D2.1 Definition of SPARCS Holistic Impact Assessment Methodology and Key Performance Indicators

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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-M18** The task develops an integrated framework for the holistic assessment of the SPARCS interventions in the demo sites (lighthouse and Fellow cities). The methodology will build 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 will be 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). […] different types of indicators will be 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 normalization 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.				
Participants	VTT, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV, RIL, FHG, BABLE, SPI, NEW,				

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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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

TABLE OF CONTENTS

Table of Contents ... 5

List of Figures ... 7

List of Tables ... 8

List of Abbreviations ... 9

Executive Summary ... 10

1.Introduction ... 13

1.1 Purpose of the document ... 14

1.2 Relation with other tasks ... 15

2.Smart City Indicators: From macroscopic Indicators to comprehensive low-level KPIs ... 17

2.1 Definition of KPIs ... 17

2.2 General KPI related considerations for cities ... 19

2.3 Specific KPI related considerations of SPARCS ... 20

3.Review of known assessment methodologies and key performance indicators for CITIES ... 25

3.1 Analysis of Morgenstadt assessment methodology ... 26

3.2 Review of CITYkeys indicators for smart city projects and smart cities ... 31

3.3 Review of SCIS key performance indicators ... 34

3.4 Review of CIVITAS process and impact evaluation framework ... 36

3.5 Review of Triangulum impact assessment methodology ... 38

3.6 Summary ... 41

4.SPARCS impact assessment methodology ... 43

4.1 SPARCS Top-down Impact Analysis and initial KPI definition ... 45

4.2 SPARCS Bottom-up and Technical interventions analysis ... 50

4.2.1 Bottom-up approach ... 50

4.2.2 Technical intervention Analysis ... 54

4.3 Holistic framework definition ... 55

4.4 Data collection methodology ... 56

4.5 Normalisation methodology definition ... 64

4.6 Process Evaluation ... 65

5.Conclusions ... 67

6.References ... 69

7.Appendices ... 71

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

A. Leipzig Bottom-up approach table 71
B. Technical intervation analysis 73
C. KPIs description and calculation 74

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

LIST OF FIGURES

Figure 1: "Initial SPARCS Evaluation and Assessment Framework" roadmap........................11
Figure 2: SPARCS cities........................13
Figure 3: SPARCS' methodology action plan........................15
Figure 4: Relation of T2.1 with other tasks of the SPARCS Project........................15
Figure 5: Types of indicators in a smart city context (Artley & Stroh, 2001)........................19
Figure 6: Demonstration actions in LHCs of SPARCS........................22
Figure 7: Allocation of SPARCS Smart Cities Demonstration Actions........................23
Figure 8: Morgenstadt's phase I results........................28
Figure 9: Morgenstadt model........................29
Figure 10: Morgenstadt's generic action model........................31
Figure 11: Smart City in the context of CITYkeys........................32
Figure 12: CITYkeys' three bottom line approach........................33
Figure 13: CITYkeys' additional approaches........................34
Figure 14 SCIS activities........................35
Figure 15: SCIS KPIs list........................36
Figure 16: Civitas measures........................37
Figure 17: CIVITAS' impact evaluation........................37
Figure 18: CIVITAS' process evaluation........................38
Figure 19: Triangulum's' seven steps methodology........................40
Figure 20: SPARCS seven steps Holistic Impact Assessment Methodology........................44
Figure 21: SPARCS' KPIs Levels........................51

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

LIST OF TABLES

Table 1: Morgenstadt framework indicators structure 30
Table 2: CITYkeys indicator framework structure 34
Table 3: KPIs overview from relevant projects 42
Table 4: Top – Down analysis' KPIs 45
Table 5: : KPIs derived from Impact Analysis 47
Table 6: Initial SPARCS KPIs categorization 48
Table 7: KPIS overview from analyzed frameworks 49
Table 8: Espoo Bottom-up analysis' KPIs 51
Table 9: District allocation of Espoo KPIs 53
Table 10: Espoo KPIs in Macro/City level 53
Table 11: Espoo KPIs from technical analysis 54
Table 12: Data related to KPIs from Impact analysis 57
Table 13: Interventions' KPIs and data needed for their calculation 59
Table 14: Data's availability template 64

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

LIST OF ABBREVIATIONS

CIBSE	Chartered Institution of Building Services Engineers
D	Deliverable
DoA	Description of Actions
EU	European Union
EC	European Commission
FC	Fellow City
GA	Grant Agreement
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LHC	Light House City
M:CI	Morgenstadt: City Insights
SCIS	Smart Communities Information System
SPARCS	Sustainable Positive and zero cARbon CommunitieS
T	Task
WP	Work Package

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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-centered, environmentally friendly smart cities.

