Battery systems safety extremely depends on the package temperature regulation. An accidental damaged cold reservoir or cooling pipeline of the battery cooling system can cause a burn down of the whole bus.
SAFETY	HV components - safety	• Protection against electric shock • Protection against direct contact to HV components and cables • Protections against water effects • Post-crash electrical safety • Requirements with regard to installation and functionality of RESS in a vehicle (crash resistance, fire, isolation) • Training for behaviour with HV components (do not repair or test anything) • Warnings, lights and safety protocols
SAFETY	Functional safety	Standards like ISO 62626 and different standardization programs are focusing on functional safety for HD-BEV's.
SAFETY	Driver training regarding driving style	• The regenerative braking causes wheel slip, or ABS events, in very slippery

Area	Needs for the deployment of large fleets of electric buses	Description
		conditions by having less direct control over rear wheel braking. • The high torque of electric drivetrains has impact to the passengers safety. This can cause tumbling persons while accelerating the bus to fast. Rapid acceleration can also cause rear wheel slip.

Table 4 Requirements of vehicle manufacturers

4.5 VIEW AND REQUIREMENTS OF CHARGING INFRASTRUCTURE OPERATORS

4.5.1 State of the Art of Charging infrastructure:

Charger infrastructure:

The EVSE opportunity chargers for application with automatic pantograph contacting systems are mainly designed as a stand-alone product, requiring solely a mains grid connection. They are initially dedicated for use on an LV or MV AC and 50/60 Hz grid.

Most infrastructure suppliers need from the grid 400Vac, three phase connection and PE/PEN need to be supplied.

Besides the AC grid connection, a power converter is needed to provide DC output and a connection for the EV connection, a connector or Automatic Coupling Device.

Furthermore the communication between the EVSE and EV is important to establish a working charging connection. The ISO 15118 is a standard that aims to give communication requirements for all types of charging, allowing interoperability between charging systems and EVs. This standard also allows communication of information from the EV and EVSE to third parties (fleet operator, aggregator, etc.), making Vehicle-to-Grid communication possible.

In order to monitor the charging sessions a so called OCPP (Open Charge Point Protocol) protocol is used. This an application protocol for communication between EV charging stations and control management system. It can also be used by the control management system to control the charging profile of an EVSE.

Automatic Coupler Device:

Regarding the state of the art of charging infrastructure, especially Opportunity Charging, one key feature is the type of charging technology and the coupler system itself. In general there are two different charging technologies which can be used for Opportunity Charging. These can be subdivided in inductive and conductive charging technologies.

The coupler systems are based on conductive charging and pantograph technology. The pantograph systems for recharging battery-driven buses need to have special 4-pole contact interface with DC+, DC-, PE and CP (control pilot) for communication and safety aspects. The pantograph systems need also to align the parking tolerances at the charging spot and movements of the vehicle and mast during the charging process. Another aspect is the necessary charging time. Therefore, the pantographs need to get fast connection to the counterpart and need to be able to transmit high power for very short charging times.

Wireless/inductive charging is still a relatively new technology in development. In wireless charging, the main principle is that an inductor is used to create an electromagnetic field, while a second inductor in the charging device is used to take the energy of the created field and convert it into an electric current that charge the battery

4.5.2 Development of Charging infrastructure:

Increase of charging power:

- Due to the increasing battery size for electric buses, the demand to charge with higher powers is increasing. Currently the maximum power for opportunity charging is 450 kW and is limited by the maximum current of the pantograph, which is typically around 600A. In order to offer higher charging powers of 600 kW a new design pantograph is required that can do > 800A. Development of a 600 kW system depends on the availability of the new design pantograph. Expected timeline for first field tests is end of 2018.

Reduction of charging time duration:

- Due to the increase in the number of heavy electric vehicles in the transportation systems, another point to consider in the near future is the charging time. In general terms, the charging time can be considered as 10% or less of the driving time. End-of-line electric bus fast charging takes about 10 minutes now, which should be reduced in the near future.

Smart Charging:

- The concept of Smart Charging is mostly meant to describe the balance of the required availability of the electric buses with the energy load (and together with that also the energy cost) of the electricity grid. Current Smart Charging functionality is mostly managed by a Back Office, setting the maximum charging power of the various electrical buses. In the future more integration with the fleet management systems, as implemented and used by the Public Transport Operators, is expected.

Main Topics	Topic explanations/Requirements
Smart charging	The concept of Smart Charging is mostly meant to describe the balance of the required availability of the electric buses with the energy load (and together with that also the energy cost) of the electricity grid. Current Smart Charging functionality is mostly managed by the Back Office, setting the maximum charging power of various chargers (and coupled electrical buses). In the future more integration with the fleet management systems, as implemented and used by the Public Transport Operators, is expected. There is communication between the EVSE and the Charging Station Operator (CSO), for instance when the EVSE has to communicate charging data to the central system of the CSO. The communication can also go the other way around when using Smart Charging for instance. OCPP (Open Charge Point Protocol) is an application protocol for communication between EV charging stations and control management system. The currently most used version of OCPP is OCPP 1.6. Compared to OCPP 1.5 the following functionality is added (among others): • Smart Charging support for load balancing and use of charge profiles

<table>
<tr><th>Main Topics</th><th>Topic explanations/Requirements</th></tr>
<tr><td></td><td>OCA will publish the final version of OCPP2.0 in 2018, adding the following functionalities (among others):

Added Smart Charging functionalities: For topologies with an Energy Management System (EMS), a local controller and for integrated smart charging of the EV, Charging Station and Charging Station Management System.
Support for 15118: Regarding plug-and-charge and smart charging requirements from the EV.
</td></tr>
<tr><td>Power converter</td><td>The role of the power converter is to execute the galvanic isolated power conversion from AC to DC, control the DC output voltage and current and protect the EVSE and EV. Based on both the EV and EVSE capabilities, limits in DC charging current and voltage are communicated and agreed upon. Based on both the EV and EVSE capabilities, limits in DC charging current and voltage are communicated and agreed upon. After the IEC 61851 defined start-up sequence, the charging process is started.

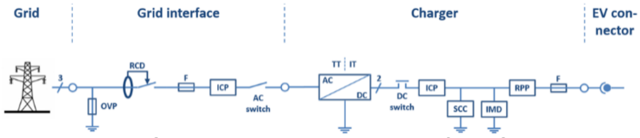


Figure 4: HPC charger system overview for AC connection</td></tr>
<tr><td>Use of transformer</td><td>Regarding the grid interface, it should be noted that a transformer can be necessary when the charger is connected to the MV (Medium Voltage) grid. European standard EN 61936-1 gives general requirements for the grid interface when connecting an installation at a voltage higher than 1 kV. These requirements ensure safety and proper operation of the installation. MV grid is usually around 10 or 20kV</td></tr>
<tr><td>Power quality for the voltage</td><td>Another important standard regarding the interaction with the grid is EN 50160. It sets the minimum requirements in terms of power quality for the voltage at the Point of Common Coupling (PCC) where the installation is connected to the distribution network. More specifically, it concerns:

Harmonics
Voltage variations
Requirements in case of voltage dip or interruption of supply
</td></tr>
<tr><td>Communication system</td><td>The communication protocols between the EV and the EVSE are relatively well standardized and described in detail in these standards:

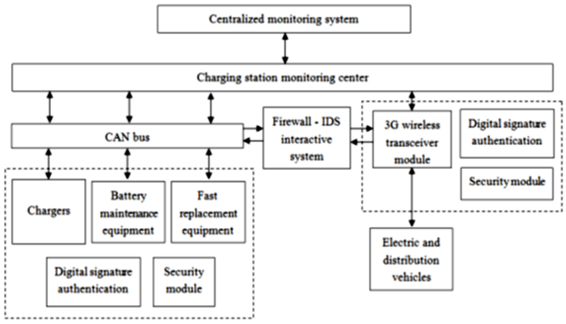
IEC 61851-24, Electric vehicle conductive charging system Part 24: Digital communication between an EV charging station and an electric vehicle for control of DC charging.
</td></tr>
</table>

<table>
<tr><th>Main Topics</th><th>Topic explanations/Requirements</th></tr>
<tr><td></td><td>

DIN 70121, Electromobility – Digital communication between a DC EV charging station and an electric vehicle for control of DC charging in the Combined Charging System (CCS).
IEC 15118-1, Road vehicles: Vehicle to grid communication interface. Part 1: General information and use-case definition (Edition 2.0, DIS, 2016)
ISO/IEC 15118-2, Road vehicles: vehicle to grid communication interface –Part2: Technical protocol description and Open Systems Interconnections (OSI) layer requirements (Edition 2.0, CD, 2016)
ISO/IEC 15118-3, Road vehicles: Vehicle to grid communication interface communication interface Part3: Wired physical and data link layer requirements (Edition 1.0, IS, 2015)
ISO/IEC 15118-5, Road vehicles: Vehicle to grid communication interface - Part 5: Physical layer and data link layer conformance test (Edition 1.0, DIS, 2016)
ISO/IEC 15118-8, Road vehicles: Vehicle to grid communication interface communication interface Part1718: Wireless physical and data link layer requirements (Edition 1.0, DIS, 2016)

