



Assessment and Monitoring Framework

Project deliverable D4.1



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SCALE Project Executive Summary

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed. The project will test and validate a variety of smart charging and V2X solutions and services in 13 Use Cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Greater Munich Area (GER), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders. SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

SCALE's consortium comprises 29 cutting-edge European e-mobility actors covering the entire smart charging and V2X value chain (equipment and charging manufacturers, flexibility service providers, research and knowledge partners, public authorities, consumer associations, etc.) It is led by ElaadNL, one of the world's leading knowledge and innovation centres in smart charging and charging infrastructure.

SCALE partners

List of participating cities:

- Oslo (NO)
- Rotterdam & Utrecht (NL)
- Eindhoven (NL)
- Toulouse (FR)
- Greater Munich Area (GER)
- Budapest & Debrecen (HU)
- Gothenburg (SE)

List of partners:

- (Coordinator) STICHTING ELAAD NL
- POLIS - PROMOTION OF OPERATIONAL LINKS WITH INTEGRATED SERVICES, ASSOCIATION INTERNATIONALE POLIS BE
- GoodMoovs NL
- Rupprecht Consult – Forschung & Beratung GmbH RC DE
- Trialog FR
- WE DRIVE SOLAR NL BV NL
- UNIVERSITEIT UTRECHT NL
- LEW Verteilnetz GmbH DE
- BAYERN INNOVATIV - BAYERISCHE GESELLSCHAFT FÜR INNOVATION UND WISSENSTRANSFER MBH DE
- ABB BV NL

- Enervalis BE
- GEMEENTE UTRECHT NL
- Equigy B.V. NL
- SONO MOTORS GMBH DE
- Meshcrafts As (Current) NO
- Research Institutes of Sweden AB SE
- ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (CERTH) GR
- FIER Automotive FIER NL
- Emobility Solutions Kft. HU
- Serviced Office Belbuda Kft HU
- Enedis FR
- L'ASSOCIATION EUROPEENNE DE LA MOBILITE ELECTRIQUE (AVERE) BE
- Norsk elbilforening NO
- VDL ENABLING TRANSPORT SOLUTIONS BV NL
- Urban Electric Mobility Initiative UEMI DE
- Renault FR
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Report executive summary

Key words

Monitoring Framework, KPI repository, KPI cards

Summary

Key Performance Indicators (KPIs) can act as a universal instrument to evaluate the progress of smart charging and V2X strategies, supporting the monitoring of relevant solutions and projects. The definition of a KPI is “a quantifiable measure used to evaluate the success of an organization, employee, etc. in meeting objectives for performance”. The key difference between KPIs and other indicators is that KPIs are directly relevant to a goal, a target, or an objective.

The main target is the development of an open system architecture for smart charging and V2X, which will build upon and will enhance the existing open standards and royalty free protocols by enabling interoperability throughout the EU and by having independent validated data stream and transparency. A successful framework should carefully address possible challenges in timeframes spanning from prior to beyond the project implementation life cycle.

In this context, several initiatives propose different monitoring and assessment KPI frameworks for smart charging and V2X solutions promoting the cooperation and exchanging of know-how among the operators. The selection of the most appropriate KPIs for smart charging and V2X projects remains difficult though, as it requires expert knowledge. There are hundreds of KPIs available, and the selection of the most suitable KPIs for each case is a challenging task. The smart charging concept includes a variety of interrelated dimensions, and therefore the process of evaluation through KPIs is challenging, because, on the one hand, it should satisfy smart charging needs while on the other hand should allow an effective comparison on a national or international level with V2X solutions.

This deliverable's primary goal is to provide a comprehensive list of KPIs as well as the monitoring of the KPIs aspects in order to specify SCALE's impact, that is based on a methodological approach that considers the stakeholders' requirement, the technologies to be employed, and the literature of widely acknowledged frameworks to facilitate comparability of results. Additionally, this deliverable offers advice on the specific infrastructures needed for KPI monitoring and measurement. It is necessary to completely specify the KPIs that will be chosen, including their formulas, suggested data sources and collection techniques, specifications, and spatiotemporal levels of evaluation. A total of thirty-eight (38) KPIs have been defined, covering the short- and medium-term (24 KPIs) and long-term (14 KPIs) scopes of SCALE and being perfectly in line with SCALE's anticipated impacts and outcomes.

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List of abbreviations and acronyms

Acronym	Meaning
B2B	Business-to-business
B2C	Business-to-Consumer
CIVITAS	City-VITAlity-Sustainability. Initiative of the European Union to implement sustainable, clean and (energy) efficient urban transport measures.
CMP	Congestion management process
CPO	Charge Point Operator
EC	European Commission
EO	Expected Outcome
GA	Grant Agreement
GHG	Greenhouse Gas
KoM	Kick-off Meeting
KPI	Key Performance Indicator
KPI	Key Performance Indicator
KIP	Key Impact Pathway
RTO	Real-time operating system
WP	Work Package

1 Purpose of the deliverable

1.1 Attainment of the objectives and explanation of deviations

The objectives related to this deliverable have been achieved in full and as scheduled.

1.2 Intended audience

SCALE incorporates a series of smart charging and V2X solutions to accelerate the transition in a new era of e-mobility, where interoperability problems will be addressed, aiming at increasing their credibility among its users. Therefore, the project success can only be evaluated through specific and tailored KPIs, which need to be defined according to the scope of the specific need of the EV users, charging station operators and energy providers, while the measurement and the monitoring of those KPIs shall ensure their achievement. To this end, the core objective of this deliverable is to provide an appropriate list of KPIs based on a methodological approach that will consider the needs of the stakeholders, the technologies to be implemented, and the literature of widely used frameworks to promote comparability. This deliverable provides also guidance on specific infrastructures required for the KPIs' measurements and monitoring. The KPIs to be identified need to be fully defined including formulas, recommendations for data sources and collection methods, requirements, and spatiotemporal levels of assessment. They also need to be inclusive, specific, and transparent to minimize any misinterpretations and assess all levels of the charging processes, from grid to X, where X stands for i) home (Cluster A), ii) business (Cluster B) and iii) depot (Cluster C), including both light and heavy-duty vehicles (Cluster D) and smart public charging. Through this process, the KPI list will serve as a basis for the implementation and evaluation activities in SCALE, not only in terms of technological performance but also at the level of social engagement, acceptance, and diffusion towards scalable and replicable innovations. The intended audience includes other organizations interested in promoting smart charging infrastructure in addition to SCALE's partners who will be monitoring SCALE's short-, medium- and long-term results. Moreover, one key requirement for the selection of the KPIs deals with the need to be representative for the various services to be demonstrated in the course of SCALE, while being numerically limited and feasible to be measured. Furthermore, this deliverable provides an appropriate list of the aspects related to the security (cyber and physical) of the charging stations, as well as the specific infrastructures via which this security can be achieved.

1.3 Links with other work packages/deliverables

There is a strong linkage of D4.1 with the activities in WP1: "Analysis of user & stakeholder needs, planning requirements and development of a system architecture for smart charging & V2X". Especially T1.2 and the respective deliverable D1.2: "Stakeholder analysis report" which focus on the analysis of challenges, barriers, and participation motives of stakeholders will provide a solid basis on the technical, economic, environmental, and societal requirements underlying SCALE's implementation. Relevant feedback will be capitalized during T1.2 to ensure that SCALE's final repository is aligned as much as possible to the stakeholders' requirements. D4.1 is also relevant to T1.3, which assesses the planning procedures for mobility transition to support integrated planning of mobility and energy systems. Moreover, D4.1 of WP4, "Report on the SCALE Assessment and Monitoring Framework", provides the necessary framework to assess the demos activities prepared in T3.1 and executed in T3.2. D4.1 will finally inform the simulating mass deployment in T5.3 of WP5, "Preparing for mass- deployment: exploitation, policy & legal recommendations, and standardization" by suggesting policy options related to technical or legal standards as a response to the outdated and fragmented legal, market and regulatory framework. D4.1 will also inform T5.5 on promoting the evolution of existing standards and protocols.

1.4 Structure of Deliverable 4.1

D4.1 is structured in five (5) chapters as follows:

Chapter 1- Purpose of the Deliverable

This chapter clearly describes the aim of the deliverable, its relationship with other tasks and the structure of information included.

Chapter 2 - Context

This chapter gives a summary of the SCALE Use Cases, upon which the KPI repository is based, and outlines the Key Impact KPI categories.

Chapter 3 - Methods for Short-, medium- term evaluation

This chapter presents in a comprehensive way, the methodology applied to extract the final SCALE KPI repository. A step-by-step approach is adopted to ensure that significant KPIs as imposed both by the project needs and requirements from literature, standards, strategic plans, and initiatives, have been considered, while keeping the complexity and extent of the repository manageable. A short-, medium- term timescale is considered, to support the successful monitoring of SCALE's expected outcomes.

Chapter 4 – Long-term evaluation pathway (impact-oriented) results

This chapter explains the suggested list of KPIs to be used for assessing SCALE activities over the long term (during the project's exploitation). Here, the emphasis is on highlighting several crucial indicators that must be kept track of in the future to determine whether the intended impact of SCALE has been realized. Since these KPIs cannot be measured and validated during SCALE implementation, a more simplified approach is used in comparison to Chapter 3, focusing more on offering general recommendations that can support the sustainability of the project.

Chapter 5 - KPI Cards

This chapter provides the KPI Cards, which includes the definition of each KPI, the partner responsible to measure it, the mathematical formula to be used for the KPI calculation, the recommended unit of Measurement, the relevant stakeholders as well as the Use Cases in which each KPI will be monitored.

Chapter 6 – Infrastructure and Monitoring Equipment – Specifications and Implementation Pathway

This chapter refers to the existing equipment, which is used for the monitoring of the KPIs aspects and for the project's security. Also, describes the implementation pathway of the monitoring and the security process.

Chapter 7 - Conclusions

This chapter offers an overview of the major issues addressed by this deliverable, as well as a conclusion that emphasizes the significance of D4.1.

Annex

An explanation of the supporting data in the SCALE D4.1 annexes can help and deepen comprehension of the issues presented in the report's main body. Due to the length of this report, the KPI cards are also included in the ANNEX for readers who want to review the information connected to each KPI in greater depth.



2 Context



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2 Context

SCALE aims to develop and utilize a Monitoring Framework including a list of Key Performance Indicators (KPIs) as the project's instrument to evaluate smart charging and V2X solutions developed during the project. The general concept for defining SCALE's monitoring framework is to define two different sets of KPIs – the first set of KPIs can be linked with the expected outcomes of the project focusing on the short/medium term (until the end of SCALE) and therefore include KPIs that are strongly recommended to be measured by all Pilot Sites. The second set of KPIs could be optional and linked to specific Use Cases, based on the characteristics of each one of them (Use Case). Both sets should share a common basis – being aligned and serve the needs of SCALE Key Impact Pathways (KIPs). SCALE addresses several layers of innovation activities: technologies, process, operational and business model innovation, adopting a systems approach to smart charging and V2X solutions. This will be achieved through the definition and **implementation** of three (3) KIPs addressing Scientific, Societal (inc. Environmental) and Economic/Technological Impact in full alignment with HORIZON EUROPE Legislation¹.

An initial summary of the thirteen (13) Use Cases provided during the proposal phase aids in comprehension and directs the selection of pertinent KPIs that will facilitate the monitoring of the solutions developed and tested within SCALE. The fundamental KPI dimensions are then analyzed, and the viewpoints of the stakeholders are examined.

2.1 Brief overview of SCALE Use Cases

SCALE demonstrates and tests under real-life operational conditions a total of 20 innovative charging concepts and solutions in **twelve (12) different Use Cases** covering an **overarching Use Case**. Each Use Case comprises of a certain combination of charger, vehicle type, and service tested, meaning that charging point concepts include unidirectional static, dynamic and bidirectional charging, and various charging power outputs. The **twelve (12) Use Cases** are **classified** under four **(4) identified Innovation Clusters** that will be validated with the involvement of 800 pilot users (Task 3.2, D3.2), based on the various site types and the specific user groups. In this context, SCALE serves as the first-of-its-kind knowledge platform & database, that will systematically collect experience and share knowledge and lessons learnt for those 4 smart charging & V2X innovation areas.

Innovation Clusters group innovative **Smart Charging & V2X solutions**. The Smart charging and V2X Clusters will be deployed in the 10 European countries considering 20 scalable charging concepts (**charging scenarios**) developed in line with each Use Case's needs and ensuring co-optimization of users, businesses/buildings, power grids and society. The 13 use-cases will be studied under real-life testing phase with at least 20 users each. The Overarching Use Case and the 4 Innovation Clusters are presented briefly below:

¹ Regulation (EU) 2021/695, OJ L 170/1, Article 50 & Annex V 'Time-bound indicators to report on an annual basis on progress of the Programme towards the achievement of the objectives referred to in Article 3 and set in Annex V along impact pathways'

- **Overarching Use Case:** This Use Case is set-up to prove the potential of the V2X services being scaled. In Utrecht, a bi-directional ecosystem, which supports power system stability, prevents grid reinforcements costs, and lowers the peak load of the power system. The entire fleet of V2G cars is owned by a professional entity, facilitating bundling and intelligent charging management. The charging scenarios include the demonstration of services as the a) congestion management, b) grid balancing (via AFRR), c) demand charge reduction, d) time-of-use price arbitrage, e) maximized feed in of renewables and virtual power plant.

- **Cluster A:** This is a Vehicle to Home (V2H) cluster and implements the V2X concept for private residential users. Charging of EVs will take place predominantly at home. Focus is mostly on reducing costs and increase of usability for users to ensure high participation throughout society. Charging scenarios in Cluster A include the demonstration of services as the a) demand charge reduction, b) time-of-use price arbitrage, c) self-consumption, d) maximized feed in of renewables.

- **Cluster B:** This is a Vehicle to Business (V2B) cluster and considers the V2X concept at work / at the office. It examines the potential of smart charging and V2X services, on a wider scale than that of Cluster A, because of the centrally control charging, long stationary time, and an already high uptake of EVs in company fleets. Charging scenarios include the demonstration of services as the a) demand charge reduction, b) time-of-use price arbitrage, c) maximize feed in of renewables, d) self-consumption.

- **Cluster C:** This is a Vehicle to Depot (V2D) cluster, which is relevant to the smart charging of light and heavy-duty vehicles, trucks and transport and logistics activities etc. Heavy duty vehicles require larger batteries and thus larger charging times. In this context, their utilization rate i.e., the time that they are on the road is essential. A charging solution with local battery storage will be deployed to increase charging speed without costly grid reinforcements. Also, cost reductions can be achieved via charging and V2X services to enable load balancing services and reduce peak loads on the power system. Charging scenarios include the demonstration of services as the: a) demand charge reduction, b) peak shaving, c) time-of-use price arbitrage, d) behind the meter charging power, e) virtual power plant.

- **Cluster D:** This is a Vehicle to Public (V2P) cluster, that entails the available V2G public infrastructure and its impact through the large amount of available parked EVs. Municipalities and parking operators will be supported to manage energy demand, relieve local congestion, and reduce peak loads. Charging scenarios include the demonstration of services as the a) demand charge reduction, b) peak shaving, c) time-of-use price arbitrage. Table 1 illustrates the Use Cases per Innovation Cluster.

Table 1: Use Cases per Innovation Cluster

INNOVATION CLUSTER	USE CASE
 OVERARCHING USE CASE	UC 00 Bi-directional ecosystem via combined V2G service from large car sharing program under a single owning entity (500 cars&3000 chargers)

 VEHICLE TO HOME	UC A.1 Smart charging & V2X concept for site self-consumption in single family housing
	UC A.2 Extension to V2G services enabling participation in energy market
 VEHICLE TO BUSINESS	UC B.1 Station-based B2B car-sharing with demand side management
	UC B.2 Fixed and opportunity charging for employees and visitors of multi brand car dealership
	UC B.3 Smart charging in car dealer's depot
	UC B.4 Public and private V2G chargers at office locations
 VEHICLE TO DEPOT	UC C.1 Station-based Serviced Office B2B car-sharing with demand side management
	UC C.2 DC high power highway charging system with local RE generation & storage
	UC C.3 Virtual power plant at heavy-duty depot with renewable energy generation and second life battery storage
	UC C.4 Smart charging of light commercial vehicles
 VEHICLE TO PUBLIC	UC D.1 EV chargers in the Oslo University parking lot to be retrofitted with smart charging feature
	UC D.2 V2X and smart charging combined with PV installation & stationary storage at a large-scale shopping center

Table 2, includes a summary of the SCALE Use Cases as well as important site-specific Use Case characteristics offering a clear insight and understanding of the scope and principal objectives of each Use Case.

Table 2 Description of SCALE Use Cases

SCALE Use Cases Basics	
UC 00 Bi-directional ecosystem via combined V2G service from large car sharing program under a single owning entity	
Brief Description	This Use Case examines the scaling-up potential of V2X services offered by a bi-directional ecosystem supporting grid stability and flexibility capacity and using an owned fleet of 500 V2G cars, that will be coordinated under the construction and management of a Virtual Power Plant.
Location	Public and office parking, Utrecht, Netherlands (NL)
Partners	We Drive Solar, Utrecht, Equigy, Enervalis, Utrecht University, Hyundai, GoodMoovs, Renault
Specifics	500 V2G capable cars and 3000 V2G capable charging points, delivering congestion management
Charging concepts	V2G
UC B.1 Station-based B2B car-sharing with demand side management	
Brief Description	This Use Case aims to develop a business case of the EV car sharing program for the supply and demand side. The main pilot goals through this process are to achieve cost reduction through smart charging integrated with the building EMS and local renewable

	energy generation, but also by the V2X service (self-consumption). As an additional goal, the increased use of the car sharing program by determining what influences mobility mode choice is expected.
Location	Debrecen/Budapest, Hungary (HU)
Partners	E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault
Specifics	4 EVs with V2X capable chargers with a local RE generation at Debrecen
Charging concepts	AC Smart charging, V2X
UC B.2 Fixed and opportunity charging for employees and visitors of multi brand car dealership	
Brief Description	The specific Use Case will exploit fixed and opportunity charging options for visitors, based on multiple brands of EVs to increase utilization of generated renewable energy through self-consumption, demand charge reduction, and energy storage and consequently achieve reduction of energy costs and higher quality of the power flexibility from the V2G service.
Location	Budapest, Hungary (HU)
Partners	E-Mobility Solutions, ABB, Enervalis
Specifics	32 chargers (2 visitors per day)
Charging concepts	AC & DC Smart charging and V2X, local RE generation (400 kW PV), stationary batteries
UC B.3 Smart charging in car dealer's depot	
Brief Description	The individual Use Case will utilize smart charging points for the needs of a car company seeking for the optimal charging strategy in terms of self-consumption through energy and battery charging modelling and simulation, as well as to preventing further grid reinforcements by limiting the needed power.
Location	Toulouse, France (FR)
Partners	Enedis, Current
Specifics	From 30 to 50 EVs need to be charged at about 50% SOC every day for delivery.
Charging concepts	Smart charging + local RES generation (12 MW PV installation)
UC B.4 Public and private V2G chargers at office locations	
Brief Description	The concept of interoperable, both public and private, charging points placed at working environments, through implementing the ISO15118-20, will be tested under this Use Case, aiming to increase grid flexibility by delivering power back to the DSO via V2G capabilities as well as to reduce costs via peak shaving and demand charge reduction.
Location	Gothenburg, Sweden (SE)
Partners	Chalmers, Polestar, RISE
Specifics	1 public V2G charger (DC) & 1 private V2G charger (AC), total of 2 V2X capable cars.
Charging concepts	AC & DC Smart charging and V2G
UC C.1 Station-based Serviced Office B2B car-sharing with demand side management	
Brief Description	The particular Use Case will take place in two specific pilot sites in Norway dealing with two different "delivery vehicle-sharing" schemes. The main goal of this Vehicle-to-Depot Use Case is to reduce complexity for the drivers of delivery trucks regarding billing & authorization (plug & charge), increase usability by integrating the control mechanism interface with the fleet management system and ensure interoperability via ISO15118-20, paving the way towards electrification of the entire fleet.
Location	Oslo, Norway (NO).
Partners	Current, ABB

Specifics	ASKO site: 1 light-weight delivery truck - Oslo harbor site: 1 heavy-duty truck
Charging concepts	DC smart charging from 24 to 350kW
UC C.2 DC high power highway charging system with local RE generation & storage	
Brief Description	The smart and V2X charging potential of heavy-duty vehicles (HDV) through stationary batteries will be examined in order to increase charging power without grid reinforcements. The Use Case demonstrations and activities focus on finding the optimal setup of highway power charging infrastructure for HDV through simulation. In this vein, the Use Case envisions to meet customer expectations, facilitate charging on demand, and enable predicted (dynamic) charging time and pre-booking.
Location	Eindhoven, Netherlands (NL)
Partners	VDL, Current, ABB, Enervalis
Specifics	3 150 kW DC V2X chargers, local renewable energy generation & stationary batteries
Charging concepts	Smart charging and V2X
UC C.3 Virtual power plant at heavy-duty depot with renewable energy generation and second life battery storage	
Brief Description	In this Use Case, a Virtual Power Plant (VPP) for a specific heavy-duty depot will be employed to cut dependence on the grid and thus reduce costs by managing renewable energy generation and local on-site storage via second-life battery packs, to optimize the smart charging and V2X services.
Location	Eindhoven, Netherlands (NL)
Partners	VDL, Enervalis
Specifics	4 charging points, heavy-duty vehicles
Charging concepts	Virtual power plant with smart charging and V2X
UC C.4 Smart charging of light commercial vehicles	
Brief Description	The smart charging potential of light duty vehicles on reducing the peak load and increasing the renewable energy utilization will be investigated, in order to generate cost savings by preventing grid reinforcements.
Location	Rotterdam / Utrecht, Netherlands (NL)
Partners	ElaadNL, FIER
Specifics	31 light commercial vehicles, local RES generation (feed in of PV)
Charging concepts	AC Smart charging
UC D.1 EV chargers in the Oslo University parking lot to be retrofitted with smart charging feature	
Brief Description	This Use Case is a profitable business case dealing with the upgrade of the EV charging points in the parking of Oslo university through the integration of smart charging management infrastructure, aiming to reduce cost for charging, while delivering enough power in time. In addition, the EV smart charging and building energy management systems will be coupled with open interface to enable dynamic load balancing.
Location	Oslo, Norway (NO)
Partners	Current
Specifics	40-50 chargers converted from static- to dynamic chargers
Charging concepts	AC & DC Smart charging
UC D.2 V2X and smart charging combined with PV installation & stationary storage at a large-scale shopping center	

Brief Description	An innovative concept that integrates V2X and smart charging schemes with PV and storage systems, will be deployed in this Use Case. Through the planned infrastructure installations, the pilot aims to develop a green micro-grid to reduce grid dependency as well as to achieve multi-location <i>demand</i> -side & load-management. The increase of plug-in rate will be also targeted via a loyalty program motivating customers to utilize smart and preferred charging behavior.
Location	Hungary (HU), 14 different locations
Partners	EMS, ABB, Enervalis
Specifics	120 charging points with variable load, two V2X chargers
Charging concepts	Smart charging & V2X, local PV installation, stationary batteries

2.2 Key Impact categories

This section describes the key impact pathways as set out by HORIZON EUROPE Legislation² reflecting SCALE's commitment to contribute to addressing societal challenges, improving industrial competitiveness, and strengthening the European research area and innovation ecosystem. The stakeholder's perspective is analyzed to reflect the diverse interests and needs of various groups and individuals, who have a stake in research and innovation activities related to advancing smart charging infrastructure and facilitating the mass deployment of electric vehicles.

