D2.2 Definition of SPARCS Holistic Impact Assessment Methodology and Key Performance Indicators (updated version)

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Deliverable administration					
No & name	**D2.2** Definition of SPARCS Holistic Impact Assessment Methodology and Key Performance Indicators				
Status	Released	**Due**	M22	**Date**	2021-07-31
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Description of the related task and the deliverable. Extract from DoA	**T2.1: Demo Evaluation, Impact Assessment and Cost-Benefit Analysis Framework and Associated Key Performance Indicators (VERD) M1-M22** The task develops an integrated framework for the holistic assessment of the SPARCS interventions in the demo sites (Lighthouse and Fellow cities). The methodology builds upon the "Morgenstadt assessment framework" as a multidisciplinary approach for analysing complex urban systems and deriving applied, locally adapted smart city strategies and intervention roadmaps. The framework has already been tested as successfully applied to SCC1 Fellow Cities Prague, Leipzig and Sabadell within the EU SCC1 project "Triangulum". The SPARCS assessment framework has been enhanced with the city level KPIs from relevant projects and initiatives (CITYkeys; SCIS; CIVITAS) in order to investigate how these can be extended in order to perform a complete (quantitative and qualitative) assessment of the impact achieved by the different interventions and technologies deployed in the demos from an Energy Perspective (energy efficiency, RES integration, CO2 emissions reduction, air quality, electro mobility penetration, smart grid stability), Economic Perspective (energy costs reduction, revenue streams from market transactions, energy network investment deferral, business models viability, return on equity, incremental payback period, financial and economic net present value), Social Perspective (citizen engagement, user acceptance, comfort and air quality, security of supply, number of new jobs created, growth of SMEs, data security and privacy) and Technology Perspective (system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements). In this context different types of indicators have been utilized to enable continuous monitoring (throughout the execution of the demos) and holistic assessment of the project impact, including a) Interventions Indicators (number of solutions, number of technological components installed), b) Impact Indicators (as described before) and c) Replication Indicators, enabling accurate projection of the Impact Indicators considering wide capability and deployment of interventions at the Lighthouse, Fellow and other cities. Finally, emphasis will be given on introducing an appropriate normalisation methodology for the assessment of Impact Indicators, towards a) enabling the objective and accurate and normative baselining of the current situation/performance of the SPARCS demos, b) measuring and verifying the impact achieved by the different solutions deployed (individually and integrated), and c) adopting a cross-city approach when assessing the impact and replication potential of different solutions, thus enabling evidence-based deployment prioritization and objective evaluation of cost-effectiveness and sustainability in different city scales and contexts. This updated version of the report documents an integrated and holistic methodology for impact assessment, introducing a wide					

	variety of indicators listed under 3 main categories: (i) Intervention indicators, (ii)Impact indicators and (iii) Replication indicators.		
Participants	VTT, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV, RIL, FHG, BABLE, SPI, NEW, CVUT, SUITE5, LCE, CiviESCo		
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About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. SPARCS facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating Virtual Positive Energy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organizations, city planning and decision-making entities, transforming cities to carbon-free inclusive communities. Lighthouse cities Espoo (FI) and Leipzig (DE) implement large demonstrations. Fellow cities Reykjavik (IS), Maia (PT), Lviv (UA), Kifissia (EL) and Kladno (CZ) prepare replication with hands-on feasibility studies. SPARCS identifies bankable actions to accelerate market uptake, pioneers innovative, exploitable governance and business models boosting the transformation processes, joint procurement procedures and citizen engaging mechanisms in an overarching city planning instrument toward the bold City Vision 2050. SPARCS engages 30 partners from 8 EU Member States (FI, DE, PT, CY, EL, BE, CZ, IT) and 2 non-EU countries (UA, IS), representing key stakeholders within the value chain of urban challenges and smart, sustainable cities bringing together three distinct but also overlapping knowledge areas: (i) City Energy Systems, (ii) ICT and Interoperability, (iii) Business Innovation and Market Knowledge.

Partners

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LIST OF ABBREVIATIONS

BEST	Building Energy Specification Table
BEv	Battery Electric vehicle
BL	Building block level
CDD	Cooling Degree days
CIBSE	Chartered Institution of Building Services Engineers
CO_2-eq	Equivalent CO_2
D.	Deliverable
DL	District level
DoA	Description of Actions
DSCR	Debt Service Coverage Ratio
DPBP	Discounted Payback Period
EC	European Commission
EU	European Union
Ev	Electric vehicle
FC	Fellow City
GA	Grant Agreement
GHG	Greenhouse gas emissions
GSHP	Ground source heat pump
HDD	Heating Degree Days
HEv	Hybrid Electric vehicle
ICT	Information and Communication Technologies
IRR	Internal rate return
KPI	Key Performance Indicator
KW	Kilo Watt
KWh	Kilo watt hours
LHC	Light House City
LLCR	Loan life coverage ratio
M:CI	Morgenstadt: City Insights
ML	Macro level
MW	Mega watt
P2H	Power to heat
PED	Positive energy district
RES	Renewable energy sources
ROI	Return of Investment
SAIDI	System Average Interruption Duration index
SAIFI	System Average Interruption Frequency Index
SCIS	Smart Communities Information System
SPARCS	Sustainable Positive and zero cARbon CommunitieS
T.	Task
VPP	Virtual power plant
WP	Work Package

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EXECUTIVE SUMMARY

SPARCS develops a new form of smart cities framework with the ultimate goal of achieving zero carbon emissions in European cities by 2050. A multi-disciplinary consortium of over 30 European partners has been formed to define strategic methodologies, actions and evaluation processes with the aim to transform European cities into citizen-centred, environmentally friendly smart cities.

The scope of Task 2.1 and the respective deliverable of this report, is the definition of a continuous monitoring and assessment process of the impact that will be achieved by the SPARCS interventions in the demo sites of Lighthouse's Cities, Espoo in Finland and Leipzig in Germany, as well as the support of the replication model for the SPARCS Fellow cities, Kifissia (Greece), Kladno (Czech Republic), Lviv (Ukraine), Maia (Portugal) and Reykjavik (Iceland).

In order to define the SPARCS Holistic Evaluation and Assessment Framework, there were seven main steps followed.

As a first step, an extensive review of **five prominent projects**, relevant to our scope, was performed. The outcome of this analysis was the **collection of more than 350 Key Performance Indicators (KPIs)** that have been used within smart city evaluation frameworks as well as the evaluation of four prominent methodologies regarding the process and impact evaluation.

Subsequently, an in-depth analysis on SPARCS objectives was carried out using two approaches.

- **A top-down approach** was based on the overarching objectives of SPARCS and gathered 29 relevant KPIs; 22 were taken from the pool of the analysed prominent projects, while the remaining seven were defined by the SPARCS team.
- **A bottom-up approach**, carried out by the cities' representatives and technical experts of SPARCS, was based on the planned SPARCS demo site actions and revealed a set of more than 100 additional -impact perspective- KPIs.

As a next step, the availability of the required data linked to the outlined KPIs provided to the Lighthouse Cities was checked, and several meetings took place among technical partners and LHCs' consortiums in order to finalise the impact KPIs list. Additionally, specific KPIs' factors and data related to individual interventions were discussed and the KPIs list was further enhanced with a set of intervention indicators.

In parallel there was a close collaboration with relevant partners for the definition of the replication indicators that are valid in SPARCS project in order to have a holistic framework that could cover the future -KPIs- needs of FCs in their implementation phase, in which tailored solutions from LHCs could be successfully replicated.

In order for KPIs to be meaningful and objectively comparable to each other we have devised a normalisation approach that allows data to be detached from the particularities and exogenous characteristics of cities and as such to be considered as a useful tool for city planners and stakeholders.

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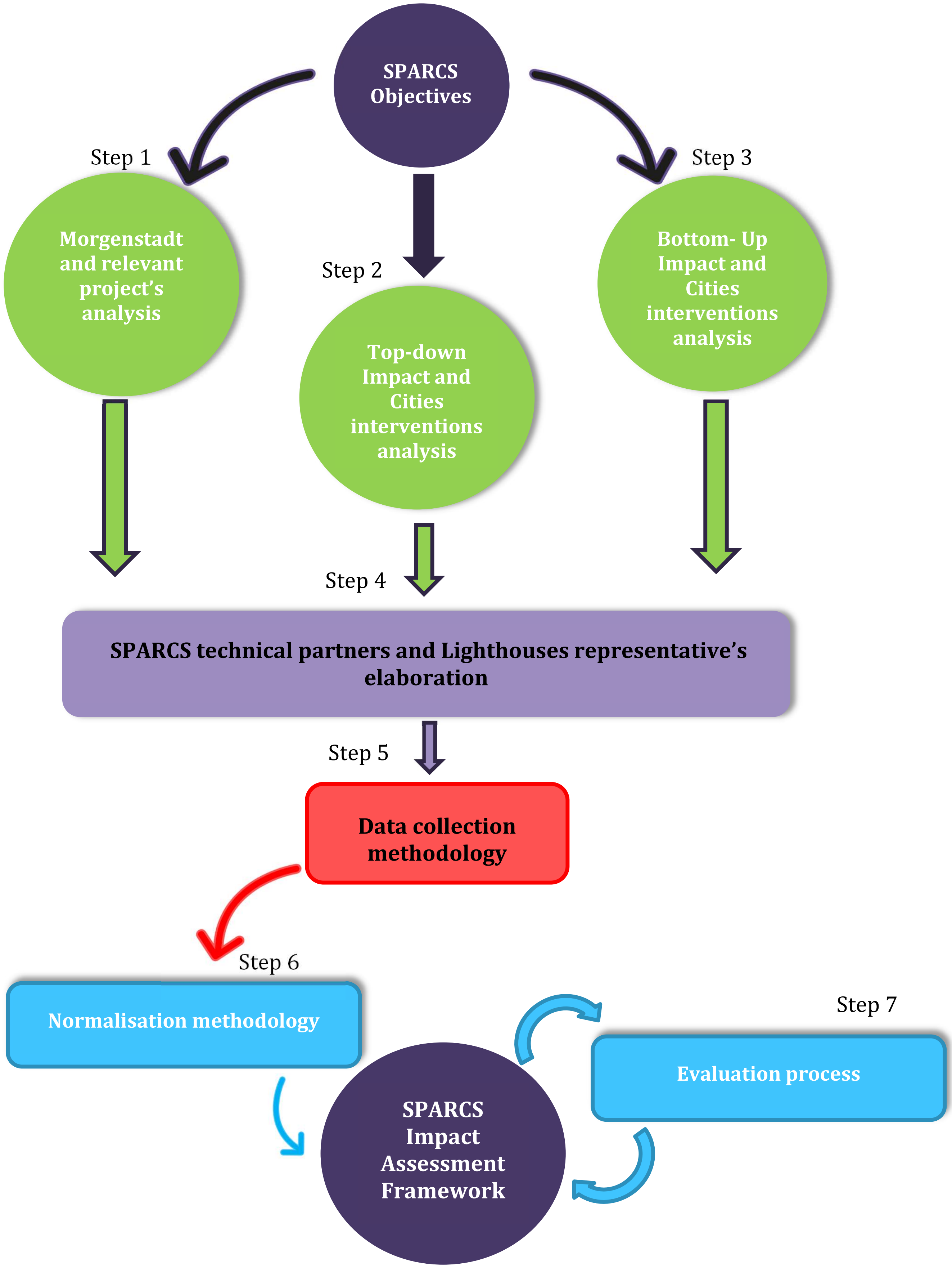

Figure 1: SPARCS Framework

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As a final step a process evaluation was proposed in order to assess the project's execution throughout its whole duration as well as to validate the soundness of the framework.

The report of this deliverable is organized in five chapters that are presented below:

Chapter 1 summarises the objectives of Task 2.1 introducing the purpose of the deliverable as well as the correlation with other tasks of SPARCS Work Packages.

Chapter 2 defines the criteria and the Key Performance Indicators (KPIs) as metrics of Smart City Evaluation frameworks. It further describes their importance in the evaluation process and presents the necessary criteria for an appropriate selection of the most relevant KPIs over a wide list of smart cities' related metrics. Moreover, analysis is conducted and an association is provided regarding the selection of KPIs in the different levels of implementation.

Chapter 3 has as a main target to present an overview of the H2020 projects related to SPARCS that were used as basis for the proposed assessment framework. The methodology applied in each of the most prominent H2020 Smart Cities projects together with the KPIs used in their framework, is extensively analyzed.

Chapter 4 presents the overall methodology that has been formulated for the SPARCS assessment framework, which emanated from an extensive review of past and parallel projects and passed through the prism of SPARCS objectives. A mapping of appropriate KPIs is conducted in relation to SPARCS targets. Moreover, the evaluation of the appropriateness and soundness of available KPIs for the needs of SPARCS project is presented.

Chapter 5 lays out the main conclusions of the holistic evaluation performed for the definition of the SPARCS assessment framework and summarises the main lessons learnt through the process of derivation. Moreover, suggestions are provided concerning the next steps that could be undertaken to enhance the framework along with a normalisation methodology approach.

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1. Introduction

The transition of passive, reactively changing processes and infrastructure of existing European cities towards more citizen-centric, environmentally-friendly Smart Cities comprises a high priority in the European's Commission agenda ("Marketplace of the European Innovation Partnership on Smart Cities and Communities," n.d.). The SPARCS project works towards an ambitious target; to gather learnings from all previous prominent Smart Cities related projects and formulate an informed, robust and novel methodology for assessing and abetting the Smart City transformation in the SPARCS cities.

This document focuses on the thorough analysis and critical review of relevant European projects and initiatives, towards proposing a novel evaluation framework to be used in the SPARCS project. The Morgenstadt framework is considered as a reference framework for integrated analysis in assessing the sustainable urban development of any city; it has been studied as the basis for the SPARCS impact assessment methodology as it encompasses learnings from a number of European Cities transformation processes and has evolved through its application in Lighthouse Cities.

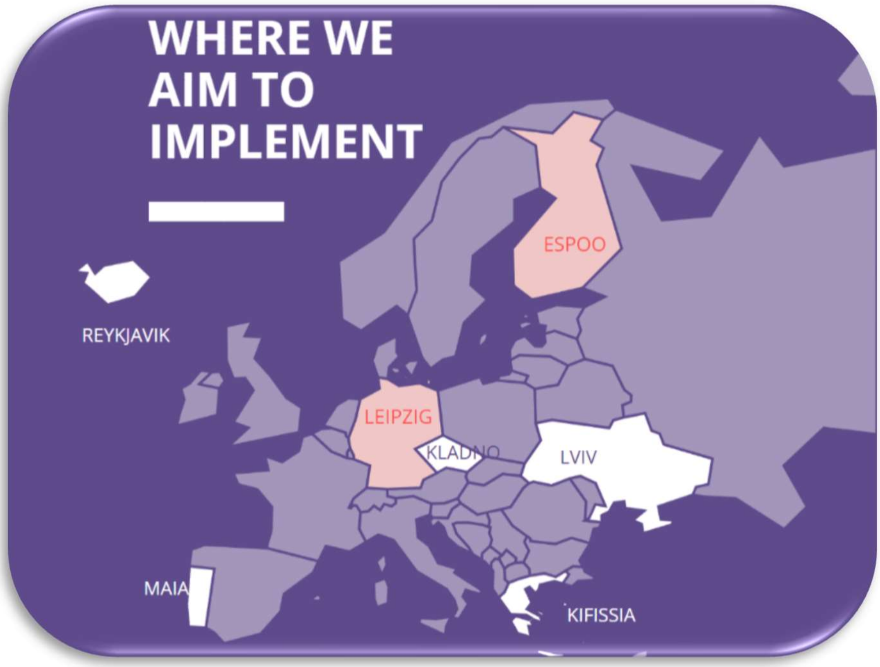

Figure 2: SPARCS cities

The use of metrics and particularly Key Performance Indicators (KPIs) becomes more and more necessary in monitoring the progress of activities and evaluating the achieved impact. In order to ensure completeness of our work, a detailed understanding of four additional prominent methodologies from relevant projects (CITYkeys[1]; SCIS[2]; CIVITAS[3],

[1] CITYkeys is a H2020 project that started in 2015: http://www.citykeys-project.eu/

[2] SCIS (Smart Cities Information Systems) is a knowledge platform: https://smartcities-infosystem.eu/

[3] Civitas is an initiative for sustainable transport that started in 2002: https://civitas.eu/

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Triangulum[4]) was achieved and resulted in the evaluation of the appropriateness and soundness of the KPIs these projects proposed in their Smart City projects, which is presented herewith.

The SPARCS project objectives have dictated the proposal of further KPIs; we have derived and present them in this document, in order to succeed in providing a holistic and robust qualitative and quantitative assessment of the impact achieved by the different interventions and technologies deployed in the demo sites from:

- an Energy perspective,
- an Economic perspective,
- a Social perspective
- a Technological perspective
- an Environmental perspective
- a Governance perspective
- a Mobility perspective and
- a Citizens' engagement perspective, in the SPARCS cities.

1.1 Purpose of the document

The main objective of Task 2.1 is to analyse, evaluate and define a robust and valid methodology for the holistic assessment of SPARCS interventions in Lighthouse Cities (LHCs) and Fellow Cities (FCs). The monitoring process ensures that the goals and the long-term strategy are reviewed on a regular basis, it measures and keeps track of their progress, and it reveals potential shortcomings and deviations related to the targets. The impact assessment of the project's interventions, against the established baselines, evaluates the replication potential of the proposed solutions at wider city scales. In this document, a number of distinct steps were taken as a methodological approach to achieve this objective.

Initially, an in-depth analysis of the SPARCS requirements, to understand its needs, was conducted. The analysis is divided into two parts; one is based on the general objectives of this innovation program and follows a top-down approach and the other one is based on specific actions to be implemented in cities and follows a bottom-up approach. The outcome is the indicators and data relevant to the realisation of the interventions, that must be measured by LHCs.

Thereafter, the Morgenstadt assessment framework was studied as the reference model for the definition of the SPARCS impact assessment methodology; this is due to the wide acceptance of this framework (*Morgenstadt City Challenge*, n.d.) as a multidisciplinary approach for the evaluation of sustainable urban development.

Recent initiatives and projects on smart cities including CIVITAS, SCIS, CITYkeys and Triangulum were studied rigorously, in order to define the basis of SPARCS assessment framework for the complete qualitative and quantitative assessment definition. The metrics used in each initiative were studied and categorized based on their relevance to SPARCS objectives.

[4] Triangulum is a H2020project stared in 2015: https://www.triangulum-project.eu/

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The set of metrics and standards related to smart city objectives from LHCs are used to formulate SPARCS's framework. The informed choice of appropriate metrics is critical in achieving accuracy, robustness, applicability and scalability of our proposed method. In SPARCS, indicators related to social, economic, energy and technology aspects are fundamental in assessing sustainability, efficiency, security and scalability for transforming European cities into smart cities. So, the collaboration with LHCs and technical partners was a critical part of the whole process for the definition of a holistic and accurate framework.

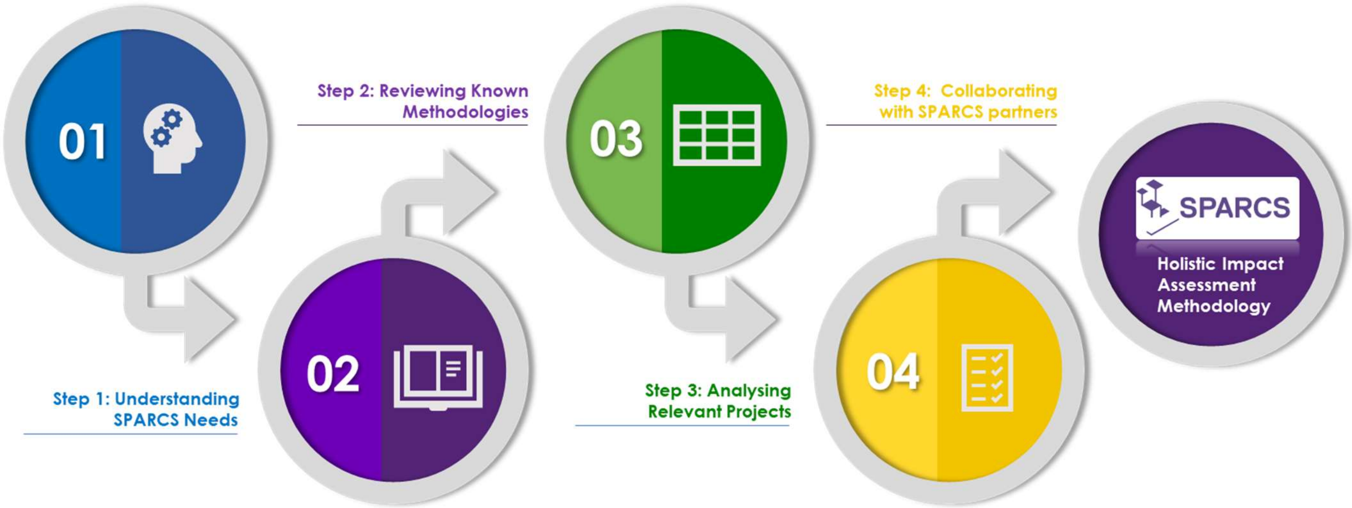

Figure 3: SPARCS' methodology action plan

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1.2 Relation with other tasks

Task 2.1 has strong relations with seven other tasks from four different WPs within SPARCS.

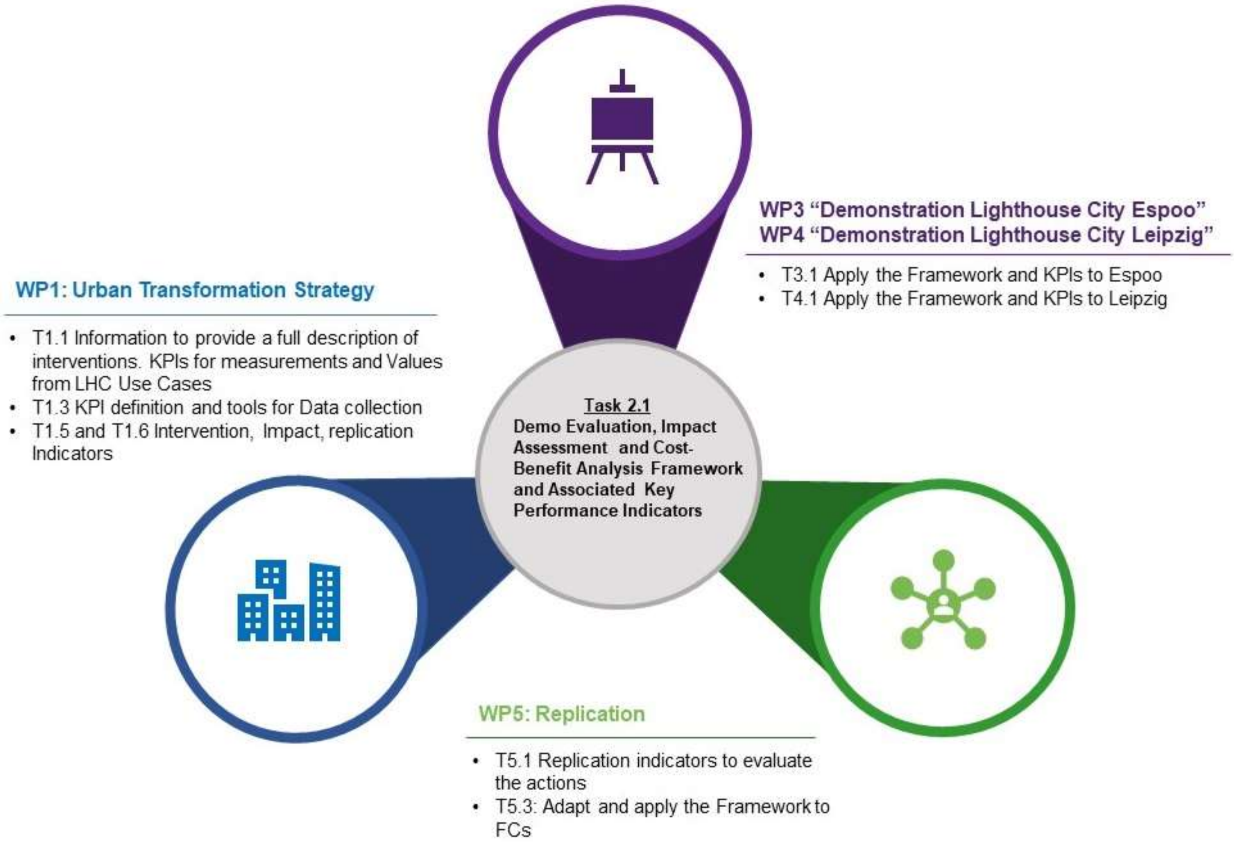

Figure 4: Relation of T2.1 with other tasks of the SPARCS Project

In WP1 "Urban Transformation Strategy", there is a direct link with four tasks:

- T1.1 developed a city diagnosis process allowing to accurately understand (qualitatively and quantitatively) the ground conditions of the LHCs in order to address current and forthcoming sustainability challenges. As part of the diagnosis process the task will focus on the preliminary data collection and analysis done in the present task. This evaluation framework will support the information collection process for the Use Cases from each of the LHCs, providing details about the impacts of the interventions.
- T1.3 has the objective of providing an appropriate visualization environment building up on the methodology developed in T2.1; this will allow any city to measure the performance of its Positive Energy Districts/Blocks, and, in the long term, to track its own progress in its urban transformation pathway and corresponding implementation process of the underlying measures to achieving the city vision.
- T1.5 settles a disruptive and customized business model as a horizontal synergic synthesis coming from several sources, especially from WPs and tasks related to the acceptance, acknowledgement, involvement of the stakeholders.

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- T1.6 targets to actively involve and empower citizens and relevant stakeholders in the process of conceiving developing and delivering the city vision, putting into practice the concepts of co-creation, co-development and co-implementation. Through that process customized KPIs presented in T2.1 will be used to evaluate the quality of the collaborative work and the impact of the solutions on the ground, assessing the feedback of the implemented strategies through solution-specific questionnaires.

In WP3 "Demonstration Lighthouse City Espoo" and WP4 "Demonstration Lighthouse City Leipzig" there is a connection with two tasks:

- T3.1 and T4.1 ensure the achievement of the objectives, the coordination and co-operation within Espoo and Leipzig demonstrations, with parallel work packages as well as other interest groups. The project management is carried out via a participative and proactive process by the local Coordination Teams which among other actions they will provide the necessary data for the calculation of the KPIs as well as the will validate and apply the KPIs derived from T2.1 in order to monitor the Lighthouses' project progress with SPARCS assessment framework.

In WP5 "Replication" there is a link with two tasks:

- T5.1 aimed at creating rich, expert-curated, neutral interoperable solution packages, based on the Use Cases from the Lighthouse Cities, focused on helping cities implement and replicate these solutions under context-specific circumstances. Replication indicators proposed in this deliverable will be used to evaluate the implemented actions.
- T5.3 provides an evidence base and in-depth understanding for key systems in the SPARCS Fellow Cities as a basis for the development of long-term visions, smart city strategies and the development of locally adapted interventions in the area of positive energy blocks. To this end Work Package leaders and partners will adapt and apply the joint assessment framework as lined out in T2.1 to each Fellow City.

2. Smart City Indicators: From Macro-Indicators to comprehensive Local-level KPIs

Espoo and Leipzig, the Lighthouse cities in the SPARCS project, aim to establish a strong presence at the front of the Smart City transition and transform into global lighthouse examples for other cities to follow. Innovative Smart City solutions planned, require a holistic monitoring and assessment framework, allowing for both immediate, and long-term impact evaluation. The extension of SPARCs solutions to wider city scales at the Lighthouse, Fellow cities and beyond, will be the test for evaluating their replication potential.

Indicators that are able to capture the key expected impacts across the demonstration activities offer the required information to perform a qualitative and quantitative analysis of the integrated solution into the city's infrastructure. They provide a way to effortlessly measure, comprehend and evaluate results and lead to more effective actions and informed decision making, by utilizing the insights provided. In a smart city context, the usage of indicators contributes to the evaluation of specific targets calibrating the progress toward sustainable development goals.