Communication shall be done in accordance with these standards.</td></tr>
<tr><td>Safety and security</td><td>
Safety: HPC charger system overview for AC connection (as reported in previous Figure 4)
<table>
<tr><th>Abbreviation</th><th>Meaning</th><th>Explanation</th></tr>
<tr><td>RCD</td><td>residual-current detection</td><td>protection against an earth fault</td></tr>
<tr><td>F</td><td>fuse per conductor</td><td></td></tr>
<tr><td>ICP</td><td>in-rush current protection</td><td>limits current at start-up</td></tr>
<tr><td>OVP</td><td>over-voltage protection</td><td></td></tr>
<tr><td>TT</td><td>terra-terra</td><td>earth to earth; total system earth</td></tr>
<tr><td>IT</td><td>isolation-terra</td><td>earth isolated; not connected to earth</td></tr>
<tr><td>SCC</td><td>short-circuit check</td><td>check for short circuit in the cable</td></tr>
<tr><td>IMD</td><td>insulation monitoring device</td><td>monitors the insulation w.r.t. PE</td></tr>
<tr><td>RPP</td><td>reverse-polarity protection</td><td>protects against polarity reversal</td></tr>
</table>
Figure 5 List of abbreviations referred to infrastructure system

Security: Information security protection structure of charging station</td></tr>
</table>

Main Topics	Topic explanations/Requirements
	 Figure 6 Information security protection structure of charging station
Capability of fast charging station to charge with multiple output voltages	Most fast charging stations are able to charge with multiple output voltages. These voltage levels depend on the output power of these types of charging stations and shall support a full range from 150V up to 900V
Charging time no more than 10% of driving time	Due to the increase in the number of heavy electric vehicles in the transportation systems, another point to consider in the near future is the charging time. In general terms, the charging time can be considered as 10% or less of the driving time. Charging an electric bus takes about 10 minutes now, which should be reduced in the near future. Therefore, problems such as reducing the efficiency of the transport system should be avoided. In addition, one of the objectives of ASSURED is to be able to perform opportunity charging of heavy vehicles in about 5 minutes. This charging time can be expected lower after ASSURED.
Availability pf grid connection during peak times	Regarding the grid interface, it should be noted that a transformer can be necessary when the charger is connected to the MV (Medium Voltage) grid. European standard EN 61936-1 gives general requirements for the grid interface when connecting an installation at a voltage higher than 1 kV. These requirements ensure safety and proper operation of the installation. MV grid is usually around 10 or 20kV. Another important standard regarding the interaction with the grid is EN 50160. It sets the minimum requirements in terms of power quality for the voltage at the Point of Common Coupling (PCC) where the installation is connected to the distribution network. More specifically, it concerns: • Harmonics • Voltage variations • Requirements in case of voltage dip or interruption of supply The DC charger can also have DC input (taken into consideration in IEC 61851-23), for instance if it is

Main Topics	Topic explanations/Requirements
	connected to DC overhead lines of trams, trolleybus or trains. In this case, a DC/DC converter with galvanic disconnection is used.
Interoperability of coupler devices	• The coupler systems should be designed according the following standards: • IEC 61851-1:CDV, Electric vehicle conductive charging system - Part 1: General requirements (Edition 3.0, CDV) • IEC 61851-23-1:WD, Electric vehicle conductive charging system – Part 23-1: DC charging with an automatic connection system • IEC 62196-1:2014, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: 2014 • IEC 62196-2:2016, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories (Edition 1.0, 2011-10) • IEC 62196-3:2016, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: 2014 • ISO 17409:2015, electrically propelled road vehicles. Connection to an external electric power supply. Safety requirements • IEC 61140:2016, Protection against electric shock - Common aspects for installation and equipment • IEC 60664-1:2007, Insulation coordination for equipment within low-voltage systems. Part 1. Principles, requirements and tests • EN50124-1:2001, Railway applications - Insulation coordination - Part 1: Basic requirements; Clearances and creepage distances for all electrical and electronic equipment
Monitoring system of the state of charge and charging system capacity	OCPP (Open Charge Point Protocol) is an application protocol for communication between EV charging stations and control management system. The currently most used version of OCPP is OCPP 1.6. OCA will publish the final version of OCPP2.0 in 2018. Other protocols: OSCP, OCP, SCADA, etc.

Table 5 Requirements of charging system operators

5. Definition of KPIs and relationships

5.1 General overview

This chapter has its focus on the definition of all the "nodes" that compose the KPI Tree, whose structure is described in the previous chapters.

The approach used for the determination of KPIs' levels is mainly the top – down, once defined the general criteria; those ones were selected in accordance with requirement inputs from stakeholders and expected impacts of ASSURED.

Criteria are considered as first level KPIs, identified by the first number of the KPI record. The several levels in which each KPI is subdivided in are, in sequence, the latter numbers of the record (separated by a dot). A different strategy is adopted in the spreadsheet KPI Tree, in which the record numbers are the same, but the first level KPI is considered the first subdivision after the criterion. To avoid unclarity, it's proposed to use the following scheme, in which the green dots represent the intermediate KPIs and rectangles the final level – and measurable – KPIs :

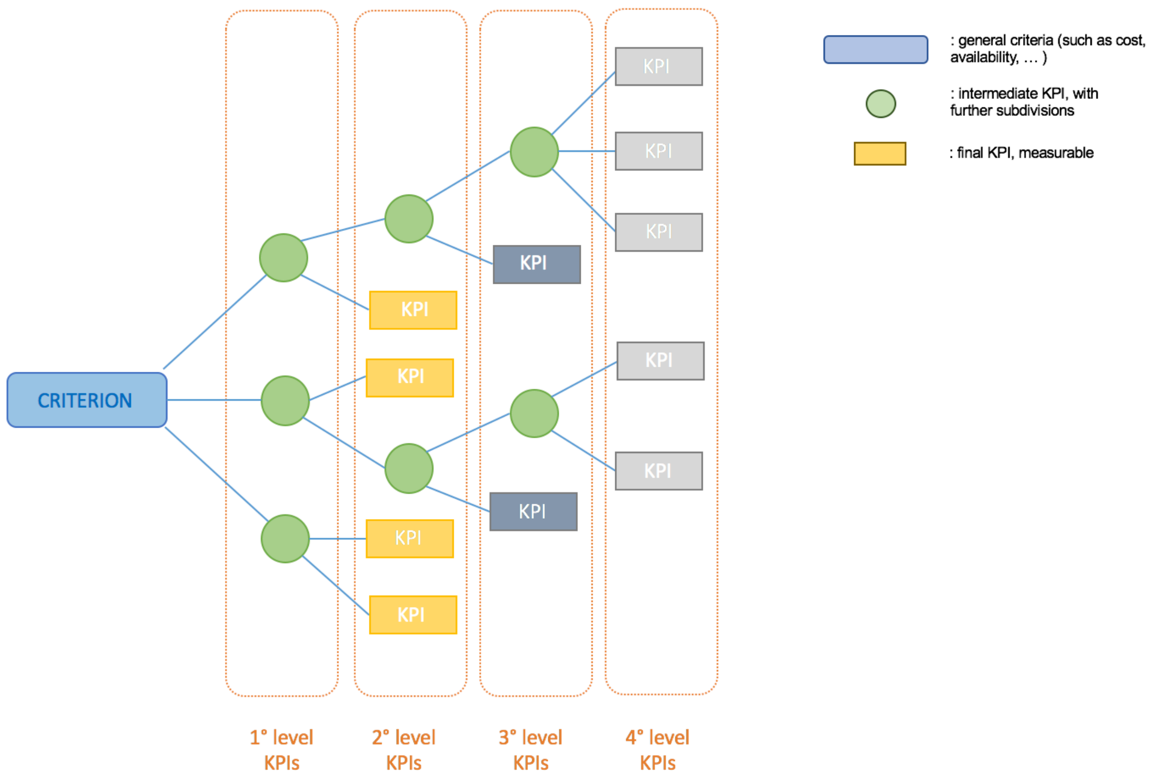


Figure 7 KPI structure, from criteria to measurable KPIs

5.2 Cost (KPI n° 1)

5.2.1 1° level

KPI 1.1 : **Capex**: Capital expenses

KPI 1.2 : **Opex:** Operating expenses

KPI 1.3 : **End of Life:** cost due to dismantling of components and selling of them in a secondary market

KPI 1.4 : **Revenues**: revenues related to passenger payload

5.2.2 2° level

KPI 1.1 - Capex

KPI 1.1.1 : **Vehicle**: capex related to the purchase of the vehicle (including the cost of the battery)

KPI 1.1.2 : **Infrastructure:** capex related to the purchase and installation of the recharging point/station

KPI 1.1.3 : **Power Grid:** capex related to the purchase of the electricity

KPI 1.2 - Opex

KPI 1.2.1 : **Vehicle operation**: opex related to the operational activity of the vehicle

KPI 1.2.2 : **Power Grid:** opex related to the power grid operational activity

KPI 1.2.3 : **Infrastructure:** opex related to infrastructure operational activity

KPI 1.2.4 : **Maintenance:** opex related to maintenance of system’s components

KPI 1.3 – End of Life

KPI 1.3.1 : **Dismantling:** cost due to dismantling of vehicle and infrastructure, when they complete their life cycle

KPI 1.3.2 : **Selling of materials and components, or second life :** cost for giving a second life to vehicle’s components during the end of life or for selling activities

KPI 1.4 - Revenues

KPI 1.4.1 : **Vehicles:** revenues depending on the vehicle battery system

5.2.3 3° level

KPI 1.1.1 - Vehicle

KPI 1.1.1.1 : **Battery**: capex related to the purchase of the only battery

KPI 1.1.1.2 : **Electric bus/truck**: capex related to the purchase of the electric vehicle (Bus or Truck) excluded the cost of the battery

KPI 1.1.2 - Infrastructure

KPI 1.1.2.1 : **Opportunity charging system**: capex related to the purchase of the opportunity charging system

KPI 1.1.2.2 : **Depot charging system**: capex related to the purchase of the overnight charging system

KPI 1.1.2.3 : **Installation cost**: capex related to the installation cost of the charging system

KPI 1.1.2.4 : **Smart charging**: capex related to the purchase of the Smart charging hardware