2.2.1 Impact Categories

In line with Horizon Europe legislation¹, the SCALE KPIs will be selected to reflect three complementary key impact categories revealing the non-linear nature of R&I investments. Those key impact categories are Scientific, Societal (inc. Environmental) and Economic/Technological. Those key impact categories are used as the principal guidance to ensure that the KPIs to be selected will be relevant to those categories, covering all major aspects, which affect the sustainability of a V2X network. The data behind the key performance indicators will be collected in a centrally managed and harmonized way and at the appropriate level of granularity with minimal reporting burden on the beneficiaries. Finally, SCALE aims to adopt a holistic performance framework, corresponding not only to the type of solutions and Use Cases to be implemented, but also in line with the key objectives that are set out by SCALE. The following section provides a short description of the key impact categories.

2.2.1.1 Scientific

SCALE envisages having scientific impact by creating high-quality new knowledge, strengthening human capital in R&I, and fostering diffusion of knowledge and open science. Progress towards this impact will be monitored through proxy indicators set along the following three key impact pathways: creating high-quality new knowledge, strengthening human capital in R&I, and fostering diffusion of knowledge and open science.

² Regulation (EU) 2021/695, OJ L 170/1, Article 50 & Annex V 'Time-bound indicators to report on an annual basis on progress of the Programme towards the achievement of the objectives referred to in Article 3 and set in Annex V along impact pathways'

2.2.1.2 Societal (incl. Environmental)

The anticipated societal impact of SCALE aims to address the policy priorities of the Union and global challenges, including the SDGs, and be in accordance with the principles of the 2030 Agenda and the objectives of the Paris Agreement. Through R&I, delivering benefits and impact through R&I missions and European Partnerships, and strengthening the uptake of innovation in society in the long run, shall contribute to people's well-being. For instance, social performance is vital to determining how well the project supports citizen and social actor participation in planning, decision-making, and implementation processes through citizen-driven innovation mechanisms. As a result, some of the socially relevant KPIs are important for raising public awareness and gauging satisfaction with the services offered. Investigation into the public's perception of the location of the charging stations will also take place.

2.2.1.3 Technological and Economic

SCALE is expected to have technological and economic impact by influencing the creation and growth of companies, especially SMEs including start-ups, by creating jobs and leveraging investment of R&I. This progress shall be monitored with proxy indicators set along the following key impact pathways: generating growth based on innovation, creating more and better jobs, leveraging investments in R&I. In SCALE technological and economic progress shall be achieved through the participation of various actors in different sectors (i.e., RTOs, SMEs including technology providers, OEMs etc) from 6 European countries. To validate newly implemented technologies and spur further investments, subcategories of technical advancement shall also monitor factors as i) the deployed systems' energy efficiency, and ii) the flexibility (local-behind the meter flexibility, local flexibility for the DSO, system flexibility for the TSO), accuracy. The economic-related KPIs are anticipated to offer data pertaining to cost-saving measures for all stakeholders, including energy providers, charging infrastructure operators, and EV owners.

3

Methods for Short-, medium-term evaluation pathway results



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3 Methods for Short-, medium- term evaluation

SCALE's methodology for extracting the short/medium-term KPIs is based on five (5) consecutive steps, to ensure that call expected outcomes, as specified in Call HORIZON-CL5-2021-D5-01-03 (System approach to achieve optimized Smart EV Charging and V2G flexibility in mass-deployment conditions (2ZERO)), and significant aspects related to the evaluation of smart charging and V2X solutions as imposed by external sources (e.g., strategic plans, initiatives, scientific literature) are both considered. The definition and selection of the KPIs is based on a mixed top-down and bottom-up strategy that starts with reviewing the relevant literature, projects, strategic plans and standards, and technical studies to compile a potential KPI list relevant to SCALE outcomes and then refining this list to a more condensed yet complete set of purpose-fitted KPIs for the impact assessment of SCALE pilots and Use Cases. In this context, KPIs are defined in close collaboration with the design-experts of the SCALE architecture and the Use Cases Leaders to assess as holistically as possible, the impact of the SCALE solutions and facilitate their replication and scaling-up in other European contexts with different climate and socio-economic conditions. The five methodological steps are described in detail in the following sections.

3.1 Step 1: SCALE's expected outcomes

SCALE envisions to generate several outcomes covering the scientific (Sc), societal (SE) including environmental, technological, and economic (TE) domains, which serve the needs of SCALE selected KPIs. These outcomes are in accordance with the Call's Expected Outcomes, which are summarised in the Grant Agreement (GA No. 101056874) and are presented in Table 3.

Table 3: SCALE expected outcomes as defined in the GA

Call Expected Outcomes (EO)	SCALE Outcomes (O)
EO #1: Definition of the optimal smart charging concepts able to cope with several million of Electric Vehicles (EV) deployed in different environments.	Technological/ Economic
	O1.1: Adaptation of legal, market and regulatory frameworks for smart charging on the local, national, and European level
	O1.2: Lessons Learned for mass market beyond 4 innovation clusters covering majority Use Cases
	Social / Environmental
EO #2: Development of smart charging strategies and control mechanisms that and the efficiency of the whole energy system, increasing the use of renewable electricity harnessing unused EV storage capacity, whilst minimising grid reinforcements and energy generation needs.	O1.3: Fast replication and deployment of public charging infrastructure concepts accessible beyond the project's lifetime
	Technological/ Economic
	O2.1: Enhance EV satisfaction for smart charging and V2X applications to at least 90%
	O2.3: Development and validation of at least 5 control signals given to end users including potential of local RES generation
	Social / Environmental
	O2.4: Reduce GHG emissions by at least 20% (En/So)

EO #3: Innovative concepts and technologies performances to create affordable, user-friendly smart and bidirectional (V2X, where X can be G for Grid, H for Home and B for Business) charging solutions, co-optimising the needs of EV users, of the house/building and of the supplying grid.	Technological/ Economic O3.1: Development of 20 validated and scalable smart charging concepts in the Use Case pilots implemented in at least 15 cities and regional authorities O3.2: Optimizing charger utilization through increasing average plugin rate from 3% to 10% in public parking places O3.4: Increased affordability by generating revenues for EV drivers through V2G
	Scientific O3.3: Generating new knowledge on EV behavioral research, feeding to the research community
	Technological/ Economic O4.1: Minimization/elimination of the impacts on EV battery and the components of the power system O4.2: Quantification of V2X battery degradation and associated costs Scientific O4.3: New knowledge generation on finding optimum between AC and DC public chargers on cost and technological trade-offs necessary for commercializing both chargers and EVs
EO #4: A better understanding of the operational and economic trade-offs for the user and the vehicle e.g., cost of battery damage, additional cost for electronics to enable V2G, and on the charging (e.g., installation cost, battery degradation) infrastructure of the different smart and bidirectional (V2G) charging approaches and technologies (for instance AC vs DC), as well as the costs for the different actors involved	Technological/ Economic O5.1: Standardization and seamless integration of charger interface with cross-sectoral devices and systems e.g., a home/building energy management system or a third-party fleet management system O5.2: EV charging infrastructure roll out and EU-wide replication through the +15 cities as well as scenarios implementation towards EV uptake O5.3: Improved trip time planning and EV charging location routing via optimal interconnection of the EV charging infrastructure planning tool with the fleet management tool
EO #5: Contribution to the integrated planning process of systems aimed at exploiting cross-sector mutual benefits (G2X and V2X)	Technological/ Economic O6.1: Benchmarking and standardizing solutions in line with the market developments of complementing systems of V2X interface O6.2: Standardization of requirements for data collection and management with user integrity, privacy and GDPR in the smart charging ecosystem O6.3: Open protocols streamlined, standardizing charger procurement specifications in JPP towards making V2X solutions affordable O6.4: OEMs outside of consortium adopting ISO 15118-20 standards for interoperability
EO #6: Contribution to the standardisation process of interfaces for V2X	Technological/ Economic

EO #7: Assess customer expectations & implement an open architecture (not proprietary) concerning smart and bidirectional charging solutions, as key success factors to build a mutually beneficial charging experience for the user & for the grid	O7.1: Harmonization of communication with any compliant charger
EO #8: Demonstrate V2X potential in encouraging renewable energy growth through the integration with low power renewable energy sources (e.g., photovoltaics on the roof or in parking lots), by reducing energy exchange with the grid (in both directions) by 50%	Technological/ Economic O8.1: Reduce interaction with the grid by 50% O8.2: Developing new revenue generation business model with VPP O8.3: Validation of V2X system an open interface systemic solution towards the uptake of such charging hubs by +15 cities and more public transport authorities in the longer run

To assess and validate whether SCALE will satisfy its expected outcomes, it is necessary to build up and define appropriate KPIs, which are related to the project expected outcomes and KIPs. Following a thorough literature study approach described below, the SCALE anticipated outcomes, as presented in Table 3, were connected with pertinent KPIs in Step 2.

3.2 Step 2: Extended KPI pool capitalizing information from other sources

The goal of Step 2 is to review well-known and widely acknowledged sources, to identify appropriate KPIs that can provide suitable metrics for monitoring and evaluating the SCALE's expected outcomes, presented in Step 1.

In order to guarantee that cutting-edge KPIs will be taken into account for inclusion in SCALE's KPIs repository, a literature review on already existing indicator sets was deployed i.e., in a) EU-wide evaluation frameworks like SCIS³, CIVITAS⁴, smart city projects, V2G, smart charging, urban and sustainable mobility projects, b) publications in scientific journals, c) strategic plans and initiatives related to sustainability, e-mobility, etc., d) international and EU standards (e.g., ISO 37120:2018, ISO 37122:2019), and e) strategic plans and initiatives (e.g., UN's Sustainable Development Goals). Indicators focusing on energy and environmental aspects from different projects have been collected and additional ones have been included through the analysis of demonstration projects in scope. The main aim of this indicator list was to allow for comparability between projects. A brief description of the main sources of KPIs is presented below.

3.2.1 EU-wide evaluation frameworks

SCALE examined thoroughly the CIVITAS methodology, in order to select potential KPIs based on specific criteria and ensure uniformity with other European mobility strategies, also capitalizing on the outcomes and lessons learned from Smart Cities and Communities (SCC) projects via including the updated Smart Cities Information System framework (SCIS, 2018), which even though it is mainly applicable in SCC projects,

³https://smartcities-infosystem.eu/sites/www.smartcities-infosystem.eu/files/document/scis-monitoring_kpi_guide-november_2018.pdf

⁴ 2020 CIVITAS. Cleaner and Better Transport in Cities. Refined CIVITAS process and impact evaluation framework accessible at: <https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b4b337fe&appId=PPGMS>

Energy Efficient buildings (EeB) and designated projects funded under the calls for Energy Efficiency (EE), it takes into account mobility aspects and includes mobility-oriented KPIs.

3.2.2 CIVITAS

The CIVITAS Initiative is a network of cities for cleaner and better transport in Europe, and it has proposed a set of indicators to assess the performance of sustainable urban mobility CIVITAS defines indicators for urban mobility and offers a refined process for impact evaluation. The CIVITAS framework consists of detailed guidelines for a solid CIVITAS 2020 evaluation approach to achieve consistent and useful results. To understand the impact of CIVITAS measures, CIVITAS assessment framework groups indicators according to six (6) categories: a) society-people b) society – governance, c) transport system, d) economy, e) energy, and f) environment. Each category is composed of indicators classified into three types:

- **Key indicators:** important indicators to understand the impact of the CIVITAS measures in the six main CIVITAS impact categories; these indicators are accompanied with proposed definition, units, and measurement methods to make the results transparent for others
- **Intermediate indicators:** indicators used to derive with further calculations, eventually using also other indicators, the impact in the CIVITAS impact categories; eventually these indicators are used to show the influence of the measure on an interesting aspect of the mobility system
- **Additional indicators:** additionally, other indicators used to understand specific aspects of the impact of a measure or as an alternative for the key indicators making use of available data.

For the selection of indicators for the CIVITAS project, the main criteria follow included:

- **Relevance:** each indicator should represent an assessment criterion, i.e., have a significant importance for the evaluation process.
- **Completeness:** the set of indicators should consider all aspects of the system/concept under evaluation.
- **Availability:** readily available for entry into the monitoring system.
- **Measurability:** the identified indicators should be capable of being measured objectively or subjectively.
- **Reliability:** clarity of definition and ease of aggregation.
- **Familiarity:** the indicators should be easy to understand.
- **Non-redundancy:** indicators should not measure the same aspect of an assessment criterion.
- **Independence:** small changes in the measurements of an indicator should not impact preferences assigned to other indicators of the evaluation model.

In total, seventy-five (75) key performance indicators (including key indicators, intermediate indicators, and additional indicators) from the CIVITAS evaluation framework were examined.

3.2.3 Smart Cities Information System (SCIS)

The SCIS KPI guide: a) provides a description of key performance indicators and their application to the different objects of assessment, b) identifies the data requirements for their calculation and c) describes the methodology for the calculation of these indicators. Thus, SCIS provides an excellent baseline for KPIs selection to be used in SCALE's own framework/repository incorporating indicators relevant to SCALE Use Cases. The framework structure designed for the evaluation of the performance of a city's energy transition

is based in the definition of city indicators in two clusters: a) Core KPIs: technical (3 KPIs), environmental (3 KPIs), economic (5 KPIs), ICT (7 KPIs), mobility (9 KPIs); b) Supporting KPIs (10 KPIs).

3.2.4 FESTA Handbook

The FESTA project although it mainly aimed at providing a methodology and guidance for field operational tests (FOT) of intelligent transport systems, parts of the FESTA Handbook⁵ also provides valuable guidance on conducting experimental procedures and performing impact assessment. The FESTA project proposes techniques on defining indicators related to driving performance and safety, system performance and influence on driver's behaviour, environmental performance, traffic efficiency, acceptance and trust and distinguishes KPIs in:

- a) direct raw measures, measures logged directly from a sensor.
- b) derived measures, a variable, which is a combination of two or several direct or other derived measures.
- c) self-reported measures, gathered from either questionnaire, rating scales, interviews, focus groups, or other methods requiring introspection on the part of the participant
- d) situational variables, properties of the traffic system that the vehicles have driven in, logged in as direct measures or computed like derived measures.

3.2.5 Smart city projects and EV charging/e-mobility projects frameworks and initiatives

Horizon projects, also try to monitor the impact of smart charging infrastructure, even within the framework of smart city projects is also available and have accumulated substantial experiences and lessons learned. SCALE seeks to capitalize on this understanding and build upon it. Given that there are hundreds of these projects, the following process was used to filter pertinent projects and list KPIs that are relevant for SCALE:

- A search for similar evaluation frameworks was conducted using the Cordis EU platform. A filtering procedure was applied to reduce the vast number of available projects. Only H2020 projects starting from 2017 and beyond were included in the analysis to reflect that information available is up to date. The following keywords were also applied in the search engine: “mobility” “V2X solutions”, and “charging”. Cordis returned 86 results-projects meeting the pre-mentioned criteria.
- These projects were quickly evaluated (e.g., by checking their abstracts and websites) to examine their relevance with SCALE scope, and if relevant were catalogued in a list. For projects included in this list, a more detailed search was conducted to find if there are public deliverables including information regarding their evaluation framework, assessment methods utilized and specific KPIs proposed.
- The KPIs included in these deliverables were recorded and, finally, further assessed for their suitability to be included in the SCALE KPI pool. KPIs that are already covered by the initial screening of expected SCALE outcomes developed in Step 1 were not considered for inclusion, as well KPIs that are dealing with very project-specific issues (being addressed by only 1 project unless this is highly relevant also for SCALE). Extra emphasis was paid to avoid double-counts. This initial evaluation was performed by the members of the CERTH Scientific Team, Task Leader of D4.1.

⁵ FESTA Handbook available at: <https://www.connectedautomateddriving.eu/wp-content/uploads/2021/09/FESTA-Handbook-Version-8.pdf>

- In total twelve (12) projects were identified, that are highly relevant to SCALE and their KPIs are publicly available. Key info for these projects is presented in Table 4.
- It should be noted that only projects for which a detailed list of all KPIs was publicly available are included in the analysis (serving as potential sources for feeding SCALE's KPI pool)

Table 4 Indicative assessment frameworks of EV charging/e-mobility and smart city evaluation.

Project Name	<u>echarge4Drivers</u> - Electric Vehicle Charging Infrastructure for improved User Experience
Short Description: The project will develop and demonstrate user-friendly charging stations and innovative charging solutions as well as smart charging services for the users. By capturing users' perceptions and expectations on the various charging options and their mobility and parking habits, eCharge4Drivers will organize demonstrations in 10 areas across Europe, including metropolitan areas and Trans-European Transport Network (TEN-T) corridors. Assessment Framework: The KPI framework is divided in quantitative and qualitative. The formers are measured using data collected from charging points, and back-end systems operated by CPOs and eMSPs, while the latter are measured with data collected through survey and interview forms. While quantitative KPIs will mainly be used to assess the Usage and Technical Performance impact areas, the qualitative KPIs will be used for assessing the impact areas related to the Quality of Experience and Acceptance of the demonstrations. Qualitative KPIs will be used to assess more in general the Reference: D6.1 eCharge4Drivers Impact Assessment Methodology, accessible at: https://echarge4drivers.eu/wp-content/uploads/2022/05/eCharge4Drivers_D6.1_eCharge4Drivers-Impact-Assessment-Methodology_v1.0_FINAL.pdf	
Project Name	<u>SolutionsPlus</u> - Integrated Urban Electric Mobility Solutions in the Context of the Paris Agreement, the Sustainable Development Goals, and the New Urban Agenda
Short Description: SOLUTIONSplus project aims at setting up a global platform for shared, public and commercial e-mobility solutions. The developed platform is used to kick-start the transition toward low-carbon and sustainable mobility in urban areas through innovative and integrated mobility solutions. Assessment Framework: A reference KPI list is formulated and contains three sub-lists: 1) weighted KPI list including mandatory KPIs for all demos within the SOLUTIONSplus project but with different weighting factors for different demos, 2) common (non-weighted) KPI list aiming to complement the information collected via weighted KPIs to cover additional aspects of the demos, and 3) additional (non-weighted) KPI list covering proposed KPIs from demonstration cities; these are often specific to few cities and hence not mandatory for all demonstration cities. The developed evaluation method is especially useful for comparing and deciding on different e-mobility solutions for projects where the KPIs are different in nature and stakeholders have different needs and expectations. Reference: D1.2-Evaluation Framework, User Needs, and data requirements accessible: https://www.solutionsplus.eu/_files/ugd/de12cd_5067dc2c35e447db8bcc63f9c05590ed.pdf	
Project Name	<u>SHOW</u> - SHared automation Operating models for Worldwide adoption
Short Description: The SHOW project aims to support the migration path towards effective and persuasive sustainable urban transport through technical solutions, business models and priority scenarios for impact assessment, by deploying shared, connected, electrified fleets of automated vehicles in coordinated Public Transport (PT), Demand Responsive Transport (DRT), Mobility as a Service (MaaS) and Logistics as a Service (LaaS) operational chains in real-life urban demonstrations. Assessment Framework: In SHOW project the criterion of traffic safety is one of criteria developed from the holistic impact framework defined within the M3ICA. The innovative solutions characterization in	

general, has been an important step towards the definition and selection of proper KPIs that can relate to specific interventions.

Reference: D9.2: Pilot experimental plans, KPIs definition & impact assessment framework for pre-demo evaluation, accessible at: https://show-project.eu/wp-content/uploads/2021/04/SHOW-WP09-D-UIP-003-01_-_SHOW_D9.2_Pilot_experimental_plans_SUBMITTED.pdf

Project Name **IRIS** - Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

Short Description: The IRIS project focuses on the smartification of the energy grid, through increased RES penetration and novel energy storage solutions, facilitated by an advanced electrified urban transport system serving both mobility needs and additional electricity grid flexibility requirements.

Assessment Framework: IRIS assessment framework estimates the impact of both conventional and innovative solutions using KPIs categorized in six (6) dimensions: technical, environmental, economic, social, ICT and legal. The proposed framework assesses solution related to: Smart renewables and closed-loop energy positive districts, Smart Energy Management and Storage for Grid Flexibility, Smart e-Mobility Sector, and City Innovation Platforms (CIP), and Citizen Engagement and Co-Creation. Its KPI framework consists of 75 indicators categorized in the above dimensions. The part of IRIS assessment framework related to mobility aligns well with SCALE's activities and goals.