Yet, the identification of the appropriate indicators poses a huge challenge, since it requires a thorough analysis of the project's high-level targets along with the intervention and action specifics. Hence, the utilisation of best practices, in order to define the Key Performance Indicators serving as the basis of the monitoring and impact assessment Framework, is recommended.

In the following sections, Key Performance indicators will be introduced, along with proven methodologies to guide their optimum identification, which will be utilized during the definition of the SPARCS impact assessment methodology in Chapter 4. In addition, general consideration dealing with smart cities and their challenges will be analysed, providing a first overview of macroscopic indicators to be considered in this context. Finally, the SPARCS project implementation plans, with a first analysis of the demonstration actions and the corresponding assessment levels will be covered, demonstrating clearly the need to introduce low-level and comprehensive indicators, leading to valuable conclusions regarding impact achieved, effectiveness of actions and replicability potential in other contexts.

2.1 Definition of KPIs

Key Performance Indicators (KPIs) are specific measurements used to gauge performance and evaluate the effectiveness of a process. They originate from business management, where they are typically used to evaluate performance and facilitate the decision-making. They can help incorporate physical and social science knowledge into decision-making and they provide an early warning to prevent setbacks.

The definition of KPIs is complex and is often confused with other business metrics. The main difference is that KPIs are associated with a critical goal or a specific target that leads in accurate and measurable results. Each KPI is a metric but not every metric is a KPI; the same metric may be a KPI on one level but not on another. That means that KPIs are a dynamic concept that changes according to the circumstances and need to be redefined in each case.

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The explosion of data nowadays provide numerous metrics that often leads to countless indicators and this makes their definition and usability problematic. So, there are different ways for experts to properly approach the KPIs and have a limited resources evaluation of a project's actions. A very relevant and widespread approach is the adoption of SMART criteria, thus being, Specific, Measurable, Attainable, Relevant and Timely (Artley & Stroh, 2001).

In addition to the SMART approach, a guide to the correct set of KPIs can be developed, by identifying specific needs and outcomes associated with the interventions that are implemented. The following questions are asked in this regard and help optimize the selection of KPIs for smart city implementations (Artley & Stroh, 2001).

Are we doing things right?

It is the efficiency that indicates the degree to which the process produces the required output at minimum resource cost.

Are we doing the right things?

It is the effectiveness that indicates the degree to which the work product conforms to requirements. Helps to understand if the outcome is the desirable one.

Another way of defining KPI´s is based on CIVITAS framework (Rooijen, T. van, Nesterova, 2013), according to which each set of KPIs should be characterized by:

- 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 affect preferences assigned to other indicators of the evaluation model.

Generally, the indicators in a smart city context are divided into five types according to (Artley & Stroh, 2001):

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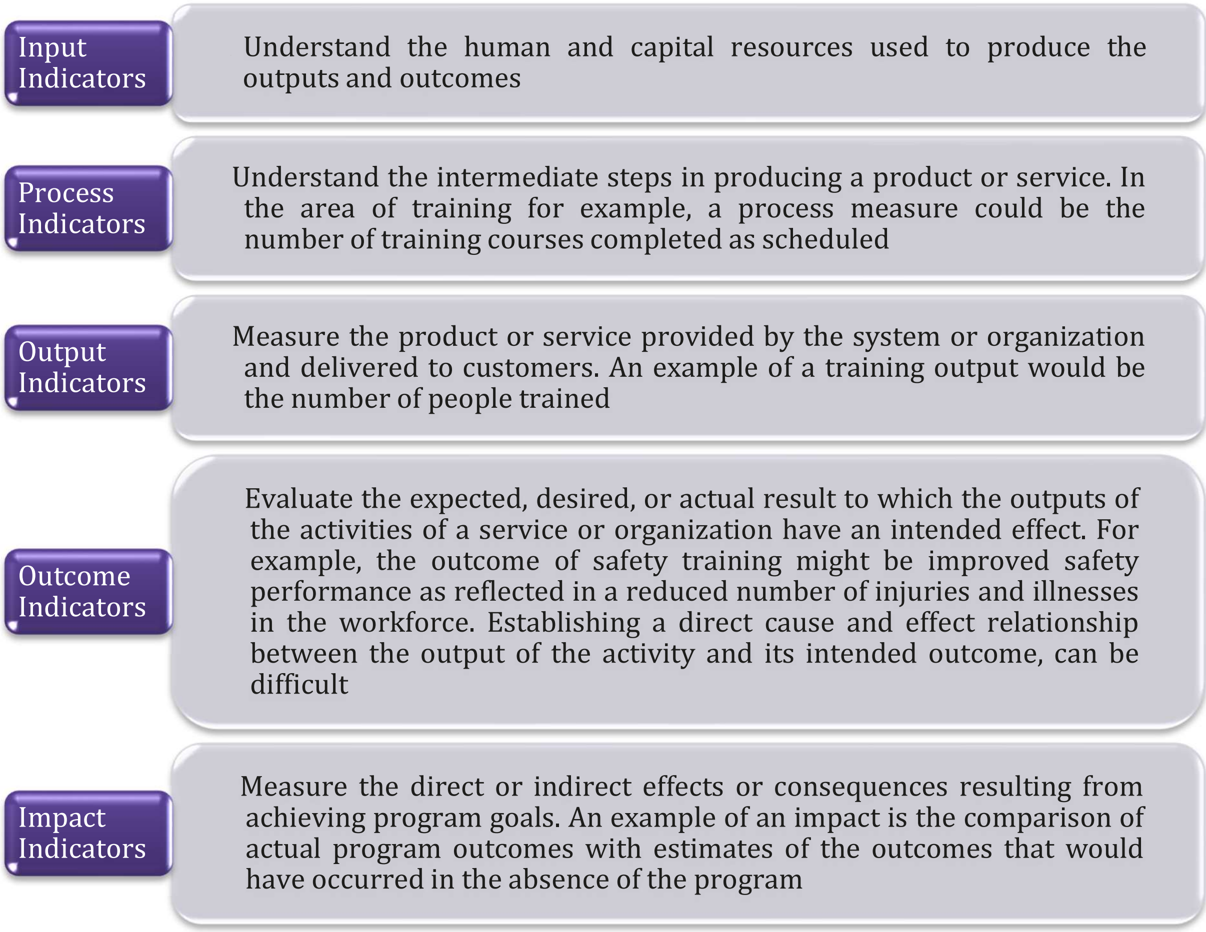

Figure 5: Types of indicators in a smart city context (Artley & Stroh, 2001)

Smart city indicators are categorised in different aggregation levels such as city level and project level; but depending on the needs of the project, the categorization can be more specific, including single building, set of buildings and neighbourhood /district. As there are different types of indicators, it is significant to focus on the "key" operative word that leads to instrumental measures for the assessment framework and helps to understand the current state of the cities and the desired level of performance that is planned to be achieved.

The aforementioned approaches that aim to the valid definition of the KPIs, are taken into consideration for the needs of SPARCS, focusing into the main targets of the project and the desirable impacts.

2.2 KPI considerations for smart cities

According to the United Nations (UN-DESA, 2018), 68% of world's population is projected to live in urban areas by the year 2050; cities therefore are anticipated to face new challenges in integrating sustainably further populace. Cities will be required to transform their infrastructures in a smarter, more efficient and resilient way so that sustainable development to be a part of their long-term strategy and a better quality of life to be provided to their citizens. The advantages of cities in net-zero transitions vary greatly

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from one city to another, but they all have considerable power to turn national ambition into practice(IEA, 2021) .

The European Commission ("Smart cities | European Commission," n.d.) defines smart city as "a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business". A smart city aims to improve urban life through more sustainable integrated solutions and addresses city-specific challenges from different policy areas such as energy, mobility and transport, and ICT.

In recent years, cities have adopted the smart city context as part of their development plan, realizing the need for a more interactive and responsible city administration. In order to evaluate their progress towards their sustainable goals it is necessary to use the appropriate indicators to measure their performance.

The definition of a methodology that can be adopted by any city to contribute to its transformation towards a smart city, is important and in line with the vision of the European Commission (Marijuan & Pargova, n.d.). The EU's green agenda for urban areas (Manville et al., 2014) promotes horizontal initiatives that develop common methods for the evaluation and monitoring of smart city communities. In these methods, the use of KPIs is needed to the areas where cities mostly have to measure their smart city performance, taking under consideration factors such as:

- **Energy Perspective**, with the usage of indicators covering for example the energy efficiency, the RES integration, CO2 emissions reduction, the air quality, the smart grid stability, etc.
- **Economic Perspective**, covering measurements for the energy costs reduction, revenue streams from market transactions, the energy network investment deferral, the business models viability, the return on equity as well as the incremental payback period, etc.
- **Social Perspective**, with indicators for the citizen engagement, the user acceptance, the comfort and air quality, number of new jobs created, etc. taken under consideration and
- **Technology Perspective**, with indicators for system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements being in focus.

Stepping in on existing and proven city strategies and assessment methodologies, while identifying the SPARCS project specificities and needs, will allow the rollout of an extensive monitoring and evaluation program, with associated Key Performance Indicators, for the holistic assessment of the project's interventions.

2.3 Specific KPI related considerations of SPARCS

The SPARCS project emphasizes in achieving carbon-free urban communities by implementing and integrating actions in various levels such as e-mobility (e-mobility hub), technologies for the energy positivity of buildings and districts (ICT solutions), smart heat, flexible grid management (Virtual power plant), energy storage (regenerative geothermal system, seasonal phase change material thermal storage and big batteries), along with citizen's engagement, smart business models and city governance. In addition, in order to sustainably transform and develop the urban environments of European cities and beyond, the reduction of consumption and the transition to renewable energy production as well as the management of energy in a more environmentally friendly way is promoted by replicating in the five Fellow Cities a part of the solutions applied in the two Lighthouse Cities.

Within SPARCS, a number of 44 innovative interventions consisting of various actions, are applied in the two Lighthouse Cities and focusing on the interconnection between buildings and districts, advanced management and efficiency of RES-generated energy, surplus energy storage, transition to electromobility, development of business models and in Positive Energy Districts urban planning.

These planned interventions are divided into five demonstration actions and three levels of assessment. The categories, that also are visible in Figure 6, are:

Demonstration actions

- Positive energy transformation
- Electrical mobility
- Digital Integration
- New Economy
- Urban innovation ecosystem

Levels of assessment

- Building block-level interventions (BL)
- District level interventions (DL)
- Macro-level interventions (ML)

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Figure 6: Demonstration actions in LHCs of SPARCS

The demonstration actions of SPARCS are further allocated as follows and their breakdown is visualized in Figure 7:

- 18 actions are focused on building interventions for upgrading buildings into interconnected user inclusive energy generators
- 12 actions are focused on advanced energy management at district level
- 13 actions are focused on advanced energy management at building level,
- 8 actions are focused on energy storages,
- 19 actions are focused on EVs
- 9 actions are focused on Energy Efficiency integration into the district energy infrastructure
- 13 actions are focused on creation of virtual positive energy communities
- 6 actions are focused on city platforms data collection
- 13 actions are focused on business/ financing and governance models, including the creation of innovation ecosystem hubs
- 7 actions are focused on regulations

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- 7 actions are focused on Positive Energy District urban planning

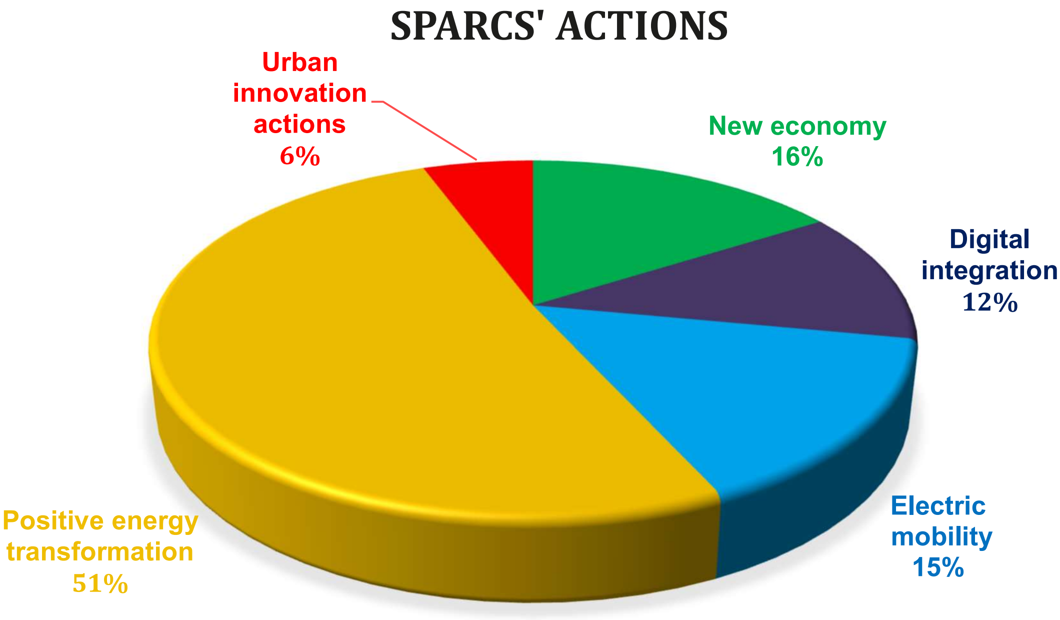

Figure 7: Allocation of SPARCS Smart Cities Demonstration Actions

The **Building Block Level** interventions aim to provide buildings with innovative technologies transforming them to energy infrastructures capable to integrate renewable energy systems, energy storage and electric vehicles. At the same time, existing energy management schemes of buildings are upgraded with new operational functionalities where the energy consumers are producers as well; the main purposes of business and financial models in this level are the participation in multiple alternative markets through the ownership of assets and the increased citizen involvement.

The **District Level** interventions aim to the optimization of energy use considering behavioural patterns, among the surplus of produced energy in buildings, that are heading towards the district energy infrastructures such as Virtual Power plant and local energy storage. Bidirectional EV-stations are emplaced among the district and thus, e-cars can potentially be used for peak load control. Meanwhile user centric platforms are deployed, and virtual energy communities are established providing a peer-to- peer energy exchange and advanced control of the energy flow.

The **Macro Level** interventions aim to leverage the demonstrated solutions in building block and district levels in respect of city planning. Regulatory and financial aspects are planned and implemented, while investment projects and actions ensure the successful replication of the demos deployed in a city level. The participation of citizens in urban planning will form the basis for the upcoming innovative ecosystem and will lead to the carbon free city vision.

Analysing the interventions at three levels in both Lighthouse cities, the necessary data for the selection and definition of the KPIs used in our proposed assessment framework emerges. The data needed is linked with various urban sectors including energy, mobility,

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economy etc. The implemented actions as well as the monitoring and evaluation process refer to macro-level, district level and building block level. Whether cities have this data available is very important in the context of the present evaluation framework, as it comprises a way to compare the state of progress before and after the implementations. So, in order to ensure that the necessary data is available and subsequently the final KPIs list is successful in regards of comprehensiveness, several meetings took place among technical partners and LHCs consortia during the duration of this task in order to build a common understanding on the purpose of each indicator in the context of the planned city actions and interventions.

Further examination of the interventions, identifying impact areas of specific actions and levels of assessment, will guide the process of building the holistic monitor and assessment framework in Chapter 4.

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3. REVIEW OF KNOWN ASSESSMENT METHODOLOGIES AND KEY PERFORMANCE INDICATORS FOR CITIES

In order to monitor and evaluate the impacts from the implemented actions, SPARCS proposes a methodology framework which can serve as the basis for any smart city evaluation process. For the creation of this framework, relevant H2020 projects and initiatives are analysed to achieve a complete understanding of the existing state of the art and address any possible weaknesses from previous smart city evaluation framework efforts. Among existing urban indicator frameworks, five complementary approaches are deeply analysed in this chapter due to their relevance to SPARCS.

The Morgenstadt framework, is a multidisciplinary research initiative involving a number of European cities. It defines, categorizes and forms a KPI list, identifies Key action fields and impact factors providing information for the current status of the cities and future potential actions

CITYkeys, defined a holistic indicator framework. CITYkeys aimed at facilitating and enabling stakeholders in projects or cities to learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework

SCIS, defined a common platform for data collection and monitoring. SCIS is a knowledge platform to exchange data, experience and know-how and to collaborate on the creation of smart cities. Focusing on energy, mobility & transport and ICT, SCIS showcases solutions in the fields of energy-efficiency in buildings, energy system integration, sustainable energy solutions on district level, smart cities and communities and strategic sustainable urban planning

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CIVITAS, is a H2020 city transport initiative aiming at analysing transport metrics. The Civitas initiative is a network for cities that aims to achieve a significant change in the modal split towards sustainable, efficient and cleaner transport modes, by introducing ambitious measures and policies. Proposes KPIs concerning mostly the Transportation sector

TRIANGULUM, is a recently completed SCC1 lighthouse project, based as well on the Morgenstadt framework,, that presented a process of evaluation and monitoring which adopted a seven-stage impact assessment methodology supporting replication by ensuring compatibility with other generic smart city assessment frameworks

3.1 Analysis of Morgenstadt assessment methodology

Morgenstadt City Insights (M:CI) is a network that consist of partners coming from different actions fields like research institutes, industry and municipalities. It was founded in 2012 by Fraunhofer IAO together with the Morgenstadt Innovation Network to fulfil the necessity to answer a superficially simple question; what helps cities to become more sustainable? In order to provide an answer to this question the network studied six cities (Tokyo, Berlin, New York, Singapore, Freiburg and Copenhagen), that were considered to be leading examples worldwide in terms of sustainable development, and analysed their approach towards Smart City transformation. According to World Commission on Environment and Development (WCED, 1987) *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."; a* definition that served as a guide vision for the start-up alliance between industry, politics, city administrations, and research. One of the main goals of the Morgenstadt network is the creation of a structure so that a generic analysis of the sustainable development of any concerned city could be possible. Thus, the following core aspects of sustainability were defined for the purposes of M:CI and were the basis for the final report:

- reduction of emissions,
- improvement of human health,
- increase of resilience of physical infrastructures and social networks with regard to adverse events (of catastrophic dimension) as well as developments of radical change,
- decrease of the societal and physical vulnerabilities of urban societies with regard to multiple man-made and naturally caused hazards,
- improvement of health of urban ecosystems,

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- increase of social well-being and life expectancy,
- creation of stable, long-term-oriented economic structures,
- to improve the security of supply,
- reduction of social inequalities,
- reduction of energy consumption per capita,
- handling of raw materials with respect to the environment.

In the first phase of the M:CI which lasted 18 months, an on-site research with a multidisciplinary approach was conducted in the aforementioned six cities, with over 50 participating researchers from partner institutes. During that period, strategic contacts were established in the selected cities so that direct insight into important fields became possible while interviews and workshops with relevant stakeholders facilitated the sharing of significant expertise for cities strategies, aims and best practices. The researchers focused on over than 100 best practices categorized in eight urban sectors; energy, security, mobility, building, water, productions and logistics, governance and internet and communications technologies (ICT). Thus, they had the opportunity to study the critical factors that make cities more effective in use of energy and resources while simultaneously to create the conditions that maximize the quality of living allocated to their residents.

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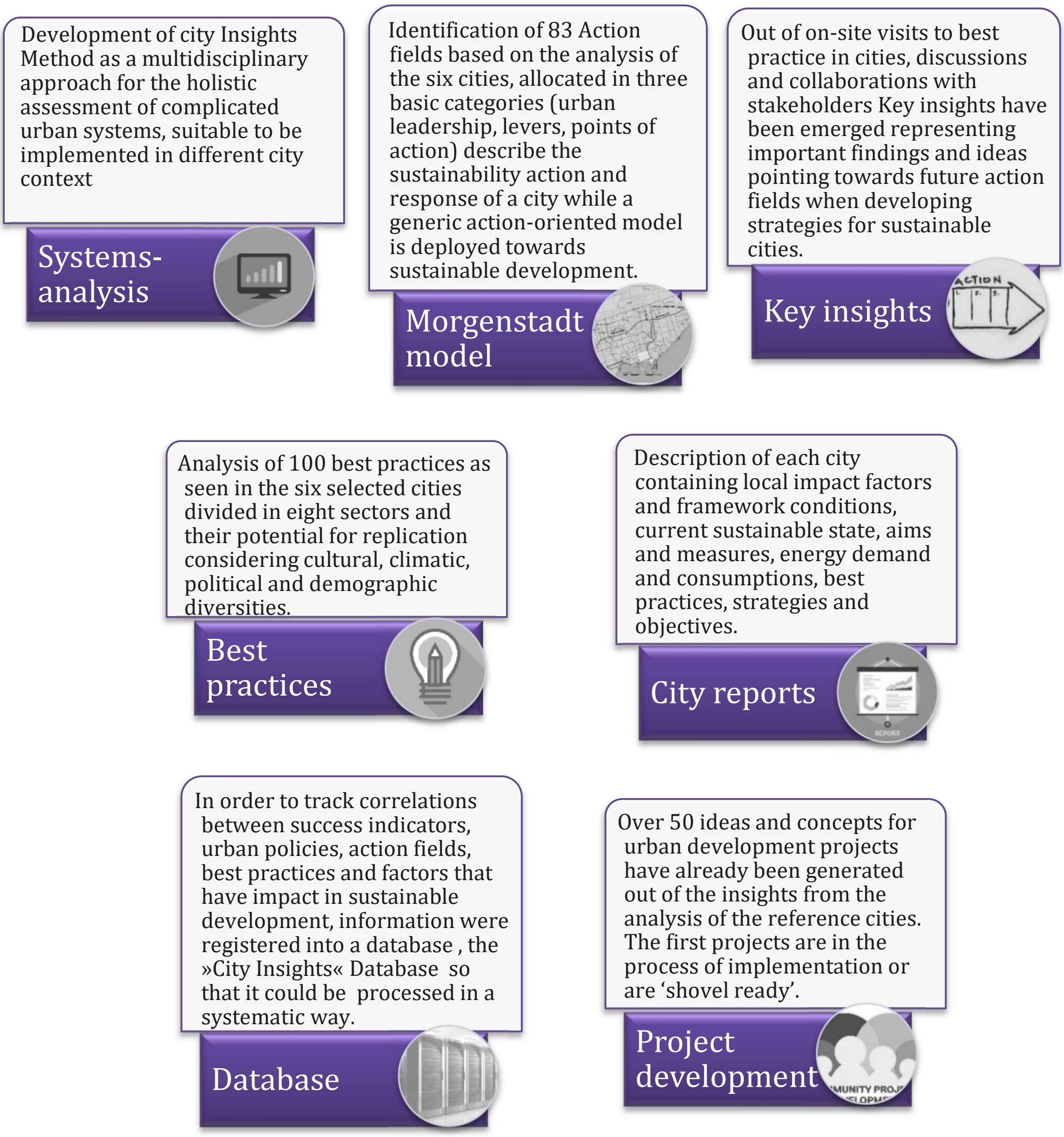

Figure 8: Morgenstadt's phase I results

A concept of the triple-bottom-line (social, economic, and ecologic aspects), served as the guiding framework for analysis and classification, whereas a main thesis of Morgenstadt was formed indicating that single solutions tend to support only one (or a few) aspect(s) of sustainability, while the right combination of solutions at city level can increase overall sustainability.

The results of phase I were generated with regard to the seven categories that presented in Figure 8.

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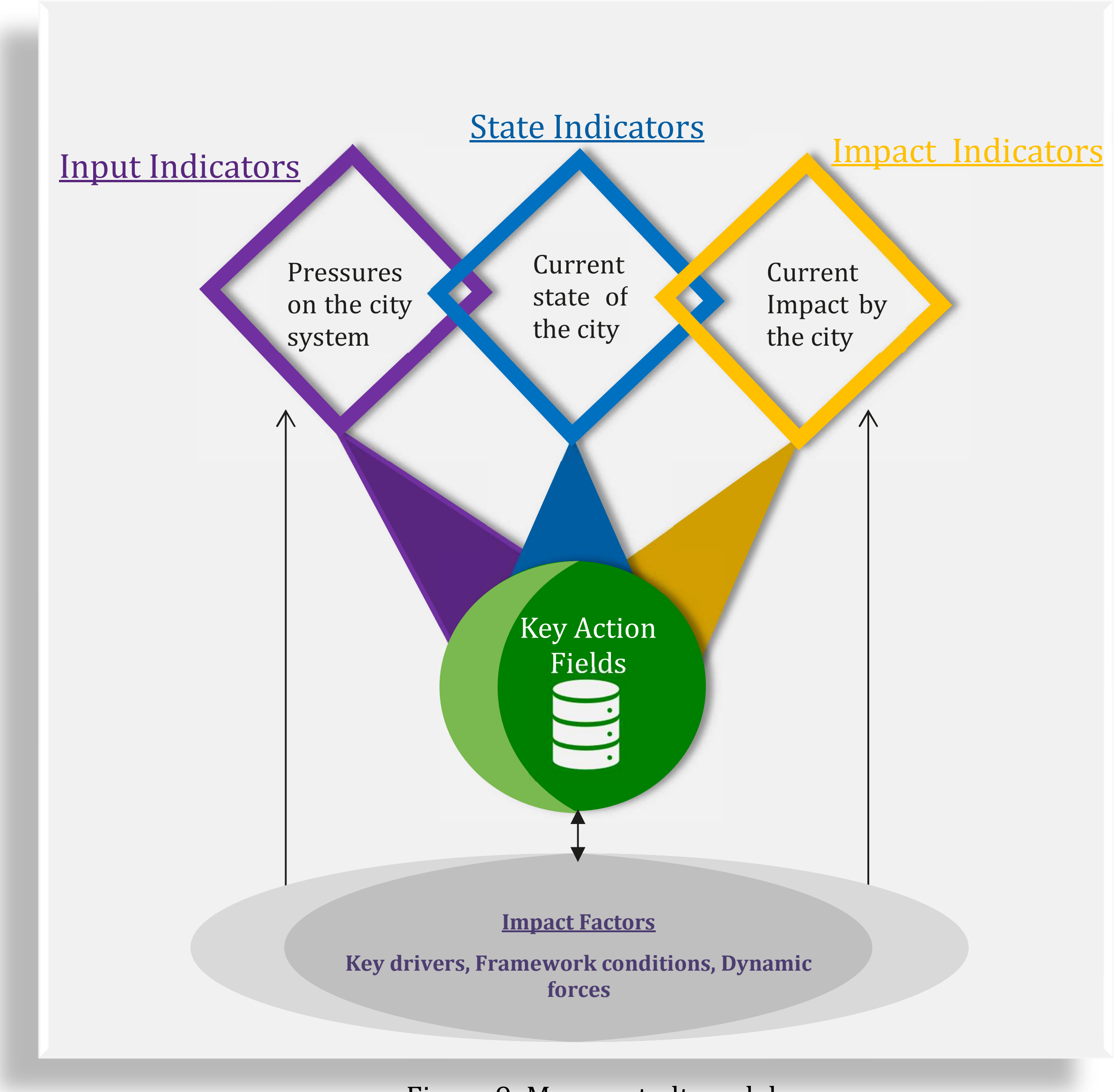

Figure 9: Morgenstadt model

After analysing the six selected cities, solutions and concepts were generated and implemented for urban sustainable development. It became clear that in order to create sustainable systems, focus on functionality, easy access and high efficiency of use are necessary. Thus, the aim of phase I was to identify a state-of-art of sustainable urban system and to create a starting point for the research and development of innovations in future urban systems. In order to assess the status quo on sustainable development of any given city the Morgenstadt assessment framework defines KPIs, identifies Key action fields and Impact factors; each one of these three level of analysis, provides different information for the city.

More than 300 indicators from eight different sectors have been defined in order to measure the city's performance and the social, economic and environmental status as well. The availability of data only for certain cities and the definition of indicators differently in cities led to a revision of the Morgenstadt indicators and produced a total of 107 urban indicators classified in three categories, that determine the current situation

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and can be used generally. The classification of the KPIs followed the SMART criteria for the definition of indicators as mentioned in chapter two. The three indicator categories are:

a) **Pressure Indicators** - indicate which pressures exist on the city system from the different sectors and from the social, economic and environmental point of view.

b) **State Indicators** - describe the current state of the environment, the society, the economy and the different technology sectors within the city.

c) **Impact Indicators** - show which impact the city system has on the environment, the society, the economy and long-term resilience.