KPI 1.1.3 - Power Grid

KPI 1.1.3.1 : **Isolation and grounding system (safety):** capex due to the purchase od safety instruments and systems

KPI 1.1.3.2 : **ICT compliance**: capex due to the purchase of Smart charging ICT system

KPI 1.2.1 - Vehicle operation

KPI 1.2.1.1 : **Energy efficiency:** energy efficiency during the vehicle operation, influence the opex of the vehicle

KPI 1.2.1.2 : **Vehicle energy consumption**: opex related to the energy consumption of the vehicle

KPI 1.2.1.3 : **Electric vehicle downtime**: opex due to the downtime period of the vehicle

KPI 1.2.1.4 : **Energy cost**: opex due to the energy cost

KPI 1.2.2 - Power Grid

KPI 1.2.2.1 : **Electricity network losses**: opex due to electricity losses during electricity distribution

KPI 1.2.3 - Infrastructure

KPI 1.2.3.1 : **Electricity network losses**: opex due to losses in the distribution network

KPI 1.2.4 - Maintenance

KPI 1.2.2.1 : **Vehicle**: opex related to the maintenance of the vehicle, both scheduled and unscheduled

KPI 1.2.2.2 : **Infrastructure**: opex related to the maintenance of the charging infrastructure, both scheduled and unscheduled

KPI 1.2.2.3 : **Power Grid**: opex related to the maintenance of the power grid, both scheduled and unscheduled

KPI 1.3.1 - Dismantling

KPI 1.3.1.1 : **Vehicle**: dismantling cost of only vehicle (and battery), excluded infrastructure

KPI 1.3.1.2 : **Infrastructure**: dismantling cost of only infrastructure, excluded vehicle components

KPI 1.4.1 - Vehicle

KPI 1.4.1.1 : **Number of passengers**: the number of passengers is fundamental for the computing of the payload, that is one the main factor that contributes to the revenues

5.2.4 4° level

KPI 1.1.2.2 - Depot charging system

KPI 1.1.2.2.1 : **Charging point**: capex related to charging point's purchase cost
KPI 1.1.2.2.2 : **Charging pole**: capex related to charging pole's purchase cost
KPI 1.1.2.2.3 : **Charging station**: capex related to charging station's purchase cost

KPI 1.2.2.1 - Vehicle

KPI 1.2.2.1.1 : **Scheduled vehicle repair cost**
KPI 1.2.2.1.2 : **Unscheduled vehicle repair cost**
KPI 1.2.2.1.3 : **Scheduled battery repair cost**
KPI 1.2.2.1.4 : **Unscheduled battery repair cost**
KPI 1.2.2.1.5 : **Scheduled charger repair cost**
KPI 1.2.2.1.6 : **Unscheduled charger repair cost**

KPI 1.2.2.2 - Infrastructure

KPI 1.2.2.2.1 : **Scheduled repair cost**
KPI 1.2.2.2.2 : **Unscheduled repair cost**

KPI 1.2.2.3 - Power Grid

KPI 1.2.2.3.1 : **Scheduled repair cost**
KPI 1.2.2.3.2 : **Unscheduled repair cost**

KPI 1.3.1.1 - Vehicle

KPI 1.3.1.1.1 : **Dismantling cost of battery**
KPI 1.3.1.1.2 : **Dismantling cost of vehicle**

KPI 1.3.1.2 – Infrastructure
KPI 1.3.1.2.1 : **Dismantling cost**

5.3 AVAILABILITY / STABILITY (KPI N° 2)

5.3.1 1° level

KPI 2.1 : **Vehicle**: availability of the vehicle operation
KPI 2.2 : **Power Grid**: stability of the power grid
KPI 2.3 : **Infrastructure**: availability of the charging infrastructure

5.3.2 2° level

KPI 2.1 - Vehicle

KPI 2.1.1 : **Operation**: availability of the vehicle in terms of time and distance of service
KPI 2.1.2 : **Charging**: availability of the vehicle considering the charging time, both opportunity or overnight

KPI 2.1.3 : **Maintenance**: availability of the vehicle considering the maintenance time, both scheduled and unscheduled

KPI 2.2 – Power Grid

KPI 2.2.1 : **Power demand for opportunity charging stations**: availability of energy for opportunity charging system

KPI 2.2.2 : **Power demand for overnight charging stations**: availability of energy for overnight charging system

KPI 2.2.3 : **Maintenance**: availability of the power grid considering the maintenance time, both scheduled and unscheduled

KPI 2.2.4 : **Power Quality**: stability of the power grid in terms of power quality

KPI 2.3 – Infrastructure

KPI 2.3.1 : **Interoperability level**: availability of the charging infrastructure in terms of interoperability of systems/technologies

KPI 2.3.2 : **Maintenance**: availability of the charging infrastructure considering the maintenance time, both scheduled and unscheduled

KPI 2.3.3 : **Current quality**: stability of the charging infrastructure in terms of current quality

KPI 2.3.4 : **Number of charging points**: availability of charging points in the city

KPI 2.3.5 : **Number of charging stations**: availability of charging stations in the city

5.2.3 3° level

KPI 2.1.1 - Operation

KPI 2.1.1.1 : **Electric driving distance**: availability of the vehicle related to distance that can be covered

KPI 2.1.1.2 : **Electric driving time**: availability of the vehicle in function of the time of service with a certain amount of charge

KPI 2.1.1.3 : **Interoperability** : availability of equivalent vehicles for carrying out the same service

KPI 2.1.1.4 : **Modularity of drivetrains for buses** : availability of the vehicle in function of the interchangeability of propulsion system within different route lengths and topography

KPI 2.1.1.5 : **Modularities of batteries** : availability of vehicle thanks to modularity and stackability of batteries

KPI 2.1.2 - Charging

KPI 2.1.2.1 : **Time for opportunity charging**: availability of the vehicle in function of the time for opportunity charging

KPI 2.1.2.2 : **Time for overnight charging in depot**: availability of the vehicle in function of the time for overnight charging

KPI 2.1.3 - Maintenance

KPI 2.1.3.1 : **Scheduled vehicle repair time**

KPI 2.1.3.2 : **Unscheduled vehicle repair time**

KPI 2.1.3.3 : **Scheduled battery repair time**

KPI 2.1.3.4 : **Unscheduled battery repair time**

KPI 2.1.3.5 : **Scheduled charger repair time**

KPI 2.1.3.6 : **Unscheduled charger repair time**

KPI 2.2.3 - Maintenance

KPI 2.2.3.1 : **Scheduled maintenance time**

KPI 2.2.3.2 : **Unscheduled maintenance time**

KPI 2.2.4 - Power quality

KPI 2.2.4.1 : **Slow voltage variations**: stability of the power grid related to variations of slow voltage

KPI 2.2.4.1 : **Fast voltage variations**: stability of the power grid related to variations of fast voltage

KPI 2.2.4.1 : **Total Harmonic Distortion (THD)** : stability of the power grid related to the harmonic distortion

KPI 2.3.1 - Interoperability level

KPI 2.3.1.1 : **Charging point technical features**: availability of charging point due to standardization and authentication methods

KPI 2.3.1.2 : **System features**: availability of charging system due to interoperability and use of data

KPI 2.3.1.3 : **Business & legal features**: availability of charging system due to interoperability of payment and legal features

KPI 2.3.2 - Maintenance

KPI 2.3.2.1 : **Scheduled maintenance time**

KPI 2.3.2.2 : **Unscheduled maintenance time**

KPI 2.3.3 – Current quality

KPI 2.3.3.1 : **Phase of voltage relative to current**: availability of the charging point related to the negative effects of reactive power

KPI 2.3.3.2 : **Total Harmonic Distortion (THD)**: availability of the charging point related to harmonic currents

KPI 2.3.3.3 : **Peak current**: availability of the charging point related to peak current

5.3.4 4° level

KPI 2.3.1.1 – Charging point technical features

KPI 2.3.1.1.1 : **Authentication media**: availability of the charging system related to acknowledgment of users

KPI 2.3.1.1.2 : **Plug and socket compliancy**: availability of the charging system related to standardization of connections and standards

KPI 2.2.1.2 - System features

KPI 2.3.1.2.1 : **Interconnection**: availability of the charging system related to the interoperability of the system

KPI 2.3.1.2.2 : **Data exchanges**: availability of the charging system related to the use of data communication systems

KPI 2.3.1.3 – Business & legal features

KPI 2.3.1.3.1 : **Roaming agreements between operators**: availability of the charging system related to agreements between operators responsible of payment and legal issues

5.4 Reliability (KPI n° 3)

5.4.1 1° level

KPI 3.1 : **Number of Failures (per operational hours)**: reliability related to the presence of failures (in unit of time) of the system and subcomponents

5.4.2 2° level

KPI 3.1 - Number of Failures (per operational hours)

KPI 3.1.1 : **Vehicle**: reliability related to the presence of failures (in unit of time) of the vehicle

KPI 3.1.2 : **Battery**: reliability related to the presence of failures (in unit of time) of the battery

KPI 3.1.3 : **Infrastructure**: reliability related to the presence of failures (in unit of time) of the charging infrastructure

KPI 3.1.4 : **Power grid**: reliability related to the presence of failures (in unit of time) of the power grid

5.5 Environmental impacts (KPI n° 4)

5.5.1 1° level

KPI 4.1 : **Pollutant emissions**: environmental impacts of the ASSURED solutions due to pollutant emissions

KPI 4.2 : **CO2 emissions**: environmental impacts of the ASSURED solutions due to CO2 emissions

KPI 4.3 : **Noise and vibrations**: environmental impacts of the ASSURED solutions due to noise and vibrations