The scope of Task 2.1 and the respective deliverable report D2.1, 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 initial version of SPARCS Holistic Evaluation and Assessment Framework, there were three 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 primary set of 10 additional KPIs. This is an ongoing process and the final list of KPIs will be provided in the updated version of this deliverable in March 2021.

As a final step, the availability of the required data linked to the outlined KPIs provided to the Lighthouse Cities and a seven steps methodology was proposed for the SPARCS Holistic Impact Assessment Framework.

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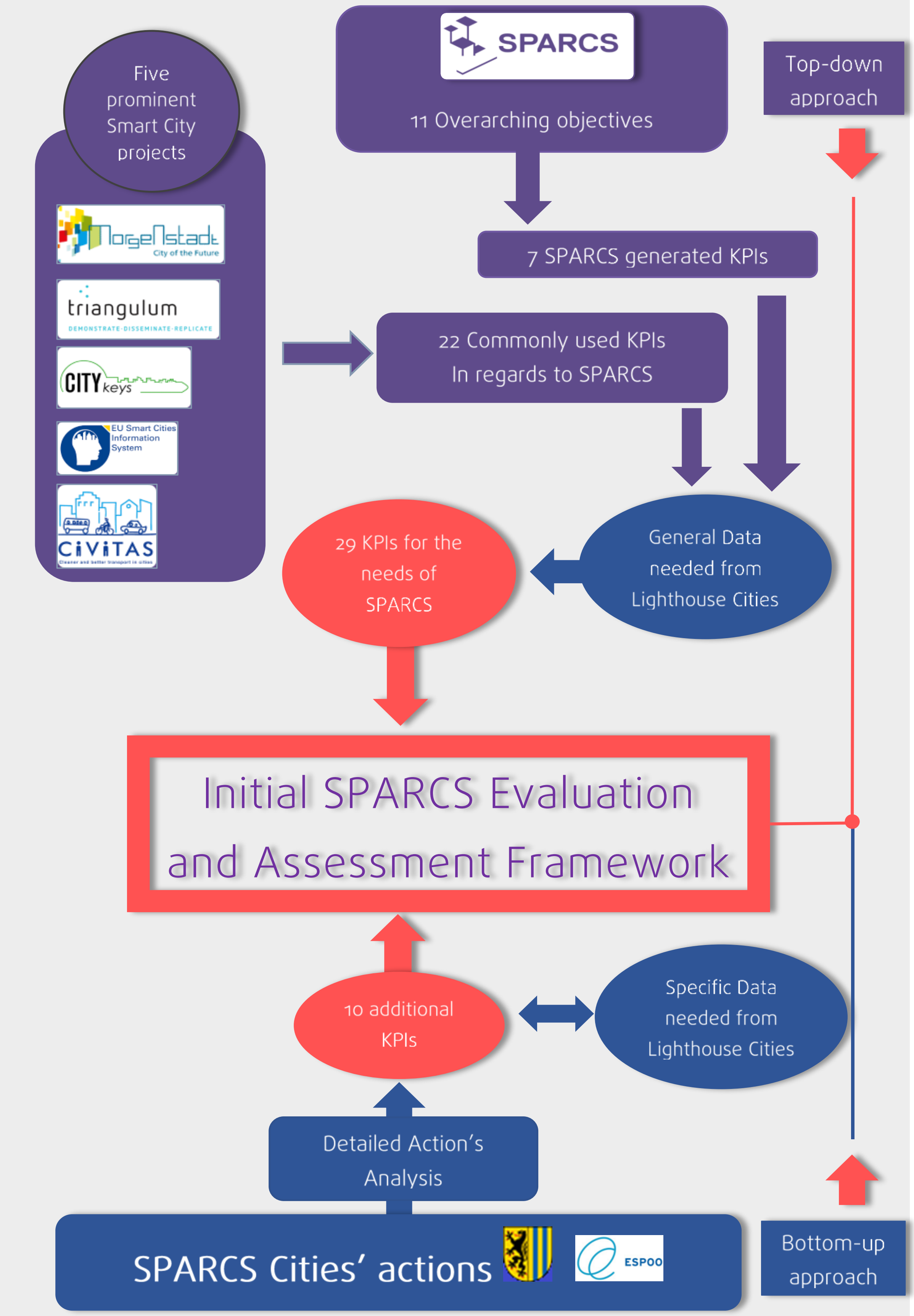