According to (Radecki et al, 2013) key action fields provide the priorities and strategies that cities address towards sustainability. They are the actions and the responses that cities present and through their assessment, cities' profiles are created so that a dynamic comparison of deployed measures and interventions can be analysed. The researchers, after comparing and integrating all action fields from the six selected cities, structured a generic action model that is used as the foundational basis for the Morgenstadt framework and is visualized in Figure 9, consisted of 83 fields divided in three basic categories as follows in Table 1.

Table 1: Morgenstadt framework indicators structure

Pressure Indicators	State indicators	Impact indicators
Political Pressures (3)	Environmental Quality and Energy (3)	Environmental impact from combustion processes (2)
Pressures on Resilience (5)	State of Energy System (5)	Mobility impact (1)
Environmental Pressures (3)	State of Security System (1)	Impact from built environment (5)
Pressures from the energy system (2)	State of Transport System (16)	Impacts from economic system (4)
Socio-economic pressures (4)	Production & Resources (2)	
Pressures on Resilience (5)	State of Water System (10)	
Pressures from Transport & Production (4)	State of governance System (7)	
Pressures from water system (2)	Buildings (1)	
Pressures from built environment (7)	Economics (4)	
	Social (4)	
	ICT (5)	

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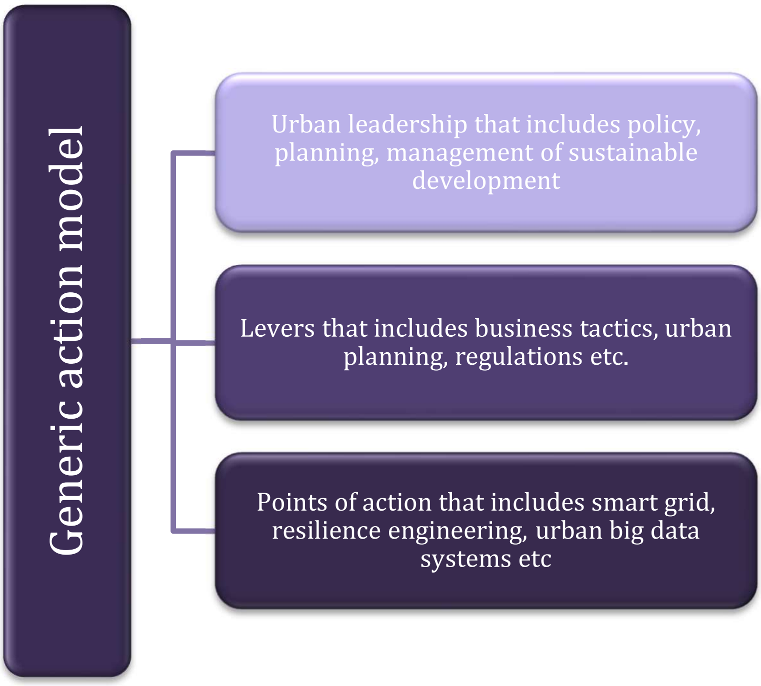

Figure 10: Morgenstadt's generic action model

Moreover, the researchers conducted a cross-impact analysis of key action fields in order to highlight the interconnectedness of actions in cities and to present clusters of action fields that address sustainable urban development with coherent strategies.

The identification of Impact factors is the third level of analysis within the Morgenstadt model and uncovers the reasons that progress in a specific urban system happens, or doesn't happen. It shows the external pressures, the dynamics and the social, political and financial junctures that are present within a city and have an impact on the decision progress. In addition, the identification of impact factors helps to understand why certain issues are very important for some cities and meaningless in others.

3.2 Review of CITYkeys indicators for smart city projects and smart cities

The CITYkeys project started in 2015 within the H2020 Smart Cities Framework Initiative ("CITYKeys - Home," n.d.) as a horizontal activity to support all the smart city lighthouse projects. Its main goal is to define common indicators for evaluation of the lighthouse projects. Furthermore, its purpose was to support the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the continuous growth and densification of cities and the Union's 20/20/20 energy and climate targets. Therefore, CITYkeys aimed to facilitate and enable stakeholders in projects or cities to learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework (Bosch et al., 2017).

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In the context of CITYkeys, a smart city that efficiently mobilizes and uses available resources including, but not limited to social and cultural capital, financial capital, natural resources, information and technology. The indicators for smart cities focus on monitoring the evolution of a city towards an even smarter city. The time component - "development over the years"- is an important feature. The city indicators may be used to show to what extent overall policy goals have been reached, or are within reach (Bosch et al., 2017).

According to CITYkeys a smart city project is a project that:

- has a significant impact in supporting a city to become a smart city along the four axes of sustainability mentioned above
- actively engages citizens and other stakeholders
- uses innovative approaches
- is integrated, combining multiple sectors.

CITYkeys, in order to evaluate the smart city projects, has analysed the contribution of interventions towards the city targets and objectives, with regard to sustainable development. Thus, it focused mainly on impact indicators that are applicable to all types of contexts, through which cross-sectoral solutions could be easily evaluated. The indicator framework did not put focus on isolated, sector specific solutions and so the occurrence of double indicators was minimized. Moreover, a subdivision of the evaluation framework in impact categories allowed more flexibility than a subdivision in driving forces, actors or sectors. It is worth mentioning that impact indicators motivate cities to

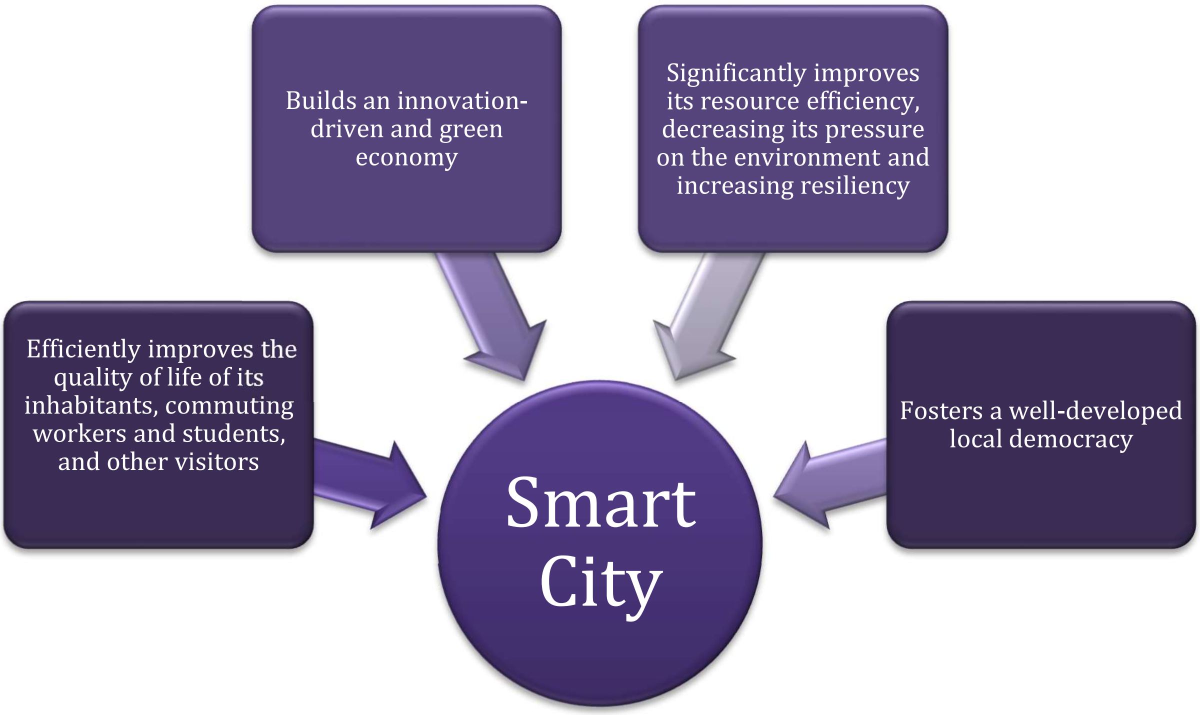

Figure 11: Smart City in the context of CITYkeys

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find their own solutions for achieving a certain target or performance, instead of prescribing the measures that have to be implemented, at risk that standardized solutions might be outdated within a few years.

As already reported, indicators and KPI's should express as precisely as possible to what extent an aim, a goal or a standard has been reached or even surpassed. Data that are not linked to specific goals of projects are commonly used as quantitative information in general, but are not suited for the evaluation process

The CITYkeys assessment method and the indicators are used to evaluate the success of smart city projects and the possibility to replicate the successful projects in other contexts. In the development of the indicator systems for urban development there is a wide acceptance in the triple bottom line of social sustainability (People), environmental sustainability (Planet) and economic sustainability (Prosperity). According to (Bosch et al., 2017) the definitions of these three approaches are illustrated in the following Figure 12. Apart from the three aforementioned categories, there are two other categories used to evaluate smart cities and are visualized in the following Figure 13; Governance, assessing the importance of a city's internal and external factors, and the Propagation for assessing the up-scaling potential of the implementations.

Definition of People

The People side of sustainability refers to the long-term attractiveness of cities for a wide range of inhabitants and users. Aspects include quality of living for everyone, especially for the most vulnerable citizens, education, health care, social inclusion, etc

Definition of Planet

The "Planet" aspect of sustainability in the first place refers to contributing to a 'cleaner' city with a higher resource efficiency and biodiversity and being better adapted to impacts of future climate change such as (in Europe) increased flooding risk, more frequent heat waves and droughts. Included in this theme are thus less consumption of fossil fuels and more generation and use of renewable energy, lower waste generation and less air pollution. As our planet extends beyond the city boundary, impacts of urban consumption in other parts of the world, are explicitly included

Definition of Prosperity

Contributing to a prosperous and equal society and supporting affordable, green and smart solutions. On the project level Prosperity stands for economic viability and the value of a smart city project for a neighbourhood, for its users and its stakeholders, and even its indirect economic effect on other entities. Economic or financial indicators often need to be accompanied with an in-depth description of the business case, as single indicators are insufficient to evaluate e.g. the distribution of costs and investments

Figure 12: CITYkeys' three bottom line approach

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Definition of Governance

Contributes to a successful process of project implementation as well as to a city with an efficient administration and a well-developed local democracy, thereby engaging citizens proactively in innovative ways

Definition of Propagation

Improving the replicability and scalability of smart city project solutions at wider city scale. Propagation is about the potential for dissemination to other locations, other contexts and other cities. Propagation (both transfer to other locations and countries, and up-scaling from small single projects) depends in the first place on inherent characteristics of the (innovative) smart city project. In practice propagation also depends on external factors such as market conditions.

Figure 13: CITYkeys' additional approaches

The CITYkeys assessment framework consists of 101 indicators for project performance assessment and additionally indicators for cities' smart city performance assessment. The main themes and sub-themes of CITYkeys indicators for lighthouse project performance assessment are presented in the following Table 2 (Bosch et al., 2017).

Table 2 : CITYkeys indicator framework structure

People	Planet	Prosperity	Governance	Propagation
•Health (3) •Safety (4) •Access to other services (7) •Education (3) •Diversity & social cohesion (3) •Quality of housing and the build environment (6)	•Energy & mitigation (7) •Materials, water and land (10) •Climate resilience (1) •Pollution &waste (4) •Ecosystem (2)	•Employment (2) •Equity (2) •Green economy (3) •Economic performance (5) •Innovation (95) •Attractiveness &competitiveness (1)	•Organisation (6) •Community involvements (5) •Multi-level governance (2)	•Scalability (10) •Replicability (8)

3.3 Review of SCIS key performance indicators

SCIS is the other H2020 horizontal activity, aiming to support all the smart city lighthouse projects with the development of a common platform for monitoring data collection and analysis. The SCIS is a knowledge platform to exchange data, experience and know-how and to collaborate on the creation of smart cities, providing a high quality of life for its citizens in a clean, energy efficient and climate friendly urban environment. SCIS encompasses data, experience and stories collected from completed, ongoing and future projects. With focus on energy, mobility & transport and ICT, SCIS showcases solutions in the fields of energy-efficiency in buildings, energy system integration, sustainable energy

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solutions on district level, smart cities and communities, and strategic sustainable urban planning ("About the Smart Cities Information System (SCIS) | Smartcities Information System," n.d.)

The overall goal of SCIS is to foster replication; SCIS therefore analyses project results and experiences to:

1. Establish best practices which will enable project developers and cities to learn and replicate.

2. Identify barriers and point out lessons learned, with the purpose of finding better solutions for technology implementations and policy development.

3. Provide recommendations to policy makers and policy actions needed to address market gaps.

The activities of the project are presented in the following Figure 14.

SCIS focuses on the development of indicators to measure technical and economic aspects of energy related measures and contributes to a general Smart Cities KPIs framework through the definition of indicators at the energy level. The implementation of SCIS indicators has been done through alignment with other initiatives and already existing indicators. Different frameworks for KPIs have been analysed and compared. 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 the indicator list is to allow for comparability between projects.

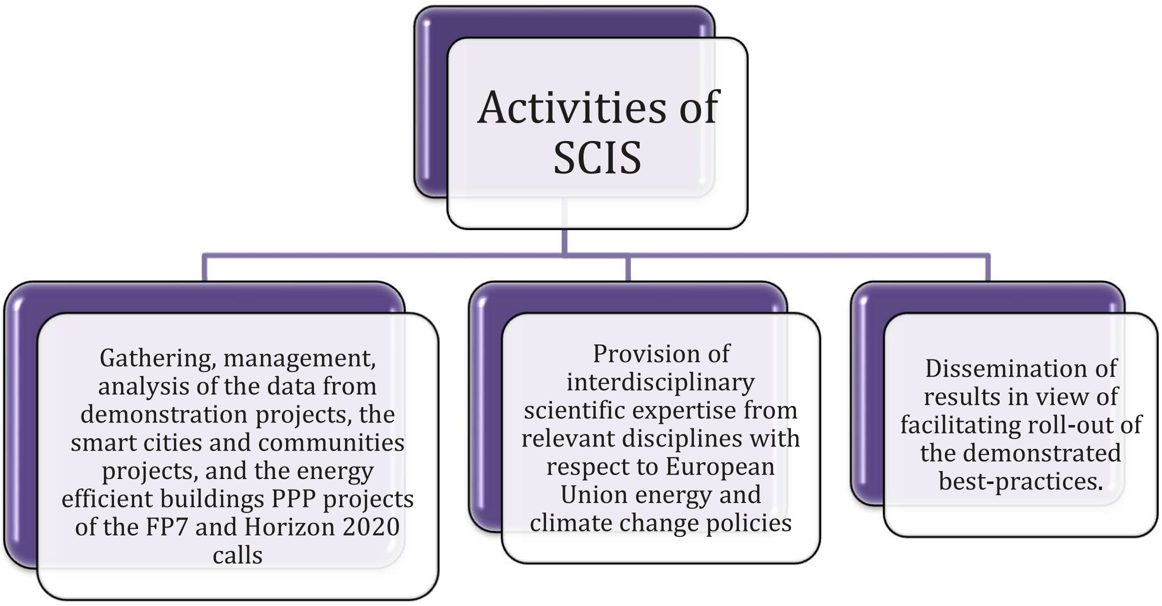

Figure 14: SCIS activities

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In Figure 15 below are presented the KPIs in SCIS that are divided in two cluster (Marijuán, Etminan, & Möller, 2018) :

- Core KPIs: those KPIs identified as the most relevant for SCIS and should be implemented by the projects in the scope of SCIS. Some of these KPIs may not apply to all projects, being its use beyond the scope

- Supporting KPIs: those KPIs relevant for SCIS, being its use recommended.

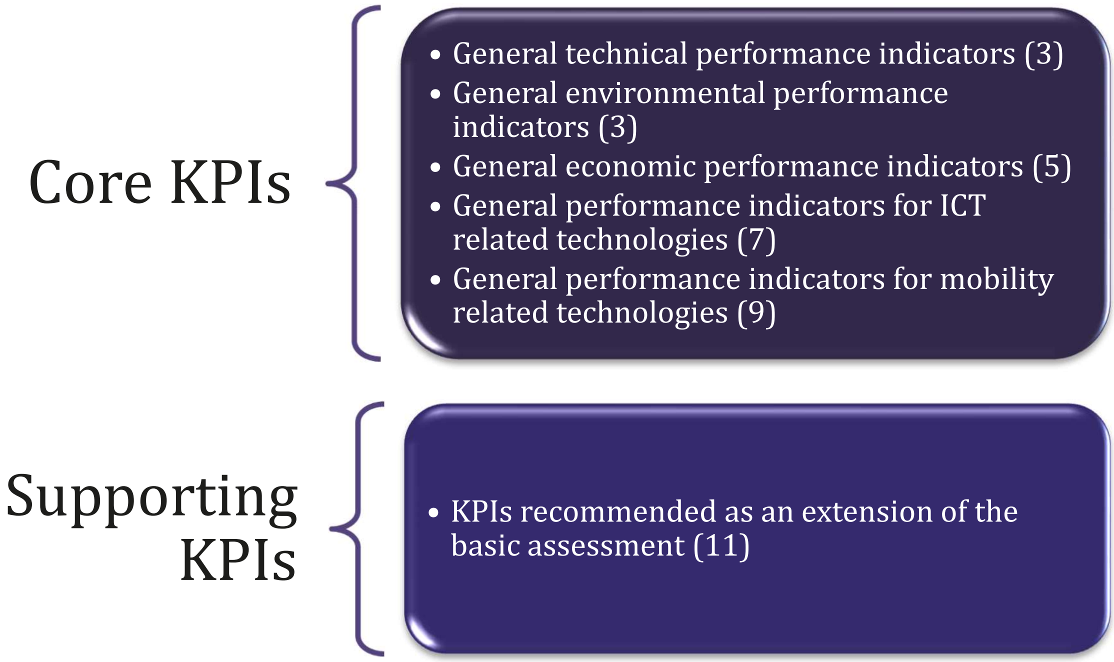

Figure 15: SCIS KPIs list

3.4 Review of CIVITAS process and impact evaluation framework

The Civitas initiative is a network for cities that aims to achieve a significant change in the modal split towards sustainable, efficient and cleaner transport modes, by introducing ambitious measures and policies. It was launched by the European Commission in 2002 and since then has supported over 80 cities implementing more than 800 innovative transport measures like clean fuels and cars, collective passenger transport and less car depended lifestyles. According to the CIVITAS concept, a measure is a mobility related action, implemented by city's managers or by government's stakeholders.

An important part of the CIVITAS initiative is the evaluation, a tool to understand what works, what doesn't and the reasons for this. It is important to consolidate the nature and extend of the impacts derived from the measures applied.

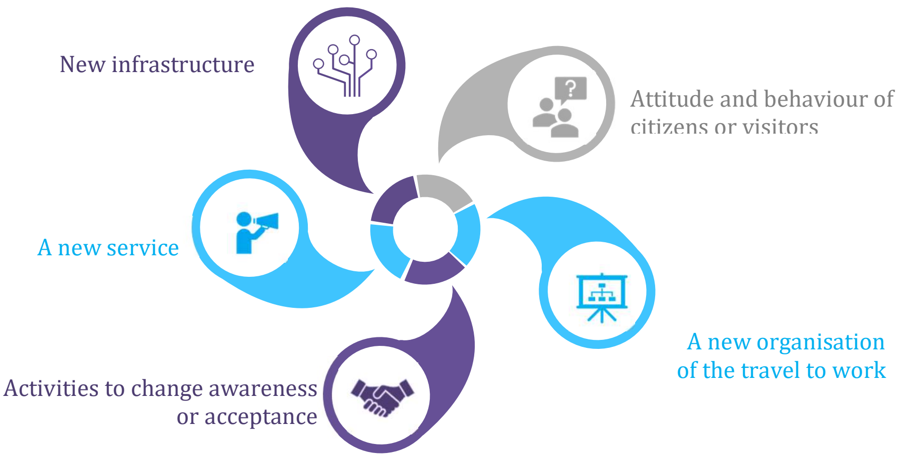

Figure 16: Civitas measures

In the latest issue of CIVITAS (Rooijen, T. van, Nesterova, n.d.) the evaluation task is divided into process evaluation and impact evaluation. It involves a number of people and projects with the most important being the Project Evaluation Manager (PEM), the Local Evaluation Manager (LEM), the Measure Leaders (ML) and the Site Coordinators (SC).

Impact evaluation and process evaluation are performed by the Local Evaluation Manager and the Measure Leader with the support of the Project Evaluation Manager and the Site Coordinator.

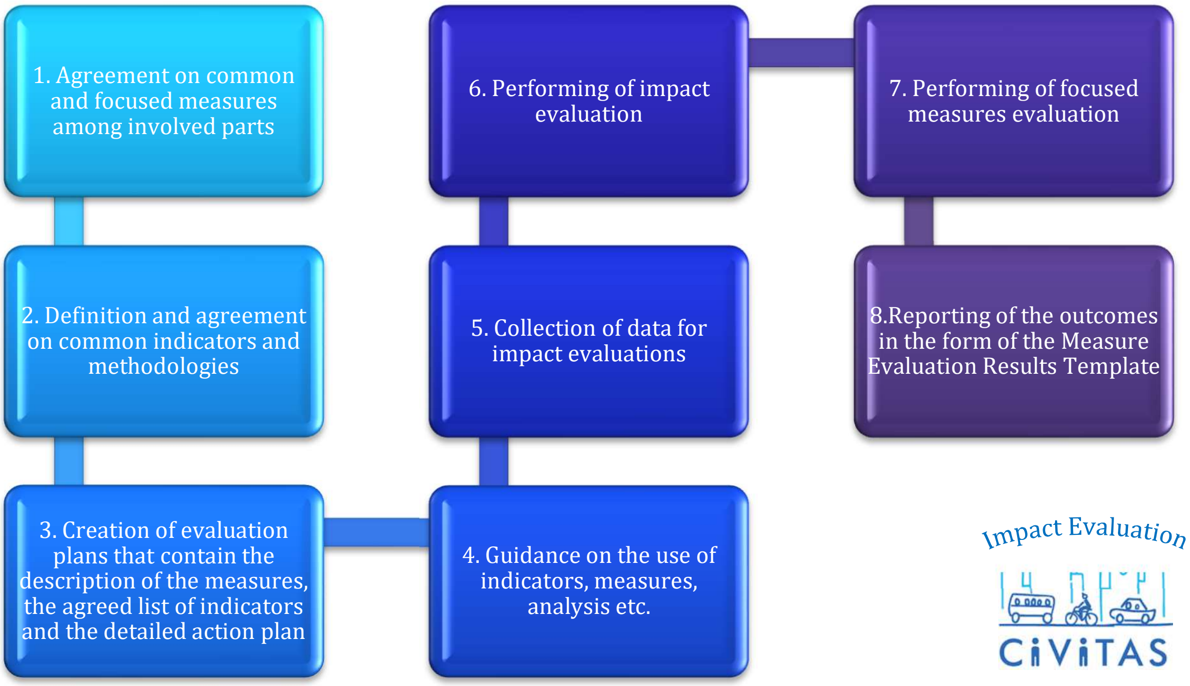

Figure 17: CIVITAS' impact evaluation

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The impact evaluation includes the evaluation of a wide range of technical, social, economic and other impacts of the measures resulted from the implementation by the cities and consists of the following steps. Both, impact evaluation and focused measures, are based on the "before and after" comparisons that are necessary to asset subsequent changes deriving from CIVITAS implementations and describe the added value cities gained from this initiative. In order to provide such continent comparisons, the "before", "after" and "Business as Usual" situations make available a common structure for the conduction of surveys and other measurements needed.

Process evaluation involves the evaluation of the processes of preparation, implementation and operation of measures, including the roles of information, communication and participation. The main goal of the process evaluation procedure is to develop new findings about factors of success, and strategies to overcome possible barriers during the implementation phase by analyses of all relevant information (Rooijen, T. van, Nesterova, 2013).

The process evaluation consists of the steps that are illustrated in Figure 18.

3.5 Review of Triangulum impact assessment methodology

The Triangulum project was a H2020 EU funded project (2015-2020), with the objective to demonstrate, disseminate and replicate innovation, urban solutions and a thorough replication framework for EU's future smart cities. Manchester (UK), Eindhoven (NL) and Stavanger (NO) constitute Triangulum's "Lighthouse" cities, serving as testbeds for the development and exploitation of innovative smart solutions concentrating on energy, sustainable mobility, ICT and commercial opportunities.

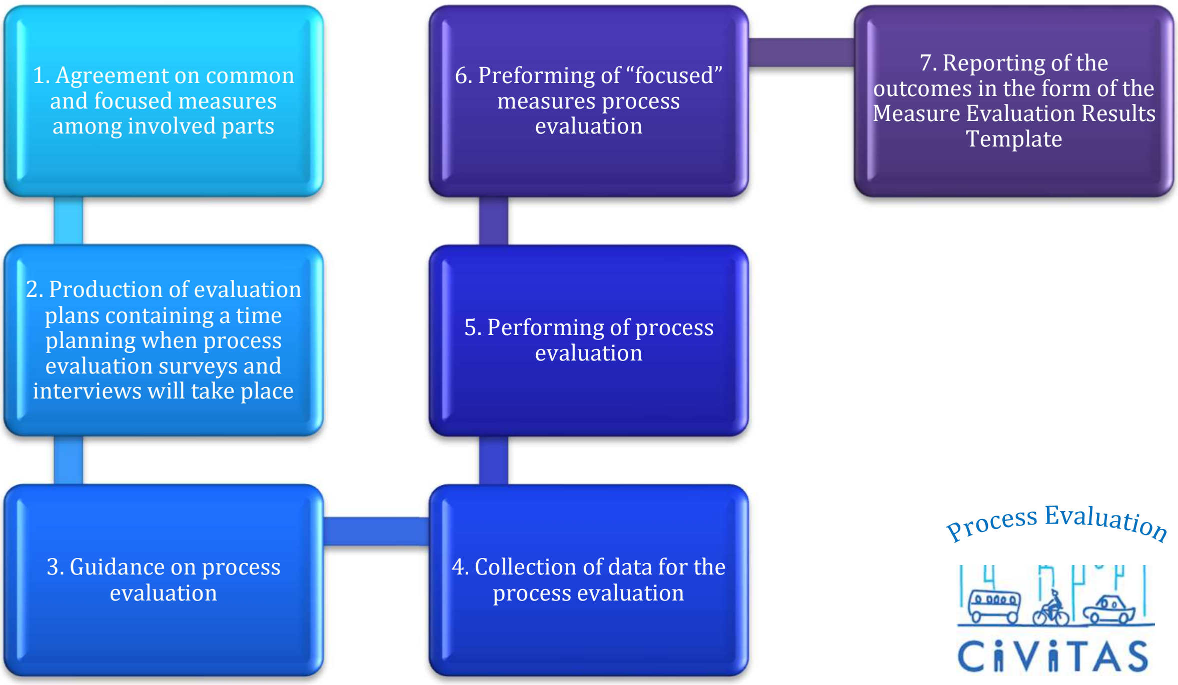

Figure 18: CIVITAS' process evaluation

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The project was carried out by an interdisciplinary consortium of 22 partners formed by industry, research stakeholders and municipalities. Triangulum's mission was to develop and implement smart solutions and strategies to improve the efficiency of commerce and governance and decrease greenhouse gas emissions in the Lighthouse cities and replicate these outcomes in the "Follower" cities of Leipzig (D), Prague (CZ) and Sabadell (ES) as well as in the "Observer" city of Tianjin (CHN).

Triangulum adopted a seven-stage impact assessment methodology towards the development of adequate indicators and the calculation of replication impacts. It was designed to ensure compatibility with other generic smart city assessment frameworks, such as CITYkeys and SCIS. Triangulum's methodology for selecting adequate indicators concentrated on impact assessment rather than developing KPIs for the buildings and or cities in which the modules are implemented. The developed impacts and indicators aimed to indicate the effectiveness of each module by comparing values at the project's baseline with those after Triangulum's completion.

As mentioned previously, Triangulum's methodology consists of seven stages which are detailed below, along with their corresponding activities.