5.6 Performance (KPI n° 5)

5.6.1 1° level

KPI 5.1 : **Vehicle**: indicators related to vehicle performance characteristics

KPI 5.2 : **Battery**: indicators related to battery performance characteristics

5.6.2 2° level

KPI 5.1 - Vehicle

KPI 5.1.1 : **Length type**: performance of the vehicle associated to the length of the vehicle

KPI 5.1.2 : **Effective usable driving energy**: performance of the vehicle associated to the energy available for driving

KPI 5.1.3 : **Empty weight**: performance of the vehicle associated to the empty weight of the vehicle

KPI 5.1.4 : **Total passenger capacity**: performance of the vehicle associated to the total passenger capacity

KPI 5.1.5 : **Maximum payload**: performance of the vehicle associated to the maximum payload

KPI 5.1.6 : **Total weight**: performance of the vehicle associated to the total weight of the vehicle

KPI 5.1.7 : **Lifetime**: performance of the vehicle associated to the lifetime of the vehicle

KPI 5.1.8 : **Total continuous power**: performance of the vehicle associated to the maximum power sustainable for a long time

KPI 5.1.9 : **Motor peak power**: performance of the vehicle associated to the maximum power sustainable for a short time

KPI 5.1.10 : **Maximum torque**: performance of the vehicle associated to the maximum torque of the vehicle

KPI 5.1.11 : **Effective electric driving energy of the vehicle**: performance of the vehicle associated to the (effective) driving energy

KPI 5.1.12 : **Maximum electric driving range fully charged**: performance of the vehicle associated to the maximum electric driving range in a fully charged situation

KPI 5.1.13 : **Maximum electric driving energy fully fast - charged**: performance of the vehicle associated to the maximum electric driving range in a fully fast - charged situation

KPI 5.1.14 : **Possible daily fully operation time**: performance of the vehicle associated to the maximum operation time of the vehicle per day

KPI 5.1.15 : **Maximum climb rate**: performance of the vehicle associated to the maximum climbing rate feasible for the vehicle

KPI 5.1.16 : **Consumption of HVAC**: performance of the vehicle associated to the consumption of energy due to HVAC

KPI 5.2 – Battery

KPI 5.2.1 : **Nominal capacity**: performance of the battery associated to the nominal capacity

KPI 5.2.2 : **Storable energy**: performance of the battery associated to the energy that can be stored in a battery

KPI 5.2.3 : **Maximum charge current**: performance of the battery associated to the maximum sustainable charge current

KPI 5.2.4 : **Maximum continuous discharge charging**: performance of the battery associated to the maximum sustainable discharge current

KPI 5.2.5 : **Nominal battery voltage**: performance of the battery associated to the nominal battery voltage

KPI 5.2.6 : **Working voltage range**: performance of the battery associated to the difference between maximum and minimum voltage in working conditions

KPI 5.2.7 : **Charging current over 5 min**: performance of the battery associated to the maximum current that can be achieved during 5 min of opportunity charging

KPI 5.2.8 : **Charging power over 5 min**: performance of the battery associated to the maximum power that can be achieved during 5 min of opportunity charging

KPI 5.2.9 : Maximum charging capability : performance of the battery associated to the maximum power that can be transferred in the battery during a charging

KPI 5.2.10 : **SOC range (min/max)** : performance of the battery associated to the difference between maximum and minimum values of State of Charge

KPI 5.2.11 : **Range for operational temperature**: performance of the battery associated to the range temperature (for operability)

KPI 5.2.12 : **Number of maximum full (80%) charge cycles**: performance of the battery associated to the number of fully charge cycles leading to a 80% rest capacity

KPI 5.2.13 : **Expected calendar life**: performance of the battery associated to expected lifetime

KPI 5.2.14 : **Dimension of battery system enclosure**: performance of the battery associated to the battery system enclosure

KPI 5.2.15 : **Battery system weight**: performance of the battery associated to the weight of the battery system

5.7 Quality of service (KPI n° 6)

5.7.1 1° level

KPI 6.1 : **Passengers' satisfaction**: comfort due to satisfaction of passengers

KPI 6.2 : **Driver's satisfaction**: comfort due to satisfaction of driver

5.7.2 2° level

KPI 6.1 - Passengers' satisfaction

KPI 6.1.1 : **Noise comfort**: comfort due to noise comfort from passengers' point of view

KPI 6.1.2 : **Thermal comfort**: comfort due to HVAC comfort from passengers' point of view

KPI 6.1.3 : **Commercial speed**: comfort due to commercial speed from passengers' point of view

KPI 6.2 - Driver's satisfaction

KPI 6.2.1 : **Noise comfort**: comfort due to noise comfort from driver's point of view

KPI 6.2.2 : **Thermal comfort**: comfort due to HVAC comfort from driver's point of view

5.8 Relationships between Performance Indicators

As reported in the chapter 2.3, the selection methodology of KPIs can be considered as an integration of both top – down and bottom – up approach. For what concerns the top – down approach, KPIs are cascaded to several levels starting from the general criteria typical of local public and freight transportation. The KPIs of the different levels of the KPI Tree are unique in terms of definition, but there are some relationships between performance indicators amenable to some key criteria of ASSURED, such as energy consumption, vehicle capacity, vehicle performance, Smart Charging and comfort related to noise.

5.8.1 Energy consumption

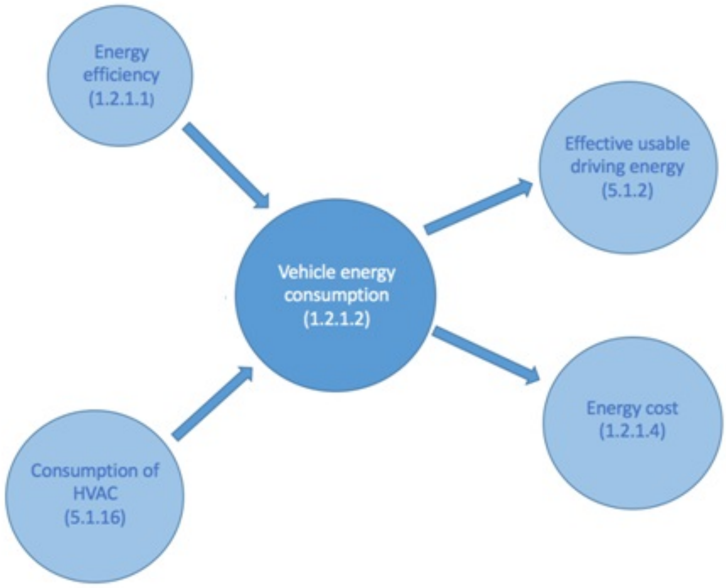


Figure 8 KPIs related to energy consumption

Energy consumption of the vehicle is a performance indicator that has strong relationships with other KPIs, both in terms of inputs and outputs: the consumption of energy is due to efficiency of the vehicle operation and to the energy used for the HVAC systems (especially in winter and summer time).

Also the external temperature could affect the energy consumption, because in conditions of low temperature the performance of batteries is reduced.

The consumption of energy has an important role in the effective usable driving energy, after deduction of the energy used for non-driving activities, and to the energy cost; the latter is the cost for purchasing energy for all the vehicle operations.

5.8.2 Vehicle capacity

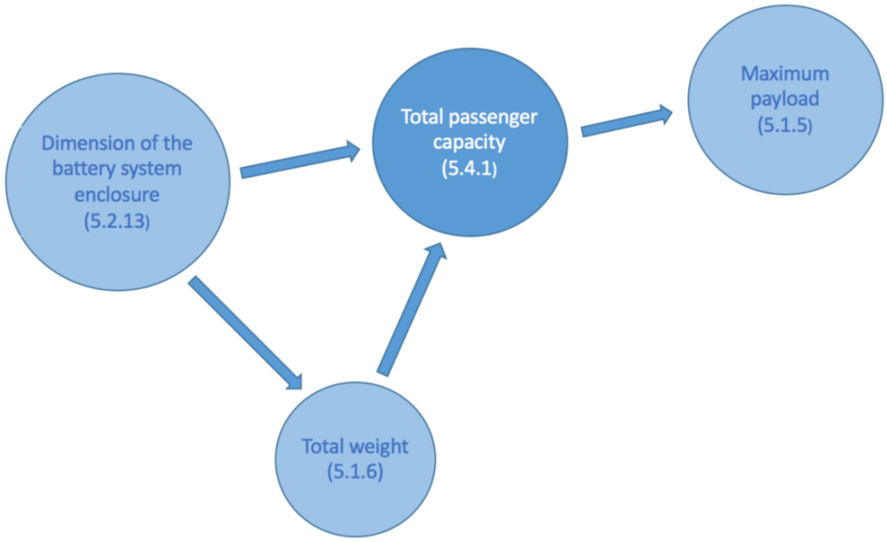


Figure 9 KPIs related to capacity of the vehicle

The vehicle capacity, expressed in number of passengers, is influenced by the dimension of the battery system enclosure (that is relevant for heavy duty vehicles) and by its weight. The passenger capacity is a function of the free weight available for people, subtracting the weight of the battery system from the total weight of the vehicle.

The number of people that an electric bus can host determines the maximum payload, which is likely to influence the prices of the tickets.

5.8.3 Vehicle performance

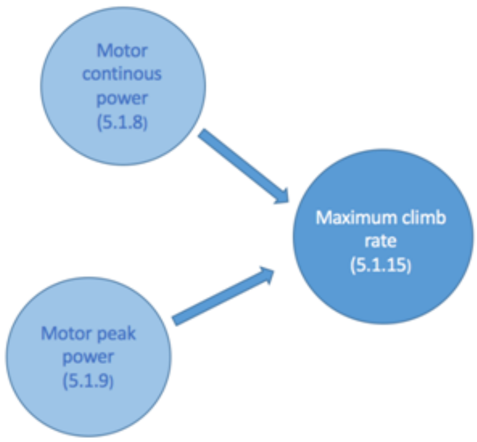


Figure 10 KPIs related to the performance of the vehicle

The maximum climb rate, as the capacity of a heavy duty vehicle to carry out hills, is the result of performance features of the vehicles, such as motor continuous and peak power.