Figure 1: "Initial SPARCS Evaluation and Assessment Framework" roadmap

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

Chapter 1 summarizes 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-related to SPARCS- H2020 projects 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 SPARCS objectives prism. 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 summarizes 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 normalization 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.

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], 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 and
- a Technological perspective,

in the SPARCS cities.

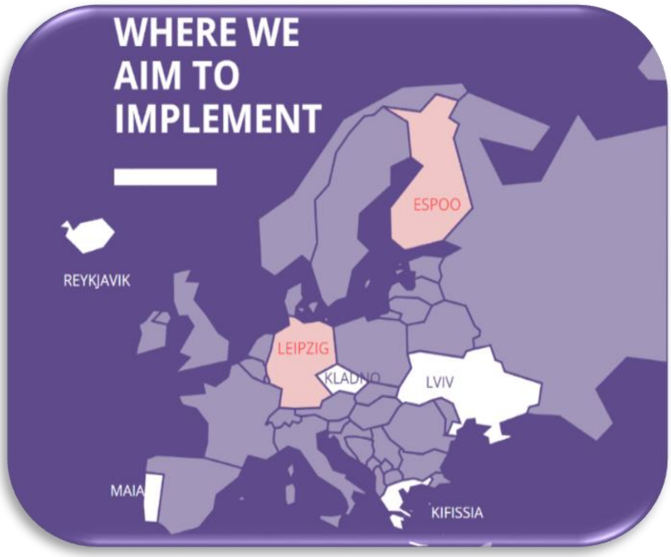

Figure 2: SPARCS cities

[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/

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

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1.1 Purpose of the document

The main objective of Task 2.1 is to analyze, 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, the SPARCS Deliverable 2.1 (D2.1), an initial version of the SPARCS framework which will be finalized in the next deliverable D2.2, is presented. 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, is conducted. It is divided into two parts; the former is based on the general objectives of this innovation program and follows a top-down approach and the latter is based on specific actions to be implemented in cities and follows a bottom-up approach; as an outcome, the analysis results in indicators and data relevant to the realization 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.

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 technologic aspects are fundamental in assessing sustainability, efficiency, security and scalability for transforming European cities into smart cities.

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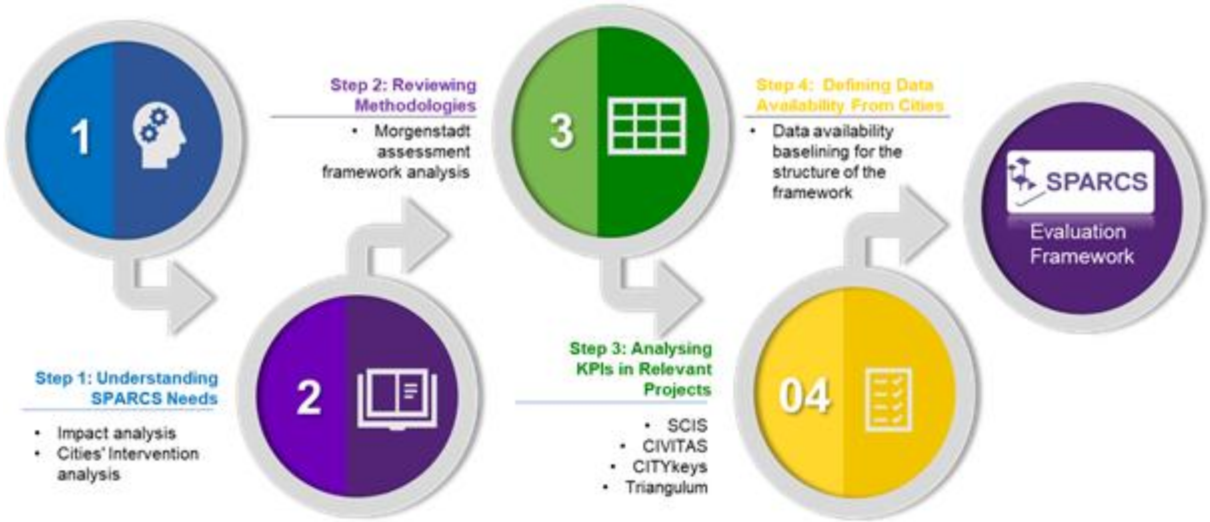