1. ***Review of existing literature and frameworks*;** during this stage, a thorough desk study of key publications on sustainability and smart city evaluation frameworks and metrics is undertaken, to identify adequate impact indicators capturing Triangulum's impacts and determine the approach to be followed for data collection and monitoring during the project's implementation.
2. ***Identify and document expected outcomes;*** during this stage the city task groups responsible for delivering Triangulum's modules, are engaged (through participation in group meetings, workshops, semi-structured interviews, etc.), towards identifying the scope and expected outcomes of each module. In each Lighthouse city, a responsible partner is tasked with the development of the impact indicators and associated reports for the modules of each local partner.
3. ***Co-produce and document impacts, indicators and datasets***; utilizing the expected module outcomes and upon the literature review, a set of impact indicators are proposed including quantitative units, which are then refined upon review and collaborative input and comments from the task group.
4. ***Align and verify impacts, indicators and metrics***; this stage consists of aligning the proposed impact indicators for each module with known smart city indicator frameworks (e.g. CITYKeys and SCIS), with other relevant indicators across ICT energy domains, mobility activities across the three cities and with replication metrics. The aligned impacts, indicators and metrics are verified by the task groups through their feedback.
5. ***Preparation for impact calculation***; this stage consists of a) the baseline data collection, b) the description of the methodology to be followed for calculating impacts and c) identification of any datasets deemed useful for impact calculation. These three distinct activities are carried out through continuous engagement of the data owners in workshops and interviews, as well as by task groups completing a data intake form formally specifying the indicators and methodology to be followed for calculating them.
6. ***Storage of data to be used in impact calculation***; during this stage the necessary datasets (provided by the stakeholders and the data intake forms) for the impact

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calculation are imported into an open data platform/data hub, offering dynamic assessment and monitoring.

7. ***Impact calculation***; during this last stage, supported by the cloud data hub and depending on the data and metadata provided by the task group delivering the module, the quantitative values for each impact indicators are calculated.

The seven stages of Triangulum's approach are illustrated in Figure 19. The methodology followed by Triangulum regarding the identification of Impact indicators and mapping of data, was based initially on the preliminary expected impacts and indicators identified from the Lighthouse and Follower cities; these were categorized into the five impact domains of mobility, user engagement, socio-economic/financial, energy and ICT deployment. The next steps of the work consisted of a two-stage review of the expected impacts, to identify what cities require to measure, as well as allow a direct comparison between cities and domains, and highlight the replication potential of successful smart city technologies.

During the first stage, all the preliminary expected impacts and indicators were cross-referenced with the Lighthouse cities proposals, and the project as a whole, in order to identify the follow aspects:

- If the use of a metric was not indicated
- If the use of a metric was implied
- If the use of the metric was necessitated
- If the metric was not applicable to the city and/or project.

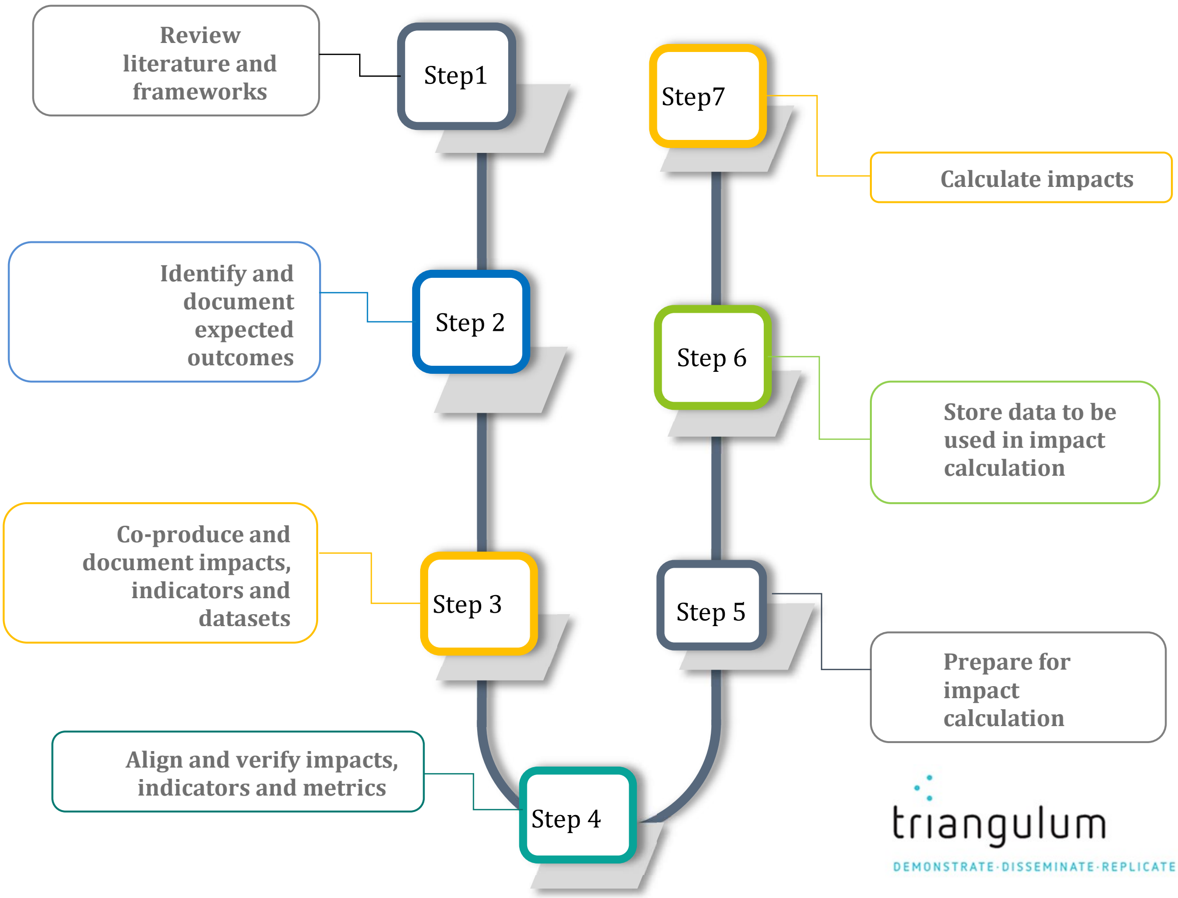

Figure 19: Triangulum's' seven steps methodology

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As an outcome of this work, an impact mapping table was created, enabling cross-linking of the cities and their achievements. During the second stage, the initial impact mapping table was presented to the Lighthouse cities to validate it, enabling also cities to update their commitments in view of other's cities obligations. As an outcome of this two-stage validation, an updated impact mapping table was generated underlining possible areas for comparison and learning between the Lighthouse cities.

3.6 Summary

This chapter analysed the monitoring and evaluation frameworks of prominent programs in the Smart Cities domain. We evaluated all methodologies and detailed the steps and benefits of each framework.

Following the analysis performed in the context of this chapter, it is evident that the structure and the process of the Morgenstadt framework, matches with the planned activities of the SPARCS project, allowing an in-depth insight into the status of the city, emphasising on local characteristics, and proposing practices that promote its smart features. The potential of the Morgenstadt framework, serving as a multidisciplinary approach for analysing complex urban systems and deriving applied, locally adapted smart city strategies and intervention roadmaps, will be fully demonstrated when applied in the fellow cities. This will happen by supporting the targeted "Packaged Solutions" creation that present an excellent foundation for the identification of the indicators for the impact assessment methodology, based on the identified city needs and knowledge gaps, as well as the pool of Key Performance Indicators that will be defined in this deliverable, split into pressure, state and impact areas.

Additionally, in order to have a holistic assessment of the deployed actions towards sustainable development and carbon-free communities, the analysis of initiatives and projects under the EU's Horizon 2020 umbrella is very important, providing additional KPIs and methodologies that can enhance the SPARCS framework, turning it into a complete impact assessment methodology, in order to successfully cover all implementation activities of the project.

In the table 3 below, an overview of the KPIs available in the Morgenstadt, SCIS, CITYkeys, CIVITAS, and Triangulum frameworks is presented. It allows a straightforward verification of their characteristics, including the number of indicators for each framework, the type of indicators, the assessment scale they are applied and the related impact categories.

In the next chapter, relevant parameters will be taken under consideration, identifying a stepwise approach to define the SPARCS Holistic Impact Assessment Methodology and the related Key Performance Indicators.

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Table 3: KPIs overview from relevant projects

	Morgenstadt	SCIS	CITYkeys	CIVITAS	Triangulum
Number of indicators	107	38	101	30	79
Type of indicators	Pressure, State, Impact	Core and Supporting impact	Impact	Process, Impact	Impact
Assessment scale	City	City, District, Building	City	City	City, District, Building
Impact categories covered	Energy, Mobility, ICT, Economy/Governance, Urban resilience, Emission excess, Innovation Leadership, Budget allocation	Technical, Environmental, Economic, ICT, Mobility	People, Planet, Prosperity, Governance, Propagation	Global Environment, Quality of life, Economic success, Mobility system performance	Energy, Transport, Socioeconomic, Citizen engagement, ICT

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4. SPARCS IMPACT ASSESSMENT METHODOLOGY

The user-driven and demand-oriented smart energy solutions, integrated into cities' infrastructures, innovative governance and citizens' inclusion actions, offer operational means for the cities' transition to a low-carbon and resource efficient economy. The seven SPARCS cities are committed to the common goal for achieving a sustainable, carbon neutral urban environment by 2050 at the latest, defining ambitious target outcomes, and monitoring progress towards these targets. SPARCS 100+ demonstration actions are strategically aligned to maximise the impacts towards these targets.

To define the SPARCS Holistic Impact Assessment Methodology and the related Key Performance Indicators, a seven-step approach is introduced, as shown in Figure 20.

As **step 1**, the methodology introduces the detailed analysis of the "Morgenstadt assessment framework" as well as the evaluation of 4 Smart City projects related methodologies. This step, which is already covered in Chapter 3, serves as a basis for the subsequent actions, providing guidance, best practices and lessons learned from similar endeavours.

The methodology, in **step 2**, adopts a Top-down approach to identify the main list of KPIs, drilling into the core of the SPARCS project as a Smart City initiative, which lies on the interventions and the impact that the planned actions will deliver. This step is analysed in section 4.1 below.

In **step 3**, which will be examined in section 4.2, a complementing Bottom-up method is followed, working with the city stakeholders to co-produce and enhance the list of KPIs, by analysing in detail all planned city interventions and identifying the resultant impacts.

Step 4 of the methodology, elaborates on the required assessment of the final list of indicators that will be used for the needs of the SPARCS project, from the SPARCS technical partners as well as from the City representatives of Leipzig and Espoo, in order to enhance or modify it as required, clarify open points and build a common understanding on the purpose of each indicator in the context of the planned city actions. Details of this step are part of section 4.3.

In section 4.4, with a complete set of KPIs available, a detailed data requirements analysis to calculate the indicators is performed, followed by a verification of the availability of that data with the city partners, consisting the **step 5** of the methodology.

The following step, namely the normalisation methodology in **step 6,** deals with the introduction of a tool for the assessment of the KPIS, towards the objective evaluation of the SPARCS interventions and the easy cross-city adoption. This step is captured in section 4.5.

Finally, in section 4.6 and under **step 7,** the SPARCS process evaluation approach and its corresponding activities are introduced, allowing a complete impact assessment verification, regarding efficiency and effectiveness of the achieved results.

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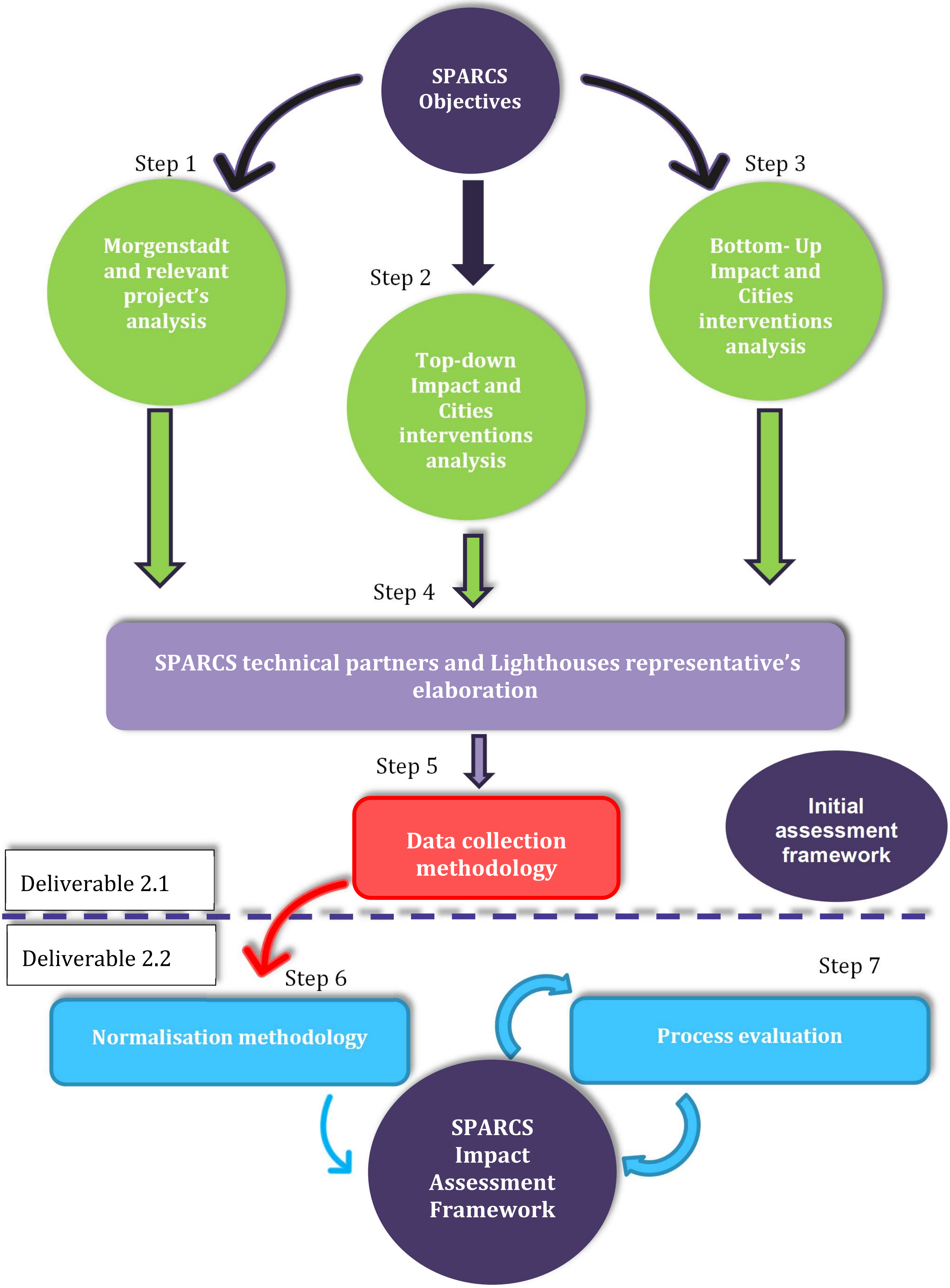

Figure 20: SPARCS seven steps Holistic Impact Assessment Methodology

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4.1 SPARCS Top-down Impact Analysis and initial KPI definition

The target of SPARCS is to develop a methodological approach allowing cities to have an integrated strategy at their disposal that paves the way to effective transformation in their urban ecosystems. Upon the successful realization of the decarbonisation targets of the lighthouse cities, with the deployment of tailor-made interventions, addressing their needs, requirements and ambitions, the key targets are:

(i) the increased integration of renewable energy in the generation process,

(ii) an optimized excess heat management method,

(iii) the optimisation of the local energy systems in presence of distributed renewables, storage, demand side management and e-mobility energy resources,

(iv) an improved energy performance of buildings and districts through human-centric building control optimization, advanced retrofitting and optimization of district-wide network operation,

(v) and the reduction of GHG emissions and improvement of local air quality and urban well-being.

These key targets are captured in the project's contract via general impacts and eleven supplementary impacts, planned to be evaluated in the Lighthouse and Fellow cities participating in the project, as listed in the table 4 below.

Since analysing the SPARCS impacts is the equivalent of identifying the key strategic objectives the project is trying to gauge, a top-down analysis and the introduction of KPIs, as specific measurements to turn the determination of achieved impacts into quantifiable targets, is required. In the following table 4 and by following the SMART criteria introduced in Chapter 2.1, Key Performance Indicators are listed, based on the analysis performed. It should be noted here that the KPIs referring to the increase / decrease of a measurement are a comparison with the current situation which means that the baseline is the situation before the implementation of the planned interventions.

Table 4: Top – Down analysis' KPIs

Impacts	Impact Description	Key Performance Indicators
General impacts	Return of Investments, Payback Time, Debt Service Coverage Ratio, Carbon emission reduction, RES share, Energy savings	- ROI - Payback time - Debt Service Coverage Ratio - Total electricity demand reduction - Total heating demand reduction - Reduction of CO_2-eq emissions - Share of RES increase

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Impact 1	SPARCS fosters meeting Global and EU climate mitigation and adaptation goals and national and/or local energy, air quality and climate targets, as relevant	- Reduction of CO_2-eq emissions - Air quality
Impact 2	SPARCS increases significantly the share of renewable energy, excess heat recovery, appropriate storage solutions and their integration into the energy system; and reduces greenhouse gas emissions	- Share of RES increase - Excess Heat recovery ratio - Increase of integrated systems share - Energy Storage Increase
Impact 3	SPARCS leads the way towards wide scale roll out of Positive Energy Districts (PED)	- Decrease of energy import share
Impact 4	SPARCS significantly improves energy efficiency, district level optimized self-consumption, and reduced curtailment by demonstrating Positive Energy Blocks, going well beyond current building regulations	- Increase of Citizens participation in market - Peak load (electricity) reduction - Peak load (heating) reduction - Self -consumption rate Increase - Onsite Energy Ratio (OER)
Impact 5	SPARCS increases the uptake of E-mobility solutions	- EV car sharing rate increase - Increase of EVs share in local transportation - Transport behaviour - Increase of EV (smart) charging points - Utilization of charging stations
Impact 6	SPARCS improves air quality	- Air quality
Impact 7	SPARCS maximizes the replicability potential	- Replication strategy
Impact 8	SPARCS contribution to the improvement of innovation capacity and integration of new knowledge	- Annual number of new patents
Impact 9	SPARCS will trigger the creation of new market opportunities, strengthening the competitiveness and economic growth	- Job creation
Impact 10	Increase citizens quality of life, health and well-being	- Increase citizens quality of life health and well-being
Impact 11	SPARCS contribution to the European policies and supports the development of standards	- Number of contributions to European Standardization Organizations

As analysed in chapter 2.3, interventions and corresponding foreseen impacts can be transversal among the different levels, in order to deploy solutions at building levels that enable technical functionalities, services, data collection, and behavioural changes at higher levels. **Building block level** (BL) interventions and **District level** (DL) interventions are complemented with **Macro level** (ML) interventions which support the smooth deployment of actions at both levels from city planning, regulatory and financing aspects and set the replication frame for rolling out a wide deployment of the demonstrated solutions. However, in some cases, due to the nature of the planned interventions BL and DL are consider as the same.

In the following table 5, the initial 29 key performance indicators are listed, as derived from the impact analysis performed, accompanied by originating impact and the planned assessment level.

Table 5: KPIs derived from Impact Analysis

#	KPIs	Impacts	Level
1	Reduction of CO_2-eq emissions	General Impacts, Impact 1, Impact 6	Macro/District/BL
2	Air quality	Impact 1, Impact 6	Macro /District/BL
3	Share of RES increase	General Impacts, Impact 2	Macro /District/BL
4	Excess Heat recovery ratio	Impact 2	Macro /District/BL
5	Increase of integrated systems	Impact 2	Macro /District/BL
6	Decrease of energy import share	Impact 3	District
7	Total energy demand reduction	General Impacts	Macro /District/BL
8	Total heating demand reduction	General Impacts	Macro /District/BL
9	Increase of Citizens participation in market	Impact 4	District/BL
10	Self-consumption rate increase	Impact 4	District/BL
11	EV car sharing rate increase	Impact 5	Macro /District
12	Increase of EVs share in local transportation	Impact 5	Macro /District/BL
13	Transport behaviour	Impact 5	Macro /District/BL
14	Increase of EV (smart) charging points	Impact 5	Macro /District/BL
15	Utilization of charging stations	Impact 5	District/BL
16	Energy Storage Increase	Impact 2	District/BL
17	Peak load (electricity) reduction	Impact 4	District/BL
18	Peak load (heating) reduction	Impact 4	District/BL
19	Onsite Energy Ratio (OER)	Impact 4	District/BL
20	Total generation curtailment	Impact 4	District/BL
21	Utilization of charging stations	Impact 5	Macro /District
22	Replication strategy	Impact 7	City
23	Annual number of new patents	Impact 8	Macro
24	Job creation	Impact 9	Macro /District
25	Increase citizens quality of life, health and well-being	Impact 10	Macro /District/BL

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26	Number of contributions to European Standardization Organizations	Impact 11	Macro
27	Return of Investments	Overall Impact	Macro /District
28	Payback Period	Overall Impact	Macro /District
29	Debt Service Coverage Ratio	Overall Impact	Macro /District

4.2 SPARCS Bottom-up and Technical interventions analysis

The analysis of the general impact targets of SPARCS is the first step towards understanding the needs of the SPARCS project. To complement the KPIs needed to assess the specific interventions planned for each lighthouse city, a detailed analysis of their explicit actions must be performed, which has been approached by running two parallel activities:

- A bottom-up method that involves the city stakeholders, in which the impact assessment for each action and intervention, together with corresponding indicators are co-produced, to document the anticipated impacts of each activity in terms of the partner's own ambitions. A bottom-up approach represents a best practice in sustainability indicator development towards urban transformation, leveraging the unique opportunities of the Lighthouses to learn through working with partners on live demonstration projects.
- A detailed analysis of the actions and interventions from the technical partners, by verifying the corresponding descriptions in the project contract. With this parallel activity, a high level and unbiased analysis of the planned development and its related impacts is guaranteed.

4.2.1 Bottom-up approach

Working on the lowest level, each action is analysed by the city partners and more specifically from the corresponding action leader. Defined action level KPIs are consolidated to identify intervention level KPIs, which in turn serve as the basis for the definition of KPIs on the district level. Following the same approach, the macro/city level KPIs are based on the district level KPIs. Figure 21 below, depicts the different levels and relationship between them.

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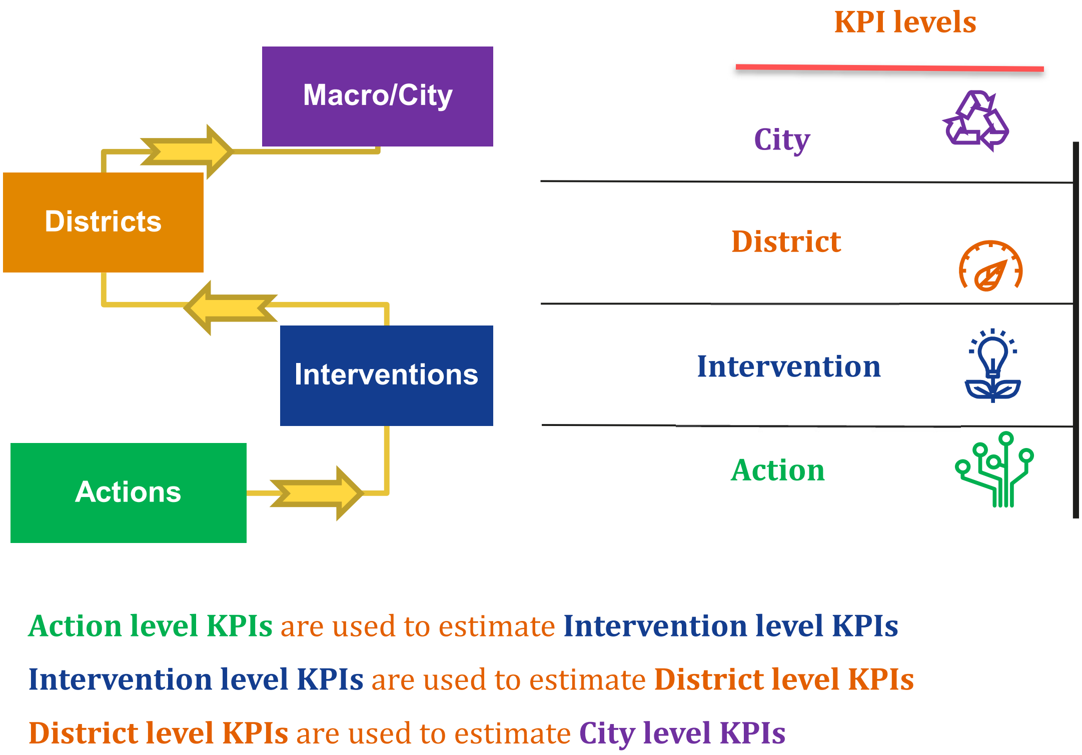

Figure 21: SPARCS' KPIs Levels

Table 6 presents the results of the bottom-up approach concept followed for the activities planned in the city of Espoo. To simplify the presentation of the results, the action level KPIs are already consolidated in the intervention level and in the first column, the intervention identification and title are listed. In the second column, the number of actions per intervention is provided while the third column captures the KPIs per intervention, proposed from the city partners, responsible for their implementation.

Table 6: Espoo Bottom-up analysis' KPIs

Interventions Espoo	# of actions	KPIs
E1 - Solutions for Positive Energy Blocks	6	-The sum of renewable energy and heat generated in the block plus certified green energy divided by consumed total energy in the block "OER"
E2 - Boosting E-mobility uptake	3	-kWh charged to EVs, -Number of different EV charging stations
E3 - Engaging users	3	-Number of people aware of existing solutions, -Did you feel that you had a real possibility to impact current situation/change? (questionnaire after user engagement activities)
E4 - Smart Business Models	1	-How well does the business model(s) cover the four lenses of innovation?

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E5 - Solutions for Positive Energy Blocks	3	-Percentage of locally produced energy (heat, cool, electricity) compared to baseline, -Percentage of onsite RES compared to demand -Percentage of onsite RES compared to max potential
E6 - ICT for Positive energy blocks	3	-Percentage of flexibility compared to baseline, -Prediction accuracy of flexibility
E7 - New E-mobility hub	3	-Percentage of flexibility compared to baseline, -Prediction accuracy of flexibility
E8 - Engaging users	3	-Percentage of flexibility compared to baseline, -Prediction accuracy of flexibility
E9 - Smart Business models	1	-Customer/user interest in new business models
E10 - Solutions for Positive Energy Blocks	3	-On-site energy ratio, -Number of early-stage solutions investigated
E11 - Engaging users	1	-Targeted share of bicycle and pedestrian mobility mode
E12 - ICT for Positive energy blocks	3	-Model developed and cost-benefit analysis completed for Blockchain
E13 - E-mobility in Kera	2	-Estimated share of vehicle- km by chargeable vehicles, Hybrid Electric vehicle (HEV), Battery Electric vehicle (BEV) excl. bicycles
E14 - New economy/ Smart governance models	1	-Number of stakeholders in cocreation -Percentage stakeholder satisfaction
E15 - Virtual Power Plant	2	-Number of flexible loads: typology/type, capacity (kWh), response delay -Number of blockchain platforms
E16 - Smart heating	1	-Number of buildings connected to smart heating service
E17 - Virtual twin	2	-Usefulness of the tools to create new PEDs in the city
E18 - EV charging effects to grid	1	-How much lower is the peak power demand when using the developed charging strategies as compared to the normal case? -Number of innovative energy technologies incorporated in virtual twin for simulation purposes
E19 - Sustainable lifestyle	2	-Number of residents responded to SPARCS activities -Healthy lifestyle indicators
E20 - District development	1	-Energy infrastructure smart building requirements
E21 – Air Quality	1	-PM10 -NOx
E22 -Co-creation for Positive Energy District development	2	-Number of relevant stakeholders engaged -Acceptance of smart city Espoo concept
E23 - New economy/ Smart business models	2	-Number of new projects generated and volume of funding

Consolidating the intervention KPIs in the district level, the following table 7 presents the district KPIs for the city of Espoo, as recognized from the city representatives. The first column lists the different Espoo districts, while the second and the third columns are

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providing information about the number of interventions per district and the identified district KPIs respectively.