5.8.4 Smart charging

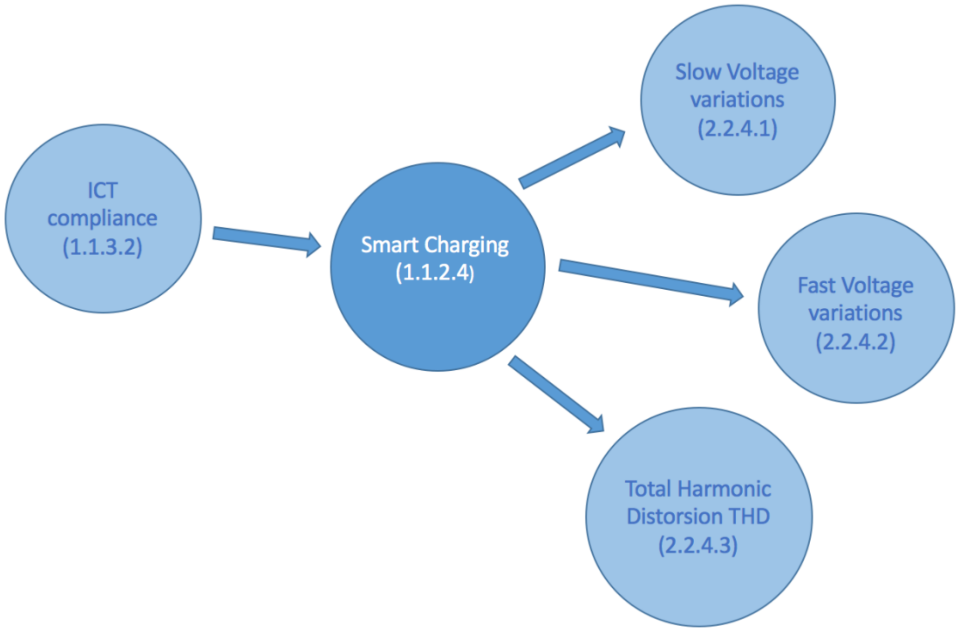


Figure 11 KPIs related to smart charging

Smart Charging system, thanks to the use of dedicated ICT software, could allow the increase of the maximum EV penetration without grid reinforcement, minimizing the effects on the power quality (in terms of harmonic distortion and variation in voltage).

5.8.5 Comfort related to noise

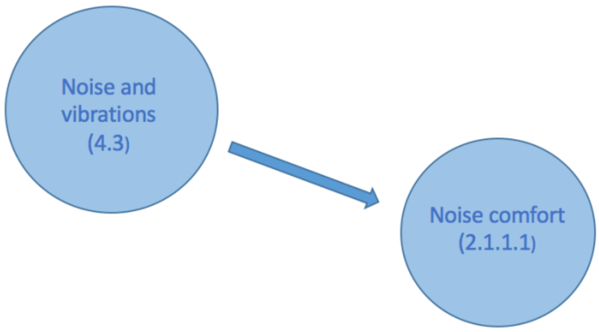


Figure 12 KPIs related to noise comfort

Noise emissions and vibrations are obviously the main aspect to be considered for the noise comfort evaluation.

6. DEFINITION OF THE KPIs MEASUREMENT PLAN

This chapter is dedicated to the definition of the KPIs Measurement Plan, the instrument that defines what the KPIs are (in terms of detailed description), what are the unit of measurement and in which way it will these be evaluated.

The selected KPIs used to fill in the table are the ones that are actually measurable, representing the last level of each KPI. Therefore, the table includes all the measurable KPIs, independently by their level.

In the KPI Detail column a short description of the indicator is reported. The analysis will be performed with respect to a defined baseline taking into consideration same unit of measurement and method for evaluation.

This kind of information will be addressed to use case demonstrator responsible, in order to avoid incomprehension; for each KPI the record code, the name, a short description, the unit of measurement and the evaluation method is reported.

An example is given below:

KPI code	KPI Name	KPI Detail (description)	Unit of measurement	Evaluation method
…	…	…	…	…
…	…	…	…	…

6.1 Cost (KPI n°1)

KPI code	KPI Name	KPI Detail (description)	Unit of measure[6]	Evaluation method
1.1.1.1	Battery	Battery's purchase cost	€	From survey
1.1.1.2	Electric bus/truck	Vehicle's purchase cost	€	From survey
1.1.2.1	Opportunity charging system	Opportunity charging system's purchase cost	€	From survey
1.1.2.2.1	Charging point	Depot charging system's purchase cost	€	From survey
1.1.2.2.2	Charging pole	Depot charging system's purchase cost	€	From survey
1.1.2.2.3	Charging station	Depot charging system's purchase cost	€	From survey
1.1.2.3	Installation cost	Cost of the charging system's installation	€	From survey
1.1.2.4	Smart charging	Smart charging hardware's purchase cost	€	From survey
1.1.3.1	Isolation and grounding system (safety)	Isolation and grounding system's purchase cost	€	From survey
1.1.3.2	ICT compliance	Smart charging ICT system's purchase cost	€	From survey
1.2.1.1	Energy efficiency	Cost due to energy efficiency	€	Estimated

[6] All costs are reported in Euros but they shall be further detailed in next steps of the analysis. The cost could be expressed as delta respect a defined baseline or with reference to a specific elements (e.g. €/km, €/ton.km, €/passenger.km)

KPI code	KPI Name	KPI Detail (description)	Unit of measure[6]	Evaluation method
1.2.1.2	Vehicle energy consumption	Cost due to energy consumption of the vehicle	kWh	Calculated
1.2.1.3	Electric vehicle downtime	Cost due to downtime of the vehicle	€	Estimated
1.2.1.4	Energy cost	Cost of the energy consumption	€	Calculated
1.2.2.1	Electricity network losses	Cost due to electricity network losses during electricity distribution	€	Calculated
1.2.3.1	Electricity network losses	Cost due to losses within the own distribution network	€	Calculated
1.2.2.1.1	Scheduled vehicle repair cost	Cost for the scheduled maintenance of the vehicle	€	Estimated
1.2.2.1.2	Unscheduled vehicle repair cost	Cost for the unscheduled maintenance of the vehicle	€	Estimated
1.2.2.1.3	Scheduled battery repair cost	Cost for the scheduled maintenance of the battery	€	Estimated
1.2.2.1.4	Unscheduled battery repair cost	Cost for the unscheduled maintenance of the battery	€	Estimated
1.2.2.1.5	Scheduled charger repair cost	Cost for the scheduled maintenance of the charger	€	Estimated
1.2.2.1.6	Unscheduled charger repair cost	Cost for the unscheduled maintenance of the charger	€	Estimated
1.2.2.2.1	Scheduled repair cost	Cost for the scheduled maintenance of the infrastructure	€	Estimated
1.2.2.2.2	Unscheduled repair cost	Cost for the unscheduled maintenance of the infrastructure	€	Estimated
1.2.2.3.1	Scheduled repair cost	Cost for the scheduled maintenance of the power grid	€	Estimated
1.2.2.3.2	Unscheduled repair cost	Cost for the unscheduled maintenance of the power grid	€	Estimated
1.3.1.1.1	Dismantling cost of battery	Cost for the dismantling of the battery	€	Estimated
1.3.1.1.2	Dismantling cost of vehicle	Cost for the vehicle disposal	€	Estimated
1.3.1.2.1	Dismantling cost	Cost for the infrastructure disposal	€	Estimated
1.3.2	Selling of materials and components, or second life	Cost due to a change in second life possibilities, or the re-use of valuable materials	€	Estimated
1.4.1.1	Number of passengers	Revenues due to the variation of payload in function of the number of passengers	€	Measured

Table 6 Measurement plan of Cost KPIs

6.2 Availability / Stability (KPI n°2)

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
2.1.1.1	Electric driving distance	Electric driving distance	Km	From survey
2.1.1.2	Electric driving time	Electric driving time	hours	From survey
2.1.1.3	Interoperability	Availability of equivalent vehicles for carrying out the same service	-	Estimated