Reference: D1.1-Report on the list of selected KPIs for each Transition Track, accessible: <https://irismartcities.eu/public-deliverables>

Project Name **REPLICATE** – Renaissance of Places with Innovative Citizenship and Technologies

Short Description: REPLICATE is a European research and development project relevant to SCALE, as it deals with the deployment of energy efficiency, mobility and ICT solutions in city districts. REPLICATE aims to significantly increase resource and energy efficiency, improve the sustainability of urban transport, drastically reduce greenhouse gas emissions and improve the quality of life for citizens across Europe.

Assessment Framework: REPLICATE KPI framework defines seven (7) dimensions to classify the indicators: City description (5 indicators), Energy and Environment (14 indicators), Mobility and Transport (14 indicators), which are also relevant to SCALEs, Infrastructures for innovation (6 indicators), Governance (5 indicators), Social (5 indicators) and, Economy-Finance (7 indicators). As a result of this process the city level KPIs framework for REPLICATE project contains a total of 56 KPIs. Regarding the evaluation level of analysis, indicators were also classified according to the applicability scale at three (3) levels: a) National / Regional, b) Local / City, c) District.

Reference: REPLICATE-D10.2: Report on indicators for monitoring at city level, accessible: <https://replicate-project.eu/public-deliverables-download/>

Project Name **MATCHUP** – Maximizing the Upscaling and replication potential of high-level urban transformation strategies

Short Description: MatchUp aims to create and adopt solutions in energy, mobility, and ICT in order to improve the quality of life for citizens and boost the local economies. MatchUp provides with a consistent method to make an advanced city diagnosis and assess the progress of the cities towards sustainability and smartness.

Assessment Framework: MATCHUP project structured its evaluation framework based on the concept of sustainable development, utilizing two (2) evaluation levels (city level and project level) and in the definition of indicators that evaluate the status before the project implementation and the improvements achieved during the transformation process. The indicators have been classified under three (3) dimensions that comprise the term sustainability: environment, economy and social, also grouped into four (4) fields of the implemented solutions: Energy in Sustainable buildings and districts, Mobility and Transport and City infrastructure, ICT and Urban Platforms and Non-Technical actions related to Citizens and Society resulting in a sum of 188 indicators.

Reference: MatchUp-D1.1: Indicators tools and methods for advanced city modelling and diagnosis, accessible: https://www.matchup-project.eu/technical-insights/	
Project Name	<u>SMARTEnCITY</u> – Towards Smart Zero CO₂ Cities across Europe
Short Description: SmartEnCity's main objective is to develop highly adaptable and Europe-wide replicable strategies towards the transition into sustainable, smart and resource-efficient cities, by improving energy efficiency and maximising renewable energy supply. The project is mainly associated with the implementation of energy efficiency and RES measures in dwellings and vehicles.	
Assessment Framework: <u>SMARTEnCITY</u> proposes a methodology for evaluating the performance of the interventions using indicators which have been selected from SCIS platform and CITYkeys project. The framework structure was built upon the performance of the interventions demonstrated in the project: district renovation, urban mobility and citizen engagement as well as the social acceptance and the environmental benefits. KPIs are grouped into four (4) categories: technical, environmental, social and economic. Such structure is aligned with the scheme proposed by SCIS. The protocols of evaluation are Energy Assessment, ICT, LCA, Mobility and Cross-Cutting. A list of KPIs for each category (technical, environmental, social, and economic) and by type of intervention (district renovation, mobility and citizen engagement) is provided, with a total of 149 indicators	
Reference: SmartEnCity - D7.2: KPIs Definition available: https://smartencity.eu/media/smartencity_d7_2_kpis_definition_v1.0.pdf	
Project Name	<u>MYSMARTLIFE</u> – Smart Transition of EU cities towards a new concept of Smart Life and Economy
Short Description: MySMARTLife project aims at the development of an Urban Transformation Strategy to support cities in the definition of transition models, to reach high level of excellence in the development process, addressing the main city challenges and demonstrating Smart PEOPLE and Smart ECONOMY concepts. Its envisaged Advanced Urban Planning consists of an integrated approach for the planned solutions based on a rigorous impact assessment, an active citizen engagement in the decision-making process and a structured business approach from the city business model perspective and the identification of the most promising replicable actions to be included in the future city plans. To this end, around 150 actions are foreseen to be implemented in the three cities in technological and non-technological domains including the smart mobility domain.	
Assessment Framework: MySMARTLife proposes the deployment of solutions and actions and their evaluation across six (6) fields: Energy & Environment, Mobility & Transport, Urban Infrastructure, Citizens, Economy, Governance. MySMARTLife groups indicators in five (5) specific categories: energy, environmental, economic, social and policy impacts. Specific categories of indicators have been defined for the two level of evaluation, that are classified also according to different criteria such as the relevance of evaluation (core and complementary indicators) and the data collection methods (from metering as primary, from formulas or interviews as secondary). The total number of KPIs used are 151 indicators.	
Reference: D5.1-Integrated Evaluation Procedure, accessible: https://www.mysmartlife.eu/publications-media/public-deliverables/	
Project Name	<u>TRIANGULUM</u> – The Three Point Project / Demonstrate. Disseminate. Replicate.
Short Description: TRIANGULUM proposes a novel form of smart district development that integrates energy, ICT, sustainable transportation, and business opportunities to improve the efficiency of commerce and governance as well as reduce greenhouse gas emissions.	
Assessment Framework: The mapping and evaluation framework of the project was based on a series of expected impacts across the LH cities, relevant to the five (5) impact domains of Energy, Transport, Citizen Engagement, Socio-economic/financial and ICT deployment. The framework includes a set of indicators and quantifiable units for assessing the impacts of the respective commitments of the cities. The definition process led to a total of 79 indicators.	

Reference: TRIANGULUM-D2.1: Common Monitoring and Impact Assessment Framework, accessible: https://www.triangulum-project.eu/?page_id=119				
Project Name	<u>GROWSMARTER</u> – Transforming Cities for a Smart, Sustainable Europe			
Short Description: GrowSmarter project focuses on demonstrated solutions for higher RES penetration, advanced mobility system and decreasing CO2 emissions in the urban environment, by implementing several measures related to Low Energy Districts, Integrated Infrastructure and Sustainable Urban Mobility.				
Assessment Framework: The assessment framework structure is based on the definition of city indicators in three (3) main dimensions: better quality of life, Environmental, Economical, and various sub-domains, agreed upon relevant goals. The measures divided into the above 3 main categories of interventions, depend on the type of measure in the evaluation plan and each of the categories contain measures from different “Smart Solutions”. The first category, Low Energy Districts, is divided into two sub-categories: Building Evaluation and Local Evaluation. For each measure, at least one KPI is defined resulting in a total of 104 indicators.				
Reference:	GROWSMARTER-D5.1:	Evaluation	Plan,	accessible: https://grow-smarter.eu/inform/publications/
Project Name	<u>+CityxChange</u> – Positive City ExChange			
Short Description: +CityxChange ambition to achieve sustainable urban ecosystems that have zero emissions and establish a 100% renewable energy city-region by 2050.				
Assessment Framework: The KPI Framework developed for the +CityxChange Project includes KPIs defined by the SCIS, as well as KPIs that are specifically defined for this project. The KPIs are categorized into three core topics; 1) Integrated Planning and Design (IPD), for assessing the impact of sub-activities associated to larger interventions that aim to set up tools and local regulations for short- and long-term planning purposes. The tasks measured address key aspects that would assist in getting the first project interventions rolled-out; 2) Common Energy Market (CEM), for assessing certain interventions that have changed due to ongoing roll-out and evolution of the project; 3) CommunityxChange (CxCh), for assessing the effect of interventions on the public uptake and participation.				
Reference:	D7.1 is publicly available, https://cityxchange.eu/knowledge-base/approach-and-methodology-for-monitoring-and-evaluation/			
Project Name	<u>STARDUST</u> – Enlighting European Cities			
The STARDUST project tackles urban challenges by designing and implementing innovative smart solutions in three Lighthouse cities (Tampere, Trento, Pamplona) with a holistic approach. Moreover, four Follower cities (Cluja-Napoca, Derry, Kozani, Litomerize) provide an avenue to cultivate tailored replication strategies that resonate the project’s actions across Europe. More specifically, the main objectives are: • Establishing a constellation of cities offering sustainable and energy efficient living conditions. • Creating a network of smart ecosystems rooted on pro-active engagement among citizens, policy makers, industry, and research institutions. • Launching the Open City Information platform, an ICT toolkit that provides highly valuable sets of structured data and information to citizens, cities, and innovation actors. • Demonstrating the feasibility of the implemented smart solutions and their scalability, cost-efficiency, and bankability under the context of eco-innovation.				
Assessment Framework: The framework structure and methodology are designed to monitor and assess the impacts of the project on different time scales: i) Immediate progress evaluated through concrete output indicators; ii) Achieved impacts assessed by impact indicators; iii) Long-term effects evaluated through scalability of the solutions implemented based on scenarios in the Lighthouse cities and follower cities and their replication potential in other cities in Europe. There are 17 indicators for assessing the performance of 5 different clusters (Building and Energy, e-Mobility, ICT, Common City Level, and Long-Term Effects).				

Reference: STARDUST WP6 deliverable, not yet available online.

3.2.6 Scientific publications

In addition to Horizon projects, scientific papers are also available offering various assessment frameworks that attempt to gauge the performance of smart charging infrastructure evaluate on different levels. In Table 5 a list of relevant frameworks is presented as identified in the literature (scientific journals). To narrow down the vast number of potential frameworks that could be included in this Table, only holistic frameworks that can assess various aspects of smartness were included (e.g., papers only dealing with mobility, or ICT were excluded from the analysis) whereas specific KPIs should be clearly presented.

Table 5. Indicative KPI frameworks applicable to e-mobility and smart city projects/solutions from scientific sources.

Source	Assessment Framework
Caballini et al. ⁶	This paper provides a methodology to select, calculate and analyze a set of KPIs with the aim of defining reference model cities and then measuring the level of preparedness of a city with respect to electric mobility and with a focus on the charging infrastructure. The KPIs proposed are grouped in the following categories: Civil and Social, Transport, EV charging infrastructure, EV charging services economics, Smart charge/ICT system, and EV Environmental impact.
Van den Hoed et al. ⁷	This report offers a collection of the main research findings assembled from research projects carried out in recent years. It includes key takeaways from data analysis on the topics of charging infrastructure performance, policies to stimulate effective roll-out, smart charging and segment studies such as electric taxis. Practical insights and tools that can support policymakers in their quest to develop effective charging infrastructure are offered. Overall, eleven result indicators and thirteen performance indicators were identified as most relevant monitoring instruments for policymakers engaged in the roll-out of public charging infrastructure.
Lucas et al. (2018) ⁸	This study defines an assessment methodology, composed of eight indicators, allowing a comparison among EV public charging infrastructures. The proposed indicators capture the following: energy demand from EVs, energy use intensity, charger's intensity distribution, the use time ratios, energy use ratios, the nearest neighbour distance between chargers and availability, the total service ratio, and the carbon intensity as an environmental impact indicator.

⁶ Caballini, Claudia and Agudin, Alvaro Mendez and Aznar, Gregorio Fernandez and Deflorio, Francesco Paolo and Herman, Leopold and Knez, Klemen, Are Cities Ready for Electric Mobility? A Kpi-Based Comparison Across Europe. Available at SSRN: <https://ssrn.com/abstract=4055433> or <http://dx.doi.org/10.2139/ssrn.4055433>

⁷ E-mobility. Getting smart with data accessible at: https://www.evdata.nl/wp-content/uploads/2019/06/HvA_Emob_DIGI02.pdf

⁸ Lucas, A.; Prettico, G.; Flammini, M.G.; Kotsakis, E.; Fulli, G.; Masera, M. Indicator-Based Methodology for Assessing EV Charging Infrastructure Using Exploratory Data Analysis. *Energies* 2018, *11*, 1869. <https://doi.org/10.3390/en11071869>

Vertiniquie et al. (2019)⁹	This study is based on the GreenCharge project and aims to demonstrate the feasibility of developing mobility and energy solutions that are sustainable, affordable, secure, and inclusive, and integrated with user-centric infrastructure and services towards e-mobility. Based on CIVITAS Evaluation Framework it defines a KPI List group in five categories: a) Transport system (3 KPIs), Energy (6 KPIs), Economy (4 KPIs), Environment (1 KPI), Society-people (7 KPIs).
Angelakoglou et al. (2019)¹⁰	The specific study introduces a framework including six (6) steps for determining a repository of KPIs that can evaluate both business-as-usual and novel technologies and services related to smart city solutions. The implementation of the proposed framework led to the development of a repository of 75 KPIs categorized in six (6) dimensions (technical, environmental, economic, social, ICT and legal KPIs) with the corresponding levels of assessment and stakeholders' group of interest and indicative thresholds for monitoring performance. This framework was built upon the experiences gained during the IRIS SCC project.
Akande et al. (2019)¹¹	The specific study proposes a framework for assessing and ranking cities based on how smart and sustainable they are. Hierarchical clustering and principal component analysis (PCA) are applied to select and cluster 32 KPIs into three (3) thematic areas : a) Economy (7 KPIs); b) Environment (12 KPIs) and c) Society and Culture (13 KPIs). KPIs included in this framework are mostly fitted to assess smartness aspects on a city level.
Huovila et al. (2019)¹²	To help cities in their choice, this paper compares seven recently published indicator standards for Smart sustainable cities (ISO 37120:2018, ISO/DIS 37122:2018, ETSI TS 103463, ITU-T Y.4901, 4902, 4903, SDG 11+ monitoring framework). A taxonomy was developed to evaluate 413 indicators against five conceptual urban focuses (types of urban sustainability and smartness), ten sectoral application domains (energy, transport, ICT, economy, etc.) and five indicator types (input, process, output, outcome, impact). The results clearly discriminate between indicator standards suited for evaluating the implementation of predominantly smart city approaches versus standards more focused on sustainability assessment. SCALE can potentially be fed by KPIs included in this study.
Tan et al. (2017)¹³	The specific study proposes an indicator framework for the assessment of smart cities putting emphasis on low-carbon city aspects. A total of 20 KPIs are

⁹ S. Venticinque, R. Aversa, B. Di Martino, M. Natvig, S. Jiang and R. E. Sard, "Evaluating Technology Innovation for E-Mobility," *2019 IEEE 28th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE)*, 2019, pp. 76-81, doi: 10.1109/WETICE.2019.00023.

¹⁰ Angelakoglou K., Nikolopoulos N., Giourka P., Svensson I.L., Tsarchopoulos P., Tryferidis A., Tzovaras D. (2019), A methodological framework for the selection of key performance indicators to assess smart city solutions, *Smart Cities*, 2, 269-306.

¹¹ Akande A., Cabral P., Gomes P. and Casteleyn S. (2019), The Lisbon ranking for smart sustainable cities in Europe, *Sustainable Cities and Society*, 44, 475-487.

¹² Huovila A., Bosch P., Airaksinen M. (2019), Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when. *Cities*, 89, 141-153.

¹³ Tan S., Yang J., Yan J., Lee C., Hashim H. and Chen B., (2017), A holistic low carbon city indicator framework for sustainable development, *Applied Energy*, 185, 2, 1919-1930.

	separated into seven (7) assessment categories : a) Energy pattern; b) Water; c) Social and living; d) Carbon and environment; e) Solid waste; f) Urban mobility and g) Economic. threshold values to monitor performance and impact during POCITYF.
Girardi and Temporelli (2017)¹⁴	The specific study proposes a new methodological approach, called Smartainability, that can estimate through quantitative and qualitative KPIs to what extent smart cities are more sustainable (and smart) due to the deployment of innovative technologies. The assessment is performed prior to the application of the respective technologies, an attribute that could be useful for POCITYF to preliminary assess the impacts and benefits of its many innovative elements to be demonstrated. The methodology was built upon the Guidelines for conducting a cost-benefit analysis of Smart Grid projects, a study made by European Commission JRC, and Smart Cities – Ranking of European medium-sized cities, realized by Vienna University of Technology, University of Ljubljana and Delft University of Technology. Four (4) dimensions of analysis are applied: a) Environment; b) Economy; c) Energy and d) Living. The methodology has been tested only on a district level (Expo Milano 2015 site) so far. Further recommendations are available for the implementation on a city level, including a set of 28 KPIs and a new dimension – People – which evaluates the community life improvement.
Dall'O et al. (2017)¹⁵	The specific study provides a method for assessing the smartness of a city through a set of indicators focusing on small and medium-size cities and communities. The KPIs selected are consistent with the ISO 37120 standard and are inspired by the environmental indicators included in Sustainable Energy Action Plans under the Covenant of Mayors Initiative, making them highly relevant to POCITYF's objectives. A total of 70 KPIs are structured around seven (7) evaluation areas : a) smart economy (7 KPIs); b) smart energy (12 KPIs); c) smart environment (6 KPIs); d) smart governance (12 KPIs); e) smart living (17 KPIs); f) smart people (8 KPIs) and g) smart mobility (8 KPIs).
Hara et al. (2016)¹⁶	The specific study proposes a set of KPIs for smart cities based on the Gross Social Feel-Good Index. The KPIs are structured upon four (4) layers : a) 1 st layer includes the triple bottom line (Environment, Economy, Society) and Satisfaction generic categories; b) in the 2 nd layer the Society category is further split into safety, health and comfort; c) the 3 rd layer includes a total of 16 KPIs utilized to assess the 2 nd layer (environment/natural resource, energy, cost performance, accident, natural disaster, crime, information security, health

¹⁴ Girardi P. and Temporelli A., (2017), Smartainability: a methodology for assessing the sustainability of the smart city, *Energy Procedia*, 111, 810-816.

¹⁵ Dall'O G., Bruni E., Panza A., Sarto L. and Khayatian F. (2017), Evaluation of cities' smartness by means of indicators for small and medium cities and communities: A methodology for Northern Italy, *Sustainable Cities and Society*, 34, 193-202.

¹⁶ Hara M., Nagao T., Hannoe S. and Nakamura J. (2016), New Key Performance Indicators for a Smart Sustainable City, *Sustainability*, 8, 206; doi:10.3390/su8030206

	management, prevention of illness, medical treatment, stress, diverse opportunities, barrier free, simplicity, ubiquitous, citizen's degree of satisfaction); d) the 4 th layer includes the data needed (52 sub-KPIs) to calculate the KPIs in the 3 rd layer.
Lombardi et al. (2012)¹⁷	The specific study introduces a framework for classifying smart city performance indicators building upon the triple helix model and utilizing Analytic Network Process. The triple helix model was modified adding another unifying factor to the analysis, namely civil society (along with University, Government and Industry). A total of 63 KPIs are proposed, organized into five (5) clusters : a) smart governance (related to participation) – 7 KPIs; b) smart human capital (related to people) – 12 KPIs; c) smart environment (related to natural resources) – 19 KPIs; d) smart living (related to quality of life) – 13 KPIs and e) smart economy (related to competitiveness) – 12 KPIs.

The process of populating the SCALE's KPI pool is further aided by the inclusion of specific e-mobility-related KPIs identified in the frameworks above. Finally, databases created by international strategical planning initiatives, agreements, evaluations, as well as by international and European standards, can be used to extract a wide range of indicators. Below, we list the most pertinent and contemporary frameworks that were used in the development of the SCALE KPI framework.

3.2.7 International Strategic Initiatives and ISO Standards

United for Smart Sustainable Cities (U4SSC) initiative

The "United for Smart Sustainable Cities" (U4SSC) is a UN initiative coordinated by ITU, UNECE and UN-Habitat, and supported by CBD, ECLAC, FAO, ITU, UNDP, UNECA, UNECE, UNESCO, UN Environment, UNEP-FI, UNFCCC, UNIDO, UNU-EGOV, UN-Women and WMO to achieve Sustainable Development Goal 11: "Make cities and human settlements inclusive, safe, resilient and sustainable". The indicators are categorized in 3 dimensions: **Economy**, **Environment** and **Society and Culture**. Within each dimension, sub-dimensions provide focus on more specific areas of performance and progress. The indicators are further subdivided into **core** and **advanced** indicators. Core indicators are those that should be able to be reported on by all cities, provide a basic outline of smartness and sustainability and higher levels of performance can generally be achievable. Advanced indicators provide a more in-depth view of a city and measure progress on more advanced initiatives; however, they may be beyond the current capabilities of some cities to report or implement. The framework contains in total **91 KPIs** divided in each dimension as follows:

- Economy: 45 KPIs
- Environment: 17 KPIs
- Society and Culture: 29 KPIs

We note here that not all the categories included under each dimension/subdimension are relevant to SCALE goals. Thus, only a part of the indicators, are included in the KPI pool for SCALE.

¹⁷ Lombardi P., Giordano S., Farouh H. and Yousef W. (2012), Modelling the smart city performance, *Innovation – The European Journal of Social Science Research*, Vol. 25, No. 2, 137-149.

ISO/FDIS 37122 – Indicators for Smart Cities¹⁸

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The indicators detailed in ISO 37120 have quickly become the international reference point for sustainable cities. ISO/TC 268/WG2 experts have identified the need for additional indicators for smart cities. ISO 37122 complements ISO 37120 (see below) and establishes indicators with definitions and methodologies to measure and consider aspects and practices that dramatically increase the pace at which cities improve their social, economic, and environmental sustainability outcomes. It is thus another source framework from which KPIs can be chosen towards the SCALE KPI repository.

The indicators inside this framework are clustered under **23 categories**: Economy, Education, Energy, Environmental and Climate Change, Finance, Governance, Health, Housing, Population and Social Conditions, Recreation, Safety, Solid Waste, Sport and Culture, Telecommunications, Transportation, Urban/local Agriculture and Food Security, Urban Planning, Wastewater and Water. A total of 80 KPIs are identified but are not relevant to SCALE. A selection of KPIs relevant to SCALE project are considered for the extended pool. Concerning SCALE, the relevant categories are Economy (4 KPIs), Energy (10 KPIs), Environment and Climate Change (3 KPIs), Transportation (14 KPIs). Thus, a total number of **31 KPIs** are considered for the extended pool for SCALE.