Table 7: District allocation of Espoo KPIs

Districts of Espoo	# of interventions	KPIs
Lippulaiva	4	-The sum of renewable energy and heat generated in the block plus certified green energy divided by consumed total energy in the block "OER" -kWh charged to EVs -Number of different EV charging stations -Percentage of people aware of existing solutions -Likert – 1-5 Did you feel that you had a real possibility to impact current situation/change? (Questionnaire after user engagement activities) -How well does the business model(s) cover the four lenses of innovation?
Kera	5	-Carbon footprint -Number Stakeholders involved in design and co-creation -Number early stage solutions investigated -On-site energy ratio
Sello	5	-Carbon footprint reduced in mobility -Citizen interest & awareness in sustainable solutions & concepts -Energy performance prediction accuracy & flexibility

Finally, considering the district level KPIs, the resulting Macro/City level KPIs of Espoo are listed in the table 8 below. Similarly, to the previous table, the second column shows the number of interventions planned on this level and the third column the proposed macro level KPIs.

Table 8: Espoo KPIs in Macro/City level

Macro/ City	Number of interventions	KPIs
Espoo	9	-Tools available / actively used for PED city planning -Co-creation level -Number of PEDs in city master plan -Citizen engagement assessment through social media -Multiplayer effect (Leveraging new funding and new projects) -The level of renewable energy and heat generated (OER) -Carbon footprint reduced in mobility -Co-creation level (incl. both companies and citizens) -Solutions replicated successfully

Equivalent tables, depicting the bottom-up activities taking place in the city of Leipzig can be found in Appendix A.

4.2.2 Technical intervention Analysis

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With the intension to perform an unrestricted analysis of the interventions, technical partners used the detailed description of actions and interventions planned for each city as a foundation to identify the KPIs necessary to assess them.

In the following Table 9, similarly to table 6, the name of each intervention planned for the city of Espoo and the corresponding number of actions per intervention are listed, but accompanied in this case, with the KPIs identified from the project's technical partners. The table lists in the third column only additional KPIs, compared to the list of KPIs already identified in the Top-down approach in step 2 and listed in table 4.

Table 9: Espoo KPIs from technical analysis

Espoo Interventions	Number of actions	Key Performance Indicators
E1 - Solutions for Positive Energy Blocks	6	-Share of RES increase annually -Annual district RES Generation increase -District Fossil fuels Energy Generation decrease -Energy storage increase -Total energy demand reduction -Peak Load Reduction -Heat Recovery Ratio -Reduction of the energy production cost -Reduction of the customer energy cost -Accuracy of forecasting -Energy performance prediction deviation -Accuracy of Generation forecasting -Accuracy of storage utilization -Open District Heating increase rate -Reduction of CO_2 emissions
E2 - Boosting E-mobility uptake	3	-Increase in shared EVs availability -Increase of integrated smart EV charging units -Increased level of utilization of EV charging stations -Demand from all EV mobility modes; impact on the grid -Demand Response/Flexibility increase from EV smart chargers
E3 - Engaging users	3	-Total energy demand reduction -Increase of citizens using EV modes -Number of people aware of the existing solutions - before and after interventions -How valuable are the developed solutions for the development of future districts? -Number of youngsters using environmentally friendly modes -Degree of young users' satisfaction to Lippulaiva compared to all users -How well does the solution(s) cover the four lenses of innovation (desirability, feasibility, viability and sustainability)? -Reduction of CO_2 emissions

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E4 - Smart Business Models	1	-Increase of citizens contribute in BM creation -Number of co-created solutions -Number of actions replicated -How many people tried new solutions? -Number of citizens involved in planning initiatives for positive energy districts -Number of stakeholders involved in planning initiatives for positive energy districts -Number of co-creation sessions for positive energy districts -Did you feel that you were able to affect and participate in the ideation of future directions? -How well does the business model(s) cover the four lenses of innovation (desirability, feasibility, viability and sustainability)?
E5 - Solutions for Positive Energy Blocks	3	-Total energy demand reduction -Peak Load Reduction -Increase of district thermal energy export share -Decrease of energy import share in the district -Energy Storage (Batteries, Buildings, etc) -Number of equipment (#) -Storage type (type) -Storage capacity (MWh) -Accuracy of flexibility available -District self-consumption rate -Open District Heating increase rate -Accuracy of forecasting -Energy performance prediction deviation -Accuracy of Generation forecasting -Accuracy of storage utilization -Reduction of CO_2 emissions
E6 - ICT for Positive energy blocks	3	-Reduced System Average Interruption Duration index (SAIDI) -Reduced System Average Interruption Frequency Index (SAIDI) -Demand Response/Flexibility increase -Total flexibility available (KW) -Flexibility % of normal load. -Flexibility provided (KWh) -Number of requests that are initially accepted but declined afterwards; overwrites. -Accuracy of flexibility available -Accuracy of forecasting -Energy performance prediction deviation -Accuracy of Generation forecasting -Accuracy of storage utilization -Activation quality -Services dispatch success rate in VPP -Energy from VPP(MWh) -Energy to VPP(MWh) -Flexibility triggered as part of a VPP action
E7 - New E-mobility hub	3	-Increase of integrated smart EV charging units -Increase in shared EVs availability

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		-Increased level of utilization of EV charging stations -Demand from all EV mobility modes; impact on the grid -Demand Response/Flexibility increase from EV smart chargers -Accuracy of forecasting -Energy performance prediction deviation -Accuracy of Generation forecasting -Accuracy of storage utilization -Satisfaction of minimum charging level for commercial EVs -Monetary gains for EV charging operator -Monetary gains for EV user -Reduction of CO2 emissions
E8 - Engaging users	3	-Number of citizens involved in planning initiatives for positive energy districts -Number of stakeholders involved in planning initiatives for positive energy districts -Increase of citizens using EV modes -Increase of citizens contribute in solution creation -Number of co-created solutions -Number of actions replicated -Number of people tried e-mobility solutions? -Percentage of people are aware of the existing solutions before and after interventions -How valuable are the developed solutions for the development of future districts?
E9 - Smart Business models	1	-Number of co-creation sessions for positive energy districts -Increase of citizens contribute in BM creation -Number of co-created solutions -Number of actions replicated -Number of people tried e-mobility solutions? -Did you feel that you were able to affect and participate in the ideation of future directions? -How well does the business model(s) cover the four lenses of innovation (desirability, feasibility, viability and sustainability)?
E10 - Solutions for Positive Energy Blocks	3	-Increase of utilization of the Espoo 3D City model -Annual primary energy consumption for commercial and residential buildings -Payback period of the system -Demand Response/Flexibility increase; -Buildings/Prosumers in focus -Total flexibility available (KW) -Flexibility % of normal load. -Flexibility provided (KWh) -Number of demand requests -Number of demand responses -Increase of district thermal energy export share -Decrease of energy import share in the district

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E11 - Engaging users	1	-Improvement of the Modal Split towards non pollutant mobility habits -Total energy demand reduction -Increase of citizens using EV modes -How much was the awareness of the city planning people improved? -Were the insights useful for the city planning authorities? -How valuable are the developed solutions for the development of future districts?
E12 - ICT for Positive energy blocks	3	-5G utilization increase -Number of new and improved new services -Utilization of blockchain technology -Energy transfers through blockchain transactions -Volume of exchanges/ transactions (monetary) over blockchain -Energy Storage increase -Number of equipment (#) -Storage type (type) -Storage capacity (MWh) -Reduced System Average Interruption Duration Index (SAIDI) -Reduced System Average Interruption Frequency Index (SAIFI)
E13 - E-mobility in Kera	2	-Improvement of the Modal Split towards non pollutant mobility habits -Increase in shared EVs availability -Increased level of utilization of EV charging stations -Demand from all EV mobility modes; impact on the grid -Demand Response/Flexibility increase from EV smart chargers -Monetary gains for EV charging operator -Monetary gains for EV user -User satisfaction of minimum charging level in EVs satisfaction of minimum charging level for commercial EVs
E14 - New economy/ Smart governance models	1	-Number of co-created solutions -Number of citizens involved in planning initiatives for positive energy districts -Number of stakeholders involved in planning initiatives for positive energy districts -Number of ideas that have come up during the process with stakeholders.
E15 - Virtual Power Plant	2	-Flexibility availability -Demand response utilization -Utilization of blockchain technology -Number of smart business models created
E16 - Smart heating	1	-Annual district RES Generation increase -District Fossil fuels Energy Generation decrease -Total energy demand reduction -Peak Load Reduction

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		-Increase of district thermal energy export share -Decrease of energy import share in the district
E17 - Virtual twin	2	-Number of simulations executed via the Virtual -Twins concept -Number of innovative energy technologies incorporated in virtual twin for simulation purposes -How understandable are visualized simulation results
E18 - EV charging effects to grid	1	-Improvement of the Modal Split towards non pollutant mobility habits -Increase of integrated smart EV charging units -Increase in shared EVs availability -Increased level of utilization of EV charging stations -Demand from all EV mobility modes; impact on the grid -Demand Response/Flexibility increase from EV smart chargers
E19 - Sustainable lifestyle	2	-Share of respondents willing to commit to sustainable lifestyle -Number of created solutions -Reduction of CO_2 emissions -Greenhouse gas emissions reduction: CO_2 and CH_4, N_2O, O_3 -Improve Air Quality
E20 - District development	1	-Number of smart building requirements
E21 – Air Quality	1	-Reduction of CO_2 emissions -Greenhouse gas emissions reduction: CO_2 and CH_4, N_2O, O_3 -Improve Air Quality
E22 -Co-creation for Positive Energy District development	2	-Number of co-created models -Number and category of participants in models planning -Number of digital platforms used amount of energy managed through digital platforms -Number of actions replicated
E23 - New economy/ Smart business models	2	-Number of contributions -Involvement with the platform activities/updates -Number of smart business models created in Espoo

4.2.3 Final list of impact indicators per intervention

As mentioned in previous sections, there were three separate approaches in order to fully understand the needs of each LHC and the SPARCS project as a whole, namely top-down, bottom-up and technical interventions' analysis. Throughout this process, many KPIs were proposed that could be used for this purpose, but further evaluation and in-depth analysis was needed to define a final list of KPI interventions.

This was a challenging and lengthy process, as it was necessary to organize a large number of meetings with the cities, in which local focus groups and technical partners of the project participated. It should be noted here that due to the pandemic which entailed transport restrictions across Europe, many meetings were cancelled or postponed. This

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resulted in the conversion of physical meetings to virtual ones with the coordination of this action being quite time consuming. However, there has been excellent cooperation between all parties involved and the compilation of the final KPI lists has been successful. The aforementioned process can be considered as the 4th step of the SPARCS impact assessment methodology that was described in the beginning of this chapter. The following figure 22 summarises the actions required for the definition of the final lists of impact indicators per intervention per LHC.

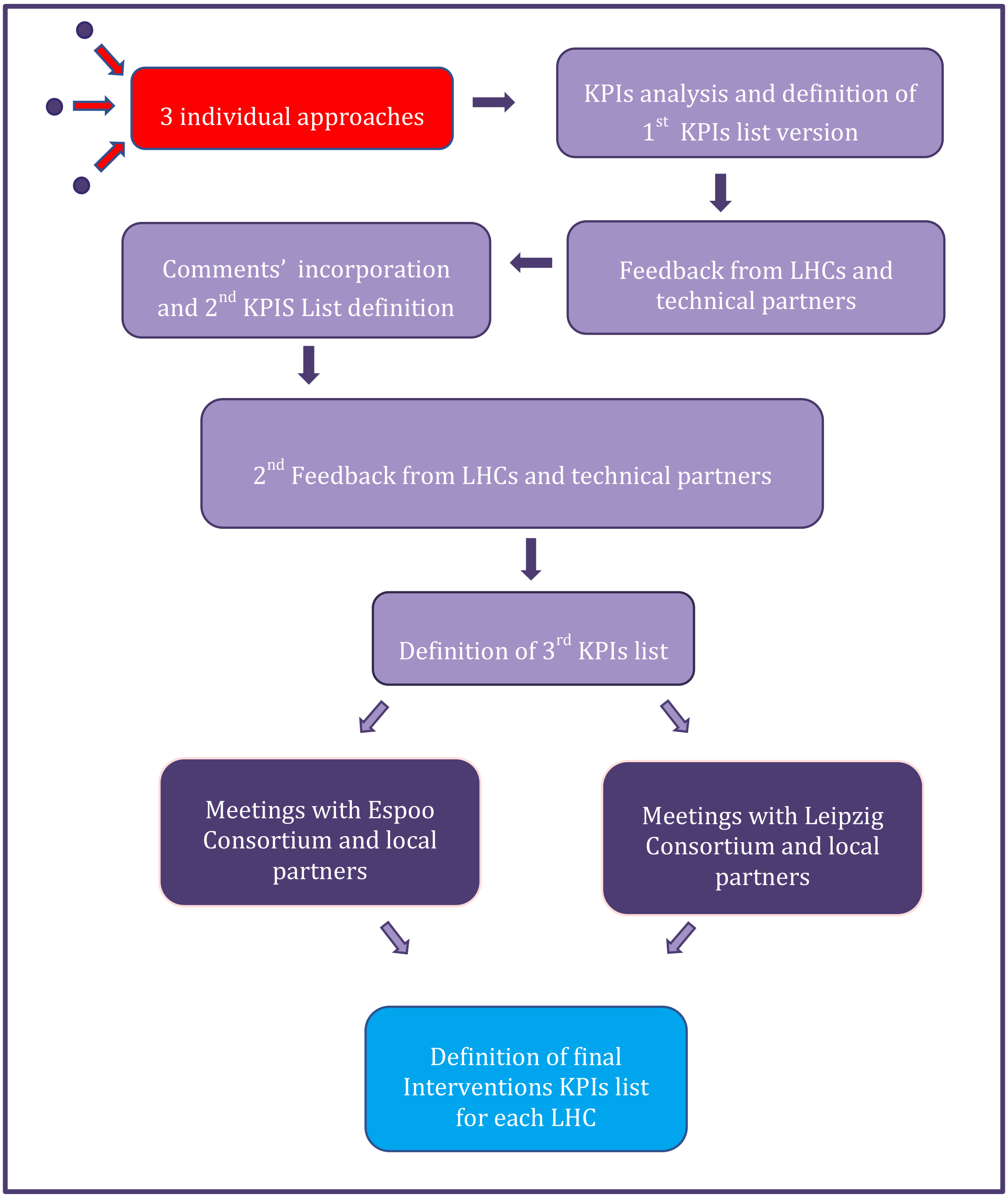

Figure 22 : Steps followed for the definition of final Intervention KPIs lists

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Initially, all KPIs from the three different approaches were collected and a first version of the interventions KPIs list was created for each city. Feedback was then requested from both cities' groups and project's technology partners. As a next step, all comments and notes were incorporated and the second versions of the KPIs lists were created. At that point a second round of feedback was requested and new comments were provided from partners. With the third version of the KPIs lists being ready, individual calls with the responsible partners of each demo area took place. The table 10 below summarises some of the planned meetings.

Table 10: Planned meetings and areas of implementation

Partners	Area of implementation	Number of calls
Espoo consortium	SPARCS overall impact KPIs Sello Lipullaiva E-mobility KPIS Macro level Citizen's engagement City wide Kera	14
Leipzig Consortium	SPARCS overall impact KPIs E-mobility KPIS Leipzig west Spinnerei KPIs Macro level City wide Virtual	11
Technical partners	SPARCS overall impact KPIs Economy Social Citizen's engagement	9

The final adjustments were made during all of these calls ;based on the availability of data and the delegation of responsibilities between the LHC partners for each demonstration area / implementation area, the next steps in completing the KPI lists were determined. These steps will be performed in other WP2 tasks that will start after this deliverable . It is worth noting that through these calls, knowledge and experience were transferred from one LHC to another, promoting the ability to build strong connections and collaborations through partners, resulting in the optimization of final outcome. In addition, as part of the engagement process, the meetings triggered the discussions on how LHC partners could capture citizens' awareness and involvement in SPARCS interventions and how these

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metrics can be measured and evaluated in order to be used as a useful tool for the needs of the project as well as for the stakeholders of the cities.

Table 11 below shows some of the Espoo KPIs and corresponding data needs associated with the first -E1 intervention. The two final KPIs intervention lists for Espoo and Leipzig can be found in Annex B.

Table 11: Espoo's Intervention- E1 KPIs

KPI	Data
Share of RES (electricity)	Total Energy consumption (electricity) (MWh)
	Energy production using RES (electricity) (MWh)
Share of RES (thermal)	Total Energy consumption (thermal)(MWh)
	Thermal energy production using RES (thermal) (MWh)
Excess Heat Recovery Ratio	Total excess heat (MWh)
	Utilization of excess heat (MWh)
Building energy efficiency measurement	Total energy demand (MWh/m2)
	Total Demand Electricity (MWh/m2)
	Total Demand Heating annual (MWh/m2)
	Total Demand Cooling annual (MWh/m2)
Energy Storage type	Type
Energy Storage number of equipment	Number
Energy Storage capacity	thermal (unit to be defined)
	electric battery (MW/MWh)
Total flexibility available (KW)	Total flexibility available (KW) considering EV charging points
Onsite energy ratio OER	Energy production using RES (MWh)
	Total energy demand (MWh)
Annual Mismatch Ratio (AMR)	District Energy import (MWh)
	Energy production using RES (MWh)

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	Total energy demand (MWh)
Energy costs per m2	Energy costs per m2

4.3 Holistic framework definition

The concept of urban transformation involves more than just creating technically sustainable urban areas and stimulating economic development: it is a multi-level and multi-dimensional approach that aims at promoting a structural transformation in the urban ecosystem, directing cities' urban development towards sustainability.

In order to perform a complete, quantitative and qualitative assessment of the impact achieved by the different interventions and technologies deployed in the demos from various perspectives, an additional step is required. For that, the replication potential of the proposed solutions is a very essential part of the process and wider-scale deployments in lighthouse and Fellow cities are taken into consideration while at the same time their deploy-ability in different city contexts is evaluated.

Taking into consideration all these parameters, the definition of a holistic approach requires consideration of specific Interventions Indicators, as well as Replication Indicators, further from adjusting the Impact indicators already identified. In that way, accurate projection of the intervention impacts will be enabled, allowing targeted and efficient deployment of similar interventions at different districts and building blocks of the Lighthouse, Fellow or other cities. Building the holistic SPARCS assessment framework, technical partners and LHC representatives were consulted, with the aim to contribute with specific know-how on the enhancement of available KPIs and with the identification of additional indicators. Several forms of feedback collection were utilized to obtain the necessary information such as workshop sessions, live consultation and clarification sessions as well as offline reviews.

4.3.1 Intervention and Replication indicators

In the context of SPARCS, the use of **Interventions Indicators** focuses mainly on the quantitative capturing of interventions and their technical characteristics, taking into account many factors, such as the number of solutions to be implemented, the number of technological components to be installed, the area to be used, the population of the area and the city, air pollution conditions, transport infrastructure, etc. Examples of such indicators, that depend on the specifics of each intervention, are listed in table 12 below.

Table 12: Intervention Indicators examples

KPI name	Area	Category
Number of installations per source (RES and non-RES)	District	Energy
Storage (type, number, capacity)	District	Energy
Size of the District	District	Physical Geography

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Population (number, age distribution, gender rates, life expectancy)	City/District	Social
Air pollution (CO_2, GHG, small particulates and THC volatile hydrocarbons)	City/District	Environmental
Transport infrastructure (Km of roads for cars, bicycles,)	District	Transport
Number of EV charging units	City/District	Transport

Replication indicators on the other hand, focus on thoroughly evaluating the replication potential of the solutions tested, considering wider-scale deployments in Lighthouse, Fellow and other cities. To achieve this target, assessing the deploy-ability of the solutions in different city contexts, considering maturity, cultural, climatic, energy market, political and demographic diversities must be evaluated.

Initially, a set of indicators that are proposed from the CITYkeys framework can be added in the pool of indicators that serve the replicability evaluation of planned interventions, as listed in the Table 13 below.

Table 13: CITYkeys replication indicators

KPI name	Definition	Unit
Social compatibility	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways they are used to do things.	Likert Scale
Technical compatibility	The extent to which the smart city solution fits with the current existing technological standards/infrastructures	Likert Scale
Ease of use for end users of the solutions	The extent to which the solution is perceived as difficult to understand and use for potential end users	Likert Scale
Ease of use for professional stakeholders	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution	Likert Scale
Trialability	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	Likert Scale
Advantages for end users	The extent to which the project offers clear advantages for end users	Likert Scale
Advantages for stakeholders	The extent to which the project offers clear advantages for stakeholders	Likert Scale

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Visibility of results	The extent to which the results of the project are visible to external actors	Likert Scale
Solutions to development issues	The extent to which the project offers a solution to problems which are common to European cities	Likert Scale
Market demand	The extent to which there is a general market demand for the solution	Likert Scale

With those indicators available, aspects such as the technical and social compatibility, advantages, and ease of use for end users and stakeholders, together with market demand and general characteristics of the interventions can be assessed for candidate districts and cities, providing a broad overview of their conformance.

In the context of SPARCS, and towards providing an enriched approach to address the replication challenge, an enhanced list of the initial definition of the Intervention Indicators is proposed. This enhanced list of indicators, serves as a City and District screening mechanism, including additional city characteristics that can serve as Replication indicators, when the specific needs of the interventions need to be evaluated. Intervention requirements are thoroughly captured in the T1.3:D1.7 and served as additional input for the identification of intervention indicators. Table 14 below lists indicators that can serve both as intervention and as replication indicators.

Table 14: Intervention/Replication indicators

KPI name	Area	Category
Annual RES generation (PV, Wind, Hydro, Biomass, other)	District	Energy
Annual non-RES generation (Diesel generators, Steam Turbines, Gas Turbine, other)	District	Energy
Annual Import/Export of energy	District	Energy
Number of installations per source (RES and non-RES)	District	Energy
Annual Open District heating utilization	District	Energy
RES penetration	District	Energy
Max RES Penetration Potential (capacity)	District	Energy
Storage (type, number, capacity)	District	Energy
Annual total demand (Electricity, Heating)	District	Energy
Peak Demand	District	Energy
Energy Cost (Electricity, Heating)	District	Energy
Size of the District	District	Physical Geography

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Orography of the District	District	Physical Geography
Temp (Max/Min/Average)	District	Physical Geography
Average Sunshine hour per year	District	Physical Geography
Average Rainy days per year	District	Physical Geography
Heating Degree Days	District	Physical Geography
Cooling Degree Days	District	Physical Geography
Population (number, age distribution, gender rates, life expectancy)	City/District	Social
Employment (Rate, unemployment male/female/youth)	City/District	Social
Air pollution (CO_2, GHG, small particulates and THC volatile hydrocarbons)	City/District	Environmental
Climate Resilience Strategy	City	Environmental
District Noise Pollution	District	Environmental
GDP per capita	City	Economy
Energy poverty status	City	Economy
Transport infrastructure (Km of roads for cars, bicycles,)	District	Transport
Transport infrastructure (Public transportation lines, number of stops)	District	Transport
Stock of vehicles (Cars, Motorcycles, Bikes, Buses)	City/District	Transport
Modal Split	City/District	Transport
Transportation deaths	City	Transport
Internet access (fixed, mobile)	City/District	Telecommunication
Legal framework compatibility	City	Governance
Budget spent on city management (Euros)	City	Governance
Number of active market participants in prosumer models	City	Citizen engagement
Number of actively involved partners in energy solutions	City	Citizen engagement

Figure 23 provides an overview of how the three assessment activities were applied sequentially in the context of SPARCS. Starting with the intervention assessment, the enhanced list of intervention indicators allows both the quantitative evaluation of the interventions and their characteristics, as well as the characterization of the city/district context in which the implementations will take place. Following this stage, the impact assessment of the interventions will occur, based on the final list of indicators as defined

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in this deliverable report. During the replication phase, a candidate city/district characterization is performed, by applying a subset of the intervention indicators, which in this stage are utilized as replication indicators.

Figure 23: Intervention, Impact and Replication assessment

To make this flow of events clearer, Figure 24 separates the different indicators in the three distinct stages.

- Enhanced list of intervention indicators is used to collect the necessary information to screen the city/district, while taking into consideration the intervention requirements.
- Impact indicators to assess the interventions; proper baselining will allow the exact evaluation of impact achieved and the normalisation process the comparison of results under different contexts.
- Replication Indicators, that are a subset of intervention indicators, are used tailored to the requirements of successful candidate interventions to be applied.

A hypothetical example of how this process would be followed is provided in Figure 25.

In the first stage, the district Lippulaiva in Espoo is screened, taking under consideration the interventions planned in this district. Intervention indicators are utilized for this purpose, such as the generation and storage status, weather characteristics like temperature and HDD/CDDs, etc.

As soon as the interventions are implemented, calculating the specific KPIs per intervention, would allow the detection of the successful ones. In the example, verifying the RES generation increase and the non-RES generation decrease, while the total energy demand of the district is also decreased, indicates that the intervention implemented to improve the self-sufficiency of the district, by utilizing PVs, storage and an automation steering system controlling them, is successful.

In the final stage, a district in Kladno considers implementing interventions to improve its self-sufficiency. Using specific replication indicators to screen the district and the requirements of the related interventions, generation, storage, and weather characteristics are captured and after verifying that the requirements are met, the intervention that is successfully implemented in the Lippulaiva district, namely the use of PV, storage, and their respective steering system, is proposed to the district of Kladno.

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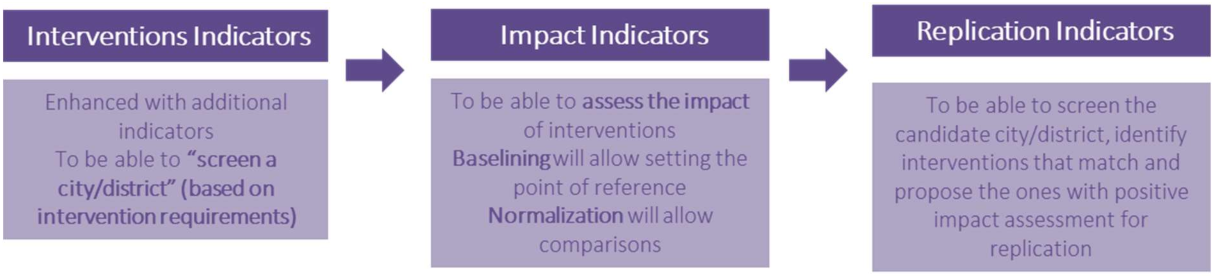

Figure 24: Intervention, Impact and Replication indicators

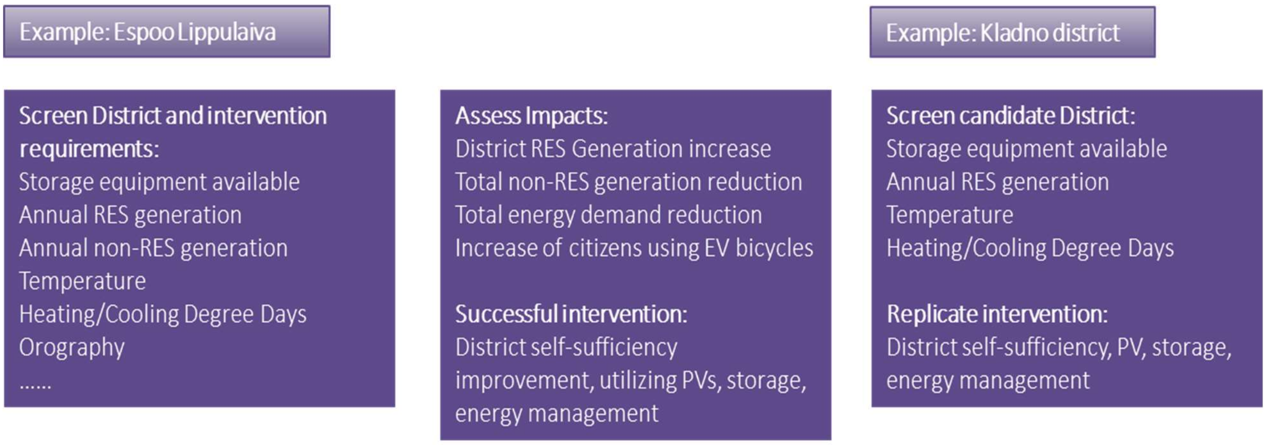

Figure 25: Replication example

Having verified all related city/district context and intervention requirements beforehand, characteristics that contributed towards successfully applying interventions in the origin cities/districts, allows, with great confidence, to proceed with the implementation of similar approaches in the candidate, target cities/districts.