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
2.1.1.4	Modularity of drivetrains for buses	Modularity of propulsion system (torque, gear ratio, recuperation system, …) in function of route length and topography	-	Estimated
2.1.1.5	Modularity of batteries	Modularity and stackability of battery system to provide the proper sizing of the storable energy for each demand of the buses, trucks and vans (also scalability of the cooling system)	-	Estimated
2.1.2.1	Time for opportunity charging	Time needed to charge the vehicle with the opportunity system	min	Measured
2.1.2.2	Time for opportunity charging in depot	Time needed to charge the vehicle in depot	hours	Measured
2.1.3.1	Scheduled vehicle repair time	Number of hours for scheduled maintenance of the vehicle	hours	Measured
2.1.3.2	Unscheduled vehicle repair time	Number of hours for unscheduled maintenance of the vehicle	hours	Measured
2.1.3.3	Scheduled battery repair time	Number of hours for scheduled maintenance of the battery	hours	Measured
2.1.3.4	Unscheduled battery repair time	Number of hours for unscheduled maintenance of the battery	hours	Measured
2.1.3.5	Scheduled charger repair time	Number of hours for scheduled maintenance of the charger	hours	Measured
2.1.3.6	Unscheduled battery repair time	Number of hours for unscheduled maintenance of the charger	hours	Measured
2.2.1	Power demand for opportunity charging stations	Energy demand for single opportunity charge	kW	Calculated
2.2.2	Power demand for overnight charging stations	Energy demand for single overnight charge	kW	Calculated
2.2.3.1	Scheduled maintenance time	Numbers of hours per year or operational hours for unscheduled maintenance	hours	Measured
2.2.3.2	Unscheduled maintenance time	Numbers of hours per year or operational hours for scheduled maintenance	hours	Measured
2.2.4.1	Slow voltage variations	Percentage variation between maximum and minimum values of slow voltage	%	Calculated
2.2.4.2	Fast voltage variations	Percentage variation between maximum and minimum values of fast voltage	%	Calculated
2.2.4.3	Total Harmonic Distortion (THD)	Measurement of the harmonic distortion	%	Calculated
2.3.1.1.1	Authentication media	Level of interoperability of the charger technical standards	Qualitative	Estimated
2.3.1.1.2	Plug and socket compliancy	Level of interoperability of the charger technical standards	Qualitative	Estimated
2.3.1.2.1	Interconnection	Level of interoperability of the charging system	Qualitative	Estimated
2.3.1.2.2	Data exchanges	Level of interoperability of the charging system	Qualitative	Estimated
2.3.1.3.1	Roaming agreements between operators	Level of interoperability of business and legal features	Qualitative	Estimated
2.3.2.1	Scheduled maintenance time	Number of hours per year or operational hours for scheduled maintenance	hours	Measured
2.3.2.2	Unscheduled maintenance time	Number of hours per year or operational hours for unscheduled maintenance	hours	Measured
2.3.3.1	Phase of voltage relative to current	Angle between current and voltage	degrees	Estimated

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
2.3.3.2	Total Harmonic Distortion (THD)	Measurement of the harmonic distortion	%	Estimated
2.3.3.3	Peak current	Maximum amount of current for a short time period	A	Estimated

Table 7 Measurement plan of Availability/Stability KPIs

6.3 Reliability (KPI n°3)

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
3.1.1	Number of Failures (per operational hours) of Vehicle	Number of failures in Time (MTBF) of the vehicle	FITs (Failures in Time)	Calculated
3.1.2	Number of Failures (per operational hours) of Battery	Number of failures in Time (MTBF) of the battery	FITs (Failures in Time)	Calculated
3.1.3	Number of Failures (per operational hours) of Infrastructure	Number of failures in Time (MTBF) of the infrastructure	FITs (Failures in Time)	Calculated
3.1.4	Number of Failures (per operational hours) of Power grid	Number of failures in Time (MTBF) of the power grid	FITs (Failures in Time)	Calculated

Table 8 Measurement plan of Reliability KPIs

6.4 Environmental Impacts (KPI n° 4)

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
4.1	Pollutant emissions	Major pollutants emissions (PA, NOx, …) according to Country Energy Mix (and energy efficiency)	g/km	Estimated
4.2	CO2 emissions	CO2 emission according to Country Energy Mix (and energy efficiency)	g/km	Estimated
4.3	Noise and vibrations	Noise impacts outside of the vehicle measured in decibels according to standard reference	db	Calculated

Table 9 Measurement plan of Environmental Impacts KPIs

6.5 Performance (KPI n° 5)

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
5.1.1	Length type	Physical dimension of the vehicle	m	Measured
5.1.2	Effective usable driving energy	Energy available for driving	kWh	Calculated
5.1.3	Empty weight	Empty weight of the vehicle	kg	Measured
5.1.4	Total passenger capacity	Maximum number of passenger	n°	Measured
5.1.5	Maximum payload	Maximum allowable payload of the vehicle	kg	Estimated
5.1.6	Total weight	Total (average) weight of the vehicle, including (average) passenger/freight	kg	Calculated
5.1.7	Lifetime	Lifetime expected of the vehicle	years	Estimated

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
5.1.8	Motor continuous power	Maximum power sustainable for a long term	kW	Calculated
5.1.9	Motor peak power	Maximum power sustainable for a short term	kW	Calculated
5.1.10	Maximum torque	Maximum torque of the motor	Nm	Calculated
5.1.11	Effective electric driving energy of the vehicle	Effective electric driving energy of the vehicle, related to the storable energy	kWh	Estimated
5.1.12	Maximum electric driving range fully charged	Driving range of the vehicle fully charged with a representative payload	km	Estimated
5.1.13	Maximum electric driving range fully fast charged	Driving range of the vehicle charged to 80% SOC with a representative payload	km	Estimated
5.1.14	Possible daily fully electric operation time	Maximum operation time of the vehicle per day	hours	Measured
5.1.15	Maximum climb rate	Maximum climbing rate of the vehicle	%	Calculated
5.1.16	Consumption of HVAC	Energy consumption due to Heating, Ventilation and Air Conditioning system	kWh	Calculated
5.2.1	Nominal capacity	Capacity of the battery	Ah	Calculated
5.2.2	Storable energy	Energy that can be stored in the battery	kWh	Measured
5.2.3	Maximum charge current	Maximum sustainable battery charge current	A	Measured
5.2.4	Maximum continuous discharge charging	Maximum sustainable battery discharge current	A	Measured
5.2.5	Nominal battery voltage	Maximum battery voltage	V	Measured
5.2.6	Working voltage range	Difference between the maximum and minimum voltage of the battery in working conditions	V	Measured
5.2.7	Charging current over 5 min	Maximum current that can be achieved during 5 min opportunity charging	A	Calculated
5.2.8	Charging power over 5 min	Maximum power that can be achieved during 5 min opportunity charging	kW	Calculated
5.2.9	Maximum charging capability	Maximum amount of power that can be transferred in the battery during a charging	kW	Measured
5.2.10	SOC range (min/max)	Maximum and minimum values of the State Of Charge	%	Estimated
5.2.11	Range for operational temperature	Range of temperature for operability	°C	Estimated
5.2.12	Number of maximum full (80%) charge cycles	Number of fully charge cycles leading to a 80% rest capacity	n°	Estimated
5.2.13	Expected calendar life	Expected calendar life	years	Estimated
5.2.14	Dimension of battery system enclosure	Maximum dimension of the battery system enclosure	mm	Measured
5.2.15	Battery system weight	Weight of the battery system	kg	Measured

Table 10 Measurement plan of Performance KPIs

6.6 Quality of service (KPI n° 6)

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
6.1.1	Noise comfort	Comfort related to noise from a passenger point of view	Qualitative	From survey
6.1.2	Thermal comfort	Comfort related to HVAC system from a passenger point of view	Qualitative	From survey
6.1.3	Commercial speed	Comfort related to commercial speed from a passenger point of view	Qualitative	From survey

KPI code	KPI Name	KPI Detail (description)	Unit of measure	Evaluation method
6.1.1	Noise comfort	Comfort related to noise from a driver point of view	Qualitative	From survey
6.1.5	Thermal comfort	Comfort related to HVAC system from the driver point of view	Qualitative	From survey

Table 11 Measurement plan of Quality of service KPIs

7. Definition of Performance Targets

Performance targets of ASSURED project are determined through an operational flow of activities that starts from the definition of the impacts expected by the call first and therefore reported in the Description of Work and the evaluation of requirements from the stakeholders point of view.

KPIs that are presented in the Tree reflect all the information included in these three steps.

7.1 Impacts expected in this call

The impacts present in the DoW are mainly related to the power quality of the grid: low impacts on the grid are expected, with a ripple amplitude of less than 5%. This parameter is fundamental concerning the stability of the grid, considering the conjunction with super fast charging technology, and the electrification of heavy-duty vehicles in large scale.

The KPIs that take into consideration these issues are listed in the following table:

Impact	KPI	
Low impact on the grid	2.2.4 Power quality	2.2.4.1 Slow voltage variations
		2.2.4.2 Fast voltage variations
		2.2.4.3 Total Harmonic Distortion (THD)
	2.3.3 Current quality	2.3.3.1 Phase of voltage relative to current
		2.3.3.2 Total Harmonic Distortion (THD)
		2.3.3.3 Peak current

Table 12 Expected impacts and related KPIs

7.2 Performance targets setting

Performance targets, derived from the impact expected in the project, are of two types: some of them are quantifiable targets that have to be achieved during the demonstrator test phase, as use case test outcomes; the remaining part is represented by general targets at project level.

The complete list of performance targets, and the KPIs to measure them, is summarised here:

Performance target		KPI
Noise level lower than 72 dB (for charging technology)		4.3 Noise and vibrations
Charging capability up to 600 kW		5.2.9 Maximum charging capability
Case 1	Super fast charging (opportunity) capability: 450 kW	5.2.9 Maximum charging capability
	Expected driving time: 16 hours	5.1.15 Possible daily fully electric operation time

Performance target		KPI
	Expected driving range: 200 km	2.1.1.1 Electric driving distance
	Time for super fast charging/hour: 5 min/hour	2.1.2.1 Time for opportunity charging
Case 2	Electric driving range: 120 km	2.1.1.1 Electric driving distance
	Maximum charging power (overnight): 450 kW	5.2.9 Maximum charging capability
	Expected energy usage: 75% less than reference bus	1.2.1.2 Vehicle energy consumption
	Noise emissions: 60 db at 30 km/h	4.3 Noise and vibrations
	Exhaust emissions: Zero local emissions	4.1 Pollutant emissions 4.2 CO2 emissions
	TCO improvement: on pair with a similar diesel bus, considering environmental cost	See chapter 7.3
Case 6	Energy efficiency: > 70% respect to Diesel ICEV	1.2.1.1 Energy efficiency
	Electric range: full for 100% electric operation between charging stations	5.1.12 Maximum electric driving range fully charged 5.1.13 Maximum electric driving range fully fast-charged
	Charging time: > 5 min	2.1.2.1 Time for opportunity charging
Case 7	Pollutant emissions: zero emissions in refuse collection, low during transport of garbage	4.1 Pollutant emissions
	Electric driving range: > 50 km	2.1.1.1 Electric driving distance
	Noise emissions: < 72 dB	4.3 Noise and vibrations
	Electrical charging capability: up to 150 km	5.2.9 Maximum charging capability
Case 8	Expected energy usage: 70% less than reference bus	1.2.1.2 Vehicle energy consumption
	Noise emissions: 60 dB at 30 km/h	4.3 Noise and vibrations
Case 9	Charging capability: up to 100 kW	5.2.9 Maximum charging capability

Performance target		KPI
	Super fast charging: < 5 min	2.1.2.1 Time for opportunity charging

Table 13 Performance targets and KPIs

We remind that the use case demonstrators of interest for the determination of performance targets are:

- Case 1: super fast DC charging (< 5 min) of IVECO BEV BUS;
- Case 2: super fast DC conductive charging of VOLVO BEV bus;
- Case 6: super fast DC conductive charging of VECTIA BEV;
- Case 7: super fast DC conductive of MAN BEV refuse collection;
- Case 8: super fast charging DC conductive of VOLVO electric refuse truck
- Case 9: fast wireless of light duty vehicle.