Figure 3: SPARCS' methodology action plan

1.2 Relation with other tasks

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

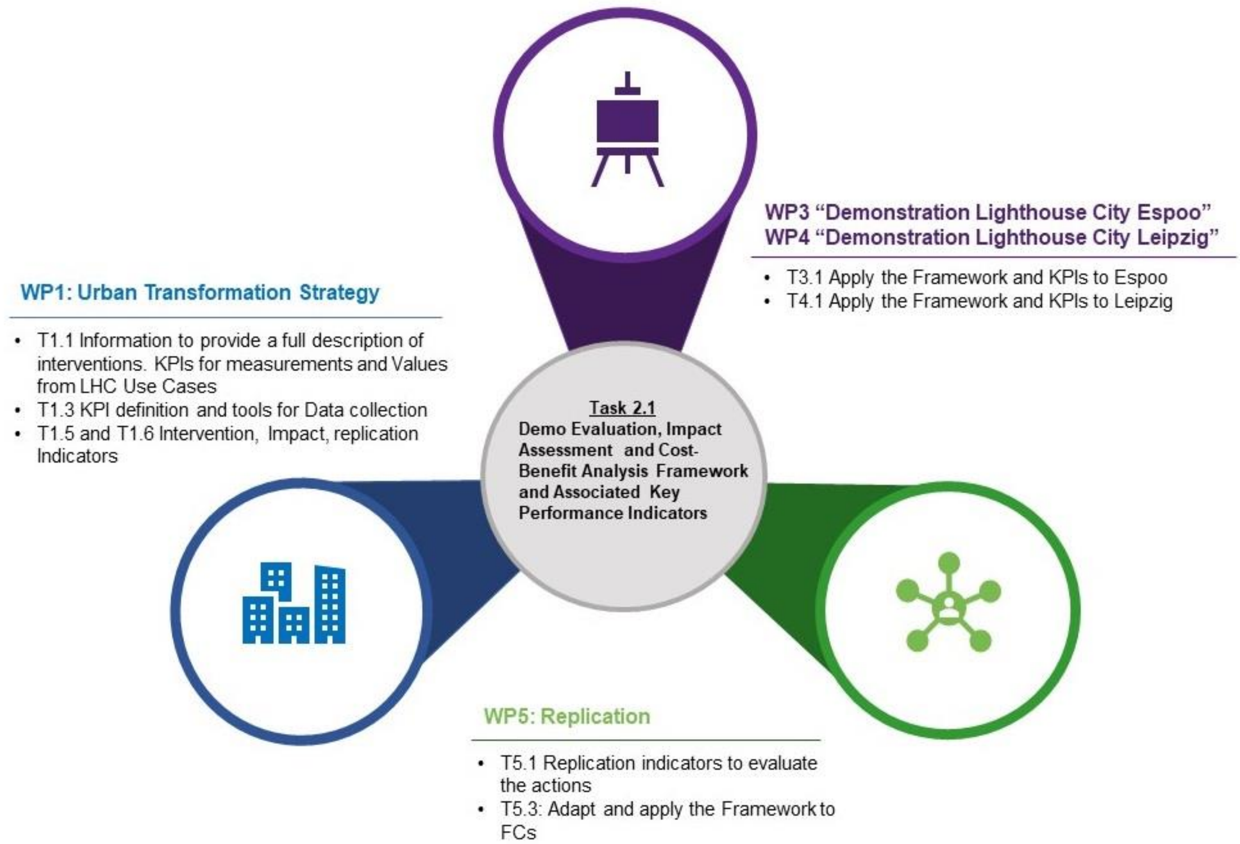

Figure 4: Relation of T2.1 with other tasks of the SPARCS Project

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

- T1.1 develops 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.
- 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.
- 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 aims to create 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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