Utilizing this approach combined with the SCIS proposed replication indicators, complements the efforts towards identifying and replicating interventions that are proven to not only be successful on the origin cities/districts, but pose also as a good fit considering specific city/district and intervention characteristics.

4.3.2 Enhanced categorization and KPIs

In order to cover all aspects of smart city needs and more specifically the needs of the SPARCS project, additional dimensions are proposed here, enhancing the initial defined categories. In the first version of this deliverable (D2.1) an initial categorization of four areas was presented namely Energy, Economic, Social and Technology. During the process of defying the final KPIs lists for the SPARCS framework and through the collaboration with project partners, became clear that more categories were required for a complete analysis in order the needs of the LHCs to be captured in comprehensive way. So, based on the expertise and the feedback of technical partners four more categories were emerged and were added on top of the existing four, namely Environmental, Governance, Citizen's engagement and Mobility.

With the new categorization presented here, there is a better understanding of the areas of application of the interventions while at the same time the KPIs become more specific

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by helping more city's stakeholders and urban planners in the selection of the targeted measurements that they should make in each case.

Table 15 below presents briefly the proposed categories as well as the KPIs' number in each one of them.

Table 15: SPARCS KPIs categorization

Category	Number of KPIs
Energy	34
Economy	13
Social	25
Environmental	6
Technology	19
Governance	20
Mobility	11
Citizens' engagement	23

Table 16 below shows some of the KPIs for the Energy, Economy and Social categories. The complete table that includes all the actual KPIs per category can be found in Annex C.

Table 16: Sample of KPIS in Energy, Economy and Social Categories

Categories		
Energy	Economy	Social
Accuracy of forecasting	Discounted Payback Period- DPBP	Increase of persons in full-time, permanent, fixed-term employment
Activation quality in VPP	Internal Rate of Return -IRR	Decrease of youth unemployment rate

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Annual district PV Generation increase	Loan Life Coverage Ratio-LLCR	Capital spending increase as a percentage of total expenditures
Decrease of energy import share in the district	Municipal involvement	Increase of the percentage of population leaving in affordable housing
Decrease of total generation curtailment	new business creation	Decrease of population living below the national poverty line

As mentioned before, in the first step of the proposed methodology, the review of various relevant projects and methodologies performed (chapter 3) and served as an excellent pool for the identification of the 29 KPIs.

Out of the 29 Impact KPIs identified for the SPARCS project a sequential verification revealed that:

- 11 KPIs were taken from the Morgenstadt framework as part of pressure, state or impact indicators
- Another 11 are used in the context of SCIS, CITYKeys, CIVITAS or the Triangulum frameworks
- 7 KPIs were not in use from any of the analysed assessment frameworks and could be considered as enhancements towards their modernization, to capture the needs of modern Smart City projects, such as those of SPARCS.

Additionally, as a result of the top-down and bottom-up impact and intervention analysis as well as the collaboration with technical partners of project, carried out in steps two to four of the current methodology, 168 KPIs were proposed to meet the needs of the SPARCS project to address aspects of intervention and replication process, based on planned LHC solutions.

Augmenting the table 3 created in section 3.6, the characteristics of KPIs identified for the Holistic framework definition of the SPARCS project are added next to the rest of analysed frameworks for an easier overview and comparison, and are illustrated in the following table 17.

Table 17: KPIS overview from analysed frameworks

	SPARCS	Morgenstadt	SCIS	CITYkeys	CIVITAS	Triangulum
Number of indicators	197	107	38	101	30	79
Type of indicators	Impact (29), Intervention (151),	Pressure, State, Impact	Core and Supporting impact	Impact	Process, Impact	Impact

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	Replication (17)					
Assessment scale	City, District, Building	City	City, District, Building	City	City	City, District, Building
Impact categories covered	Energy, Economic, Social, Technology	Energy, Mobility, ICT, Economy/ Governance, Urban resilience, Emission excess, Innovation Leadership, Budget allocation	Technical, Environmental, Economic, ICT, Mobility	People, Planet, Prosperity, Governance Propagation	Global Environment , Quality of life, Economic success, Mobility system performance	Energy, Transport, Socioeconomic, Citizen engagement, ICT

In Appendix E all KPIs identified in this step can be found, accompanied with the level of applicability, a clear definition, the related units and the calculation formulas.

In conclusion, the holistic framework presented here proposes three types of KIPs that were either found in the relevant projects studied for the purposes of this deliverable or suggested by the technical partners during the extensive collaboration carried out or created from scratch during the analysis for the needs of LHCs and project.

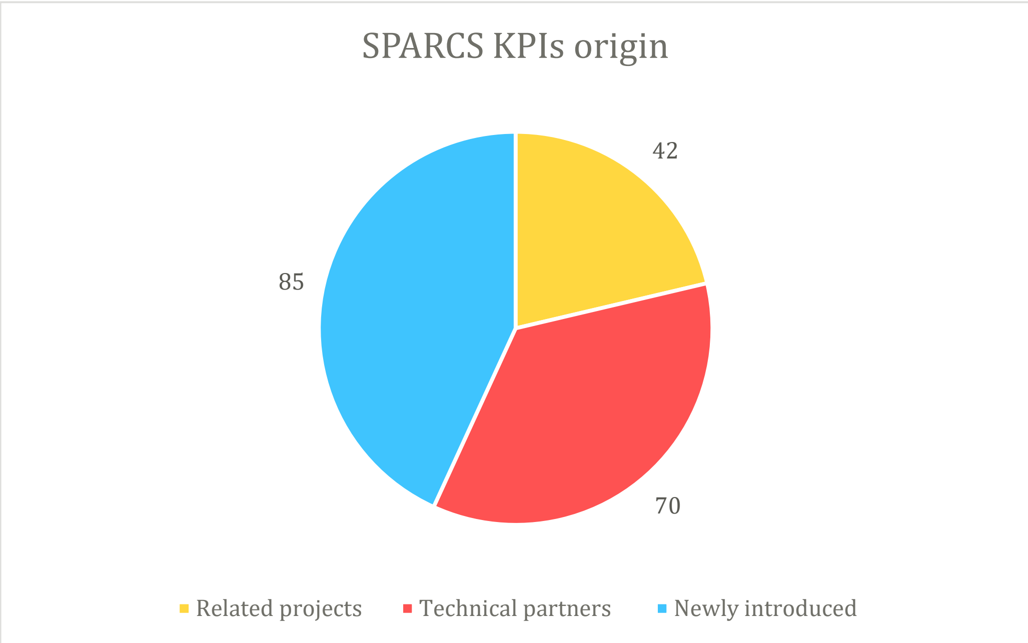

Figure 26: Origin of SPARCS proposed total KPIs

The figure 26 above, indicates the three different sources for the total number of the KPIs proposed in this framework.

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4.4 Data collection methodology

An important element of performance measurement is represented by the data collection capability, which allows the calculation of the indicators. However, applying a data collection methodology in the project context is neither easy, nor lacking obstacles, as similar activities often discover.

As the impact assessment and the decision being made based on it is significantly influenced by the data provided, providing unreliable information might seriously damage the project targets, by influencing the consortium towards making the wrong decisions.

To assist the city partners in their efforts to optimize the data gathering process and to ensure the consistency in measuring each KPI, details about the KPI definitions, the calculation formulas, data needs and limitations, must be made available.

With the KPI definitions and the calculation formulas covered already in the previous steps, analysing the KPIs identified towards data needs and limitations, is the next challenge, captured as step 5 of the methodology defined. Data needs for the calculation of the 29 KPIs identified in the top-down approach in step 2 of the methodology as well as data required for the calculation of the final list of Espoo and Leipzig KPIs identified in step 4, are thoroughly handled in the corresponding delivery D2.4 of WP2. In addition, D2.4 hosts related data characteristics, collection methods, evaluation of the feedback received and the definition method of data platform requirements that will host the data.

4.5 Normalisation methodology definition

As mentioned in previous chapters, Smart City KPIs are an important tool for assessing the results of SCC projects, as well as providing valuable information to project managers and city stakeholders. Their use is important for future urban planning as well as for the development of sustainable strategies as long as they provide the right information in the right way.

Up to this point, all the measures taken under SPARCS framework -and therefore the proposed KPIs - focus entirely on the evaluation of the planned interventions implemented by the cities of Espoo and Leipzig. In order for the results to be meaningful and objectively comparable to each other or with similar measurements / findings of relevant projects, they should be normalized, which means that they must be detached from the particularities and exogenous characteristics of cities. To achieve this, we have devised a normalisation approach that would be valuable for KPI comparisons among smart cities projects as well as to be utilized by individual cities. The following Figure 27 shows the normalisation methodology followed in SPARCS project.

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During the review conducted on the literature and the relevant H2020 smart city projects, we did not come across a standard methodology for KPI normalisation. Thus, in SPARCS project, we followed a bottom-up approach by analysing the proposed KPIs in order to define a normalisation process which could be easily applied. At the same time, it could have a major impact on both LHCs and FCs and could eventually make KPIs a powerful tool that provides important metrics and not just as numerical and statistical indicators.

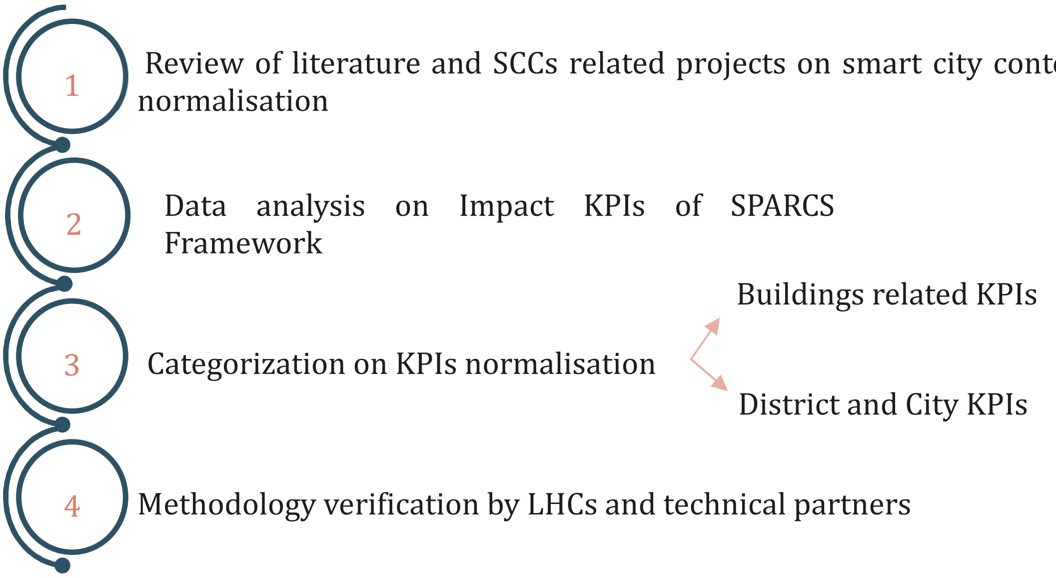

Figure 27: Normalisation methodology in SPARCS

From the analysis of the SPARCS interventions that took place for the needs of this deliverable, more than 150 KPIs emerged; as mentioned before these KPIs are categorized in various domains namely energy, mobility, economy-financial, social (citizens engagement), ICT and environmental which are further split in building, district and city level. Studying these KPIs lead us to the outcome that the most effective way towards their normalisation should be by using two different calculation methods; one in regard to the energy consumption in building level (electricity, heating, etc.) and one for all remaining KPIs under the district and city level.

Energy consumption in buildings accounts for over 40% of primary energy and around for 24% of greenhouse gas emissions. At the same time, the world's population is growing rapidly and so does the need for buildings. Hence it is important to highlight the impact that buildings could have in climate change mitigation actions as their energy-saving potential could be applicable in a large-scale demonstration. However, the energy consumption in buildings is greatly affected by important factors that have significant effect on their energy footprint. These factors such as the geographical location, the weather, the construction characteristics as well as the occupancy and the use of each examined building should be taken into consideration on the normalisation process. Therefore, a separate approach should be performed for the building related KPIs. These two calculation methods are briefly described in the following paragraphs.

Building related KPIs

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The building related KPIs have to be normalized based on weather data and the most used approach for this is to compare the data gathered to a 30-year average weather conditions (which will be used for the calculation of Degree Days) including both early baseline and monitoring consumptions. With this approach, energy data can be more appropriately normalized regardless of the year and the location variables.

Degree Days are essentially categorized using ambient air-temperature data and are divided in two distinct parts: The Heating Degree Days (HDD) and the Cooling Degree Days (CDD). These are used for calculations related to the heating and the cooling in buildings, respectively. As an example, HDD can be used to normalize the energy consumption of whole buildings with central heating.

For the calculation of HDD figures, a baseline temperature is needed to provide a measure of how much (in degrees), and for how long (in days), the ambient temperature (as ambient temperature can be used the daily mean temperature) is below that baseline. The difference of the ambient temperature from the base temperature is actually the number of the HDD for each day. Then the normalisation of energy consumption is performed by calculating the energy (in kWh) per degree day for each kWh energy-consumption data for the selected period. It should be mentioned here that it is necessary to set threshold temperatures in order to determine the limits (meaning the baseline temperature) at which heating or cooling energy is taken into account for the calculations of both HDD and CDD.

Another factor to consider when comparing the normalized consumption of buildings should be their energy classification, according to the Energy Performance Certification (EPC). In order to prepare an energy certificate, it is necessary to carry out an energy performance assessment of the characteristics and systems of the building, by gathering information about its components and energy consumption. This information is used as an input to a calculation model that evaluates the building's energy consumption under local climatic conditions and leads to an A-to-G classification that facilitates rapid comparison of buildings.

As a general comment, we should mention here that depending on the requirements of each use case, for each KPI, further values that allow appropriate comparisons, such as the size of the building / district or the number of residents / citizens, could be considered. In this context, the general approach proposed could be further enhanced depending on the needs of each use case and the availability of data. In the following figure (fig.28) the process for building KPIs normalisation is briefly presented.

The Chartered Institution of Building Services Engineers (CIBSE) has prepared operational benchmarks for 29 main categories of buildings, and has listed the different types of building and use that would be included within each of the general category descriptions. These benchmarks are expressed in terms of energy density (kWh/m2/yr.) and are expressed separately as the electrical and non-electrical (fossil/thermal) components of the benchmark. Representative emissions densities (kgCO_2 /m2/yr.) are also indicated, using appropriate CO_2 emission factors, for information only and not for use in the calculation procedure. The benchmarks have been prepared to represent building use under a number of standardized conditions (Local_Department_ for _Communities, n.d.):

- The weather year is standardized at 2021-degree days per year, to the base 15.5°C
- A defined occupancy period is noted for each category individually

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- A standard proportion of the non-electrical energy density benchmark that is considered to be related to the heating demand is noted for each building category individually.

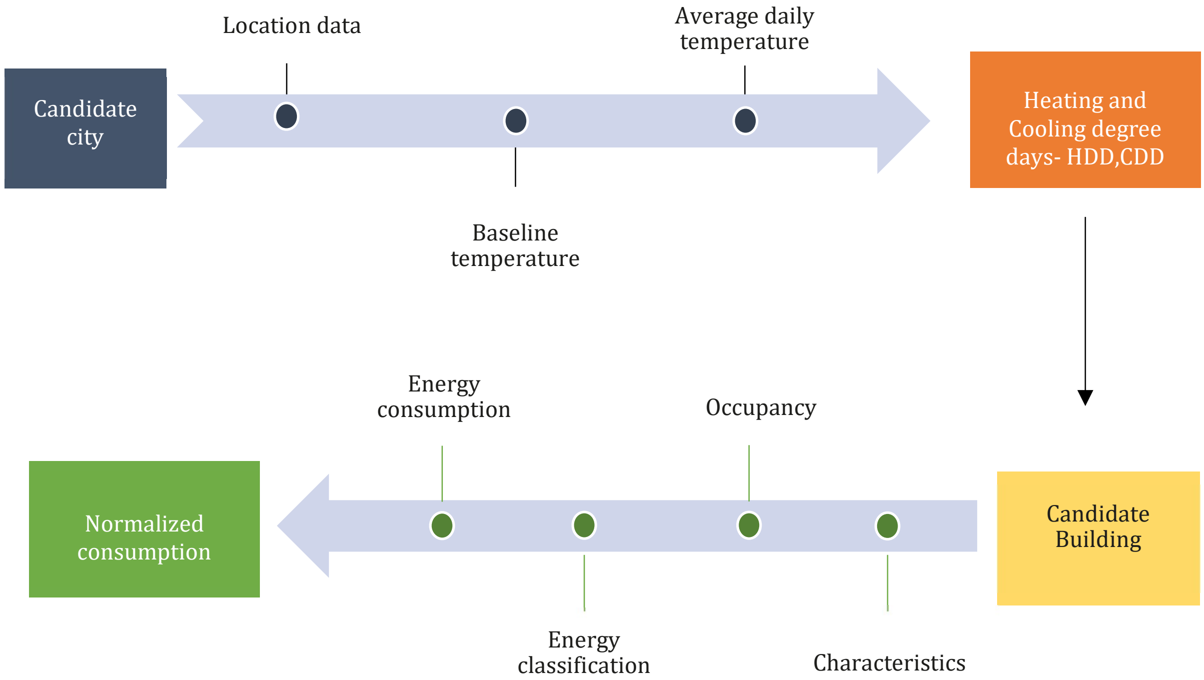

Figure 28: Building KPIs Normalisation

Additionally, according to the Building Energy Specification Tables (BEST) provided by the LHCs to the consortium , HDD and CDD have been calculated for the different districts of Espoo and Leipzig based on benchmark temperatures of 15.5°C for the HDD and 23.0°C for the CDD. These benchmarks can be used by the technical and city partners, so that buildings in the LHCs are analysed and adjustments for the location, affecting the weather region, for the hours of occupancy and for the size of each building to take place.

Expanding the building specific approach towards district and city level normalisation practices, provides comparable results also on higher assessment scales, allowing the evaluation of similarities on building blocks and large urban areas.

Non building related KPIs

There are various aspects that affect the KPIs so data needs to be analysed ad-hoc and normalized with different factors even if it belongs to the same domain. However, the general approach will remain the same.

In some cases, the normalization process is either not necessary or can be done by converting data into units of measurement, such as equipment number, measurement time, distance, etc. This simple normalization is usually included on the definition of the KPIs, so no further action is required.

On the other hand, in cases where normalization cannot be included in the definition of KPIs, the important factors required in each case will be taken into consideration e.g., the

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weather conditions for the production of energy from RES, and will be used in such a way that the final result is objective and comparable.

4.6 Process Evaluation

Evaluating the project execution needs to be covered by two complementary actions, namely the impact evaluation that was in focus in all previous steps and the process evaluation, which is the object of analysis in this step.

While impact evaluation includes the evaluation of a wide range of technical, social, economic and other impacts of the measures being implemented by the cities, the process evaluation involves the evaluation of the processes of planning, implementation and operation, aiming to understand why measures have succeeded or failed, including the role of supportive actions, such as information, communication, engagement and participation events. Building upon this objective, the process evaluation procedure targets to develop new findings about factors of success, and strategies to overcome possible barriers during the implementation and the operation phases, by analysing all relevant information.

Taking in consideration the findings of the CIVITAS framework analysis performed in chapter 3.4, an adapted process evaluation framework based on the specific needs of SPARCS, will be utilized.

4.6.1 The methodology of process evaluation

Performing a holistic approach on an intervention level, information, communication, engagement, and stakeholder's participation are factors that play a crucial role, supporting the successful implementation of individual actions. Such factors, need to be taken in consideration along the way of designing, implementing, and running each of the interventions. To accomplish this goal, each intervention should be studied in 3 separate phases, starting with the design phase, proceeding with the implementation phase, and concluding with the operation phase. Specific considerations for each step as well as how each of the phases are linked with information, communication and engagement/participation activities is analysed below.

Intervention phases and supportive actions:

The lifecycle of an intervention consists of 3 consecutive phases, namely the Design, the Implementation and the Operations phase, complemented with supportive actions, as shown in Figure 29.

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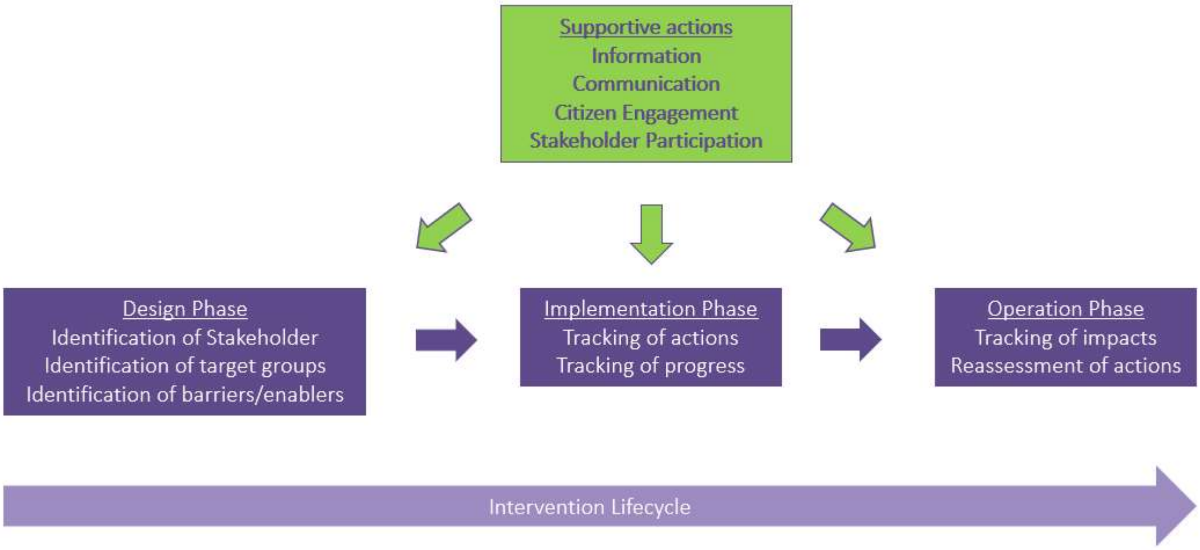

Figure 29: Process Evaluation

Design phase

The design phase includes activities such as the analysis of the challenges to the tackled and the selection -among various options- of the intervention that best addresses this challenge. It is followed by conceptualization activities such as the idea development, design approaches and preparation of initial steps. During all those activities, the identification of stakeholders, target groups and that of barriers and enablers of the chosen intervention is critical.

The formal definition of stakeholders according to (Project Management Institute (PMI®), 1996), is the "*individuals and organizations who are actively involved in the project, or whose interests may be positively or negatively affected as a result of project execution or successful project completion*". During the planning phase of an intervention it is vital that the definition of a complete set of requirements is communicated to all stakeholders in the intervention. Stakeholder identification and understanding of needs and expectations from the implementation activities, allows for the development of alliances to support those activities or to reduce the negative impact of conflicts.

During this process, and by having a good understanding of the features and benefits to be provided by the intervention, the identification of target groups and markets is taking place instantaneously. Different demands and needs of potential customers, lead to the customization of features and benefits to be offered as well as that of the supportive actions to be followed for each intervention.

Lastly, a thorough stakeholder analysis, has a positive impact on the identification of implementation catalysts and risks, since the interests of stakeholders are captured, allowing to gain a good overview of factors that can positively or negatively contribute to the implementation of the actions. Such enablers, barriers and corresponding measures to enhance the positive results or to define methods for the timely identification and removal of obstacles, are addressed during the planning phase of the intervention.

To achieve those targets, supportive actions are in focus, since they allow the confirmation of interests from stakeholders and target groups as well as the identification of enablers and barriers. Examples of measures for an effective implementation of the intervention

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design phase are engagement actions for requirements definition, information campaigns for increasing awareness and communication and participatory activities with key players and target groups.

Implementation phase

During the implementation phase of an intervention focus lies on tracking the evolvement of individual actions to be followed for the successful implementation of the planned goals. Interventions become operational for the target groups and markets identified, by executing construction activities as required, complemented by supportive actions for the flawless orientation of all involved stakeholders. Tracking the progress of all actions and the dependencies among them allows for the identification of delays and the quick and targeted implementation of alternative proceedings whenever feasible, to meet the initial schedule and avoid setbacks to the rest of the interventions. Engagement of involved stakeholders as well as the proper information and communication activities throughout the entire implementation phase of the intervention are of great importance for the successful execution and conflict avoidance strategy defined during the design phase. At the end of this phase the intervention starts operation

Operation phase

The operation phase follows the implementation phase and is the period during which the intervention is made available to the public. Target groups, directly addressed by the implementation actions can utilize the intervention or are affected by the intervention results together with the rest of the stakeholders. In the context of SPARCS, a minimum operational phase of 24 months is planned for all interventions. During this period, applying the monitoring and assessment framework as defined in this deliverable, will allow for accurate impact assessment of the operational interventions, measuring their performance and effectiveness. For actions that are on track, a continuation and strengthening of all ongoing, including supportive actions, should be in focus. For cases where the impact assessment indicates shortcomings to meet the expected results, a reassessment of actions needs to be considered. It should be noted that the implementation of appropriate corrective actions is a key element of the evaluation of the process during the operation phase. It is carried out after identifying the root cause and measurable, feasible solutions with realistic deadlines that focus on addressing it, combined with supportive actions, such as conducting improved information and communication campaigns to bridge potential information gaps and benefits.

In all 3 phases, activities are executed by the Lighthouse representatives, with the support of the technical partners. In Figure 30, phases are transformed into consecutive steps to be followed for a complete process evaluation cycle.

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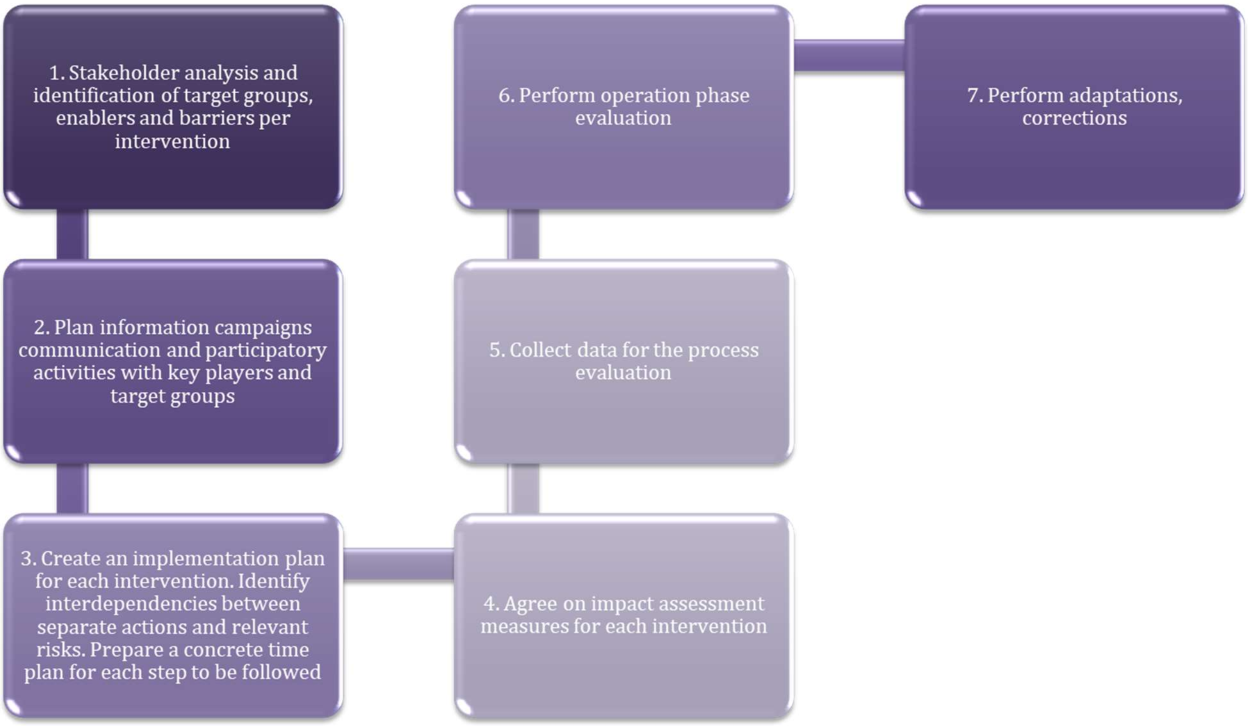

Figure 30: SPARCS Process evaluation

1. In the first step, the stakeholders for each intervention are analyzed, defining target groups and enablers/barriers per intervention.
2. Information and communication campaigns are planned, triggering participatory activities with key players and target groups.
3. An implementation plan for each intervention is created. During this process, interdependencies between separate actions and relevant risks are also identified. A concrete time plan for each step to be followed is prepared.
4. Impact assessment measures for each intervention are agreed, supporting the process evaluation targets. Evaluation plans containing a time planning when impact assessment and process evaluation surveys and interviews will take place.
5. Collection of data based on the agreed plan, serving the impact assessment and the process evaluation checks.
6. Perform operation phase evaluation, analysing planned targets and achieved goals, surveys, and questionnaires feedback.
7. Execute agreed corrective implementation and supportive actions.