ISO/FDIS 37120 – Indicators for City Services and Quality of Life¹⁹

The indicator framework of ISO 37120 focuses on city services and quality of life as a contribution to the sustainability of the city. The indicators included in ISO 37120 have been developed to help cities: measure performance management of city services and quality of life over time; learn from one another by allowing comparison across a wide range of performance measures; and support policy development and priority setting. ISO 37120 as a KPIs framework is relevant to SCALE objective of forming an open collaborative ecosystem towards improving citizens' quality of life, innovation and sustainability including indicators that are relevant to transport and mobility.

Indicators are categorized firstly into Core, Supporting and Profile indicators. Core indicators are required to demonstrate performance in the delivery of city services and quality of life. Supporting indicators are those recommended to demonstrate performance in the delivery of city services and quality of life and can be selected according to city objectives. Profile indicators are those recommended to provide basic statistics and background information to help cities determine which cities are of interest for peer comparison and are used as an informative reference.

All indicators are classified into themes according to the different sectors and services provided by a city. Indicators under each theme, where possible, are selected and paired on the basis of input and outcome indicators for further contextual analysis. The indicators inside this framework are clustered under the same 23 themes as in ISO 37122: Economy, Education, Energy, Environmental and Climate Change, Finance, Governance, Health, Housing, Population and Social Conditions, Recreation, Safety, Solid Waste, Sport and Culture, Telecommunications, Transportation, Urban/local Agriculture and Food Security, Urban Planning, Wastewater and Water. A total of 111 KPIs are identified.

¹⁸ ISO, ISO. "37122 Sustainable development in communities—Indicators for Smart Cities. 2019." International Organization for Standardization

¹⁹ ISO, ISO. "37120 Sustainable development in communities—Indicators for City Services and Quality of Life. 2018." International Organization for Standardization.

Similarly, to ISO 37122, concerning SCALE, the relevant categories are Economy (9 KPIs), Energy (8 KPIs), Environment and Climate Change (9 KPIs), Finance (5 KPIs), and Transportation (8 KPIs). Thus, a total number of **39 KPIs** were identified as potential indicators for the extended pool for SCALE.

A total of over 257 KPIs, each of which was distinct, were examined (not considering more than once KPIs that are presented in more than one project). These 257 KPIs have been chosen as being of interest and were inserted in the initial SCALE KPI pool.

3.3 Step 3: Refine KPI extended pool based on pre-defined criteria (Refinement Iteration #1)

In Step 2, various currently available indicator-based evaluation frameworks, were identified and reviewed, extracting potential KPIs that are highly relevant with SCALE's scope and ambition. This analysis resulted in an extensive pool of KPIs, including more than 257 KPIs that could be capitalized during SCALE to assess and monitor its progress.

Adopting the vast majority of these KPIs would make the monitoring process extremely overwhelming and practically difficult to implement in practice, thus in Step 3 we establish a clear selection strategy to target the most suitable KPIs for inclusion in the initial SCALE's KPI repository. The Initial SCALE KPI repository has been extracted using the four-step selection process detailed in the next subsection (see Figure 1).

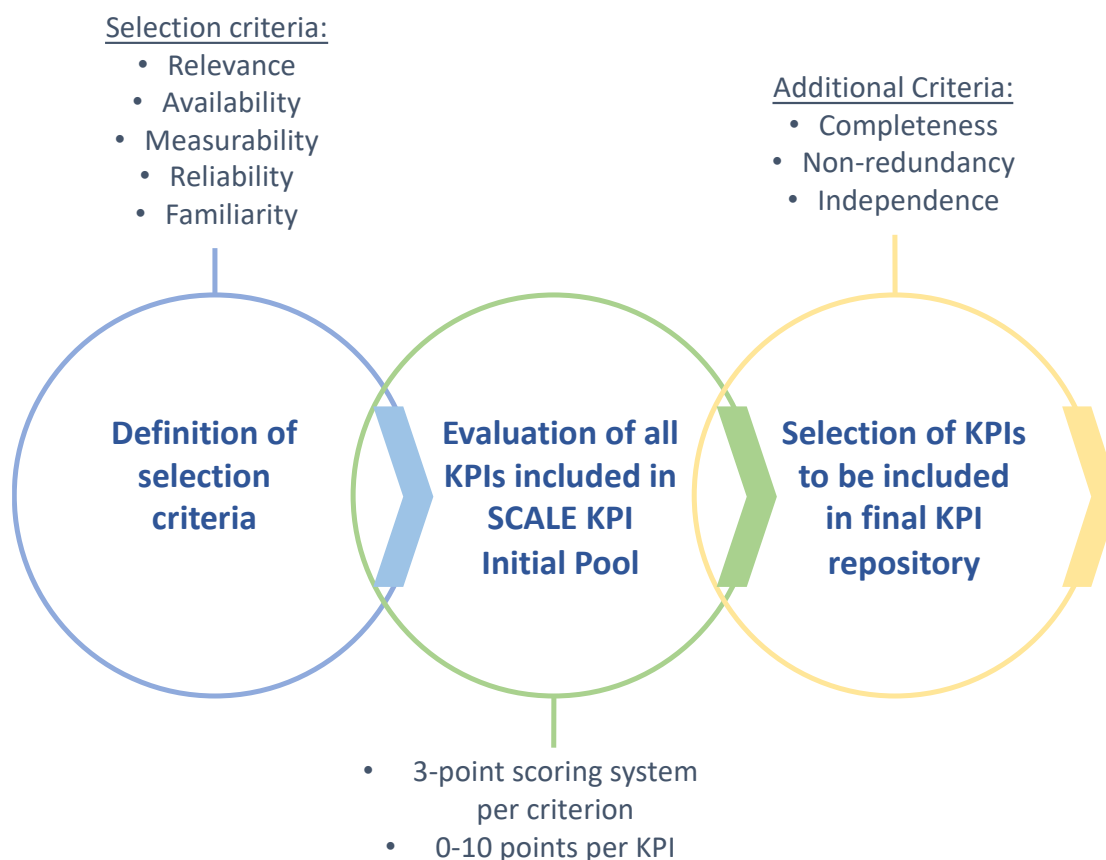


Figure 1. Selection procedure applied in SCALE Initial Pool to narrow down the KPIs

3.3.1 Definition of Criteria to narrow the initial SCALE KPI pool

SCALE utilizes five (5) selection criteria initially proposed by the CIVITAS framework²⁰ and have been subsequently adopted by several H2020 projects such as CITYkeys, POCITYF and RESPONSE to shortlist KPIs. These criteria are described below in further detail.

Criterion #1: Relevance

The specific criterion refers to the importance a KPI has for the evaluation process. In other words, the final KPIs to be included in the repository should serve as much as possible the operational objectives of the project. KPIs that are directly and/or indirectly linked with: a) SCALE Use Cases (see Section 3.1) and b) SCALE expected outcomes and impacts as defined in the project's Grant Agreement (GA), are of high relevance. KPIs should be selected and defined in such a way that the implementation of SCALE Use Cases provide a clear signal in the change of the indicator value. KPIs that are influenced by other factors not related with the implementation of SCALE are not suited. KPIs that provide an ambiguous signal (if there is doubt on the interpretation of e.g., an increase in the indicator value) are equally not suited.

Criterion #2: Availability

The specific criterion refers to the availability of data required to quantify a KPI. Data for measuring the indicator should be easily available (limited time and effort needed). Including KPIs that, while being of interest, cannot be realistically estimated during the project lifetime should be avoided. KPIs should be based, if possible, on data that either: a) are available from the technology providers or other stakeholders involved in the Use Case that is being evaluated; b) can easily be compiled from public sources and open-data repositories, and/or c) can easily be gathered from interviews-questionnaires, maps, or digital tools. KPIs that require, for instance, extensive interviews with EV-users will receive a lower score as the large amounts of data needed are too expensive to gather. The same holds for KPIs that require extensive recalculations and additional data, such as footprint indicators, and some financial indicators.

Criterion #3: Measurability

The specific criterion refers to the capability of a KPI to be measured, preferably as objectively as possible. It is also important for a KPI to reflect the changes in the measured quantities as quickly as possible, so that corrective measures can take place in time and ensure the project's success. The utilization of KPIs that are of qualitative or semi-qualitative nature (e.g., are assessed with the utilization of Likert Scales) should be avoided. However, this might not be feasible especially when for instance, social KPIs need to be included in the repository.

Criterion #4: Reliability

The specific criterion refers to the clarity of the definition of a KPI (and the calculation method). The definition and the calculation method of the KPIs should be clear and not open to different interpretations and include parameters of data collection that can affect the quality of the measurements, like spatial and temporal levels. SCALE envisions to enhance this criterion through the KPI cards (see Section 6) which will summarize key relevant info.

²⁰ Rooijen, T.; Nesterova, N. Deliverable 4.10: Applied framework for evaluation in CIVITAS PLUS II, WP4, May 31, 2013; CivitasWiki Project; Grant Agreement No.: 296081. Available online: https://civitas.eu/sites/default/files/Results%20and%20Publications/civitas_wiki_d4_10_evaluation_framework.pdf (Accessed on 26 July 2022).

Criterion #5: Familiarity

The specific criterion refers to the easiness of comprehension regarding the issue a KPI is addressing. KPIs should be easily understood by users – non experts if possible. SCALE has relied on KPIs from existing indicator-based frameworks that generally comply with this requirement, however for several cases, the KPI's definition was not clear especially for non-experts.

3.3.2 Evaluation of KPIs included in the initial SCALE KPI pool

Each KPI in the extended pool is evaluated through the utilization of a 3-point scoring system per criterion according to the guidelines below:

- 0 points: The KPI does not satisfy this criterion adequately
- 1 point: The KPI satisfies this criterion sufficiently
- 2 points: The KPI fully satisfies this criterion

This process resulted in each KPI receiving a score from 0 (minimum score) to 10 (maximum score). The evaluation was performed by a carefully selected panel of experts who are members of the SCALE consortium and have extensive experience in the design evaluation/monitoring frameworks and they also oversee SCALE implementation of the project.

3.3.3 KPIs Selection based on their score values

As a cut-off rule, a minimum score of 7 points was set for considering KPIs for selection. In case two KPIs served the same purpose, the one with the highest score was selected, whereas in case of equal scores the KPI with the highest score in relevance was selected. The following criteria were further considered while selecting KPIs:

Completeness: The set of KPIs should consider all different aspects of SCALE's scope. In that respect KPIs had to be selected to cover also various aspects of SCALE addressed within the Use Cases, such as demand flexibility, storage resiliency, smart energy consumption management, economic viability, social acceptance, smart urban mobility.

Non-redundancy: The set of KPIs should not measure the same aspect of a subtheme. Extra care was given as to not include indicators that assess the same parameter (double counting) even if the score was higher in comparison with other indicators.

Independence: Small changes in the measurements of an indicator should not influence preferences assigned to other indicators in the evaluation.

The results of the KPI evaluation strategy described above resulted in the Initial Pool of 30 KPIs presented in Table 6.

Table 6 SCALE Initial Pool of KPIs

No.	KPI	Unit
Scientific		
1	Creation and utilization of high-quality new knowledge	# citations/y
Technological / Economic		
2	Increased system flexibility for energy players	[%]

3	Increased hosting capacity for RES, electric vehicles, and other new loads	[%]
4	Data privacy - Data Safety & Level of Improvement (Improved Data Privacy)	5-point Likert scale OR #
5	Quality of Open Data	%
6	Energy demand and consumption	kWh/ (m2 month); kWh/ (m2 year); kWh/year/capita
7	Energy Savings	kWh/ (m2 year); MWh/(year)
8	Reduction in annual final energy consumption	% In kWh
9	Degree of energetic self-supply by RES	%
10	Increase in local renewable energy production	% In kWh
11	Reduced energy curtailment of RES and DER	
12	kWp photovoltaic installed per 100 inhabitants	kWp/100 inhabitant
13	Smart Storage Capacity	%
14	Integrated Building Management Systems in Buildings	%
15	Percentage of buildings in the city with smart energy meters	%
16	Total Investments	€/m2 (building company); €/kW (energy company)
17	Total Annual costs	€/year
18	Payback period	Years
19	Return on Investment (ROI)	%
20	Number of patents per 100 000 population per year (SI)	#/year
21	Electric Vehicles & Low-Carbon Emission Vehicles deployed in the area	Number; %
22	Number of EVs charging stations and solar powered V2G charging stations deployed in the area	stations/km2, %
23	Annual number of passengers (or users) of new infrastructure	#/year
24	Shared Electric Vehicles Penetration Rate	%
Social /Environmental		
25	People reached	% Of people
26	Local community involvement in the implementation and planning phase	5-point Likert scale (No unit)
27	Degree of satisfaction	% and/or 5-Point Likert Scale
28	Greenhouse Gas Emissions	kg CO2eq/ (m2 *month); kg CO2eq/ (m2 *year) kg CO2eq/ (kWh *year) - kg CO2eq/capita
29	Carbon dioxide Emission Reduction	tonnes/(year), tonnes/ha/year kg/year, %, tCO2/capita/year
30	Air quality index (Air pollution)	Index

Following the application of the evaluation procedure outlined in 3.1.3.2, the 30 KPIs (Table 6) established were again compared to the outcomes predicted by the SCALE before being shared with FIER and ENERVALIS for feedback. This refinement procedure resulted in a total of 26 KPIs, which fully cover SCALE's short/medium term scope and are fully aligned with SCALE's expected outcomes. From these KPIs, one (1) addresses the scientific KIP, five (5) address the societal (incl. environmental) KIP and twenty (20) the economic/technological KIP. It should be noted that the scientific KPI could be broken down in four different sub-indicators to better reflect the four linked outcomes (1.1, 4.1, 5.1 and 11.1), which address different scientific domains, but for simplicity reasons they are presented as one KPI here. The majority of these KPIs (19/26) must be evaluated on a Use Case level considering the location-specific impact of all SCALE V2X solutions, while the rest are evaluated at project level, and one KPI (1) on a technology level (per innovative solution as defined in SCALE). The reduced repository of KPIs that resulted after this process is presented in Table 7.

Table 7 SCALE Reduced Repository of KPIs – aligned with SCALE Expected Outcomes (Refinement Iteration #1)

S/N	KPI Title	Unit	Linked Outcomes	Evaluation Level
Scientific				
1	Creation and utilization of high-quality new knowledge	# citations/y	O1.1, O3.3, O4.3	Project Level
Societal / Environmental				
2	Increased citizen awareness on public charging infrastructure	Likert Scale (1-5)	O1.3	Project Level
3	Degree of Satisfaction	%	O2.1	Project Level
4	Greenhouse Gas (GHG) Emissions	kg CO ₂ eq/year	O2.4	Use Case Level
5	Primary energy savings in VCs	kWh/year	O2.2, O8.1	Use Case Level
Technological / Economic				
6	V2G efficiency (accounting for any electrical losses)	%/year	O2.2, O2.3, O4.2, O4.3	Use Case Level
7	Peak load reduction	MW/year, %/year	O1.3, O2.2, O3.4	Use Case Level
8	Energy exchange with the grid (bi-directional)	%/year, MWh/year	O8.1	Use Case Level
9	Energy system flexibility	MW/year	O2.2, O5.1, O6.2, O6.4, O7.1	Use Case Level
10	Reaction time to increase/decrease power delivery	Seconds	O2.2, O5.1, O6.2, O6.4, O7.2	Use Case Level
11	Degree of self-sufficiency	%/year	O2.3, O2.4, O4.1, O4.2, O4.3, O8.1	Use Case Level
12	Energy curtailment	%, MWh/y	O2.2, O8.1	Use Case Level
13	Cost savings for grid reinforcements (grid operator)	€/installed capacity/year	O2.2, O3.4, O8.1	Use Case Level
14	Cost savings for the charging station operator	€/kWh/year	O3.4	Technology Level

15	Level of interoperability (compliant with OCCP, OCPI, ISO/DIS 15118-20)	Likert Scale (1-5)	O5.1, O6.4, O7.1	Project Level
16	Utilization rate of EV chargers	%	O2.1, O3.2, O3.4, O5.3, O4.1, O4.2	Use Case Level
17	Autonomy in compliance with user requirements at departure time	%	O3.2, O5.3	Use Case Level
18	EV Battery Degradation Rate	%	O4.1, O4.2	Use Case Level
19	Diffusion to other locations	Likert Scale (1-5)	O5.1, O5.3	Project Level
20	Number of cars participating in EV sharing schemes	#	O5.2	Use Case Level
21	Average Operating Revenue	€/pkm, €/vkm	O3.4, O5.2	Use Case Level
22	Capital Investment Costs	€	O5.2	Use Case Level
23	Increased hosting capacity for RES, electric vehicles and other new loads	% /year	O2.3, O2.4, O8.1	Use Case Level
24	Quality of Open Data Sets	%/year	O1.1	Project Level
25	Degree of energetic self-supply by RES (RES consumption)	mWh/year	O2.3, O2.4, O8.1	Use Case Level
26	Accuracy of forecast in terms of grid loads (consumption)	RMSE/R2	O8.1	Use Case Level

3.4 Step 4: Link selected KPIs with Energy Management Services to be deployed in Use Cases (Refinement Iteration #2)

While the evaluation criteria listed in Step 3 are crucial based on the literature, it is equally important for the SCALE project implementation that the chosen KPIs also consider the needs and opinions of the SCALE Use-Cases' leaders. Step 4 therefore includes a second iteration of refining the KPIs (Refinement Iteration #2), in which the selected KPIs are linked with the Use Cases to be deployed and tested during SCALE. Then this list is refined based on the feedback from the Use Case managing partners and stakeholders. The list of Energy Management Services for the Use Cases was provided by the SCALE's Use Case Leader, FIER (as part of WP3). The KPIs shortlisted in Step 3 were matched with the Energy Management Services after clustering them in four different types of energy services i.e., a) 'Local Flexibility behind the meter', b) 'Local Flexibility/ DSO', c) 'System Flexibility/Wholesale market', d) 'System Flexibility/TSO', according to the overarching role they serve, having agreed this clustering with ENERVALIS and FIER. The list of Energy Management Services and their description is presented in **Table 8**.

Table 8 Energy Management Services to be deployed in SCALE

Cluster of Energy Management Services	Energy Management Services	Description
Local Flexibility / Optimization	Increase self-consumption of on-site renewable energy	When a consumer has rooftop solar with a feed-in tariff different from the supply tariff, value with V2X can be created by maximizing the consumption of locally generated solar

	Time-of-Use shifting	When a consumer is subject to time varying electricity prices in the form of static ToU, dynamic pricing, critical peak pricing value can be generated by V2X by avoiding exposure to high prices of Behind-the meter consumption
	Provide back-up power	When a grid outage is detected, the vehicle can provide back-up power to the household
	Increase Behind-the-meter charging power	At locations where priority or fast charging is needed, V2X can be used to increase the available charging power when grid connection capacity is limited
	long-term congestion management (Years ahead)	V2X can provide a non-wire alternative and expand the lifetime of the existing DSO infrastructure through long term congestion management contracts
	Operational congestion management (near real-time)	When congestion is detected in near real-time, congestion management services can be activated from V2X through non-contracted bids
Local Flexibility/DSO (congestion management)	Short term congestion management (D-1)	When congestion in the local grid is expected in D-1, V2X can provide congestion management services in short term congestion management markets through contracted bids
	Power quality control	When the operational limits (voltage, phase imbalance, etc.) of the local electricity grid are reached, rapidly discharging or charging electric vehicles could help restore the local grid within its normal operating boundaries
	Islanding mode	In situations with extreme supply shortages, certain parts of the distribution grid can be decoupled from the main grid to prevent rolling blackouts. in such situations, V2X can provide back-up power within the disconnected grid
Balance Responsibility	Reduce demand charges (peak shaving)	When a consumer is exposed to capacity related charges (€/kW over a period), such demand charges can be reduced by applying peak shaving with V2X

	Wholesale market price arbitrage	V2X capacity can be managed as a subpool within the BRP's portfolio and gain additional revenues can be charged at low price moments and discharged at high price moments (BRP provides market access)
	Intraday portfolio optimization	For BRP's with a large part of renewable energy in its portfolio, the flexibility of aggregated V2X capacity within his portfolio of grid connections can be used to compensate for the forecast errors and the imbalances in his portfolio
System Balance/TSO	FCR	Aggregated V2X capacity offered by a BSP can be called upon by the TSO to restore imbalances in a Local Frequency Control Area
	aFRR	Aggregated V2X capacity offered by a BSP can be called upon by the TSO to restore imbalances in a Local Frequency Control Area
	mFRR	Aggregated V2X capacity offered by a BSP can be called upon manually by the TSO to restore imbalances in a Local Frequency Control Area
	Strategic reserves (adequacy)	Aggregated V2X discharging ability could be used as strategic reserves and provide an alternative for thermal power plants or industrial demand response capacity to improve the adequacy of the system

This process of matching the KPIs with the energy services ensures that the KPIs to be selected for inclusion in the SCALE KPI repository would be compliant with the Use Cases developed in SCALE. This comes as a further refinement to the KPI pool presented in Table 7, considering that the derived list of KPIs included in Step 4 is defined after: a) defining the expected outcomes of SCALE (Step 1), b) conducting an extended literature research to match KPIs to the SCALE Expected Outcomes (Step 2), and c) refining the extended pool of KPIs based on pre-defined criteria according to the literature, cross-comparing the derived list with expected outcomes and accounting for feedback received by the SCALE's Use Case Leader (FIER) (Step 4).