7.3 The role of KPIs in TCO improvement

The improvement of TCO through a better understanding of the impacts of fast charging profiles on battery lifetime, sizing, safety, grid reliability and energy efficiency of the charger – vehicle combination is one of the most relevant performance targets of ASSURED.

For this reason, cost holds a major role inside the KPI Tree as the most important criterion for the achievement of the project's goal; however, several KPIs of different criteria can be connected with the achievement of the TCO optimization.

The improvement of TCO could be achieved through:

- improvement of energy efficiency;
- optimized charging operating window for selected battery technology (in order to avoid the fast degradation of battery cells);
- low impacts on battery ageing caused by super fast charging;
- low impacts on power quality and grid reliability;
- cost reduction of infrastructure (through standardization);
- minimization of energy consumption of vehicles;
- fleet design optimization with superfast charging;
- minimize the operational cost;
- improve the electric driving range;
- topology and technology optimization of scalable and modular RESS (Rechargeable Energy and Storage System) architecture;
- increase of transport electrification in urban areas.

Not all these objectives are directly quantifiable, because some of them are related to upscaling, that could contribute to the optimization of the TCO thanks to economy of scale; in this sense, the increase of transport electrification in urban areas can reduce capital and operational expenses of the entire system.

Regarding the quantifiable – and calculable – objectives, there is a correlation between the objectives and the performance indicators present in the KPI Tree attached to this document. Most of the KPIs are attributable to TCO minimization, in a direct or indirect way; however, the most relevant are those ones that contribute to the achievement of the general goals of ASSURED related to the improvement of the TCO, that are:

TCO optimization action	KPI code	KPI name
Improvement of energy efficiency	1.2.1.1	Energy efficiency
Optimized charging operating window for selected battery technology	5.2.2	Storable energy
	5.2.8	Charging power over 5 min
Low impacts on battery ageing caused by super fast charging	5.2.12	Expected calendar life
Low impacts on power quality and grid reliability	2.2.4.1	Slow voltage variations
	2.2.4.2	Fast voltage variations
	2.2.4.3	Total Harmonic Distortion (THD)
	3.1.4	Number of failures of power grid
Minimization of energy consumption of vehicles	1.2.1.2	Vehicle energy consumption
Minimize the operational cost	1.2	All the Opex KPIs
Improve the electric driving range	2.1.1.1	Electric driving distance
	2.1.1.2	Electric driving time
	5.1.12	Maximum electric driving range fully charged
	5.1.13	Maximum electric driving range fully fast charged
	5.1.14	Possible daily fully electric operation time
Topology and technology optimization of scalable and modular RESS architecture	2.3.1.1.1	Authentication media
	2.3.1.1.2	Plug and socket compliancy
	2.3.1.2.1	Interconnection
	2.3.1.2.2	Data exchanges
	2.3.1.3.1	Roaming agreements between operators

Table 14 TCO optimization and KPIs

Conclusions

The main aim of Task 2.5 is to provide the Assured project with a common tool for the evaluation of the achievements and impacts of the use case demonstrators implemented within the project.

The tool is represented by the a list of Key Performance Indicators (KPIs) linked together according to their level of specification to form the KPI Tree.

The KPI Tree defined in this deliverable represents the complete set of KPI proposed for the evaluation but the appropriate selection of KPIs needed for the evaluation of each demonstrator is case specific and performed within WP9 by the demonstrator leaders.

It is worth to be mentioned that all KPI shall be selected among the KPI Tree in order to have a common base for evaluation.

At the end of the analysis not all the KPIs could be selected, but only the ones needed to assess the achievement of each demonstrator.

The main content of this document is represented by the list of performance indicators, divided in different levels and linked to the six main criteria. But the document reports also the relationships existing among indicators, and not only with the criteria, to understand how the KPIs are interconnected and how they could influence each other.

Indeed, the work of matching and ranking the different information that is originating from requirements and from general criteria conducted in this task to create the KPI Tree makes clear that performance indicators, although they are unique in definition, can be interconnected to other indicators to evaluate specific topics (e.g. vehicle capacity, energy capacity, …).

Main criteria do not have to be considered as isolated criteria; for example, cost and performance are strictly related and in some cases KPIs related to these criteria seem to be equivalent in definition, but different in what they intend to evaluate. In this sense, unit of measurements clarify the quantity to measure.

At current stage of analysis some KPIs can be redundant or difficult to evaluate, but task T9.1 will have the major goal to assess the usability of the identified KPIs and within Task 9.1 the selection of KPI will be performed.

References

- “Specification of city and PT stakeholders strategies and needs”, POLIS (D2.1 of ASSURED);
- “Specification of grid constraints”, IBERDROLA (D2.2 of ASSURED);
- “Specification of operational requirements”, FEV (D2.3 of ASSURED);
- “Specification of fast charging infrastructure”, HELIOX (D2.4 of ASSURED);
- ASSURED City Template, POLIS (D2.1 of ASSURED)
- “Ergonomics of the thermal environment – Analytic determination and interpretation of thermal comfort using calculations of the PMV and PPD indices and local thermal comfort criteria”, ISO 7730, https://www.iso.org/standard/39155.html
- “A noise label for motor vehicles: towards quieter traffic”, Johan Sliggers, Ministry of Infrastructure and the Environment The Netherlands, January 2015, https://www.unece.org/fileadmin/DAM/trans/doc/2015/wp29grb/GRB-61-01e-Add.1.pdf;