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5. CONCLUSIONS

Smart Cities are the result of a transformation process that European cities are currently undergoing to increase efficiency, facilitate citizen engagement, reduce the environmental impact of humans and their activities, whilst digitizing and interconnecting a variety of processes and systems to simplify their lives. SPARCS is a leading incentive in a form of a European project that comprises over 30 partners and will aim to transform cities into citizen-cantered, environmentally friendly and resilient smart urban areas.

This deliverable report of SPARCS proposes a holistic assessment framework for smart cities by gathering learnings from previous prominent Smart Cities related projects and enhancing this knowledge using this consortium's expertise. The deliverable focuses on the analysis of the Morgenstadt assessment framework which was used as the basis for the SPARCS Impact assessment methodology, while it performed a thorough review of four other relevant projects: CITYkeys, SCIS, CIVITAS and Triangulum. This extensive review revealed a range of possible KPIs that can be used to evaluate the impact of smart cities interventions.

This report introduced a seven-step approach to guide the definition of the SPARCS Holistic Assessment Methodology. Building upon the analysis of Smart Cities Frameworks as step one, two subsequent steps aimed to identify the necessary KPIs proposed for the SPARCS assessment framework:

- In step two, a top-down approach was used to identify the main set of KPIs based on the core of the SPARCS project as a Smart City initiative; namely, the impact of the interventions that are planned to be implemented during the next months in the cities of Leipzig and Espoo. This analysis resulted in 29 KPIs related to SPARCS objectives. 22 of these KPIs were matched with the pool of available indicators from analysed relevant projects, while seven KPIs were newly defined.
- In step three, a bottom-up approach was used by the technical experts of SPARCS in collaboration with the city stakeholders, to enhance the core set of KPIs, analysing in detail all planned city actions from a local perspective. This collaboration captured a set of 78 newly introduced KPIs that enhanced the main defined set.

The following step four comprised of consultations of technical experts and city representatives from LHC, Leipzig and Espoo. This aimed at absorbing contributions with specific know-how on the enhancement of available KPIs and the identification of additional indicators (namely intervention and replication indicators), to establish a holistic method. This collaboration resulted in the definition of additional 90 KPIs taking into account the mobility, governance, environmental as well as citizens' engagement sectors on top of energy, economic, social and technology sectors that were proposed in the first version of this deliverable.

At step five, a data based on the KPI definitions and calculation formulas already covered in the previous steps, targeting data needs and constraint needs, was introduced. Moreover, a data availability check request towards cities was performed and the provided outputs were used as inputs to deliverable D2.4 of WP2 that is dedicated to data gathering for impact monitoring.

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The subsequent step six introduced a data normalisation methodology to detach the KPIs from cities' particularities and exogenous characteristics to allow for an objective and effective comparison.

Finally, an evaluation process was presented (step seven) to highlight new findings about success factors and strategies to overcome possible barriers and obstacles during the implementation and the operation phase.

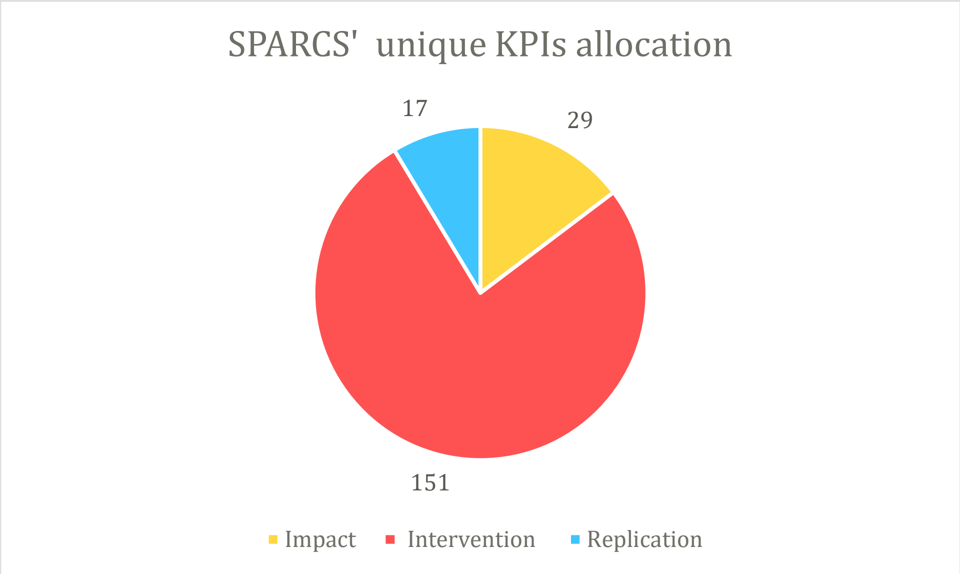

Figure 31: Unique SPARCS KPIs

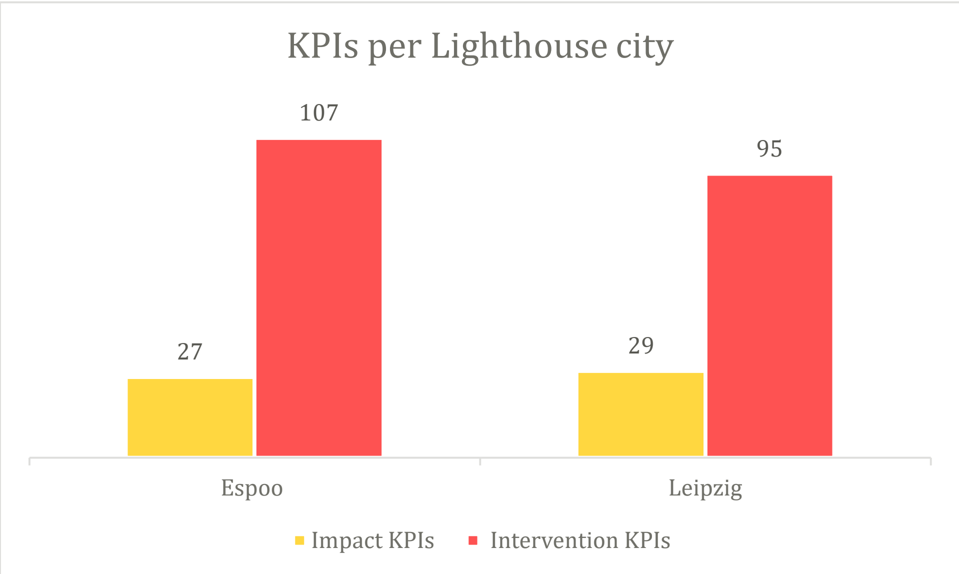

Figure 32: Number of Impact and Intervention KPIs per LHC

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7. APPENDICES

A. Leipzig Bottom-up analysis tables

Appendix table 1: Leipzig bottom-up analysis' KPIs

Leipzig Interventions	# of actions	Key Performance Indicators
L1- Intelligent EV Charging and Storage	4	-Number of parking places (car and bicycle) -Modal split, -Mobility habits -Optimization algorithm that provides bidirectional charging
L2- Micro grid inside the public grid	3	-Share of energy import or energy production self-sufficiency -Open district heating increase rate -Energy Market: participation in market type
L3- Heating Demand control	2	-Increase citizens quality of life -Health and well-being -Engagement
L4-Personalized informative billing	7	-Energy price -Citizen's engagement -Energy consumption
L5- Human-Centric Energy Management and Control DecisionSupport	2	-
L6- Decarbonization of district heating.	4	-Amount of saved CO_2 emissions -Supply of renewable heat to the 2 project specific districts -Greenhouse gas emissions reduction
L7- Heat storage (P2H)	1	-Amount of renewable heat supplied to the grid -Number of operating hours(annually) -Amount of saved CO_2 emissions
L8- ICT integration	1	-Energy Storage -Amount of saved CO_2 emissions
L9- Implementation and installation of an open standard based ICT platform that we call the "L-box"	2	-Assets added vs. total assets -Data availability of each asset -Total energy production per asset, per asset class -Total energy production of the generation portfolio -Data quality in asset inventory: existing non-NULL values vs. possible values -Number of assets which get a forecast -Uptime of platform, processes, microservices
L10- Economically reasonable integration of open and standardized sensors and systems	1	- Number of applications based on this data

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L11- Establishment of a distributed cloud centric ICT System which enables an intelligent energy management system	2	-Number of installed "zero carbon communities" -Improvement of renewable energy share -Number of battery charge and discharge actions
L12-Implementation of a human-centric interface/application	1	-
L13- Visual metaphors and constructs/dashboards for energy footprint analysis	1	-
L14-Commissioning on specific energy savings targets	1	-
L15- Integration of 2G e-bus charging points	3	-Data exchange in PED
L16- Load-balanced fleet management	4	-
L17-Conceptualization and application of a public Blockchain for transactions between energy consumers ,producers, service providers and grid system operators in a microgrid	3	-Number of (active) participants -Number of transactions; turnover -Availability of the system
L18- Integration of the planned "community energy storage" (CES) and "community demand response	4	-Data transfer rate -Time lag -Annual Mismatch Ratio (AMRx)
L19- Energy Positive District Planning	2	-Number of datasets -Number of unique visitors, -Number of integrated buildings
L20- Standard model for smart cities	1	-Number of citizens who are affected by replication measures
L21- Community empowerment support activities through dialogues transferring ownership, Knowledge transfer	4	-Advice / contacting -Advice apartment / Number of apartments in the building -Advice building / Number Buildings in the district

Appendix table 2: Leipzig districts KPIs

Leipzig Districts	# of interventions	KPIs
Baumwollspinnerei Block	3	-Utilization of local district heating -Energy storage -Renewable energy in total energy generation -Share of the renewable energy in the grid -Total Energy Production CO_2 Gas Emissions, -Air quality indicator -Quantity of energy supplied by EV charging stations

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Leipzig West	14	-Total energy demand per capita -Energy demand and consumption -Reduced energy curtailment of RES and DER -Peak load reduction -Energy to /from VPP -Total electricity consumption per capita -Utilization of local district heating -Citizen's engagement -Quantity of energy supplied by EV charging stations -Renewable energy in total energy generation -Share of the renewable energy in the grid -Total Energy Production, -Energy storage

Appendix table 3: Leipzig Macro level KPIs

Macro/ City	# of interventions	KPIs
Leipzig	4	-Market orientation -Citizen engagement -Share of the renewable energy in the grid - Annual number of new patents -Budget spent on green space management -Debt service ratio -Carbon footprint reduced in mobility -Share of traffic by bicycle mode -Share of traffic by pedestrian mode -Life expectancy at birth -Energy send from charging stations

B. Final KPIs lists

Appendix table 4: Leipzig's final intervention KPIs list

Leipzig Interventions	Number of actions	Key Performance Indicators
L1- Intelligent EV Charging and Storage	4	- Energy Storage type - Energy Storage number of equipment Increase - Energy Storage capacity Increase - Peak Load Reduction - Reduced System Average Interruption Duration Index (SAIDI) - Reduced System Average Interruption Frequency Index (SAIFI) - Demand from all EV mobility modes; impact on the grid - "User satisfaction of minimum charging level in EVs

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		- Monetary gains for user (charging costs vs flexibility revenues) - satisfaction of minimum charging level for commercial EVs (for carrying out their daily routes) - Accuracy of Generation forecasting - Accuracy of storage utilization - Increase in shared EVs availability - increase of integrated smart EV charging units - Increased level of utilization of EV charging stations
L2- Micro grid inside the public grid	3	- Decrease of energy import share in the district - Energy Storage type - Energy Storage number of equipment Increase - Energy Storage capacity Increase - Increase of district electrical energy export share - Fossil fuels Energy Generation decrease - Energy transfers through blockchain transactions - Volume of exchanges/ transactions (monetary) over blockchain - Accuracy of Generation forecasting - Accuracy of storage utilization - District self-consumption rate - Reduction of the energy production cost - Reduction of the customer energy cost
L3- Heating Demand control	2	- Total energy demand reduction - Onsite energy ratio OER - Peak Load Reduction - Energy Storage type - Energy Storage number of equipment Increase - Energy Storage capacity Increase
L4-Personalized informative billing	7	- Decrease of thermal energy import share in the district - Total thermal energy demand reduction - District self-consumption rate - Peak Load Reduction
L5- Human-Centric Energy Management and Control Decision Support	2	- Peak Load Reduction - Total energy demand reduction - Total flexibility available Increase (KW) - Flexibility increase (%) of normal load

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L6- Decarbonization of district heating.	4	- Share of RES increase (heat, solar thermal) - Heat Recovery Ratio - District self-consumption rate - Fossil fuels Energy Generation decrease - CO_2-emission reduction through RES heat increase - Fossil fuels Energy Generation decrease - Potential CO_2-reduction
L7- Heat storage (P2H)	1	- District self-consumption rate - Number of operating hours per year - Increase of district thermal energy through Power-to-Heat
L8- ICT integration	1	- District self-consumption rate
L9- Implementation and installation of an open standard based ICT platform that we call the "L-box"	2	- Share of RES increase - District self-consumption rate - Peak Load Reduction - Total flexibility available Increase (KW) - Flexibility increase (%) of normal load. - Flexibility provided (KWh) - Number of demand requests - Number of demand responses - Renumeration due to flexibility delivered - Penalty due to flexibility refusal - Number of requests that are initially accepted but declined afterwards; overwrites - Accuracy of flexibility available - Onsite energy ratio OER
L10- Economically reasonable integration of open and standardized sensors and systems	1	- Number of smart equipment - Number of digital platforms used - Number of piloted solutions
L11- Establishment of a distributed cloud centric ICT System which enables an intelligent energy management system	2	- Number of smart devices - Number of inquiries about green plug
L12-Implementation of a human-centric interface/application	1	- Total energy demand reduction - Reduction of the total energy requirement (application smart devices) - Reduction of CO_2 emissions (application smart devices) - Reduction of the customer's energy costs (application of smart devices)

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L13- Visual metaphors and constructs/dashboards for energy footprint analysis	1	- Total energy demand reduction - Peak Load Reduction
L14-Commissioning on specific energy savings targets	1	- Total energy demand reduction - Peak Load Reduction - Number of piloted solutions - How many experiments were conducted? - Number of actively involved partners in energy solutions
L15- Integration of 2G e- bus charging points	3	- Increase of EVs share in local transportation - Increase of integrated smart EV charging units - Increased level of utilization of EV charging stations
L16- Load-balanced fleet management	4	- Energy Storage V2G - Energy Storage capacity Increase from V2G - Demand from all EV mobility modes; impact on the grid - Increase of EVs share in local transportation - Increase of citizens using EV modes - Increase of integrated smart EV charging units - Increased level of utilization of EV charging stations
L17-Conceptualization and application of a public Blockchainfor transactions between energy consumers ,producers, service providers and grid system operators in a microgrid	3	-
L18- Integration of the planned “community energy storage” (CES) and “community demand response	4	-
L19- Energy Positive District Planning	2	- Professional stakeholder involvement - Strategy; - How SPARCS, supports, facilitates, accelerates the city plans

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		- Professional stakeholder involvement
L20- Standard model for smart cities	1	- Professional stakeholder involvement - Leadership - Strategy; How SPARCS, supports, facilitates, accelerates the city plans
L21- Community empowerment support activities through dialogues transferring ownership, Knowledge transfer	4	- Increase of citizens' contribution in BM creation - Number of co-created solutions - Number of actions replicated - Percentage of people are aware of the existing solutions before the interventions - Percentage of people are aware of the existing solutions after the interventions - Citizen level: How valuable are the developed solutions for the development of future districts? - Municipal level: How valuable are the developed solutions for the development of future districts? - Increased citizens' awareness for energy efficiency - increased citizens' interest for smart energy solutions - Number of people reached

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Appendix table 5: Leipzig's final intervention KPIs list

Espoo Interventions	Number of actions	Key Performance Indicators
E1 - Solutions for Positive Energy Blocks	6	- Share of RES (electricity) - Share of RES (thermal) - Excess Heat Recovery Ratio - Building energy efficiency measurement - Energy Storage type - Energy Storage number of equipment - Energy Storage capacity - Total flexibility available (KW) - Onsite energy ratio OER - Annual Mismatch Ratio (AMRx) - Energy costs per m2 - CO_2 emissions - Air quality
E2 - Boosting E-mobility uptake	3	- Demand from all EV mobility modes; impact on the grid - Ratio of peak demand from EV mobility modes to local transformer capacity - Ratio of average demand from EV mobility modes to local transformer capacity - Increase of integrated EV charging units - Level of utilization of EV charging stations - District EV parking/charging places (car and bicycle) - Increase of EVs share in local transportation
E3 - Engaging users	3	- Number of engaged stakeholders - Engagement of stakeholders - Number of co-created solutions - Improving awareness of energy positive district solutions - Likelihood for using the developed solutions
E4 - Smart Business Models	1	- Number of co-creation sessions for (energy positive) business models - Stakeholders reached to contribute in business model / solution co-creation - Engagement of stakeholders
E5 - Solutions for Positive Energy Blocks	3	- Share of RES (electricity) - Share of RES (thermal) - Energy Storage number of equipment - Annual flexibility up and down kWh

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		- Potential flexibility up and down from integrated equipment kW - GHG emission reduction from flexibility - Storage type (type) - Storage capacity (MW/MWh), - Annual Mismatch Ratio (AMRx) - Open District Heating increase rate - Increase of district thermal energy export share - Onsite energy ratio OER - Accuracy of storage utilization - Accuracy of the energy performance forecast - Accuracy of Generation forecasting - Utilization of batteries; % of energy stored and used from the battery
E6 - ICT for Positive energy blocks	3	- Total change in energy demand - Annual Mismatch Ratio (AMRx) - Change in Peak Load - Accuracy of Generation forecasting - Accuracy of storage utilization - Energy Storage number of equipment - Annual flexibility up and down kWh - Potential flexibility up and down from integrated equipment kW - GHG emission reduction from flexibility - Storage type (type) - Reduced System Average Interruption Duration Index (SAIDI) - Reduced System Average Interruption Frequency Index (SAIFI) - Accuracy of the energy performance forecast - Onsite energy ratio OER - Activation quality in VPP - District PV Generation change - Increase of integrated systems share - Energy from VPP - Energy to VPP - Energy high utilisation during downregulation - CO_2equivalent change due to the flexibility - Number of virtually-monitored devices - Number of physically-monitored devices - Accuracy of virtual energy meter - Data availability
E7 - New E-mobility hub	3	- Increase of citizens using EV modes - Demand from all EV mobility modes; impact on the grid - User satisfaction of minimum charging level in EVs - Peak load reduction

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		- Total flexibility available (KW) - Flexibility percentage of normal load. - Greenhouse gas emissions reduction - Charging time / day and charging time / month. - Charged power / month and charged power / day. - Peak demand reduction using the charging strategy - Utilization of chargers in the system after charging strategy. - Number of charging strategies simulated. - Ratio of peak demand from EV mobility modes to local transformer capacity - Ratio of average demand from EV mobility modes to local transformer capacity
E8 - Engaging users	3	- Number of engaged stakeholders - Engagement of stakeholders - Number of co-created solutions - Improving awareness of energy positive district solutions - Likelihood for using the developed solutions
E9 - Smart Business models	1	- Number of co-creation sessions for (energy positive) business models - Stakeholders reached to contribute in - business model / solution co-creation - Engagement of stakeholders
E10 - Solutions for Positive Energy Blocks	3	- Increased number of persons using Espoo 3D city model - Successful completion of the SPARCS interventions - Relation of project to city strategy - Number of promising technical and infrastructure solutions for PEDs - Utilization of energy system planning on the new urban development planning - Expected on-site Energy Ratio [%] for Kera
E11 - Engaging users	1	- Were the mobility insights useful for the city planning authorities? - Number of stakeholders reached
E12 - ICT for Positive energy blocks	3	- Identified potential 5G and blockchain solutions for Kera
E13 - E-mobility in Kera	2	- How valuable are the developed solutions for the development of future districts? - Number of e-mobility solutions introduced for replication in Kera planning phase

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		- Simulated demand for charging station in Kera area
E14 - New economy/ Smart governance models	1	- Number of citizens involved in co-creation of co-creation model - Number of stakeholders involved in co-creation of co-creation model - Experienced satisfaction of the co-creation participation - Capture if participants feel like they were able to affect the development process
E15 - Virtual Power Plant	2	- Loads connected to demand response (kW) - Rewording for consistency. Flexibility made available - Blockchain - Number of SBM piloted
E16 - Smart heating	1	- Total flexibility available Increase (KW) - Heating - Flexibility increase (%) of normal load. - Heating - Total current and potential heat load under DSM (MW) - Current and potential emission savings (CO_2 per year) - Number of buildings or apartments participating in demand response for district heating
E17 - Virtual twin	2	- Increase of utilization of the Espoo 3D City model or instead increased number of persons using Espoo 3D city model - Increase of simulations executed via the Virtual Twins concept - Number of innovative energy technologies incorporated in virtual twin for simulation purposes - Accuracy of building heating and load forecasting (% error between virtual twin and real monitored data)
E18 - EV charging effects to grid	1	- Increase of integrated public EV charging units - Peak load (electricity) reduction - Demand from all EV mobility modes; impact on the grid - Developed recommendations for future urban planning/new districts
E19 - Sustainable lifestyle	2	- Number of co-created solutions - Number of engaged stakeholders

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		- Engagement of citizens and stakeholders - Improving awareness of energy positive district solutions
E20 - District development	1	-
E21 – Air Quality	1	- Reduction of CO_2 emissions - Improve Air Quality
E22 -Co-creation for Positive Energy District development	2	- Number of citizens involved in co-creation of co-creation model - Number of stakeholders involved in co-creation of co-creation model - Experienced satisfaction of the co-creation participation
E23 - New economy/ Smart business models	2	- Number of smart business models created in Espoo - Dissemination KPIs reported as a part of WP8 activities. - Number of new innovative projects leveraged beyond SPARCS and the total volume of the additional funding.

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C. KPIs Categorization

Appendix table 6: KPIs category part A

Energy	Economy	Social	Environmental
Accuracy of forecasting	Discounted Payback Period-DPBP	Increase of persons in full-time, permanent, fixed-term employment	CO_2-eq reduction
Activation quality in VPP	Internal Rate of ReturnIRR	Decrease of youth unemployment rate	Greenhouse gas emissions reduction
Annual district PV Generation increase	Loan Life Coverage Ratio-(LLCR)	Capital spending increase as a percentage of total expenditures	Reduction of NOx, small particulates, tHC
Decrease of energy import share in the district	Municipal involvement	Increase of the percentage of population leaving in affordable housing	Noise Pollution
Decrease of total generation curtailment	new business creation	Decrease of population living below the national poverty line	Improve Air Quality
Demand from all EV mobility modes; impact on the grid	Operating cash flow	Participatory E-governance for energy services	
Demand Response/Flexibility	Participation in market type	Participatory planning initiatives for positive energy districts	Climate Resilience Strategy
District Bio Plant Generation increase	Payback period of a PED system	Stakeholder and citizen engagement through digital technologies	

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District CHP Heat Generation increase (excess heat)	Reduction of the customer energy cost	Knowledge sharing and access to information to increase citizens and stakeholders engagement	
District GSHP Heat Generation increase	Reduction of the energy production cost	Constitution of citizens' panel energy users committee	
District MW installed	Total annual cost	Co-creation initiatives (lead by partner cities) on energy positive district	
District self-consumption rate	Total investment	Education and teaching activities focused on energy transition and well-being	
Energy Storage (Batteries, Buildings, etc)	WACC	Citizens co-ownership of energy utilities	
Fossil fuels Energy Generation decrease		City sell of energy directly to citizens	
Heat Recovery Ratio		Citizen awareness of public and private energy initiatives	
Increase of district thermal energy export share		Citizen engagement in energy-saving actions	
Increase of excess heat utilization		Integration of citizen-led organizations/associations in the co-creation for Positive Energy Districts)	
Onsite energy ratio (OER)		Energy Initiatives leaded by citizens and households	

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Open District Heating increase rate		Inclusion of citizens and local communities in capitals for energy transition project leaded by private companies	
Peak Load Reduction		Integration of collective self-consumption for renewable districts into urban development plans	
Renumeration due to flexibility delivered (Euro)		Creation of community energy funds	
Services dispatch success rate (% MW) in VPP		Inclusion of hard-to-reach groups in energy transition	
Services dispatch success rate (% MW) in VPP		Participatory budgeting initiatives for energy transition	
Share of RES increase annually		Physical intervention for energy transition in distressed urban areas and deprived neighbourhoods.	
Storage energy losses		Integration of energy transition solutions into new neighbourhood developments	
Storage State of Charge			
Total energy demand reduction			
Total district energy generation			

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Appendix table 7: KPIs category part B

ICT	Governance	Mobility	Citizen engagement
5G utilization increase	How SPARCS, supports, facilitates, accelerates the city plans	Smart Charging usage- Charging infrastructure	Increase of citizens contribute in BM creation
Amount of energy managed through digital platforms	Leadership	Clean mobility utilization	Number of co-created solutions
Annual number of contributions to European Standardisation Organisations	Relation of project to city strategy	District EV parking/charging places (car and bicycle)	Number of co-created models
Annual number of new patents	Balanced project teams	Increase in shared EVs availability	Number of participants in models planning
ICT response time	Involvement of the city administration	Increase of District charging points with smart charging capability	Category of participants in models planning
Improved Cybersecurity		Increase of annual number of public transport trips per capita	
Improved Data Privacy	Monitoring and reporting	Increase of citizens using EV modes	Number of smart business models created
Increase of simulations executed via the Virtual Twins concept	Market orientation	Increase of EVs share in local transportation	How many people tried e-mobility solutions?
Increase of utilization of the Espoo 3D City model	Innovation potential	increase of integrated EV charging units	How many experiments were conducted?