Step 4 matching process was performed only with the Technological/Economic KPIs for simplifying the procedure, while the scientific and societal/environmental KPIs were finalized in Step 3. The matching process resulted into two sets of Technological /Economical KPIs as presented in Table 9, a) a set of eleven

(11) horizontal KPIs to be monitored in all Use Cases as they are directly linked with monitoring the success of SCALE and its expected outcomes, and b) thirteen (13) KPIs that are appropriate for specific Use Cases based on their unique circumstances (i.e. climate zone, size, economic and technical characteristics, use type, data availability, etc.).

Table 9 List of KPIs Matched with Energy Management Services to be deployed in SCALE

Clusters of Energy Management Services	Energy Management Services	KPIs matched with energy management services*	KPIs relevant to Types of Energy Services. This list of KPIs is also linked to the Call Expected Outcomes **
Technological / Economic			
Local Flexibility/optimization	Increase self-consumption of on-site renewable energy	Share of Energy Consumption from Behind-the-Meter Assets	• Degree of energetic self-supply by RES (RES consumption) • EV battery Degradation Rate • Utilization rate of EV chargers
	Time-of-Use shifting	Time-of-Use Load shifting	
	Provide back-up power	Outage Management	
	increase Behind-the-meter charging power	Behind-the-meter charging power	
	long-term congestion management (Years ahead)	Congestion Management & Voltage Control Cost	
	Operational congestion management (near real-time)	Operational Congestion Management (non-contracted bids)	
Local Flexibility/DSO (congestion management)	Short term congestion management (D-1)	Congestion management Income (Short term)	• Energy curtailment • V2G efficiency (accounting for roundtrip V2G losses) • Energy exchange with the grid (bi-directional) • Peak load reduction
	power quality control	Power quality control	
	islanding mode ('afschakelplan')	Back-up power in islanding mode	

Balance Responsibility	Reduce demand charges (peakshaving)	Saving from charging	• Energy curtailment
	strategic reserves (adequacy)	Reserves adequacy	
	wholesale market price arbitrage	Wholesale market price arbitrage	
	Intraday portfolio optimization	-	
System Balance/TSO	Intraday portfolio optimization	-	• Energy system flexibility • Reaction time to increase/decrease power delivery • Accuracy of forecast in terms of gridloads (consumption)
	FCR	-	
	aFRR	-	
	mFRR	-	
	strategic reserves (adequacy)	Reserves adequacy	
	long-term congestion management (Years ahead)	Congestion Management & Voltage Control Cost	
	Operational congestion management (near real-time)	Operational Congestion Management (non-contracted bids)	

* This list of KPIs represent the 'Supporting KPIs', and they should be monitored by specific Use Cases (when relevant)

** This list of KPIs is 'Core KPIs', and those KPIs should be monitored by all Use Cases

At this stage, SCALE' Use Case leader (FIER) and at least one technology provider (ENERVALIS) was then given access to the KPI list shown in Table 9 along with a draft list of the appropriate formulas for monitoring each KPI to validate the list before communicated to all Use Case leaders. Table 10 displays the KPI List that was produced because of this consultation process. The KPI List resulted from this consultation process certain KPIs (i.e. *Degree of energetic self-supply by RES (RES consumption, Amount of time providing flexibility services (locally or to the grid), Accuracy of forecast in terms of grid loads (consumption)*), were chosen to be excluded since according to the experts' opinion they were very difficult to be measured, while others were included (i.e., *self-sufficiency, and self-consumption*) as they were considered important for the

project. This consultation process resulted in a) eleven (11) compulsory KPIs for all Pilot Sites (Set #1), and b) seven (7) Use Case specific KPIs (Set #2).

Table 10. List of KPIs refined based on experts' opinion i.e., FIER and ENERVALIS

Clusters of Energy Management Services	Energy Management Services	KPIs matched with energy management services*	KPIs relevant to Types of Energy Services. This list of KPIs is also linked to the Call Expected Outcomes **
Local Flexibility/optimization	Increase self-consumption of on-site renewable energy	-	• Utilization rate of EV chargers • Self-Sufficiency • Self - consumption
	Time-of-Use shifting	Time-of-Use Load shifting	
	Provide back-up power	-	
	increase Behind-the-meter charging power	-	
	long-term congestion management (Years ahead)	-	
	Operational congestion management (near real-time)	Operational Congestion Management (non-contracted bids)	
Local Flexibility/DSO (congestion management)	Short term congestion management (D-1)	Congestion management Income (Short term)	• Energy curtailment • V2G efficiency (accounting for roundtrip V2G losses) • Energy exchange with the grid (bi-directional) • Peak load reduction • Amount of time providing flexibility services (locally or to the grid)
	power quality control	Power quality control	
	islanding mode ('afschakelplan')	Back-up power in islanding mode	

Balance Responsibility	Reduce demand charges (peakshaving)	Saving from charging	• Energy curtailment
	strategic reserves (adequacy)	Reserves adequacy	
	wholesale market price arbitrage	-	
	Intraday portfolio optimization	-	
System Balance/TSO	Intraday portfolio optimization	-	• Energy system flexibility • Reaction time to increase/decrease power delivery
	FCR	-	
	aFRR	-	
	mFRR	-	
	strategic reserves (adequacy)	Reserves adequacy	
	long-term congestion management (Years ahead)	-	
	Operational congestion management (near real-time)	Operational Congestion Management (non-contracted bids)	

* This list of KPIs represent the 'Supporting KPIs', and they should be monitored by specific Use Cases (when relevant)

** This list of KPIs is 'Core KPIs', and those KPIs should be monitored by all Use Cases

Finally, the KPI list derived in Step 4, as presented in Table 10 entered into a consultation process with all the SCALE Use Case Leaders of all Pilot Sites, Rotterdam, Utrecht, Eindhoven (NL), Greater Munich Area (DE), Debrecen/Budapest (HU), Toulouse (FR), Gothenburg (SE), Oslo (NO), who were invited to a) review the list of the KPIs and the respective formulas, b) list the KPIs that are more relevant to their Use Case, and c) propose new KPIs that are considered as relevant to the Use Cases to be deployed at each pilot. The implementation of the 5th step iteration procedure (Refinement Iteration #3), described in Section 3.1.1 - 3.1.4, led to the final repository of KPIs to be applied for SCALE.

Table 11 summarizes the final set of KPIs selected for SCALE's KPI repository based on the feedback from all the Use Case Leaders and relevant technology providers. The repository contains 17 KPIs categorized

per dimension (SC: Scientific, TE: Technological / Economic, SE: Social / Environmental). The majority of KPIs fall under the technological dimension, which is justifiable considering the scope and ambition of SCALE putting high emphasis on technologies that can optimize EV charging and support the wide-scale roll-out of EVs. Table 11 also presents the project expected outcomes, as well as the UCs with which each KPI is relevant. It must be noted that Use Case leaders at the time point that this discussion was held (January - February 2023) did not have all the specific details of their Use Case fully defined and therefore some of the Use Case specific KPIs might be subject to revision.

Table 11 The Final SCALE KPI repository (short/medium term)

S/N	KPI Name	Linked SCALE Outcomes	Linked UCs
Scientific (Project Level)			
SC.1	Creation and utilization of high-quality new knowledge	O1.1, O3.3, O4.3,	Project Level
Technological / Economic (CORE, Use Case Level/Technology Level)			
TE.1	Utilization rate of EV chargers	O2.1, O3.2, O3.4, O5.3, O4.1, O4.2	All UCs
TE.2	Self-sufficiency	O2.3, O2.4, O4.1, O4.2, O4.3, O8.1	All UCs
TE.3	Self-Consumption	O2.3, O2.4, O8.1	All UCs
TE.4	Energy curtailment	O2.2, O8.1	All UCs
TE.5	V2G efficiency (accounting for roundtrip V2G losses)	O2.2, O2.3, O4.2, O4.3	All UCs
TE.6	Energy exchange with the grid (bi-directional)	O8.1	All UCs
TE.7	Peak load reduction	O1.3, O2.2, O3.4	All UCs
TE.8	Amount of time providing flexibility services	O2.2, O5.1, O6.2, O6.4, O7.1	All UCs
TE.9	Energy system flexibility	O2.2, O5.1, O6.2, O6.4, O7.1	All UCs
TE.10	Reaction time to increase/decrease power consumption	O2.2, O5.1, O6.2, O6.4, O7.1	All UCs
Technological / Economic (SUPPORTING – Use Case Level)			
T11	Time of Use Load shifting	O2.2, O5.1, O6.2, O6.4, O7.1	UC 0.0, UC B.3, UC B.4, UC C.1, UC D.1
T12	Congestion management income (Short term)	O3.1, O7.1,	UC 0.0, UC C.1, UC D.1
T13	Power Quality control	O3.1, O8.3	UC C.1, UC D.1
T14	Backup power in islanding mode	O2.2, O5.1, O6.2, O6.4, O7.1	UC C.1, UC D.1
E15	Savings from charging station operator*	O3.4, O4.2	UC 0.0, UC B.4, UC C.1, UC D.1
T16	Reserves adequacy	O4.2	UC C.1, UC D.1

T17	Operational Congestion Management (non-contracted bids)	O4.2	UC 0.0, UC C.1, UC D.1
Social / Environmental (Project Level)			
SE.1	Citizen awareness	O1.3	All UCs
SE.2	EV User satisfaction	O2.1	All UCs
SE.3	Greenhouse Gas (GHG) Emissions	O2.4	All UCs
SE.4	CO2 Payback Time (CPBT)	O2.4	All UCs
SE.5	Diffusion to other locations	O1.2, O1.3, O8.2, O8.3	All UCs
SE.6	Number of cars participating in EV sharing schemes	O5.2	All UCs

* "Savings from charging station operator" are calculated on a technology level

More details regarding each KPI, including formula of estimation, recommended monitoring intervals, unit of measurement and others, are available in KPI cards in the following section.

4

Long-term evaluation



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4 Methods for Long-term evaluation

SCALE envisions to significantly contribute to the wider impacts specified in Destination “Clean and competitive solutions for all transport modes”, and particularly “Zero emission road transport”, to accomplish its defined success indicators. Outcomes presented in Section 2 will act as enablers for achieving these goals. The long-term impact monitoring has a more “recommendation” character and should be assessed in the future after SCALE ends and during its exploitation. SCALE expected impacts have been clearly defined in the Grant Agreement (GA) (101056874) and are summarized in Table 12.

Table 12 SCALE expected impacts as defined in the GA

Call Expected Impacts (EI)	SCALE Impacts
EI#1: Accelerated uptake of zero tailpipe emission, affordable, user-centric solutions (technologies and services) for road-based mobility all across Europe	Technological / Economic
	1.1 AC home charging cost reduction by 70%
	1.2 Scalability of smart and V2G enabled public chargers to +15 cities through standardizing join procurement requirements
	1.3 Blueprint of validated innovative Use Cases for faster replication in EU cities & regions
EI#2: Increased user acceptance, improved air quality, a more circular economy and reduction of environmental impacts.	Societal/Environmental
	2.1 Higher user acceptance across EU 2.2 Higher decentralized renewable energy penetration and self-sustainable buildings, neighborhoods, and cities
EI#3: Affordable, user-friendly charging infrastructure concepts and technologies that include vehicle-grid-interaction.	Technological / Economic
	3.1 Increase EU-wide access to interoperable, user-friendly public chargers by 50%
	3.2 Virtual Power Plant concept with circularity validated and commercialized
	3.3 Shared High Voltage charging hubs and operationalized highway charging with smart applications

	3.4 Cost savings of a billion Euro for DSOs in high EV penetration scenario through smart charging and V2X and time to market 3.5 Mandated charger specifications in joint procurement tenders ensuring interoperability and V2G feature
EI#4: Innovative Use Cases for the integration of zero tailpipe emission vehicles, and infrastructure concepts for the road mobility of people and goods.	Technological / Economic
	4.1 Seamless integration of innovative charging management system with home/building energy management system unlocking cross-sectoral benefits 4.2 Increased uptake of EVs through availability of affordable, interoperable chargers in different environments
EI#5: Effective design, assessment, and deployment of innovative concepts in road vehicles and mobility services thanks to life-cycle analysis tools and skills, in a circular economy context.	Technological / Economic
	5.1 Integrated planning tool for systemic assessment of energy needs, charger location and rollout 5.2 Innovative Use Cases coupling of renewable energy generation and unused EV battery storage

The methods used for long-term evaluation of the expected impact of SCALE can include:

- **Pre- and post-test evaluations:** Use the baseline data to benchmark outcomes before and after the SCALE interventions. This can help determine whether SCALE solutions had an impact on the desired outcome.
- **Cost-benefit analysis:** This analysis will compare the costs of SCALE intervention to the benefits that result from it. It can help determine whether the long-term benefits of an intervention justify the costs.
- **Stakeholder interviews and surveys:** To help capture the experiences and perspectives of stakeholders who have been affected by SCALE intervention, interviews and surveys to the stakeholders can be conducted. This can provide valuable information on the long-term impact of the intervention.
- **Secondary data analysis:** This involves analyzing existing data sources, such as administrative data or surveys, to understand the impact of the intervention over time.

The long-term pool of KPIs and the unit of measurement is presented in Table 13 based on the Expected Impact indicators of SCALE as presented in the GA.

Table 13 KPI pool for long term evaluation of SCALE

S/N	Name of the KPI	Unit	Linked Impact	Evaluation level
Societal/Environmental				
1	Higher user acceptance across EU	%	EI#2	Project level/EU-level
2	Higher decentralized renewable energy penetration and self-sustainable buildings, neighborhoods, and cities	%	EI#2	Project level/EU-level
Economic/Technological				

3	AC home charging cost reduction by 70%	%	EI#1	Project level / EU-level
4	Scalability of smart and V2G enabled public chargers to +15 cities through standardizing join procurement requirements	#	EI#1	Project level/EU-level
5	Blueprint of validated innovative Use Cases for faster replication in EU cities & regions	#	EI#3	Project level/EU-level
6	Increase EU-wide access to interoperable, user-friendly public chargers by 50%	%	EI#3	Project level/EU-level
7	Virtual Power Plant concept with circularity validated and commercialized	Likert Scale – 4.5/5.0 (Very High)	EI#3	Project level/EU-level
8	Shared High Voltage charging hubs and operationalized highway charging with smart applications	%	EI#3	Project level/EU-level
9	Cost savings of a billion Euro for DSOs in high EV penetration scenario through smart charging and V2X and time to market	€	EI#3	EU-level
10	Mandated charger specifications in joint procurement tenders ensuring interoperability and V2G feature	Likert Scale – 4.5/5.0 (Very High)	EI#3	Project level
11	Seamless integration of innovative charging management system with home/building energy management system unlocking cross-sectoral benefits	Likert Scale – 4.5/5.0 (Very High)	EI#4	Project level
12	Increased uptake of EVs: availability of affordable, interoperable chargers in different environments	%	EI#4	Project level / EU-level
13	Acceptance of an integrated planning tool for systemic assessment of energy needs, charger location and rollout	Likert Scale – 4.5/5.0 (Very High)	EI#5	Project level / EU-level
14	Innovative Use Cases coupling renewable energy generation and unused EV battery storage	#	EI#5	Project level / EU-level

The long term KPIs are of recommendatory nature for future SCALE solutions utilization. To clarify them and assist in their potential future implementation, a brief description for each selected KPI, including suggestions regarding their monitoring and comments on aspects that need to be highlighted is provided in Table 14.

Table 14 SCALE long-term KPIs clarifications and evaluation suggestions

S/N	Name of the KPI	Description
Societal/Environmental		
1	Higher user acceptance across EU	To monitor the use acceptance of V2X solutions across the EU a variety of methods can be used: User surveys: Conduct surveys to gather feedback from users about their experience with V2X solutions including questions about ease of use, effectiveness, and overall satisfaction. Data analytics: Collect and analyze usage data to identify trends in V2X solution adoption and usage patterns. This can include

		metrics such as the number of users, frequency of use, and duration of use. Focus groups: Organize focus groups with users to gain deeper insights into their experience with V2X solutions. This can help identify specific pain points and areas for improvement. Social media monitoring: Monitor social media channels to track user sentiment about V2X solutions. This can help identify areas of concern and provide insights into how users are using the solutions. Stakeholder engagement: Engage with key stakeholders, such as industry associations and government agencies, to understand their perspective on V2X solutions and identify opportunities to promote adoption.
2	Higher decentralized renewable energy penetration and self-sustainable buildings, neighborhoods, and cities	The implementation of smart charging infrastructure can further enhance the benefits of higher decentralized renewable energy penetration and self-sustainable buildings, neighborhoods, and cities. This can be achieved by: Optimizing energy storage: Smart charging infrastructure can help optimize energy storage by charging electric vehicles (EVs) during off-peak hours when there is excess renewable energy available. This can help balance the demand for electricity and reduce the need for non-renewable energy sources. Supporting the growth of EVs: By providing access to smart charging infrastructure, the use of EVs is encouraged, which reduce reliance on fossil-fuel-powered transportation. This can help reduce air pollution and greenhouse gas emissions and create more sustainable communities. Reducing energy costs: Smart charging infrastructure can also help reduce energy costs by charging EVs when energy is cheapest, reducing the overall cost of energy for the building or community. Enabling energy sharing: Smart charging infrastructure can enable energy sharing between EVs and buildings. EV batteries can be used to store excess renewable energy generated by buildings and then used to power the building during peak demand periods.
Economic/Technological		
3	AC home charging cost reduction by 70%	Reducing AC home charging costs by 70% can be achieved through a combination of measures that aim to make charging

		more efficient, reduce energy waste, and lower electricity costs. Some ways to facilitate this are: Time of Use (TOU) tariff: TOU tariffs can offer lower rates for electricity used during off-peak hours, which can be beneficial for EV charging. Charging during off-peak hours when electricity demand is lower can lead to lower rates and reduce costs. Smart charging infrastructure: Smart charging infrastructure can optimize charging by taking advantage of low-demand periods and integrating renewable energy sources. By charging EVs when renewable energy is most available, smart charging infrastructure can reduce costs. Energy-efficient charging equipment: Energy-efficient charging equipment, such as Level 2 chargers, can help reduce energy waste and lower costs. These chargers use less energy to charge EVs, reducing the overall cost of charging. Load management software: Load management software can optimize charging schedules to avoid peak electricity demand periods and reduce the overall energy cost. This software can also prioritize charging based on user preferences and availability of renewable energy. Energy storage: Energy storage systems can store excess renewable energy generated during off-peak hours and use it to charge EVs during peak demand periods. This can further reduce energy costs and make charging more efficient.
4	Scalability of smart and V2G enabled public chargers to +15 cities through standardizing join procurement requirements	Measuring the scalability of smart and V2G enabled public chargers can be achieved through measuring: Charging capacity: Procurement requirements can define the minimum and maximum number of electric vehicles that a smart and V2G enabled public charger must be capable of charging simultaneously. This will help to ensure that chargers are scalable and can accommodate a growing number of electric vehicles. Power output: Procurement requirements can also specify the minimum and maximum power output of the charger, which can help to ensure that the charger can provide fast charging to a growing number of electric vehicles. Interoperability: Smart and V2G enabled public chargers should be designed to work with a wide range of electric vehicles, regardless of the make or model. Procurement requirements can specify that the charger must meet certain interoperability

		standards, such as the Open Charge Point Protocol (OCPP), to ensure that it can work with a wide range of vehicles. Load management: The procurement requirements can specify that the charger should be equipped with load management capabilities, such as demand response or peak shaving, to help manage the load on the grid. This will help to ensure that the charger remains reliable and stable as more vehicles are added to the network. Cost-effectiveness: Finally, the procurement requirements can specify that the charger should be cost-effective over the long term. This can include requirements related to the charger's energy efficiency, maintenance costs, and other factors that can impact the overall cost of ownership.
5	Blueprint of validated innovative Use Cases for faster replication in EU cities & regions	The SCALE Use Cases, which examine smart charging and V2X solutions can prove impactful and relevant to other EU cities and regions. Since their technical feasibility, and the potential benefits for users and the environment will be examined, they can serve as blueprint for faster replication. Based on the results of the pilot testing, the key components of the V2X solutions, including the hardware and software required, the regulatory framework, and the stakeholder engagement strategy can be assessed for other environments. Then sharing this blueprint with other cities and regions in the EU can promote replication of the V2X and smart charging solutions.
6	Increase EU-wide access to interoperable, user- friendly public chargers by 50%	Evaluating the increase in EU-wide access to interoperable, user-friendly public charger can be achieved through measuring: Baseline assessment: This can be done by collecting data on the number of public chargers, their interoperability and user-friendliness, and their geographic distribution across the EU. Target setting: This target should be ambitious but achievable, considering factors such as budget constraints, technical feasibility, and political will. Monitoring progress: Regular monitoring of progress towards the target should be conducted, using metrics such as the number of new public chargers installed, the number of existing chargers upgraded to be more interoperable and user-friendly, and the geographic distribution of the chargers. Stakeholder engagement: Stakeholders such as EV manufacturers, charging infrastructure providers, and government agencies should be engaged to support the scaling up of public charging infrastructure. This can include initiatives

		such as funding programs, regulatory changes to encourage the installation of chargers, and industry collaborations to develop new charging technologies. Evaluation: Regular evaluation of the effectiveness of the initiatives taken to increase access to public chargers should be conducted. This can include surveys of EV owners to assess their satisfaction with the charging infrastructure, as well as assessments of the environmental and economic impacts of the increased access to public chargers.
7	Virtual Power Plant concept with circularity validated and commercialized	The concept of a Virtual Power Plant (VPP) with circularity can be validated and commercialized by following these steps: Design the VPP with circularity in mind: The VPP should be designed to optimize the use of renewable energy sources, such as wind and solar, and to minimize waste and pollution. This can include using energy storage systems to store excess renewable energy, using smart energy management systems to reduce energy waste, and utilizing energy demand response programs to better match supply with demand. Conduct pilot tests: Pilot tests should be conducted to validate the VPP's performance, including its ability to optimize the use of renewable energy sources, reduce waste and pollution, and meet energy demand requirements. Develop a business model: A business model should be developed to commercialize the VPP concept. This can include identifying potential revenue streams, such as selling excess energy back to the grid, providing energy services to customers, and participating in energy markets. Engage stakeholders: Key stakeholders, such as energy providers, regulators, and customers, should be engaged to help promote the VPP concept and to identify potential barriers to its commercialization. This can include developing partnerships with energy providers, advocating for regulatory changes to support the VPP concept, and conducting surveys to understand customer needs and preferences. Scale up: Once the VPP concept has been validated and a business model has been developed, the VPP can be scaled up to commercialize it. This can include identifying potential customers, securing financing, and building the necessary infrastructure to support the VPP. Monitor and evaluate performance: The performance of the VPP should be monitored and evaluated regularly to ensure that