2. Smart City Indicators: From macroscopic Indicators to comprehensive low-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 an immediate, as well as a long-term impact evaluation, through extrapolation of the SPARCs solutions at wider city scales in the Lighthouse, Fellow cities and beyond, 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 utilization 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 leads to countless indicators and this can make 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's 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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- **Input Indicators** — Understand the human and capital resources used to produce the outputs and outcomes
- **Process Indicators** — Understand the intermediate steps in producing a product or service. In the area of training for example, a process measure could be the number of training courses completed as scheduled
- **Output Indicators** — Measure the product or service provided by the system or organization and delivered to customers. An example of a training output would be the number of people trained
- **Outcome Indicators** — Evaluate the expected, desired, or actual result to which the outputs of the activities of a service or organization have an intended effect. For example, the outcome of safety training might be improved safety performance as reflected in a reduced number of injuries and illnesses in the workforce. Establishing a direct cause and effect relationship between the output of the activity and its intended outcome, can be difficult
- **Impact Indicators** — Measure the direct or indirect effects or consequences resulting from achieving program goals. An example of an impact is the comparison of actual program outcomes with estimates of the outcomes that would have occurred in the absence of the program

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

Smart city indicators are categorized 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 General KPI related considerations for 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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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 roll out 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

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

is promoted by demonstrating in the five Fellow Cities the solutions which are 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.

Thus, the interventions planned in SPARCS are divided into five demonstration actions and three levels of assessment. These 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 (BBL)
- District level interventions (DL)
- Macro level interventions (ML)

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

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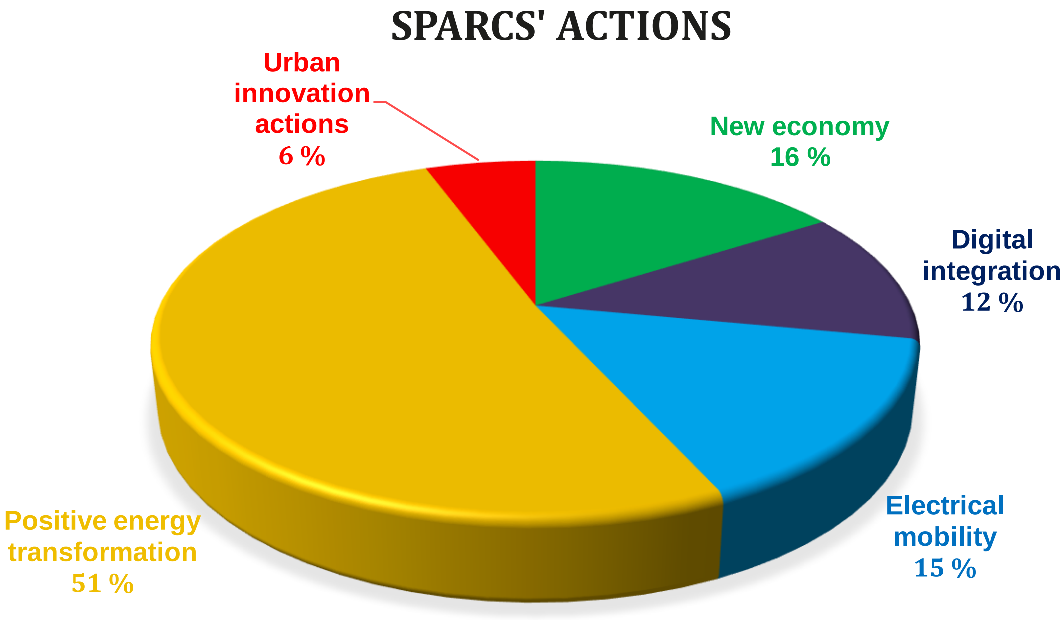

Figure 7: Allocation of SPARCS Smart Cities Demonstration Actions

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, economy etc. The implemented actions and the monitoring and evaluation process refer to macro-level, district level and building block level. Whether cities have this data

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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.