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Increased hosting capacity for RES, electric vehicles and other new loads	Municipal involvement	Increased level of utilization of EV charging stations	Did the people flow user experience improve?
Increased System Flexibility for Energy Players	Sustainability aspects in procurement	Modal split	Did the user research inspire new sustainable mobility solutions?
Number of digital platforms used	Consultation plan		% of people are aware of the existing solutions before and after interventions
Number of internet connections and mobile phones	Professional stakeholder involvement		Number of active market participants in prosumer models
Number of internet connections and mobile phones	Professional stakeholders		Number of actively involved partners in energy solutions
Number of new and improved 5G services	Local community involvement in planning / implementation phase		How much was the awareness of the city planning people improved?
Platform Downtime	Community involvement		Were the insights useful for the city planning authorities?
Reduced System Average Interruption Duration Index (SAIDI)	Stakeholder awareness and social learning		How valuable are the developed solutions for the development of future districts?
Reduced System Average Interruption Frequency Index (SAIFI)	Organizational changes and new processes		Number of co-creation sessions and citizens and stakeholders involved

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Share of integrated systems (smart control/ VPP/ storage),	Spin off activities		Did you feel that you were able to affect and participate in the ideation of future directions?
	Stakeholder satisfaction		How well does the business model(s) cover the four lenses of innovation (desirability, feasibility, viability and sustainability)?
	Successful completion of the SPARCS interventions		Number of stakeholders participating in the co-creation process
			Number of ideas that have come up during the process with stakeholders.
			number of co-creation sessions with youngsters
			Degree of young users satisfaction to Lippulaiva compared to all users
			Number of youngsters using environmentally friendly modes

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D. Intervention KPIs description and calculation

KPI Name	Accuracy of building heating and load forecasting
Level of Applicability	City ☐ District ☑ Building ☑
Description	Accuracy of building heating and load forecasting is the error between virtual twin and real monitored data
Data	-Building (heating and load) forecasting data -Real energy data
Calculation	Ratio of predicted / actual energy
Units	[%]
KPI Category	Energy

KPI Name	Accuracy of flexibility available
Level of Applicability	City ☐ District ☑ Building ☑
Description	Accuracy of flexibility available
Data	-Total flexibility available (KW) considering EV charging points, -Buildings/Prosumers, escalators/elevators
Calculation	Ratio of predicted / actual flexibility
Units	[%]
KPI Category	Energy

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KPI Name	Accuracy of Generation forecasting
Level of Applicability	City ☑ District ☑ Building ☑
Description	Predicted generation compared to the actual generation
Data	-RES predicted generation -Actual generation
Calculation	Ratio of predicted / actual generation
Units	[%]
KPI Category	Energy

KPI Name	Accuracy of storage utilization
Level of Applicability	City ☐ District ☑ Building ☑
Description	The storage utilization predicted compared to the actual utilization of the storage
Data	- Storage utilization predicted - Actual storage utilization
Calculation	Ratio of predicted / actual storage utilization
Units	[%]
KPI Category	Energy

KPI Name	Annual Mismatch Ratio (AMRx)
Level of Applicability	City ☐ District ☑ Building ☐
Description	Indicates how much energy needs to be imported into the area for each energy type on average.
Data	- Hourly difference between demand and local renewable supply (by energy type)

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	- Hourly demand (by energy type) during that same hour
Calculation	It is the annual average ratio of, for those hours when the local demand exceeds the local renewable supply
Units	[%]
KPI Category	Energy

KPI Name	Annual number of contributions to European Standardization Organizations
Level of Applicability	City ☑ District ☐ Building ☐
Description	Contributions to European Standardization Organizations
Data	Annual number of contributions to ESO
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

KPI Name	Annual number of new patents
Level of Applicability	City ☑ District ☑ Building ☐
Description	Patents filed in the context of SPARCS
Data	Annual number of patents filed in the context of SPARCS
Calculation	Cumulative measurements
Units	-

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KPI Category	ICT

KPI Name	Co-creation of development process
Level of Applicability	City ☐ District ☑ Building ☐
Description	Capture if participants feel like they were able to affect the development process
Data	Questionnaire
Calculation	Likert scale
Units	-
KPI Category	Citizen engagement

KPI Name	Decrease of energy import share
Level of Applicability	City ☐ District ☑ Building ☐
Description	Net energy imports are estimated as energy use less production. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.
Data	- Energy imported - Total energy consumed
Calculation	The percentage of energy imported as a share of the total energy consumed.
Units	(%)

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KPI Category	Energy

KPI Name	Demand from all EV mobility modes
Level of Applicability	City ☐ District ☑ Building ☑
Description	Annual energy demand from all EV mobility modes
Data	Energy demand
Calculation	Cumulative energy measurements
Units	kWh/yr
KPI Category	Mobility

KPI Name	EV parking/charging places (car and bicycle)
Level of Applicability	City ☐ District ☑ Building ☐
Description	Number of EV places
Data	-EV Car parking/charging places (#) -EV Bicycle parking/charging places (#)
Calculation	Cumulative measurements
Units	-
KPI Category	Mobility

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KPI Name	DSCR
Level of Applicability	City ☑ District ☐ Building ☐
Description	Debt Service Coverage Ratio
Data	-Net operating income -Total debt service.
Calculation	Net operating income divided by total debt service.
Units	(%)
KPI Category	Economy

KPI Name	Energy costs per m²
Level of Applicability	City ☐ District ☐ Building ☑
Description	Total energy costs of a building
Data	-Total energy costs of a building (thermal, electricity ect) -Total building area
Calculation	Cumulative measurements
Units	€/m^2
KPI Category	Energy

KPI Name	Decrease of thermal energy import share
Level of Applicability	City ☐ District ☑ Building ☑
Description	This indicator is developed through collecting data regarding the amount of heat generated (kwh/a) though district heating systems and dividing it by the total heat demand (Kwh/a)
Data	- Heat generated (kwh/a) though district heating systems

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	-Total heat demand (Kwh/a)
Calculation	Share of heat demand delivered by district heating systems.
Units	[%]
KPI Category	Energy

KPI Name	Energy Storage capacity Increase
Level of Applicability	City ☐ District ☑ Building ☑
Description	Energy storage capacity by energy type depending on storage type, e.g. the storage capacity, volume, mass, temperature, long or short-term storage
Data	Energy storage capacity by energy type
Calculation	Ratio of final energy storage capacity / initial storage capacity
Units	(%)
KPI Category	Energy

KPI Name	Energy Storage number of equipment Increase
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increase of energy storage equipment
Data	Number of new equipment installed
Calculation	Ratio of final energy storage equipment / initial storage equipment

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Units	(%)
KPI Category	Energy

KPI Name	Engagement of citizens and stakeholders
Level of Applicability	City ☑ District ☑ Building ☑
Description	Engagement of all citizens, did the citizens feel that they were able to contribute in the activity and feel engage
Data	Questionnaire
Calculation	Likert scale 1-5, (1=not at all, 2=to a little extent, 3=I don't know, 4=to some extent, 5= to a great extent)
Units	(%)
KPI Category	Citizen engagement

KPI Name	EV car sharing rate increase
Level of Applicability	City ☑ District ☑ Building ☐
Description	Increase of EV car sharing
Data	-Total number of Ev cars (number) -EVs available for sharing (number)
Calculation	Ratio of available EVs for sharing / Total EV
Units	(%)
KPI Category	Mobility

KPI Name	Excess Heat Recovery Ratio

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Level of Applicability	City ☐ District ☑ Building ☑
Description	Excess heat is the unused heat given to the surrounding environment by a heat engine in a thermodynamic process. Capturing excess heat enables it to be redirected to a function that would otherwise be using energy from the grid.
Data	-Total excess heat (MWh) -Utilization of excess heat (MWh)
Calculation	The percentage of total reused excess heat, as a share of the total produced excess heat
Units	[%]
KPI Category	Energy

KPI Name	Experienced satisfaction of the co-creation participation
Level of Applicability	City ☑ District ☑ Building ☑
Description	Experienced satisfaction of the co-creation participation
Data	Questionnaire
Calculation	Likert scale 1-5
Units	-
KPI Category	Citizens Engagement

KPI Name	Flexibility increase of normal load (electricity)
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increase in felicity of normal load (electricity)
Data	Flexibility of normal load (electricity): -Reference load profile

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	-Flexible load profile
Calculation	The deviation of the two resulting profiles
Units	[%]
KPI Category	Energy

KPI Name	Flexibility increase of normal load (heating)
Level of Applicability	City ✓ District ✓ Building ✓
Description	Increase in felicity of normal load (heating)
Data	Flexibility of normal load (heating): -Reference load profile -Flexible load profile
Calculation	The deviation of the two resulting profiles
Units	[%]
KPI Category	Energy

KPI Name	Flexibility provided
Level of Applicability	City ✓ District ✓ Building ✓
Description	Total flexibility provided
Data	Flexibility provided
Calculation	Cumulative measurements

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Units	[KWh]
KPI Category	Energy

KPI Name	Fossil fuels Energy Generation decrease
Level of Applicability	City ☑ District ☑ Building ☑
Description	Fossil fuels Energy Generation decrease
Data	-Energy derived from fossil fuels
Calculation	Ratio of measured energy derived from fossil fuels / initial measurements
Units	[%]
KPI Category	Energy

KPI Name	Heat Recovery Ratio
Level of Applicability	City ☐ District ☑ Building ☑
Description	The amount of excess energy used (heat)
Data	-Total excess heat [MWh] -Utilization of excess heat [MWh]
Calculation	Ratio of used excess heat/ total excess heat
Units	[%]
KPI Category	Energy

KPI Name	Identified potential 5G and blockchain solutions
Level of Applicability	City ☑ District ☐ Building ☐

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Description	Identified potential 5G and blockchain solutions
Data	Number of 5G and blockchain solutions
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

KPI Name	Improve Air Quality
Level of Applicability	City ☑ District ☑ Building ☐
Description	This indicator presents the improvement of air quality
Data	-Values for small particulates [ppm], -Values for tHC Volatile hydrocarbons
Calculation	Ratio of air quality measurements after/ before
Units	[%]
KPI Category	Environmental

KPI Name	Improving awareness of energy positive district solutions
Level of Applicability	City ☑ District ☑ Building ☐
Description	Improving awareness of energy positive district solutions
Data	Questionnaire
Calculation	Likert scale

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Units	-
KPI Category	Social

KPI Name	Increase citizens quality of life, health and well-being
Level of Applicability	City ☑ District ☑ Building ☐
Description	The average number of years to be lived by a group of people born in the same year, if health and living conditions at the time of their birth remained the same throughout their lives.
Data	-Population -Number of deaths at different ages
Calculation	Life expectancy at birth is calculated using a life table that takes into account the population and the number of deaths of people at different ages (different birth years) in a given year.
Units	(%)
KPI Category	Social

KPI Name	Increase in shared EVs availability
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increase of EVs available for sharing
Data	Number of EVs available for sharing
Calculation	Ratio of EVs available for sharing after/ before
Units	(%)
KPI Category	Mobility

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KPI Name	Increase of Citizens' contribution in BM creation
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increase of Citizens' contribution in BM creation
Data	Questionnaire
Calculation	Likert scale
Units	(%)
KPI Category	Citizen's engagement

KPI Name	Increase of Citizens' participation in market
Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of citizens participating in the Market
Data	Questionnaire
Calculation	Likert scale
Units	(%)
KPI Category	Social

KPI Name	Increase of citizens using EV modes
Level of Applicability	City ☑ District ☑ Building ☐
Description	Increase of citizens using EV modes
Data	-Total number of citizens [#] -Citizens using non EV vehicles to go to work -Citizens going to work using EV vehicles

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Calculation	The ratio deviation of people moving to work with and without EV
Units	[%]
KPI Category	Mobility

KPI Name	Increase of EV charging points
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increase of EV charging points
Data	-Number of EV charging points -Number of V2G EV charging points -Number of smart EV charging points
Calculation	Cumulative measurements
Units	(%)
KPI Category	Mobility

KPI Name	Increase of EVs share in local transportation
Level of Applicability	City ☑ District ☑ Building ☐
Description	Increase of EVs share in local transportation
Data	-Total number of vehicles in local transportation -Total number of vehicles in local transportation Bicycles in local transportation mode
Calculation	The ratio deviation of EVs in local transportation after/before implementations
Units	(%)

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KPI Category	Mobility

KPI Name	Increase of integrated public EV charging units
Level of Applicability	City ☑ District ☑ Building ☐
Description	Increase of integrated public EV charging units
Data	Number of public EV charging stations
Calculation	Ratio of integrated public EV chargers after/ before implementations
Units	(%)
KPI Category	Mobility

KPI Name	Increase of integrated smart EV charging units
Level of Applicability	City ☑ District ☑ Building ☐
Description	Increase of integrated smart EV charging units
Data	Number of smart EV charging stations
Calculation	Ratio of integrated smart EV charging units after/ before implementations
Units	(%)
KPI Category	Mobility

KPI Name	Increase of simulations executed via the Virtual Twins concept
Level of Applicability	City ☑ District ☑ Building ☑

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Description	Increase of simulations executed via the Virtual Twins concept
Data	Number of simulations executed via the Virtual Twins concept
Calculation	Ratio of executed simulations after/ before implementations
Units	(%)
KPI Category	ICT

KPI Name	Increase of integrated systems share		
Level of Applicability	City ✓	District ✓	Building ✓
Description	A system combines different individual systems together in order to work under a centralized control, increasing the efficiency of the individual systems and the energy management.		
Data	-Share of integrated systems		
Calculation	The percentage of integrated systems including storage devices, VPP and RES systems as a share of the individual systems installed.		
Units	[%]		
KPI Category	ICT		

KPI Name	Increased citizens' interest for smart energy solutions		
Level of Applicability	City ✓	District ✓	Building ✓
Description	Increased citizens' interest for smart energy solutions		
Data	Questionnaire		
Calculation	Likert Scale		

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Units	(%)
KPI Category	Social

KPI Name	**Increased citizens' awareness for energy efficiency**
Level of Applicability	City ☑ District ☑ Building ☑
Description	Increased citizens' awareness for energy efficiency
Data	Questionnaire
Calculation	Likert Scale
Units	(%)
KPI Category	Social

KPI Name	**Increased number of persons using 3D city model**
Level of Applicability	City ☑ District ☐ Building ☐
Description	Increased number of persons using Espoo 3D city model
Data	Number of people utilising 3D city model
Calculation	Ratio of people using Espoo 3d city model after/before implementations
Units	(%)
KPI Category	ICT

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KPI Name	Job creation
Level of Applicability	City ☑ District ☐ Building ☐
Description	The total number of unemployed persons, divided by the total labour force.
Data	Number new jobs created by SPARCS
Calculation	The unemployment rate is the percentage of the labor force that actively seeks work but is unable to find work at a given time.
Units	-
KPI Category	Social

KPI Name	Likelihood for using the developed solutions
Level of Applicability	City ☑ District ☑ Building ☑
Description	Likelihood for using the developed solutions
Data	Questionnaire
Calculation	Likert scale
Units	-
KPI Category	Social

KPI Name	Monetary gains for EV user
Level of Applicability	City ☑ District ☑ Building ☐
Description	Monetary gains for EV user
Data	-EV User charging costs -EV flexibility revenues for the user

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Calculation	Deviation between costs and revenues for EV users
Units	€
KPI Category	Economic

KPI Name	How valuable are the developed solutions for the development of future districts?		
Level of Applicability	City ☑	District ☑	Building ☑
Description	How valuable are the developed solutions for the development of future districts?		
Data	Questionnaire		
Calculation	Likert scale		
Units	-		
KPI Category	Citizens Engagement		

KPI Name	Awareness of the existing solutions before the interventions		
Level of Applicability	City ☑	District ☑	Building ☑
Description	Number of people are aware of the existing solutions before the interventions		
Data	Questionnaire		
Calculation	Likert scale		
Units	[%]		

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KPI Category	Citizens Engagement

KPI Name	Awareness of the existing solutions after the interventions		
Level of Applicability	City ☑	District ☑	Building ☑
Description	Number of people are aware of the existing solutions after the interventions		
Data	Questionnaire		
Calculation	Likert scale		
Units	[%]		
KPI Category	Citizens Engagement		

KPI Name	Number of actions replicated		
Level of Applicability	City ☑	District ☑	Building ☑
Description	The extent to which the project is copied in other cities and regions		
Data	Number of actions replicated		
Calculation	Cumulative measurements		
Units	-		
KPI Category	Governance		

KPI Name	Number of actively involved partners in energy solutions

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Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of actively involved partners in energy solutions
Data	Number of involved partners in energy solutions
Calculation	Cumulative measurements
Units	-
KPI Category	Citizen engagement

KPI Name	Number of buildings or apartments participating in demand response for district heating
Level of Applicability	City ☐ District ☑ Building ☐
Description	Number of buildings or apartments participating in demand response for district heating
Data	-Buildings participating in demand response for district heating -Apartments participating in demand response for district heating
Calculation	Cumulative measurements
Units	-
KPI Category	Citizen engagement

KPI Name	Number of co-created solutions
Level of Applicability	City ☑ District ☑ Building ☑
Description	With co-created solutions we mean all kind of novel co-design tools/methods for citizen engagement as well as different mobility concept ideas. With validated solutions, we mean tools/methods

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	and concept ideas that are developed further and validated with city's citizens and business stakeholders
Data	Number of validated solutions
Calculation	Questionnaire
Units	-
KPI Category	Citizen engagement

KPI Name	**Number of co-creation sessions for energy positive business models**
Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of co-creation sessions focus on business model co-creation
Data	Number of sessions focused on BMs
Calculation	Questionnaire
Units	-
KPI Category	Citizen engagement

KPI Name	**Number of demand requests**
Level of Applicability	City ☐ District ☑ Building ☑
Description	Number of flexibility demand requests
Data	-Number of demand requests

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	-Buildings/Prosumers, EV smart chargers, escalators/elevators
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

KPI Name	Number of demand responses
Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of flexibility demand responses
Data	-Number of demand responses -Buildings/Prosumers, EV smart chargers, escalators/elevators
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

KPI Name	Number of digital platforms used
Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of digital platforms used
Data	Number of digital platforms
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

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KPI Name	Number of innovative energy technologies incorporated in virtual twin for simulation purposes		
Level of Applicability	City ✓	District ✓	Building ✓
Description	Number of innovative energy technologies incorporated in virtual twin for simulation purposes		
Data	Number of technologies introduced in virtual twin to improve simulation		
Calculation	Cumulative measurements		
Units	-		
KPI Category	ICT		

KPI Name	Number of inquiries about green plug		
Level of Applicability	City ✓	District ✓	Building ✓
Description	Number of inquiries about green plug		
Data	Number of inquiries		
Calculation	Cumulative measurements		
Units	-		
KPI Category	Governance		

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KPI Name	Number of requests that are initially accepted but declined afterwards
Level of Applicability	City ☐ District ☑ Building ☑
Description	Number of flexibility requests that are initially accepted but declined afterwards
Data	-Number of requests that are initially accepted but declined afterwards Buildings/Prosumers, EV smart chargers, escalators/elevators
Calculation	Cumulative measurements
Units	-
KPI Category	ICT

KPI Name	Number of smart equipment
Level of Applicability	City ☐ District ☑ Building ☑
Description	Number of smart equipment
Data	-Smart meters for electricity and heating available [#] -Smart sensors for temperature, humidity, illuminance [#] -Smart actuators [#]
Calculation	Cumulative measurements
Units	-
KPI Category	Governance

KPI Name	Number of engaged stakeholders
Level of Applicability	City ☑ District ☑ Building ☑

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Description	Number of engaged stakeholders
Data	-Number of stakeholders involved in co-creation of co-creation model -Number of stakeholders reached
Calculation	Cumulative measurements
Units	-
KPI Category	Governance

KPI Name	Onsite energy ratio OER
Level of Applicability	City ✓ District ✓ Building ✓
Description	The overall balance between annual energy demand and local renewable supply
Data	- Annual energy supply from local renewable sources [all energy types together] - Annual energy demand [all energy types together].
Calculation	The ratio between annual energy supply from local renewable sources/ annual energy demand
Units	(%)
KPI Category	Energy

KPI Name	Payback time
Level of Applicability	City ✓ District ✓ Building ✓
Description	The payback period is the time it takes to cover investment costs.
Data	-Initial investment -Net cash flow per period

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Calculation	Payback Period = Initial Investment/ Net Cash Flow per Period
Units	Years
KPI Category	Economy

KPI Name	Peak load reduction [electricity]
Level of Applicability	City ☑ District ☑ Building ☑
Description	Peak load reduction [electricity]
Data	Peak demand electricity
Calculation	Deviation of energy demand after/before implementations
Units	[MWh]
KPI Category	Energy

KPI Name	Peak load reduction [heating]
Level of Applicability	City ☑ District ☑ Building ☑
Description	Peak load reduction [heating]
Data	Peak demand heating
Calculation	Deviation of heat demand after/before implementations
Units	[MWh]
KPI Category	Energy

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KPI Name	Professional stakeholder involvement evaluation
Level of Applicability	City ☑ District ☑ Building ☐
Description	The extent to which professional stakeholders outside the project team have been involved in planning and execution
Data	Questionnaire
Calculation	Likert scale
Units	-
KPI Category	Governance

KPI Name	Ratio of peak demand from EV mobility modes to local transformer capacity
Level of Applicability	City ☑ District ☑ Building ☐
Description	Peak demand from EV mobility modes to local transformer capacity
Data	-Local transformer capacity [MW] -Peak demand from all EV mobility modes [MW]
Calculation	Ratio of peak demand from EV mobility modes to local transformer capacity
Units	[%]
KPI Category	Energy

KPI Name	Ratio of average demand from EV mobility modes to local transformer capacity
Level of Applicability	City ☑ District ☑ Building ☑

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Description	Average demand from EV mobility modes to local transformer capacity
Data	-Local transformer capacity [MW] -Average demand from all EV mobility modes [MW]
Calculation	Ratio of average demand from EV mobility modes to local transformer capacity
Units	(%)
KPI Category	Energy

KPI Name	Reduced System Average Interruption Duration Index [SAIDI]
Level of Applicability	City ☐ District ☑ Building ☐
Description	Average outage duration for each customer served
Data	-Sum of all customers interruptions durations - Total number of customers served
Calculation	Sum of all customers interruptions durations /Total number of customers served
Units	minutes
KPI Category	ICT

KPI Name	Reduced System Average Interruption Frequency Index [SAIFI]
Level of Applicability	City ☐ District ☑ Building ☐
Description	System Average Interruption Frequency

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Data	-Total number of customers interruptions -Total number of customers served
Calculation	Total number of customers interruptions/ Total number of customers served
Units	Interruptions per customer
KPI Category	ICT

KPI Name	Reduction of CO_2-eq emissions
Level of Applicability	City ☑ District ☑ Building ☐
Description	Reduction of equivalent concentration of carbon dioxide emissions
Data	-Greenhouse gases -Global warming potential
Calculation	Multiply of the amount of the greenhouse gases by their Global warming potential(GWP) to convert amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.
Units	Million metric tonnes of carbon dioxide equivalents (MMTCDE)
KPI Category	Environmental

KPI Name	Reduction of the customer energy cost
Level of Applicability	City ☑ District ☑ Building ☑
Description	Reduction of the customer energy cost
Data	Energy cost per device
Calculation	Cumulative measurements
Units	€/Device

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KPI Category	Economy

KPI Name	Reduction of the energy production cost
Level of Applicability	City ☑ District ☑ Building ☑
Description	Reduction of the energy production cost
Data	Total energy production cost; price/KWh/a
Calculation	Cumulative measurements
Units	price/KWh/a
KPI Category	Economy

KPI Name	Reduction of the total energy requirement
Level of Applicability	City ☑ District ☑ Building ☑
Description	Reduction of the total energy requirement
Data	-Total energy needs for devices kWh/Device
Calculation	Ratio of energy needs after/ before implementations
Units	(%)
KPI Category	Energy

KPI Name	Relation of project to city strategy
Level of Applicability	City ☑ District ☑ Building ☐

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Description	Evaluation of the project goals towards the city goals
Data	Questionnaire
Calculation	Likert Scale
Units	-
KPI Category	Governance

KPI Name	ROI
Level of Applicability	City ☑ District ☑ Building ☐
Description	The return on investment (ROI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total incomes/net profit and the total investment of the project, usually expressed in %.
Data	- Current Value of Investment - Cost of Investment
Calculation	ROI= (Current Value of Investment−Cost of Investment)/ Cost of Investment
Units	-
KPI Category	Economy

KPI Name	Satisfaction of minimum charging level for commercial EVs
Level of Applicability	City ☑ District ☑ Building ☑
Description	User Satisfaction of minimum charging levels in EVs

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Data	Questionnaire
Calculation	Likert scale
Units	-
KPI Category	Social

KPI Name	Self-consumption rate Increase
Level of Applicability	City ☐ District ☑ Building ☑
Description	Self-consumption rate Increase
Data	-Total energy demand [MWh/a] -Total Energy Production [MWh/a]
Calculation	Total energy demand/ Total Energy Production
Units	[%]
KPI Category	Energy

KPI Name	Share of RES [electricity]
Level of Applicability	City ☐ District ☑ Building ☑
Description	Share of RES [electricity]
Data	-Total Energy consumption [electricity] [MWh] -Energy production using RES [electricity] [MWh]
Calculation	Energy production using RES / Total Energy consumption
Units	[%]
KPI Category	Energy

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KPI Name	Share of RES [thermal]
Level of Applicability	City District Building
Description	Share of RES [thermal]
Data	-Total Energy consumption [thermal][MWh] -Thermal energy production using RES [thermal] [MWh]
Calculation	Thermal energy production using RES/ Total Energy consumption
Units	[%]
KPI Category	Energy

KPI Name	Stakeholders reached to contribute in business model co-creation
Level of Applicability	City ☑ District ☑ Building ☑
Description	Stakeholders reached to contribute in business model co-creation
Data	-Number of stakeholders contributed in co-created solutions / business model co-creation -Number of stakeholders reached
Calculation	Likert scale
Units	-
KPI Category	Governance

KPI Name	How SPARCS, supports, facilitates, accelerates the city plans
Level of Applicability	City ☑ District ☑ Building ☐

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Description	Likert to evaluate if the project has benefited from and follows the smart city strategy of the city
Data	Questionnaire
Calculation	Likert scale
Units	-
KPI Category	Governance

KPI Name	Successful completion of the SPARCS interventions
Level of Applicability	City ☐ District ☑ Building ☑
Description	Successful completion of the SPARCS interventions
Data	-Number of goals achieved -Number of total goals
Calculation	Number of goals achieved/ Number of total goals
Units	(%)
KPI Category	Governance

KPI Name	Total electricity demand reduction
Level of Applicability	City ☑ District ☑ Building ☑
Description	Number of total goals
Data	Total electricity demand/year
Calculation	Ratio of electricity demand after/ before implementations

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Units	(%)
KPI Category	Energy

KPI Name	Total energy demand reduction
Level of Applicability	City ☑ District ☑ Building ☑
Description	Total energy demand reduction
Data	Total electricity demand/year
Calculation	Ratio of total energy demand after/ before implementations
Units	[%]
KPI Category	Energy

KPI Name	Total flexibility available Increase
Level of Applicability	City ☑ District ☑ Building ☑
Description	Total flexibility available Increase
Data	Total flexibility available
Calculation	Ratio of total flexibility after/ before implementations
Units	[%]
KPI Category	Energy

KPI Name	Total heating demand reduction

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Level of Applicability	City ☑ District ☑ Building ☑
Description	Total heating demand reduction
Data	Total heating demand/year
Calculation	Ratio of total heating demand after/ before implementations
Units	[%]
KPI Category	Energy

KPI Name	Transport behaviour
Level of Applicability	City ☑ District ☑ Building ☐
Description	Transport behaviour
Data	-Total number of citizens [number], -Citizens going to work using a personal [non Ev] vehicle [number], -Citizens using public transportation to go to work [number],
Calculation	Measurements and statistics on transport behaviour
Units	(%)
KPI Category	Mobility

KPI Name	Utilization of charging stations
Level of Applicability	City ☐ District ☑ Building ☑
Description	Measurements and statistics on transport behaviour

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Data	∑kWh charged or time
Calculation	Cumulative measurements
Units	[kWh]
KPI Category	Mobility

KPI Name	Utilization of energy system planning on the new urban development planning		
Level of Applicability	City ☑	District ☑	Building ☑
Description	Likert scale to capture the utilization of energy system planning on the new urban development planning		
Data	Questionnaire		
Calculation	Likert scale		
Units	-		
KPI Category	Social		

KPI Name	Utilization of the charging system		
Level of Applicability	City ☐	District ☑	Building ☑
Description	Utilization of the charging system		
Data	-Number of chargers occupied - total number of chargers		
Calculation	Ratio of chargers occupied/ total numbers of chargers		
Units	(%)		

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KPI Category	Mobility

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