		it is meeting its goals and objectives. This can include tracking energy production, revenue, and customer satisfaction levels, as well as conducting periodic assessments of the VPP's environmental and social impacts. By following these steps, the concept of a VPP with circularity can be validated and commercialized, helping to promote the use of renewable energy sources and reduce waste and pollution in the energy sector.
8	Shared High Voltage charging hubs and operationalized highway charging with smart applications	To evaluate shared high voltage charging hubs and operationalized highway charging with smart applications, the following steps can be taken: Evaluation criteria: These criteria can include factors such as charging speed, energy efficiency, reliability, user-friendliness, and cost-effectiveness. Collect data: Data should be collected on the performance of shared high voltage charging hubs and operationalized highway charging with smart applications, using metrics such as the number of charging sessions, charging times, energy consumption, and user feedback. This data can be obtained through surveys, site visits, and other means. Analyze the data: The collected data should be analyzed to determine how well shared high voltage charging hubs and operationalized highway charging with smart applications are meeting the established evaluation criteria. This analysis can help identify areas where improvements are needed and highlight best practices that can be replicated in other locations. Engage stakeholders: Stakeholders such as EV owners, charging infrastructure providers, and government agencies should be engaged in the evaluation process to provide feedback and insights into the performance of shared high voltage charging hubs and operationalized highway charging with smart applications. This engagement can also help identify opportunities for collaboration and partnerships to improve the charging infrastructure. Implement and monitor improvements: Regular monitoring and evaluation should be conducted to ensure that the improvements are effective and to identify any further opportunities for improvement. By following these steps, it will be possible to evaluate shared high voltage charging hubs and operationalized highway charging with smart applications and identify opportunities for

		improvement, leading to a more effective and efficient charging infrastructure for EVs.
9	Cost savings of a billion Euro for DSOs in high EV penetration scenario through smart charging and V2X and time to market	In terms of time to market, the deployment of smart charging and V2X technologies is already underway in many regions, but further investment and collaboration are needed to scale up these technologies and realize their full potential for cost savings. The exact timeframe will depend on factors such as regulatory support, investment levels, and technological advancements, but DSOs should prioritize the deployment of these technologies to achieve cost savings as soon as possible. To achieve cost savings of a billion Euro for DSOs (Distribution System Operators) in a high EV (Electric Vehicle) penetration scenario through smart charging and V2X (Vehicle-to-Everything) technologies, the following measures could be taken: Invest in smart charging infrastructure: DSOs should invest in smart charging infrastructure that is compatible with V2X technologies. This infrastructure should be able to support bidirectional power flows between EVs and the grid. Incentivize EV owners to participate in V2X programs: DSOs could offer incentives to EV owners to participate in V2X programs. This could include offering discounted charging rates or other financial incentives. Optimize charging schedules: DSOs could use smart charging algorithms to optimize charging schedules for EVs, taking into account the availability of renewable energy sources and the overall demand on the grid. Utilize V2X technologies to provide grid services: DSOs could use V2X technologies to provide grid services such as frequency regulation and demand response. This would enable EVs to act as a flexible resource for the grid, reducing the need for costly infrastructure upgrades. Collaborate with other stakeholders: DSOs should collaborate with other stakeholders such as EV manufacturers, charging infrastructure providers, and regulators to ensure that smart charging and V2X technologies are deployed in a coordinated and effective manner.
10	Mandated charger specifications in joint procurement tenders ensuring interoperability and V2G feature	Ensuring mandated charger specifications in joint procurement tenders to guarantee interoperability and V2G (Vehicle-to-Grid) features, requires a collaborative effort between various stakeholders, including DSOs, EV manufacturers, charging

		infrastructure providers, and regulatory bodies. The following steps should be considered: Define the specifications: The first step is to define the charger specifications required for interoperability and V2G features. This should be done in collaboration with all relevant stakeholders to ensure that the specifications are comprehensive and meet the needs of all parties. Develop standards: Once the specifications are defined, the next step is to develop standards for these specifications. This can be done through existing standards bodies or through industry consortia. These standards should be widely adopted to ensure that all chargers meet the same specifications. Include specifications in procurement tenders: The charger specifications should be included in joint procurement tenders issued by DSOs or other procurement bodies. The tenders should mandate that all chargers purchased must meet the specified interoperability and V2G features. Evaluate compliance: During the procurement process, compliance with the specified charger specifications should be evaluated through testing and certification processes. This should ensure that all chargers meet the required specifications and are interoperable with each other and the grid. Monitor and enforce compliance: Once chargers are installed, ongoing monitoring and enforcement of compliance should be done to ensure that the chargers continue to meet the specified standards. This could involve regular testing and maintenance requirements to ensure ongoing interoperability and V2G functionality. Collaborate with regulatory bodies: Finally, collaboration with regulatory bodies is crucial to ensure that the mandated charger specifications align with regulatory requirements and support the overall goals of the energy transition. This can help to create a supportive regulatory environment that encourages the adoption of interoperable and V2G-enabled chargers.
11	Seamless integration of innovative charging management system with home/building energy management system unlocking cross-sectoral benefits	Monitoring the seamless integration of an innovative charging management system with a home/building energy management system requires careful planning and attention to detail. Certain steps need to be taken to monitor the integration process: Define the integration goals: The first step is to clearly define the integration goals and objectives. This will help you to identify

		the key performance indicators (KPIs) that you will use to measure the success of the integration. Establish a monitoring plan: Create a monitoring plan that outlines the specific metrics you will track to ensure that the charging management system and energy management system are working together seamlessly. This plan should include the frequency of monitoring and who will be responsible for it. Monitor the energy usage: Use energy monitoring tools to track the energy usage of the charging management system and the home/building energy management system. This will help you to identify any inefficiencies or areas where the integration can be improved. Monitor the charging management system: Monitor the performance of the charging management system to ensure that it is functioning correctly and charging the vehicles as intended. This will also help you to identify any issues that need to be addressed. Monitor the impact on the energy grid: Monitor the impact of the charging management system on the energy grid. This will help you to ensure that the integration is not causing any negative effects on the grid. Analyze the data: Analyze the data collected during the monitoring process to identify any trends or patterns. This will help you to make informed decisions about how to optimize the integration and unlock cross-sectoral benefits. Continuous improvement: Use the data collected to continually improve the integration process and ensure that it is working as efficiently as possible. By following these steps, the seamless integration of an innovative charging management system with a home/building energy management system can be established and can unlock cross-sectoral benefits.
12	Increased uptake of EVs: availability of affordable, interoperable chargers in different environments	To monitor the increased uptake of EVs and the availability of affordable, interoperable chargers in different environments it is essential to ensure a smooth transition to a more sustainable transportation system including the following key steps: Monitor the number of EVs on the road: Use vehicle registration data or other sources to monitor the number of EVs on the road. This will help in identifying trends in EV uptake and

		target areas where the availability of affordable chargers may be needed. Monitor the availability of affordable chargers: Monitor the availability of affordable chargers in different environments, such as urban, suburban, and rural areas. This will help in identifying any gaps in the charging infrastructure and prioritize areas for investment. Monitor the interoperability of chargers: Monitor the interoperability of chargers to ensure that EV owners can use any charger regardless of the brand or location. This will help to avoid fragmentation in the charging infrastructure and promote a seamless charging experience. Analyze the data: Analyze the data collected during the monitoring process to identify any trends or patterns. This will help in making informed decisions about how to optimize the charging infrastructure and promote the increased uptake of EVs. Continuous improvement: Use the data collected to continually improve the charging infrastructure and ensure that it is meeting the needs of EV owners.
13	Acceptance of an integrated planning tool for systemic assessment of energy needs, charger location and rollout	To evaluate the acceptance of an integrated planning tool for systemic assessment of energy needs, charger location, and rollout, the following steps can be considered: Identify the stakeholders: Identify the stakeholders who will be using the integrated planning tool, such as city planners, utility companies, and EV manufacturers for determining their needs and expectations. Develop an evaluation plan: Develop an evaluation plan that outlines the specific metrics you will use to assess the acceptance of the integrated planning tool. This plan should include the frequency of evaluation and who will be responsible for it. Conduct a pilot test: Conduct a pilot test of the integrated planning tool to gather feedback from stakeholders for identifying any issues or areas that need improvement. Analyze the feedback: Analyze the feedback collected during the pilot test to identify any patterns or trends and make informed decisions about how to optimize the integrated planning tool. Conduct a survey: Conduct a survey to gather feedback from a larger sample of stakeholders to assess the overall acceptance of

		the integrated planning tool and identify any areas that need improvement. Continuous improvement: Use the feedback collected to continually improve the integrated planning tool and ensure that it is meeting the needs of stakeholders.
14	Innovative Use Cases coupling renewable energy generation and unused EV battery storage	Coupling renewable energy generation and unused EV battery storage is an innovative concept that has the potential to increase the efficiency and sustainability of both energy generation and transportation. Aome potential Use Cases for this concept include: Renewable energy storage: EV batteries can be used to store excess renewable energy generated during times of low demand, such as during the day when solar panels are producing more energy than needed. The stored energy can then be used during periods of high demand or when renewable energy generation is low. Grid stabilization: EV batteries can also be used to provide grid stabilization by smoothing out fluctuations in energy supply and demand. By providing stored energy during periods of high demand, EV batteries can help prevent blackouts and reduce the need for traditional power generation. Vehicle-to-Grid (V2G) services: EV batteries can be used to provide V2G services, which allow EV owners to sell excess stored energy back to the grid during periods of high demand. This can provide additional income for EV owners and help stabilize the grid by reducing the need for traditional power generation. Backup power: Unused EV batteries can also be used as backup power for homes and businesses in case of power outages. This can provide a reliable source of backup power that is renewable and sustainable. Charging station energy supply: EV charging stations can be powered by renewable energy sources, such as solar panels or wind turbines, and use unused EV batteries as a backup energy source. This can help reduce the environmental impact of charging stations and increase their reliability.



5

KPI Cards



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5 SCALE KPI cards

SCALE KPI cards contain all the information required for understanding and estimating KPIs included in SCALE's final KPI repository. Every KPI has also been linked with specific stakeholders (as defined in Section 2.2.2) and Use-Cases²¹ (as presented in Section 3.1.4), since not all KPIs are relevant for every stakeholder/Use-Case. Table 15 depicts both **the general KPIs**, which are expected to be measured by all pilot sites and the **optional KPIs**, which are expected to be measured only by partners in Use Cases that can contribute. KPIs to be measured are marked with an "O". For several KPIs is some Use Cases, in e.g., OO, B3, B4, C4, etc. the consortium partners were unable to confirm their measurement as this is subject to the available infrastructure for monitoring and the final setting of each Use Case. Therefore, Table 15 shall be open to any necessary revision, and **for important updates this deliverable will be revised**.

Table 15 General and Use Case specific KPIs

Partners Involved	We Drive Solar, Utrecht, Equigy, Hyundai, GoodMoovs, Renault	E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault	Emobility, Solutions, ABB, Enervalis	Enedis, Current	Chalmers, Polestar, RISE	Current	VDL, Current, ABB, Enervalis	VDL, Enervalis	ElaadNL, FIER	Current	EMS, ABB, Enervalis
Pilots	Utrecht, NL	Debrecen/ Budapest, HU	Budapest, HU	Toulouse, FR	Gothenburg, SE	Oslo, NO	Eindhoven, NL	Eindhoven, NL	Rotterdam / Utrecht, NL	Oslo, NO	Hungary
Use Case	OO	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2
General											
Utilization rate of EV chargers	O	O	O		O	O				O	O
Self-sufficiency			O		O	O	O	O		O	O
Self-consumption		O	O	O (simulated)	O	O	O	O		O	O
Energy curtailment		Only smart charging	O		O	O	O	O		O	O
V2G efficiency (accounting for roundtrip V2G losses) *	O	Only smart charging	O		O	O				O	O
Energy exchange with the grid (bi- directional)		Only smart charging	O		O	O				O	O
Peak load reduction		O	O	O (locally)	O	O	O	O		O	O
Amount of time providing flexibility services (locally or to the grid)		Only smart charging	Maybe		O		O	O			
Energy system flexibility		O	O			O	maybe	maybe		O	O
Reaction time to increase/decrease power delivery		O	O		With OEM	O	maybe	maybe		O	O
Use Case Specific											
Time-of-Use Load shifting				O	If TOU tariff used. Currently it is spot price tariff.	O				O	
Congestion management Income (Short term)						O				O	

²¹ There are originally 13 Use Cases foreseen in the GA. However, after SONO's withdrawal the Use Cases A1 and A2 are not represented by a consortium partner and therefore they are not included in this table. The table will be subject to revision provided SONO is replaced by another partner.

Power quality control						maybe				maybe	
Back-up power in islanding mode						maybe				maybe	
Saving from charging					0	0				0	
Reserves adequacy						0				0	
Operational Congestion Management (non-contracted bids)						0				0	

* This KPI can only be measured in a controlled environment. This is a combination between car/charger and type of charging fast/slow outside temperature.

In Table 16 below, the KPI card template is provided, followed by the cards filled in for all KPIs in the SCALE Repository. The card contains all the necessary information that a pilot site will need to properly measure the indicators. Regarding the relevant stakeholders list in the KPI card that will be required to be engaged to calculate the KPIs, this list is extracted from Deliverable 1.2 “Stakeholder analysis report” (please visit D1.2 for further explanations on the list of relevant stakeholders).

Table 16 KPI Card Template

KPI Code. KPI Title					
KPI Overview		Definition of the indicator and relevant details			
KPI Owner		Partner responsible for measurement/calculation (see note below)			
Recommended KPI Estimation Process		The mathematical (if applicable) formula to be used for the KPI calculation			
Recommended Unit of Measurement			Recommended Monitoring Interval		
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√	
	Consumers / E-Drivers or fleet operators			√	
	Charging point operators			√	
	Grid operators			√	
	Energy supplier / Balance responsible parties (BRPs)			√	
	RTOs			√	
Recommended Evaluation Level:					
Technology Level	√	Use Case Level	√	Project Level	√

When monitoring a project's impact, there are different levels of evaluation that can be considered. These levels are typically defined based on the scope of the evaluation and the objectives of the project. In SCALE the recommended evaluation levels are defined as follows:

Project Level Evaluation: This level of evaluation focuses on assessing the overall impact of the project on its intended beneficiaries or stakeholders. It typically involves monitoring the project's progress and outcomes against the project's goals and objectives. The evaluations include analyzing data on project inputs, activities, outputs, and outcomes. It will also involve collecting feedback from stakeholders to identify areas of improvement.

Technology Level Evaluation: This level of evaluation focuses on assessing the impact of the specific technology being used in the project. It involves evaluating the performance and effectiveness of the technology and its ability to achieve the intended outcomes.

Use Case Level Evaluation: This level of evaluation focuses on assessing the impact of the project on a specific use case or application. It involves evaluating how a technology is being used and its effectiveness in addressing the specific needs of the users.

In summary, the recommended evaluation levels for monitoring a project's impact are project level, technology level, and use case level. These levels of evaluation can help ensure a comprehensive assessment of the project's impact and identify areas for improvement.

5.1 KPI Cards in Scientific Key Impact Pathway

5.1.1 Creation and utilization of high-quality new knowledge (SC1)

SC1. Creation and utilization of high-quality new knowledge			
KPI Overview	SCALE aspires to create and use high quality new knowledge on issues relevant to: a) optimal smart charging concepts (linked with SCALE EO#1); b) smart charging strategies and control mechanisms, and the efficiency of the whole energy system, (linked with SCALE EO#2); c) affordable, user-friendly smart and bidirectional V2X (where X can be G for Grid, H for Home and B for Business) charging solutions (linked with SCALE EO#3); d) operational and economic trade-offs for the user and the vehicle SCALE (linked with SCALE EO#4); e) integrated planning process of systems aimed at exploiting cross-sector mutual benefits (linked with SCALE EO#5); f) standardization processes of interfaces for V2X (linked with SCALE EO#6); g) open architecture (not proprietary) concerning smart and bidirectional charging solutions (linked with SCALE EO#7); h) V2X potential in encouraging renewable energy growth (linked with SCALE EO#8). The specific KPI provides a metric that can track and quantify the diffusion of knowledge on these issues. Peer-reviewed publications in open access scientific journals or/and repositories, can serve as the mean to validate the credibility of SCALE results. The number of citations (a reference to the source of information used in a research) is a common way to indicate the appeal and quality of new knowledge generated by SCALE. It should be noted that SCALE also envisions to disseminate and exchange knowledge through dissemination and communication strategy.		
KPI Owner	All partners		
Recommended KPI Estimation Process	The following simple formula can be applied to estimate this KPI: $\text{Number of publications} / \text{Number of citations per year}$ The number of publications refers to the open-access publications that have been generated due to SCALE and includes a clear acknowledgement to SCALE and EC funding. The number of citations excludes self-citations. This KPI should be estimated one year after the first publication.		
Recommended Unit of Measurement	# citations/y/publication	Recommended Monitoring Interval	Annually
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		√
	Consumers / E-Drivers or fleet operators		
	Charging point operators		√

	Grid operators	
	Energy supplier / Balance responsible parties (BRPs)	√
	RTOs	√
Recommended Evaluation Level:		
Technology Level	Use Case Level	Project Level
		√

5.2 KPI Cards in Technological / Economic Key Impact Pathway (CORE KPIs)

The below KPIs are considered mandatory for the fulfilment of the purposes of the deliverable. It is highly recommended to be measured by all pilot sites. The granularity is also important in order to obtain accurate results.

5.2.1 Utilization rate of EV chargers (TE2)

TE2. Utilization rate of EV chargers			
KPI Overview	The specific KPI provides the utilization rate of a single charger which is in use to the total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible that could be used.		
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis.		
Recommended KPI Estimation Process	The following simple formula can be applied to estimate this KPI: $\text{Utilization Rate (\%)} = \frac{\text{Charging hours per day}}{24}$ Average amount of time an EV is connected to a charger for charging.		
Recommended Unit of Measurement	%	Recommended Monitoring Interval	Annually
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		√
	Consumers / E-Drivers or fleet operators		√
	Charging point operators		√
	Grid operators		
	Energy supplier / Balance responsible parties (BRPs)		
	RTOs		√
Recommended Evaluation Level:			
Technology Level	Use Case Level	√	Project Level

5.2.2 Self-sufficiency (TE3)

TE3. Self-sufficiency	
KPI Overview	Self-sufficiency of EV charging stations and EVs can contribute significantly to the sustainability of the grid by requiring less energy from the grid and by reducing the frequency of the peak load demands.
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis

Recommended KPI Estimation Process	The following formula can be applied to estimate this KPI:			
	$SSx = \frac{Elgc, x}{Eload, x}$ The self-sufficiency (SS) measures the consumption amount supplied by local generation (Elgc) the same numerator of the SC) with respect to the total consumption (Eload). It quantifies user independence from the grid.			
Recommended Unit of Measurement	%	Recommended Monitoring Interval	Monthly, annually	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			
	Consumers / E-Drivers or fleet operators		√	
	Charging point operators		√	
	Grid operators		√	
	Energy supplier / Balance responsible parties (BRPs)		√	
	RTOs		√	
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.2.3 Self-consumption (TE4)

TE.4 Self-consumption			
KPI Overview	SCALE deployment aims to advance both energy efficiency solutions and optimized self-consumption at the district level. In a smart grid, electric vehicles (EVs) can be used as a flexible demand source and as a storage option with vehicle-to-grid technology (V2G) to increase self-consumption of photovoltaic (PV) solar power, thereby reducing the impact of both PV and EV on the electricity grid. The aim of this KPI is to quantify how much of the energy produced on-site is self-consumed.		
KPI Owner	E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, Chalmers, Polestar, RISE, VDL, Current, ABB, Enervalis		
Recommended KPI Estimation Process	The following simple formula can be applied to estimate this KPI: $SCx = \frac{Elgc, x}{Egen, x}$ The Self-Consumption (SC) is defined as the amount of electricity locally generated and consumed (Elgc) to the total local generation (Egen).		
Recommended Unit of Measurement	%	Recommended Monitoring Interval	Monthly, annually
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		
	Consumers / E-Drivers or fleet operators		√
	Charging point operators		√
	Grid operators		√
	Energy supplier / Balance responsible parties (BRPs)		√
	RTOs		√
Recommended Evaluation Level:			

Technology Level		Use Case Level	√	Project Level	
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5.2.4 Energy curtailment (TE5)

TE5. Energy curtailment						
KPI Overview		Energy curtailment has a special meaning in electric power systems. It describes any action that reduces the amount of electricity generated to maintain the balance between supply and demand – which is critical for avoiding blackouts. The specific KPI gives an estimation of the energy curtailed in a specific period of time as a result of vehicle to grid operation.				
KPI Owner		We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis				
Recommended KPI Estimation Process		The percentage of electricity curtailment from DER reduction of V2X solution compared to BaU for a period of time, i.e., a year. The following simple formula can be applied to estimate this KPI: $EnI = \frac{EnI_{baseline} - EnI_{measured}}{EnI_{baseline}} \times 100$ Where: EnI is the percentage reduction in energy not injected in network due to technical and operational problems conditions [% in MWh]. EnI_{baseline} is the total energy not injected in network due to technical and operational problems under baseline condition [MWh]. EnI_{measured} is the total energy not injected in network due to technical and operational problems under new measured condition [MWh]				
Recommended Unit of Measurement		%	Recommended Monitoring Interval	Monthly, annually		
Relevant Stakeholders		Electric vehicle manufacturers (Vehicle OEM)				
		Consumers / E-Drivers or fleet operators				
		Charging point operators				
		Grid operators				
		Energy supplier / Balance responsible parties (BRPs)				
		RTOs				
Recommended Evaluation Level:						
Technology Level			Use Case Level	√	Project Level	

5.2.5 V2G efficiency (accounting for roundtrip V2G losses) (TE6)

TE6. V2G efficiency (accounting for roundtrip V2G losses)	
KPI Overview	In SCALE project the vehicle to grid efficiency is a crucial indicator that shows the difference into the amount of the energy exported from the charging station and the energy fed into the charging station. In the systems of such complexity, minor discrepancies give the reliability needed to the system.

KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis				
Recommended KPI Estimation Process	The efficiency of one charging/discharging cycle is determined by taking the ratio between the energy exported from the charging station Eout and the energy fed into the charging station E in in one charging/discharging cycle. The losses consist of all conversion losses in the charging station and in the EV battery in a full charging/discharging cycle. The following simple formula can be applied to estimate this KPI: $n = \frac{E_{out}}{E_{in}} = \frac{\sum_{t_{SoCmin},end}^{t_{SoCmax}} P_t \times \Delta t}{\sum_{t_{SoCmin},start}^{t_{SoCmax}} P_t \times \Delta t}$ Ein and Eout are determined considering the charging power over time (Pt), the duration of one timestep (Δt), the starting moment of charging at the starting SoC (tSoCmin,start), the moment the final SoC is reached (tSoCmax), and the moment the starting SoC is reached again (tSoCmin,end).				
Recommended Unit of Measurement		Recommended Monitoring Interval			
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√	
	Consumers / E-Drivers or fleet operators				
	Charging point operators			√	
	Grid operators				
	Energy supplier / Balance responsible parties (BRPs)				
	RTOs			√	
Recommended Evaluation Level:					
Technology Level		Use Case Level	√	Project Level	

5.2.6 Energy exchange with the grid (bi-directional) (TE7)

TE7. Energy exchange with the grid (bi-directional)			
KPI Overview	This KPIs measures the energy exchanged between the vehicle and the grid. It affects all the stakeholders, from the user to the CPO to the energy provider. It must be measured in daily, weekly, and yearly basis.		
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis		
Recommended KPI Estimation Process	The equation for the exchanged energy is the Energy given to the network from the EV and the energy given to the EV from the network: Eout (energy given to the EV from the network) + Ein (energy given to the network from the EV)		
Recommended Unit of Measurement	kWh/day (Exchanged)	Recommended Monitoring Interval	Daily, weekly, annually
Relevant	Electric vehicle manufacturers (Vehicle OEM)		√

Stakeholders	Consumers / E-Drivers or fleet operators	√
	Charging point operators	√
	Grid operators	√
	Energy supplier / Balance responsible parties (BRPs)	√
	RTOs	√
Recommended Evaluation Level:		
Technology Level	Use Case Level	√ Project Level

5.2.7 Peak load reduction (TE8)

TE8. Peak load reduction			
KPI Overview	Peak load is the maximum power consumption of the charging infrastructure or the building to provide certain comfort levels. Reduction is the rate of peak demand before the implementation (baseline) with the peak demand after the implementation per charger, per building, or per network. The specific KPI is calculated to know the margin of the required energy in order to understand how the system will respond.		
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis		
Recommended KPI Estimation Process	Time and locations are important to be stated, except from the load itself, since these can be used for analysing what is the best system incentive to be used (dynamic prices, price incentives and capacity tariffs). The following simple formula can be applied to estimate this KPI: $\text{Peak Load reduction (\%)} = \left(1 - \frac{P_{\text{peak}}}{P_{\text{baseline}}}\right) * 100$ Ppeak: Peak load during/after the implementation Pbaseline: Peak load before the implementation (baseline)		
Recommended Unit of Measurement	%	Recommended Monitoring Interval	Daily, Weekly
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		
	Consumers / E-Drivers or fleet operators		
	Charging point operators		√
	Grid operators		√
	Energy supplier / Balance responsible parties (BRPs)		√
	RTOs		√
Recommended Evaluation Level:			
Technology Level	Use Case Level	√	Project Level

5.2.8 Amount of time providing flexibility services (locally or to the grid) (TE9)

TE9. Amount of time providing flexibility services (locally or to the grid)	
KPI Overview	The plug-in time must be sufficient to charge the EV battery level to satisfy the charging demand for the EV owner. The least plug-in time that can be used to

	achieve the expected battery level of an EV has to be calculated. The specific KPI is strictly related both to the CPO and the user.			
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis			
Recommended KPI Estimation Process	The following equation is used for the calculation of the KPI: $t_i^{\min} = E_i^r \left(\frac{SoC_i^e - SoC_i^{\text{in}}}{P_{\max}} \right)$ Where: ○ E_i^r is the rated battery capacity of the EV. ○ SOC_i^e and SOC_i^{in} are the expected battery energy level and the battery energy level at plug-in time, respectively. ○ $P_{\max}$ is the maximum charging rate in the charging station. Considering the time available for frequency regulation has to satisfy the following constraint: $t_i^{\text{in}} < t < t_i^{\text{d}} - t_i^{\min}$ where t_i^{in} and t_i^{d} are the plug-in time and expected plug-out time of the ith EV, respectively.			
Recommended Unit of Measurement	sec	Recommended Monitoring Interval	Monthly, annually	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√
	Consumers / E-Drivers or fleet operators			
	Charging point operators			√
	Grid operators			
	Energy supplier / Balance responsible parties (BRPs)			
	RTOS			√
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.2.9 Energy system flexibility (TE10)

T10. Energy system flexibility	
KPI Overview	Energy utilities must utilize all available resources to respond to a set of demand variations and maintain the power balance, wither in terms of load or cost. Flexibility is an essential indicator in SCALE projects and should be measured either on a 15 minute basis or on an hourly basis.
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, ABB, Chalmers, RISE, Current, EMS, Enervalis
Recommended KPI Estimation Process	The equation for the calculation of the energy system flexibility is the following: $\Delta SF (\%) = \frac{\Delta SF}{P_{\text{peak}}} = \frac{SF_{R\&I} - SF_{BaU}}{P_{\text{peak}}}$

	Where: vSF is the amount of load capacity participating in demand side management [MW]. $SFR\&I$= the amount of load capacity participating in demand side management after the actions, taken as the total capacity in all UCs [kW]. $SFBaU$= the amount of load capacity taking place in demand side management in the baseline scenario [kW]. $SFBaU$ depends on the existing technologies and potential targets in the UCs and would not be always zero e.g., in the case of home-based BESS to support load shifting in off-peak hours. P_{peak}= the peak load at DSO level			
Recommended Unit of Measurement	%	Recommended Monitoring Interval	15 minutes /hourly base	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			
	Consumers / E-Drivers or fleet operators			
	Charging point operators		√	
	Grid operators		√	
	Energy supplier / Balance responsible parties (BRPs)		√	
	RTOs			
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.2.10 Reaction time to increase/decrease power delivery (TE11)

TE11. Reaction time to increase/decrease power delivery			
KPI Overview	The specific KPI measures the reaction time for the power delivery from the charging station to the EV depending on the charging station design		
KPI Owner	We Drive Solar, Equigy, Utrecht University, Hyundai, E-Mobility Solutions, GoodMoovs, DBH Serviced Office, Renault, ABB, Chalmers, Polestar, RISE, Current, EMS, Enervalis		
Recommended KPI Estimation Process	The value to the specific KPI will be provided by the OEMs and/or CPOs.		
Recommended Unit of Measurement	Secs / milliseconds	Recommended Monitoring Interval	Daily
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		√
	Consumers / E-Drivers or fleet operators		√
	Charging point operators		√
	Grid operators		
	Energy supplier / Balance responsible parties (BRPs)		
	RTOs		
Recommended Evaluation Level:			

Technology Level		Use Case Level	√	Project Level	
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5.3 KPI Cards in Technological / Economic Key Impact Pathway (SUPPORTING KPIs)

The following KPIs are considered supporting KPIs. It is not highly recommended to be measured, but they can give some more extended results supporting the purposes of the future deliverables. Therefore, for the pilot sites that could contribute towards this direction it is consisted of to proceed also with the measurments of the below KPIs.

5.3.1 Time of Use Load shifting (TE12)

TE12.Time-of-Use Load shifting				
KPI Overview	Load shifting is an electricity load management technique in which load demand is shifted from peak hours to off-peak hours of the day. The specific KPI should be measured since it gives an extra input towards the correct management of the electricity demand.			
KPI Owner	Current, Chalmers, Polestar			
Recommended KPI Estimation Process	In order to calculate the specific KPI, the below formula has to be applied: $\sum_{k=0}^n (Baseline * day ahead price) - (optimized consumption) * day price ahead)$			
Recommended Unit of Measurement	€	Recommended Interval	Monitoring	Monthly, annually
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			
	Consumers / E-Drivers or fleet operators			
	Charging point operators		√	
	Grid operators		√	
	Energy supplier / Balance responsible parties (BRPs)		√	
	RTOs			
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.3.2 Congestion management income (Short term) (TE13)

TE13. Congestion management Income (Short term)	
KPI Overview	Congestion income represents the revenue transmission system operators (TSO) collect when allocating cross-zonal capacity.
KPI Owner	Current
Recommended KPI Estimation Process	The total congestion income generated in the system can be calculated as:

	<i>Total Congestion Income = Σbuyers cash out – Σsellers cash in</i>			
	Since the Day-Ahead Market currently operates at hourly granularity, for each hour the total congestion income is the sum of all payments by buyers (consumers), minus the sum of all payments to generators. Payments are to be understood as the product of the contracted volume of energy (MWh) times the zonal price (€/MWh), resulting in an annual congestion income of €/MWh/y given in contracted bids during congestion time.			
Recommended Unit of Measurement	€/MWh/y	Recommended Monitoring Interval	Daily	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√
	Consumers / E-Drivers or fleet operators			
	Charging point operators			√
	Grid operators			√
	Energy supplier / Balance responsible parties (BRPs)			√
	RTOs			√
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.3.3 Power Quality control (TE14)

TE14. Power quality control						
KPI Overview		The quality of electric power distributed is defined by continuity of supply and eminence of voltage.				
KPI Owner		Current				
Recommended KPI Estimation Process		<i>The equation used for the calculation of the KPI is the following:</i>				
		$\Delta E_i = \int_{0^1}^t \eta p_t dt$ <i>Where: E_i is the battery capacity, η is the charging/discharging efficiency, P_t the power load in V2G mode, and ΔE_i is the change in battery energy.</i>				
Recommended Unit of Measurement		MWh/y	Recommended Monitoring Interval			
Relevant Stakeholders		Electric vehicle manufacturers (Vehicle OEM)		√		
		Consumers / E-Drivers or fleet operators				
		Charging point operators		√		
		Grid operators		√		
		Energy supplier / Balance responsible parties (BRPs)		√		
		RTOs		√		
Recommended Evaluation Level:						
Technology Level			Use Case Level	√	Project Level	

5.3.4 Back-up power in islanding mode (TE15)

TE15.Back-up power in islanding mode							
KPI Overview		Islanding is the condition in which a distributed generator (DG) continues to power a location even though external electrical grid power is no longer present. Islanding mode can guarantee the continuous electrical supply from the grid to the EV. The batteries of V2G electric vehicles will be controlled in a way that is feasible to provide backup power.					
KPI Owner		Current					
Recommended KPI Estimation Process		Single value to be provided by the CPO					
Recommended Unit of Measurement		MWh/y	Recommended Monitoring Interval	Monthly, annually			
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)						
	Consumers / E-Drivers or fleet operators			√			
	Charging point operators			√			
	Grid operators			√			
	Energy supplier / Balance responsible parties (BRPs)			√			
	RTOs			√			
Recommended Evaluation Level:							
Technology Level			Use Case Level	√	Project Level		

5.3.5 Savings from charging station operator (TE16)

TE16.Saving from charging station operator				
KPI Overview	EV owners can reduce their charging costs and even earn money by recharging their EV batteries during low-energy-price periods and discharging them during high-energy price periods. This KPI measures the above condition.			
KPI Owner	Chalmers, Polestar, RISE, Current			
Recommended KPI Estimation Process	The equation for the calculation of the KPI is given below: $\min \sum_{t=1}^T \{ (P_t^{charge} * C_t^{charge}) - (P_t^{discharge} * C_t^{discharge}) + Cdeg(Etrans) \}$ Where: Pt,charge and Pt,discharge is the charging and discharging rates of the EV battery at time t, respectively, and Ct,charge and Ct,discharge represent the charge and discharge prices of the EV power, respectively. Cdeg (Etrans) represents the cost of the battery's destruction as a function of the energy exchanged (Etrans) in V2G mode.			
Recommended Unit of Measurement	MWh/y or €/kWh	Recommended Monitoring Interval	Weekly	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√
	Consumers / E-Drivers or fleet operators			√

	Charging point operators	√
	Grid operators	
	Energy supplier / Balance responsible parties (BRPs)	
	RTOs	
Recommended Evaluation Level:		
Technology Level	√	Use Case Level
		Project Level

5.3.6 Reserves adequacy (TE17)

TE17. Reserves adequacy			
KPI Overview	Resource adequacy is the ability of a utilities' reliable capacity resources (supply) to meet the customers' energy or system loads (demands) at all hours within the study period.		
KPI Owner	Current		
Recommended KPI Estimation Process	Data can be provided by Energy supplier / Balance responsible parties (BRPs) or CPOs <i>This is something that cannot be measured. OEMs may provide the relevant info.</i>		
Recommended Unit of Measurement	MWh/y of stored energy	Recommended Monitoring Interval	Annually
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		
	Consumers / E-Drivers or fleet operators		
	Charging point operators		
	Grid operators		√
	Energy supplier / Balance responsible parties (BRPs)		√
	RTOs		
Recommended Evaluation Level:			
Technology Level		Use Case Level	√
			Project Level

5.3.7 Operational Congestion Management (non-contracted bids) (TE18)

TE18. Operational Congestion Management (non-contracted bids)	
KPI Overview	A congestion management process (CMP) is a systematic and regionally accepted approach for managing congestion that provides accurate, up-to-date information on transportation system performance and assesses alternative strategies for congestion management. The specific operations from non-contracted bids have to be calculated in order to calculate the resistance of the system.
KPI Owner	Current
Recommended KPI Estimation Process	Data can be provided by Energy supplier / Balance responsible parties (BRPs) or CPOs

	Alternatively, for each Real-time Settlement Interval, Market Participants shall be assessed for Transmission Congestion Charges (positive or negative) in accordance with the following equation:			
	$[(A - B) * C] - [(D - E) * C]$			
	Where:			
	A = The Market Participant Energy Withdrawal megawatts in real-time at the location at which both the Market Participant withdraws energy and such energy is priced.			
	B = The Market Participant Energy Withdrawal megawatts in day-ahead at the location at which both the Market Participant withdraws energy and such energy is priced.			
	C = Real-time Congestion Price.			
	D = The Market Participant Energy Injection megawatts in real-time at the location at which both the Market Participant injects energy and such energy is priced.			
	E = The Market Participant Energy Injection megawatts in day-ahead at the location at which both the Market Participant injects energy and such energy is priced.			
Recommended Unit of Measurement	€/MWh/y	Recommended Monitoring Interval	Annually	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			
	Consumers / E-Drivers or fleet operators			
	Charging point operators			
	Grid operators			√
	Energy supplier / Balance responsible parties (BRPs)			√
	RTOs			
Recommended Evaluation Level:				
Technology Level		Use Case Level	√	Project Level

5.4 KPI Cards in Social / Environmental Key Impact Pathway

5.4.1 Citizen awareness (SE.19)

SE19. Citizen awareness	
KPI Overview	In the process of GHG emission reduction, the EU has set a target for all new cars and vans in Europe to be zero emission ones by 2035. The awareness of the public regarding vehicle alternatives, including EVs is critical for their take up and the accomplishment of the EU objectives in that regard. This KPI aims to monitor citizen awareness regarding the e-mobility issues, including available EV smart charging and V2X solutions. Both the total number of people

	reached and the level of their understanding of the available solutions can be monitored.				
KPI Owner	Utrecht, ElaadNL, Enervalis,				
Recommended KPI Estimation Process	It is recommended that a general survey addressed to the residents of the areas of demonstration is employed in order to collect information. The total number of replies is to be taken into consideration for the evaluation of this KPI, in addition to the content of the replies. It is recommended that the distributed surveys include questions presenting each implemented solution of the project and ask for the level of awareness of the citizens on the subject. A 5-point Likert-Scale per question (specific solution) can be applied to express different levels of awareness: (1) fully not aware (no knowledge of the solution), (2) low awareness (citizen has heard about the solution), (3) somewhat aware (knowledge and limited understanding of functionality), (4) aware (knowledge and good understanding of functionality), (5) fully aware (extensive knowledge of the solution). The level of citizen awareness is to be reflected by the average of the received replies to all questions.				
Recommended Unit of Measurement	Likert Scale (1-5), Number (#) of people reached	Recommended Monitoring Interval	Once, after communication and dissemination activities have taken place.		
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)				
	Consumers / E-Drivers or fleet operators			√	
	Charging point operators				
	Grid operators				
	Energy supplier / Balance responsible parties (BRPs)				
Recommended Evaluation Level:					
Technology Level		Use Case Level		Project Level	√

5.4.2 Degree of satisfaction (SE.20)

SE20. EV User satisfaction	
KPI Overview	A general dissatisfaction with the available EV charging infrastructure has been observed in the recent years, as the number of EVs in Europe is growing, having to do mostly with the low availability of charging points, since it was found that almost 50% of them are concentrated in two EU countries (accounting for only 10% of the total EU surface area)²². This KPI aims to monitor the degree of EV user satisfaction with the implemented EV charging solutions. The measured results will reflect how well the user needs were evaluated and taken into consideration during the first steps and the implementation of the project.

²²<https://www.acea.auto/press-release/electric-cars-half-of-all-chargers-in-eu-concentrated-in-just-two-countries/>

	User satisfaction can be investigated with regard to different areas, e.g., perceived adequacy of the number of charging stations, as well as perceived usability and cost/quality ratio of the provided services.			
KPI Owner	Utrecht, ElaadNL, E-Mobility Solutions, Current			
Recommended KPI Estimation Process	To determine the degree of satisfaction among the EV users involved in SCALE demonstrations, relevant questionnaires should be developed and distributed. The main aim of the surveys is to determine the usability and user acceptance of the implemented EV charging solutions, including the usability of the V2G technologies. A 5-point Likert-Scale per question (specific solution) can be applied to express different levels of satisfaction: (1) very low satisfaction, (2) low satisfaction, (3) moderate satisfaction, (4) high satisfaction, (5) very high satisfaction. The following formula can be applied to estimate this the percentage of user satisfaction: Overall user satisfaction in a specific area = Percentage of people who reported a high (4) and/or very high (5) satisfaction in that area This KPI should be extracted per investigated area (different question) and should reflect the average score of all end-users interviewed.			
Recommended Unit of Measurement	%	Recommended Monitoring Interval	Once, during the real-life testing phase	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			
	Consumers / E-Drivers or fleet operators			√
	Charging point operators			
	Grid operators			
	Energy supplier / Balance responsible parties (BRPs)			
Recommended Evaluation Level:				
Technology Level		Use Case Level		Project Level
				√

5.4.3 Greenhouse Gas (GHG) Emissions (SE.21)

SE.21 Greenhouse Gas (GHG) Emissions	
KPI Overview	The transport sector accounts for about 20% of total EU GHG emissions with passenger cars and vans producing about 15% of Europe's CO₂ emissions. SCALE's expected outcomes aim to support the EU 2030 Climate Target Plan for a 55% of GHG emission reduction by 2030 through increasing the EV uptake in the EU transport market, as well as increasing renewable energy generation, energy flexibility and introducing car sharing schemes. As the share of EVs in Europe has tripled since 2020, the average CO₂ emission from

	newly registered passenger cars have decreased by 12% ²³ , making EV penetration an effective means of GHG reduction in the transport sector. To enable the comparability between systems, the emissions can be related to the size of the system (e.g., number of vehicles) and the considered interval of time (e.g., year).				
KPI Owner	Use Case Leaders				
Recommended KPI Estimation Process	In order to estimate the net greenhouse gas emissions coming from transportation, the mean fuel consumption per vehicle per fuel type is required. This value then needs to be multiplied with the mean distance travelled per vehicle and the respective emission factor for each fuel type available here, as well as the total number of registered vehicles of this type. The described calculation method for the net GHG emissions coming from transportation is summarised in the following equation: $GHG_{T_net} = \sum_i (D_m \times FC_m \times EF_i \times V_i), i: \text{fuel type}$ GHG_{T_100}: GHG emissions coming from transportation per 100.000 vehicles EF_i: Emission factor per fuel type D_m: mean distance travelled by car annually for the examined area (country) in km FC_m: mean fuel consumption per km V_i: Number of cars registered per fuel type For comparability purposes among different systems, the calculated net GHG emissions are to be divided per 100.000 vehicles.				
Recommended Unit of Measurement	kg CO ₂ eq/year/100.000 vehicles	Recommended Monitoring Interval	Twice, once at the beginning and once at the end of the project		
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)			√	
	Consumers / E-Drivers or fleet operators			√	
	Charging point operators				
	Grid operators				
	Energy supplier / Balance responsible parties (BRPs)				
Recommended Evaluation Level:					
Technology Level		Use Case Level		Project Level	√

5.4.4 CO₂ Payback Time (CPBT) (SE.22)

SE22 CO ₂ Payback Time (CPBT)	
KPI Overview	The CO₂ payback time estimates how long it will take for a renewable energy project to offset the carbon footprint during its life cycle. Monitoring this KPI offers a realistic overview of the efficiency of the implemented solutions at a