Annexes

ANNEX 1 – KPI Tree in table format

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Criterion	KPI 1° level	KPI 2° level	KPI 3° level	KPI 4° level	Unit of measurement	KPI description
1. COST	1.1 Capex	1.1.1 Vehicle	1.1.1.1 Battery		€	Battery's purchase cost (% variation)
			1.1.1.2 Electric bus/truck		€	Vehicle's purchase cost (% variation)
		1.1.2 Infrastructure	1.1.2.1 Opportunity charging system		€	Opportunity charging system's purchase cost (% variation)
			1.1.2.2 Depot charging system	1.1.2.2.1 Charging point	€	Depot charging system's purchase cost (% variation)
				1.1.2.2.2 Charging pole	€	
				1.1.2.2.3 Charging station	€	
			1.1.2.3 Installation cost		€	Cost of charging systems' installation (% variation)
			1.1.2.4 Smart charging		€	Smart Charging hardware's purchase cost (% variation)
		1.1.3 Power Grid	1.1.3.1 Isolation and grounding system (safety)		€	Isolation and grounding system's purchase cost (% variation)
			1.1.3.2 ICT compliance		€	Smart Charging ICT system's purchase cost (% variation)
	1.2 Opex	1.2.1 Vehicle operation	1.2.1.1 Energy efficiency		-	Cost due to energy efficiency
			1.2.1.2 Vehicle energy consumption		kWh	Cost due to electricity consumption of the vehicle (% variation)
			1.2.1.3 Electric vehicle downtime		€	Cost due to downtime of the vehicle (% variation)
			1.2.1.4 Energy cost		€	Cost of the energy consumption (% variation)
		1.2.2 Power Grid	1.2.2.1 Electricity network losses		€	Cost due to electricity network losses during electricity distribution (% variation)
		1.2.3 Infrastructure	1.2.3.1 Electricity network losses		€	Cost due to losses within the own distribution network (% variation)
		1.2.4 Maintenance	1.2.2.1 Vehicle	1.2.2.1.1 Scheduled vehicle repair cost	€	Cost for the scheduled maintenance of the vehicle (% variation)
				1.2.2.1.2 Unscheduled vehicle repair cost	€	Cost for the unscheduled maintenance of the vehicle (% variation)
				1.2.2.1.3 Scheduled battery repair cost	€	Cost for the scheduled maintenance of the battery (% variation)
				1.2.2.1.4 Unscheduled battery repair cost	€	Cost for the unscheduled maintenance of the battery (% variation)
				1.2.2.1.5 Scheduled charger repair cost	€	Cost for the scheduled maintenance of the charger (% variation)
				1.2.2.1.6 Unscheduled charger repair cost	€	Cost for the unscheduled maintenance of the charger (% variation)
			1.2.2.2 Infrastructure	1.2.2.2.1 Scheduled repair cost	€	Cost for the scheduled maintenance of the infrastructure (% variation)
				1.2.2.2.2 Unscheduled repair cost	€	Cost for the unscheduled maintenance of the infrastructure (% variation)
			1.2.2.3 Power Grid	1.2.2.3.1 Scheduled repair cost	€	Cost for the scheduled maintenance of the power grid (% variation)
				1.2.2.3.2 Unscheduled repair cost	€	Cost for the unscheduled maintenance of the power grid (% variation)
	1.3 End of Life	1.3.1 Dismantling	1.3.1.1 Vehicle	1.3.1.1.1 Desmaintling cost of battery	€	Cost for the dismantling of the battery (% variation)
				1.3.1.1.2 Desmaintling cost of vehicle	€	Cost for the vehicle disposal (% variation)
			1.3.1.2 Infrastructure	1.3.1.2.1 Desmaintling cost of infrastructure	€	Cost for the infrastucture disposal (% variation)
		1.3.2 Selling of materials and components , or second life			€	Cost due to a change in second life possibilities, or the re-use of valuable materials (% variation)
	1.4 Revenues	1.4.1 Vehicle	1.4.1.1 Number of passengers		l or kg	Revenues due to the variation of payload in function of the number of passengers
2. AVAILABILITY/STABILITY	2.1 Vehicle	2.1.1 Operation	2.1.1.1 Electric driving distance		km	
			2.1.1.2 Electric driving time		hours	
			2.1.1.3 Interoperability		-	Availability of equivalent vehicles for carrying out the same service
			2.1.1.4 Modularity of drivetrains for buses		-	Modularity of propulsion system (torque, gear ratio, recuperation system, …) in function of route lenght and topography
			2.1.1.5 Modularities of batteries		-	Modularity and stackability of battery system to provide the proper sizing of the storable energy for each demand of the buses, trucks and vans (also scalabilty of the cooling system)
		2.1.2 Charging	2.1.2.1 Time for opportunity charging		min	Time needed to charge the vehicle with the opportunity system (% variation)
			2.1.2.2 Time for overnight charging in depot		hours	Time needed to charge the vehicle in depot (% variation)
		2.1.3 Maintenance	2.1.3.1 Scheduled vehicle repair time		hours	Number of hours for scheduled maintenance of the vehicle (% variation)
			2.1.3.2 Unscheduled vehicle repair time		hours	Number of hours for unscheduled maintenance of the vehicle (% variation)
			2.1.3.3 Scheduled battery repair time		hours	Number of hours for scheduled maintenance of the battery (% variation)
			2.1.3.4 Unscheduled battery repair time		hours	Number of hours for unscheduled maintenance of the battery (% variation)
			2.1.3.5 Scheduled charger repair time		hours	Number of hours for scheduled maintenance of the charger (% variation)
			2.1.3.6 Unscheduled charger repair time		hours	Number of hours for unscheduled maintenance of the charger (% variation)
	2.2 Power Grid	2.2.1 Power demand for opportunity charging stations			kW	Energy demand for single opportunity charge (% variation)
		2.2.2 Power demand for overnight charging stations			kW	Energy demand for single overnight charge (% variation)
		2.2.3 Maintenance	2.2.3.1 Scheduled maintenance time		hours	Numbers of hours per year or operational hours for scheduled maintenance (% variation)
			2.2.3.2 Unscheduled maintenance time		hours	Numbers of hours per year or operation hours for unscheduled maintenance (% variation)
		2.2.4 Power quality	2.2.4.1 Slow voltage variations		%	Percentage variation between maximum and minimum values of slow voltage
			2.2.4.2 Fast voltage variations		%	Percentage variation between maximum and minimum values of fast voltage
			2.2.4.3 Total Harmonic Distorsion (THD)		%	Measurement of the harmonic distorsion
	2.3 Infrastructure	2.3.1 Interoperability	2.3.1.1 Charging points technical features	2.3.1.1.1 Autentification media	Qualitative	Level of interoperability of the charger technical standards (% variation)
				2.3.1.1.2 Plug and socket compliancy	Qualitative	
			2.3.1.2 System features	2.3.1.2.1 Interconnection	Qualitative	Level of interoperability of the charging system (% variation)
				2.3.1.2.2 Data exchanges	Qualitative	
			2.3.1.3 Business & legal features	2.3.1.3.1 Roaming agreements between operators	Qualitative	Level of interoperability of business and legal features (% variations)
		2.3.2 Maintenance	2.3.2.1 Scheduled maintenance time		hours	Numbers of hours per year or operational hours for scheduled maintenance (% variation)
			2.3.2.2 Unscheduled maintenance time		hours	Numbers of hours per year or operational hours for unscheduled maintenance (% variation)
		2.3.3 Current quality	2.3.3.1 Phase of voltage relative to current		degrees	Angle between current and voltage (% variation)
			2.3.3.2 Total Harmonic Distorsion (THD)		%	Measurement of the harmonic distorsion (% variation)
			2.3.3.3 Peak current		A	Maximum amount of current for a short time period (% variation)
		2.3.4 Number of charging points			n°	Number of positions for charging points
		2.3.5 Number of charging stations				Number of locations for charging stations
3. RELIABILITY	3.1 Number of Failures (per operational hours)	3.1.1 Vehicle			FITs (Failures in Time 10^9 hours)	Number of failures in Time (MTBF) of the vehicle (% variation)
		3.1.2 Battery			FITs (Failures in Time 10^9 hours)	Number of failures in Time (MTBF) of the battery (% variation)
		3.1.3 Infrastructure			FITs (Failures in Time 10^9 hours)	Number of failures in Time (MTBF) of the infrastructure (% variation)
		3.1.4 Power grid			FITs (Failures in Time 10^9 hours)	Number of failures in Time (MTBF) of the power grid (% variation)
4. ENVIRONMENTAL IMPACTS	4.1 Pollutant emissions				g/km	Major pollutants emissions (PA, NOx…) according to Country Energy Mix (and energy efficiency)
	4.2 CO2 emissions				g/km	CO2 emmissions according to Country Energy Mix (and energy efficiency)
	4.3 Noise and vibrations				db	Noise impacts outside of the vehicle measured in decibe according to standard reference (% variation)
5. PERFORMANCE	5.1 Vehicle	5.1.1 Lenght type			m	Vehicle classification based on lenght (% variation)
		5.1.2 Effective usable driving energy			kWh	Energy available for driving (% variation)
		5.1.3 Empty weight			kg	Empty weight of the vehicle (% variation)
		5.1.4 Total passenger capacity			n°	Maximum number of passengers (% variation)
		5.1.5 Maximum payload			kg	Maximum allowable payload of the vehicle (% variation)
		5.1.6 Total weight			kg	Total (average) weight of the vehicle, including (average) passenger/freight (% variation)
		5.1.7 Lifetime			years	Lifetime expected of the vehicle (% variation)
		5.1.8 Motor continuos power			kW	Maximum power sustainable for a long time(% variation)
		5.1.9 Motor peak power			kW	Maximum power sustainable for a short time (% variation)
		5.1.10 Maximum torque			Nm	Maximum torque of the engine (% variation)
		5.1.11 Effective electric driving energy of the vehicle			kWh	Effective electric driving energy of the vehicle, related to the storable energy (% variation)
		5.1.12 Maximum electric driving range fully charged			km	Driving range of the vehicle fully charged with a representative payload (% variation)
		5.1.13 Maximum electric driving range fully fast-charged			km	Driving range of the vehicle charged to 80% SoC with a representative payload (% variation)
		5.1.14 Possible daily fully electric operation time			hours	Maximum operation time of the vehicle per day (% variation)
		5.1.15 Maximum climb rate			%	Maximum climbing rate feasible for the vehicle (% variation)
		5.1.16 Consumption of HVAC			kWh	Energy consumption due to Heating, Ventilation and Air Conditioning system (% variation)
	5.2 Battery	5.2.1 Nominal capacity			Ah	Capacity of the battery (% variation)
		5.2.2 Storable energy			kWh	Energy that can be stored in the battery (% variation)
		5.2.3 Maximum charge current			A	Maximum sustainable battery charge current (% variation)
		5.2.4 Maximum continous discharge charging			A	Maximum sustainable battery discharge current (% variation)
		5.2.5 Nominal battery voltage			V	Maximum battery of voltage (% variation)
		5.2.6 Working voltage range			V	Difference between the maximum and minimum voltage of the battery in working conditions (% variation)
		5.2.7 Charging current over 5 min			A	Maximum current that can be achieved during 5 minutes opportunity charging (% variation)
		5.2.8 Charging power over 5 min			kW	Maximum power that can be achieved during 5 minutes opportunity charging (% variation)
		5.2.9 Maximum charging capability			kW	Maximum amount of power that can be transferred in the battery during a charging (% variation)
		5.2.10 SOC range (min/max)			%	Maximum and minimum values of the State of Charge (% variation)
		5.2.11 Range for operational temperature			°C	Range of temperature for operability (% variation)
		5.2.12 Number of maximum full (80%) charge cycles			n°	Number of fully charge cycles leading to a 80% rest capacity (% variation)
		5.2.13 Expected calendar life			years	Expected calendar life (% variation)
		5.2.14 Dimension of battery system enclosure			mm	Maximum dimension of the battery system enclosure (% variation)
		5.2.15 Battery system weight			kg	Weight of the battery system (% variation)
6. QUALITY OF SERVICE	6.1 Passengers' satisfaction	6.1.1 Noise comfort			Qualitative	Comfort related to noise from a passenger point of view (% variation)
		6.1.2 Thermal comfort			Qualitative	Comfort related to HVAC system from a passenger point of view (change in thermal comfort quality level)
		6.1.3 Commercial speed			Qualitative	Comfort related to commercial speed from a passenger point of view (% variation)
	6.2 Driver's satisfaction	6.2.1 Noise comfort			Qualitative	Comfort related to noise from the driver point of view (% variation)
		6.2.2 Thermal comfort			Qualitative	Comfort related to HVAC system from the driver point of view (change in ISO 7730:2005 thermal comfort quality level)