²³https://climate.ec.europa.eu/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

	project level in terms of mitigating the environmental impact of GHG emissions and reaching the proposed EU targets concerning CO ₂ levels reduction and climate neutrality (Fit-for-55).				
KPI Owner	CERTH, Use Case Leaders				
Recommended KPI Estimation Process	For the calculation of the CPBT, the following formula ²⁴ can be utilized:				
	$CO_2\ PBT = \frac{Indirect\ emissions}{Emission\ factor \times Annually\ produced\ energy}$				
	Indirect emissions (kg CO _{2,eq}): life cycle GHG emissions that are not included in the operation phase of the system (e.g., for manufacturing, transportation, installation etc).				
	Emission factor (kg CO _{2,eq} /kWh): emission per unit of energy produced by the grid				
	Annually produced energy (kWh/year): renewable energy produced in a year				
	The estimation of this KPI can be performed with the utilisation of the VERIFY software.				
Recommended Unit of Measurement	years		Recommended Monitoring Interval		Once, at the end of the project
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)				√
	Consumers / E-Drivers or fleet operators				
	Charging point operators				
	Grid operators				
	Energy supplier / Balance responsible parties (BRPs)				
Recommended Evaluation Level:					
Technology Level		Use Case Level		Project Level	√

5.4.5 Diffusion to other locations (SE.23)

SE23. Diffusion to other locations			
KPI Overview	Diffusion of SCALE solutions, or adopted processes, to other locations is incentivised in the project through community building and cross-fertilisation actions that are expected to communicate the results to different communities. In the context of the dissemination and exploitation of the project results and the facilitation of further market uptake of the developed solutions, the extent to which the project solutions are copied in other cities and regions needs to be measured. This KPI is responsible for monitoring this parameter.		
KPI Owner	Polis		
Recommended KPI Estimation Process	For the identification of the level of diffusion of SCALE solutions to other locations, the necessary information regarding the solutions' replication needs to be drawn from the relevant stakeholders as well as a targeted search online (including on the websites of relevant organisations). These stakeholders may		

²⁴ V. Kabakian, M.C. McManus, H. Harajli, Attributional life cycle assessment of mounted 1.8kWp monocrystalline photovoltaic system with batteries and comparison with fossil energy production system, Applied Energy, Volume 154, 2015, Pages 428-437, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2015.04.125>.

	include project partners with knowledge of the market and their professional network. A 5-point Likert-Scale per question can be applied to express different levels of diffusion: (1) very low diffusion (the solution has not been copied), (2) low diffusion (the solution has been copied once in another location within the same region), (3) moderate diffusion (the solution has been copied more than once in the same region), (4) high diffusion (the solution has been copied within and outside of the region where it was originally implemented), (5) very high diffusion (the solution has been copied within the country it was originally implemented and internationally).			
Recommended Unit of Measurement	Likert Scale (1-5)	Recommended Monitoring Interval	Once, at the end of the project	
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		√	
	Consumers / E-Drivers or fleet operators			
	Charging point operators		√	
	Grid operators		√	
	Energy supplier / Balance responsible parties (BRPs)		√	
Recommended Evaluation Level:				
Technology Level		Use Case Level		Project Level
				√

5.4.6 Number of cars participating in EV sharing schemes (SE.24)

SE24. Number of cars participating in EV sharing schemes	
KPI Overview	Optimising mobility and enhancing air quality and road safety are some of the key challenges that European cities face while seeking ways to improve transport in terms of environmental impact, accessibility and social inclusion²⁵. Car sharing schemes are explored as a solution to these issues. EV sharing schemes, specifically, can address these issues while also enhancing grid flexibility through V2G technology. SCALE envisions to improve accessibility to vehicle sharing solutions and reach mass deployment level for V2G vehicles using the city of Utrecht as a test bed. The aim of this KPI is to quantify the participation of electric vehicles in car sharing schemes within the project by estimating the number of vehicles available for sharing per 100.000 inhabitants.
KPI Owner	WDS, GoodMoovs, Polestar, Hyundai
Recommended KPI Estimation Process	EV sharing schemes are typically managed by mobility sharing service providers. The number of cars participating in EV sharing schemes can be estimated through the logs of the fleet operators participating in such schemes. Communication with the local vehicle sharing companies will be required to determine the actual number of EVs participating in sharing schemes. For government run companies, this information might be available online.

²⁵ <https://publications.jrc.ec.europa.eu/repository/handle/JRC127774>

Recommended Unit of Measurement	Number (#) of cars per 100.000 inhabitants	Recommended Monitoring Interval	Annually (or once at the end of the project)
Relevant Stakeholders	Electric vehicle manufacturers (Vehicle OEM)		
	Consumers / E-Drivers or fleet operators		√
	Charging point operators		
	Grid operators		
	Energy supplier / Balance responsible parties (BRPs)		
Recommended Evaluation Level:			
Technology Level		Use Case Level	Project Level
			√

6

Infrastructure and Monitoring Equipment – Specifications and Implementation Pathway



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6 Infrastructure and Monitoring Equipment - Specifications and Implementation Pathway

6.1 Monitoring and Security

SCALE utilizes a series of infrastructures for the monitoring of the aspects that are critical for the fulfillment of the KPIs, including the security aspects.

6.1.1 Infrastructures and Monitoring Equipment

The necessary infrastructures required for monitoring the SCALE's impact are presented in the following table.

Table 17 Infrastructure and Monitoring Equipment

KPIs / Use Cases	Monitoring Aspects	Monitoring Equipment
General		
Utilization rate of EV chargers	Active Power (kW) and Reactive (kVAR)	Power Meter
Self-sufficiency	- EV battery State of Charge monitoring - Active Energy (kWh) and Reactive (kVARh) Energy meter (of renewable energy and consumed energy)	- State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol - Power Meter
Self-consumption	Active Energy (kWh) and Reactive (kVARh) Energy meter of renewable energy and consumed energy)	Energy Meter
Energy curtailment	- EV battery State of Charge monitoring - Reduction of production of renewable energy sources	State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol
V2G efficiency (accounting for roundtrip V2G losses)	- EV battery State of Charge monitoring - Active Power (kW) and Reactive (kVAR) Power meter	- State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol - Power Meter
Energy exchange with the grid (bi-directional)	Active Energy (kWh) and Reactive (kVARh) Energy meter	Energy Meter
Peak load reduction	Controller – Observer of the consumption	State of Charge communication meter,

	Active (kW) and Reactive Power (kVAR). EV battery State of Charge monitoring	which operates under between EV and charger ISO 15118-20 protocol Power Meter
Amount of time providing flexibility services (locally or to the grid)	- Active Energy (kWh) and Reactive (kVARh) Energy meter - EV battery State of Charge monitoring	- State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol - Energy Meter
Energy system flexibility	EV battery State of Charge monitoring	State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol
Reaction time to increase/decrease power delivery	EV battery State of Charge monitoring	State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol
Optional		
Time-of-Use Load shifting	Consumption energy (kWh) monitoring for locations	Energy Meter
Congestion management Income (Short term)	- Grid Voltage Magnitude (V) monitoring - Grid Current Magnitude (A) monitoring - EV battery State of Charge monitoring	- Voltage Meter - Current Meter - State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol
Power quality control	- Active Power (kW) and Reactive (kVAR) Power meter - EV battery State of Charge monitoring	- State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol - Power Meter
Back-up energy in islanding mode	- Active Energy (kWh) and Reactive (kVARh) Energy meter - EV battery State of Charge monitoring	- State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol - Energy Meter
Saving from charging	EV battery State of Charge monitoring	State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol

Reserves adequacy	• EV battery State of Charge monitoring • Load consumption energy (kWh) monitoring	• State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol • Energy Meter
Operational Management (noncontracted bids) Congestion	• EV battery State of Charge monitoring • Grid Voltage Magnitude (V) monitoring • Grid Current Magnitude (A) monitoring	• Voltage Meter • Current Meter • State of Charge communication meter, which operates under between EV and charger ISO 15118-20 protocol

Via those infrastructures, the project aspects can be visualized and controlled to secure the normal and the optimal operation, as well as the protection, of the EV Chargers during any mode (V1G, V2G, V2X, etc.). The information provided by the monitoring equipment is visible on the dashboard of the Charge Station. In order to store this information into the cloud platform of Charging Point Operator (CPO), SCALE uses specific Application Programming Interfaces (APIs). Via those APIs, SCALE also secures the communication between the EV, charger and CPO.

6.2 Temporal Scale Measurements

The measurement and storage, in CPO, of the aforementioned information must ensure the avoidance of any time long errors and therefore the fulfillment of KPIs. For this reason, SCALE retrieve this information under a specific period of time, which is shown in the following table.

KPIs / Use Cases	measurement Frequency
General	
Utilization rate of EV chargers	Monthly
Self-sufficiency	Daily
Self-consumption	Monthly
Energy curtailment	Monthly
V2G efficiency (accounting for roundtrip V2G losses)	Daily
Energy exchange with the grid (bi-directional)	Monthly
Peak load reduction	Daily

Amount of time providing flexibility services (locally or to the grid)	Daily
Energy system flexibility	15 Minutes/ Hourly
Reaction time to increase/decrease power delivery	4/15/30 Seconds
Optional	
Time-of-Use Load shifting	Daily
Congestion management Income (Short term)	Daily
Power quality control	Daily
Back-up energy in islanding mode	Daily
Saving from charging	Daily
Reserves adequacy	Daily
Operational Congestion Management (noncontracted bids)	Daily

For the measurement of the KPIs information, under the frequency of the above table, SCALE utilizes a **Time Meter** alongside the rest of the measurement equipment.

6.3 Security Aspects

Security Aspects of EV Charge Station are separated into the following categories:

1. Cyber Security
2. Physical Security

6.3.1 Cyber Security

Through Cyber Security is defined in the different exchange protocols, the following states can be secured:

- EV Battery Availability
- Normal operation of all chargers
- Confidentiality

6.3.1.1 EV Battery Availability

The EV Battery Availability is determined by the State of Charge (SoC). It is important the detection of the SoC of any EV, which is plugged on any charger of the station and prevents overcharging or over – discharging (V2G or V2X mode) situations. For the SoC detection, the monitoring of the SoC of every plugged

EV is measured and monitored. The operation of the charger, on which the EV is plugged, terminates whenever the SoC of this EV's battery is under 20% or over 80%, approximately.

6.3.1.2 Normal operation of all chargers

For the normal operation of all chargers, it is important the detection of the electrical data to the input and output of every charger. These data are:

- The Voltages
- The Currents

These data should not surpass a maximum value (mostly the nominal one) and fall under a minimum value. The value of this data should be determined for the precisely communication between the charger and the EV's battery. This communication takes into account the energy consumption (kWh) of the Electrical Grid's Loads and the energy production (kWh) of the Electrical Grid's Distribution Energy Resources (if they exist). For the detection of the aforementioned data, the voltage and current are measured and monitored on every charger alongside with the consumed and produced energy.

6.3.1.3 Confidentiality

The data that is collected by the operation and the control of the chargers should be transmitted only between project partners. However, there are several cyber hazards which has to be eliminated in order to achieve this transmission. Those attacks can be:

- A Spoofing, where a cyber attacker masquers as a project partner taking access to the project data.
- A Malware software
- A Hacking

For this reason, SCALE utilizes a cyber protective system, which ensures the followings:

- Only members of the project, who are identified physically, can have access to the project's data.
- Protection against malware software via an antivirus system
- Strong encryption with generated of new passwords and keys after a period of time.

6.3.2 Physical Security

Physical security aims to defend the charge station against attacks that can, physically, damage or terminate the operation of the EV chargers. These attacks may be the followings:

- Damages because of weather conditions (freeze/overheat of the charger's hardware on cold/hot environment, flood on heavy precipitation, etc.)
- Destruction because of Lighting
- Exportation of the software system's data
- Robbery of the hardware system or robbery of the entire charger

For the protection against those attacks, SCALE utilizes the followings:

- A system which ensures that the charger's interior temperature lies between the limits that are provided by the manufacturer.
- A waterproof protective shell against extreme precipitation.
- Lighting protection
- Strong encryption to the software's data via a driver (usb, cd, etc.)

- Security system against robbery and damage by people

6.4 Implementation pathway of monitoring

The implementation of the monitoring follows the next pathway:

1. Hardware communication (via plug in) between EVs and charger station.
2. Software communication (via APIs) between EVs, charger station, CPO and local Distribution Network.
3. Measurement of the KPIs information via the monitoring equipment under the Chapter 6.2 time period.
4. Visualization of the KPIs information on charger's dashboard and on CPO
5. Storage of the KPIs information into the CPO cloud platform.



7

Conclusions



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056874.

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7 Conclusions

To track all SCALE activities over the long-term (during project exploitation), as well as the short- to medium-term (until the project's end), a repository of customised metrics and key performance indicators (KPIs) was created in D4.1. Two timescales—short/medium-term and long-term—were considered to effectively monitor SCALE's projected outcomes and impacts. A particular process was used to complete the final short- and medium-term SCALE KPI repository, and cards were created for each of these KPIs with their essential insights. A general guide on variables and criteria that should be considered in the future to monitor the long-term performance of SCALE and quantify the suggested KPIs was provided for the long-term KPIs identified. A total of thirty eight (38) KPIs have been defined, covering the short- and medium-term (24 KPIs) (see Table 11) and long-term (14 KPIs) scope (see Table 13) of SCALE and being perfectly in line with SCALE's anticipated impacts and outcomes

SCALE makes use of a number of monitoring infrastructures that are described in Chapter 6 in order to guarantee the achievement of the KPIs, the security of EVs and Charge Stations, as well as the appropriate functioning and communication between Charge Station, EVs, and Distribution Network. These infrastructures run and offer information for a period of time to guarantee that no long-term errors take place. Through particular APIs that SCALE uses, the provided data is stored on CPO cloud.

D1.4 is important for the SCALE project in order to assess project development and make adjustments to meet all of the SCALE objectives. An updated version of this Deliverable will be offered in case significant revisions take place in order to guarantee that the final KPI repository is compliant and appropriately reflects the significant outcomes to be accessed by other SCALE processes.



8

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Annex



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9 Annex

SCALE applies the technologies and new knowledge available on smart charging, V2X and V2G, to develop a systemic solution to intelligently harness the synergies between the energy and the transport sector. SCALE focusses on preparation for mass market deployment of smart charging and V2X concepts at EU level, by preparing a blueprint for replicating in different cities and regions while acknowledging the different starting points e.g., EV penetration rates, context conditions and diverse challenges. SCALE outcomes in terms of scalability and commercialization potential, are applicable to a wide range of environments and will directly contribute to one or more main impacts, as targeted under the 2ZERO initiative, speeding up the transition towards an affordable zero tailpipe emissions road transport system. SCALE outcomes include both 'Scale' (Si), and 'Significance' (Si) oriented benefits. SCALE's expected outcomes are outlined below:

Expected Outcome #1: Definition of the optimal smart charging concepts able to cope with several million of Electric Vehicles (EV) deployed in different environments.	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 1.1 (Si): Field applications of the smart charging concepts are standardized so that authorities can adapt the needed legal, market and regulatory frameworks on the local, national, and European level.	Economic / Technological
Outcome 1.2 (Sc): SCALE's knowledge base created in 13 pilot demonstration in the form of lessons learnt from Innovation Clusters, will be extended to mass market covering the expected 30 million EVs by 2030 (Economic/Technological) in different environments offering innovative Use Cases for the integration EVs, and infrastructure concepts.	Economic / Technological
Outcome 1.3 (Sc) SCALE stakeholders and their networks are accessible beyond the project's lifetime (Societal) which will achieve fast replication and deployment of public charging infrastructure concepts, necessary to cope with the anticipated take up of EVs in Europe.	Societal
Expected Outcome #2: Development of smart charging strategies and control mechanisms that and the efficiency of the whole energy system, increasing the use of renewable electricity harnessing unused EV storage capacity, whilst minimising grid reinforcements and energy generation needs.	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 2.1 (Si): User-centric charging strategies enhancing their satisfaction by at least 90%.	Economic / Technological
Outcome 2.2 (Si & Sc): Extract energy flexibility for all involved stakeholders which effectively reduces the need for grid reinforcements at the local distribution level by as much as 50%	Economic / Technological
Outcome 2.3 (Si): Develop and validate at least 5 control signals given to end users including potential of local renewable energy generation.	Economic / Technological
Outcome 2.4 (Si&Sc): Cutting down GHG emissions by at least 20% from higher uptake of EVs, increased renewable energy generation & minimizing energy generation needs.	Societal

Expected Outcome #3: Innovative concepts and technologies performances to create affordable, user-friendly smart and bidirectional (V2X, where X can be G for Grid, H for Home and B for Business) charging solutions, co-optimising the needs of EV users, of the house/building and of the supplying grid.	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 3.1 (Sc): Developing 20 validated and scalable smart charging concepts through demonstrations in the Use Case pilots specific to user groups implemented in at least 15 cities and regional authorities participating in SCALE as reference group members.	Economic / Technological
Outcome 3.2 (Si): Optimizing charger utilization through increasing average plug- in rate from 3% to 10% in public parking places.	Economic / Technological
Outcome 3.3 (Si): Generating new knowledge on behavioural research, feeding to the research community (societal).	Societal
Outcome 3.4 (Sc): <i>Reducing</i> the cost of charging by commercializing AC V2G charging and by generating revenue through the possibility of participating in the local energy market supplying the surplus energy back to the grid.	Economic / Technological
Expected Outcome #4: A better understanding of the operational and economic trade-offs for the user and the vehicle (e.g; cost of battery damage, additional cost for electronics to enable V2G), and on the charging (e.g., installation cost, battery degradation) infra- structure of the different smart and bidirectional (V2G) charging approaches and technologies (for instance AC vs DC), as well as the costs for the different actors involved.	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 4.1 (Si): Minimize/eliminate the impacts on EV battery and the components of the power system.	Economic / Technological
Outcome 4.2 (Si): Quantify the degradation of battery (if any) and the corresponding costs (Economic/Technological) for EV owners (private and shared).	Economic / Technological
Outcome 4.3 (Si) Generate new knowledge on finding optimum between AC and DC public chargers on cost and techno- logical trade-offs necessary for commercializing both chargers and EVs (Scientific) making solutions affordable.	Scientific
Expected Outcome #5: Contribution to the integrated planning process of systems aimed at exploiting cross-sector mutual benefits (G2X and V2X).	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 5.1 (Si): Open interface feature of the developed charger management system will seamlessly integrate with home/building energy management system or a third-party fleet management system unlocking a layer of flexibility to the overall energy demand management strategies	Economic / Technological
Outcome 5.2 (Sc): EV charging infrastructure roll out extending it EU wide through the +15 cities that are part of reference groups cutting planning costs as well as additional tool procurement costs. Furthermore, the tool will be used to create future implementation scenarios (towards 2030 & beyond) for policy development resulting in accelerating the uptake of EVs and offering an affordable, user-centric mobility service tool for cities.	Economic / Technological
Outcome 5.3 (Sc): complement the fleet management tool VDL for providing better planning ability of trip time, location of the charging hubs on the highway, while it supports the decision of the power system and technology needs making electric	Economic / Technological

mobility a matter of course even for heavy-duty vehicles by 2025, accelerating EV adoption and definition of innovative Use Cases and thereby reducing environmental impacts.	
Expected Outcome #6: Contribution to the standardisation process of interfaces for V2X	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 6.1 (Si): Benchmarking and standardizing in line with the market developments of complementing systems that are going to work in tandem with the SCALE V2X interface such as renewable energy generation, home/building energy management system and V2G interaction stream among others significantly enhancing the scalability of the entire ecosystem through effective design, assessment and deployment of innovative concepts at the intersection of power and transport system.	Economic / Technological
Outcome 6.2 (Si & Sc): Standardization of requirements for data collection, transmission, and management via secure channels by the various actors in the charging eco-system, enabling decisions and actions on smart charging and V2X (complemented by data-privacy/GDPR and required regulation for making this data available)	Economic / Technological
Outcome 6.3 (Si): Make open protocols mainstream and avoid competition lock-out and making the solutions affordable to end users (Economic/Technological)	Economic / Technological
Outcome 6.4 (Sc): Encourage more OEMs adopting standard 15118-20 for smooth communication with chargers deployed in majority of the cases, making 50% of all chargers in the EU based on open protocols by 2030 (Economic/Technological) which levels the playing field and increases market competition making smart charging & V2X experience ... affordable and user friendly.	Economic / Technological
Expected Outcome #7: Assess customer expectations & implement an open architecture (not proprietary) concerning smart and bidirectional charging solutions, as key success factors to build a mutually beneficial charging experience for the user & for the grid.	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 7.1 (Si): Harmonize the communication with any compliant charger.	Economic / Technological
Expected Outcome #8: Demonstrate V2X potential in encouraging renewable energy growth through the integration with low power re- newable energy sources (e.g., photovoltaics on the roof or in parking lots), by reducing energy exchange with the grid (in both directions) by 50%	
Description (as provided in Section 2.1 and 2.3)	KPI (Type)
Outcome 8.1 (Si): Reduction of energy exchange with the grid in one direction for charging heavy- duty buses and coaches by 100% (self-sustainable test centre) and by 50% in the other direction in the V2G application (Economic/Technological).	Economic / Technological
Outcome 8.2 (Sc): Develop a business model leading to a two-fold target (a) by running the test centre through virtual power plant concept using old heavy duty EV batteries as stationary storage, giving them a second life, and also by harnessing solar rooftop PV, and (b) by offering the multiple clean high voltage chargers for public transport and private bus and coach customers generating additional revenue leading to the innovative Use Cases for the integration of EVs, and infrastructure concepts.	Economic / Technological
Outcome 8.3 (Sc): An open interface systemic solution validates such a sophisticated system leading to the uptake of such charging hubs by +15 cities and more public	Economic / Technological

transport authorities in the longer run leading to accelerated uptake of EVs even in the public domain and reducing the environmental impacts significantly. Thus, SCALE solves challenges with local green energy generation profiles, leading to increased user acceptance, improved air quality, a more circular economy and reduction of environmental impacts.