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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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, 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 fulfill 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 analyzed 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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

- 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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

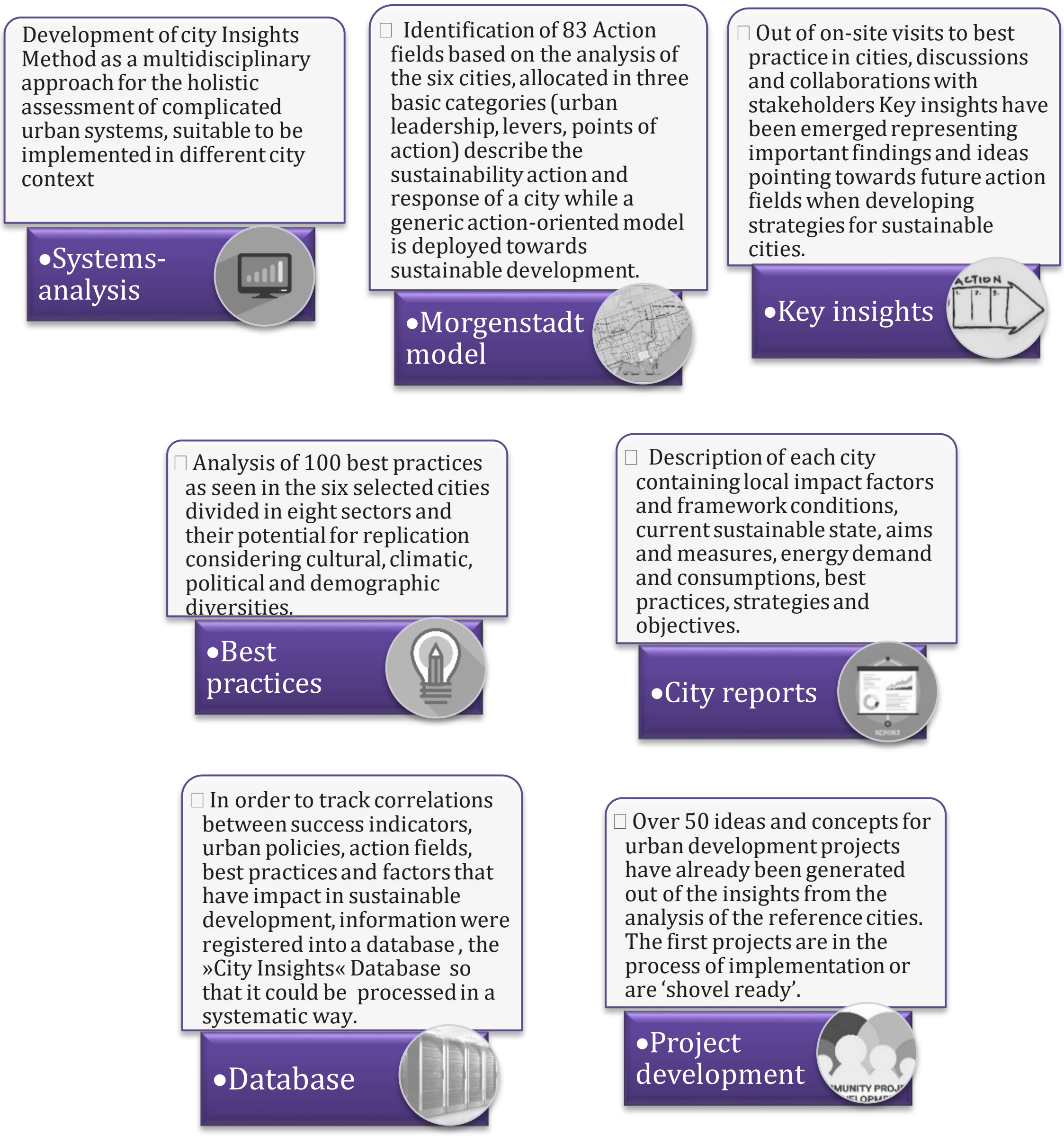

Figure 8: Morgenstadt's phase I results

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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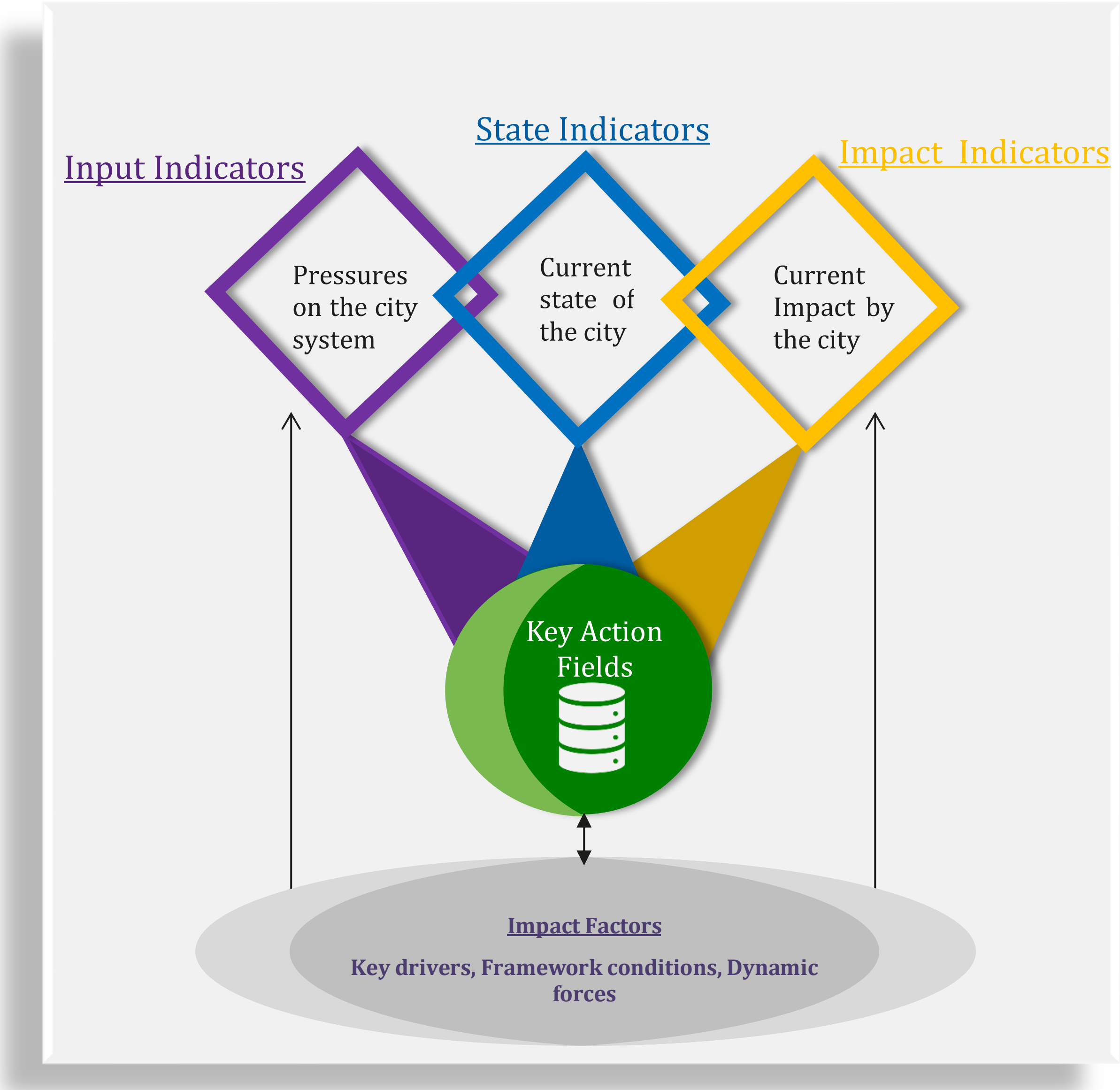

Figure 9: Morgenstadt model

After analyzing 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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

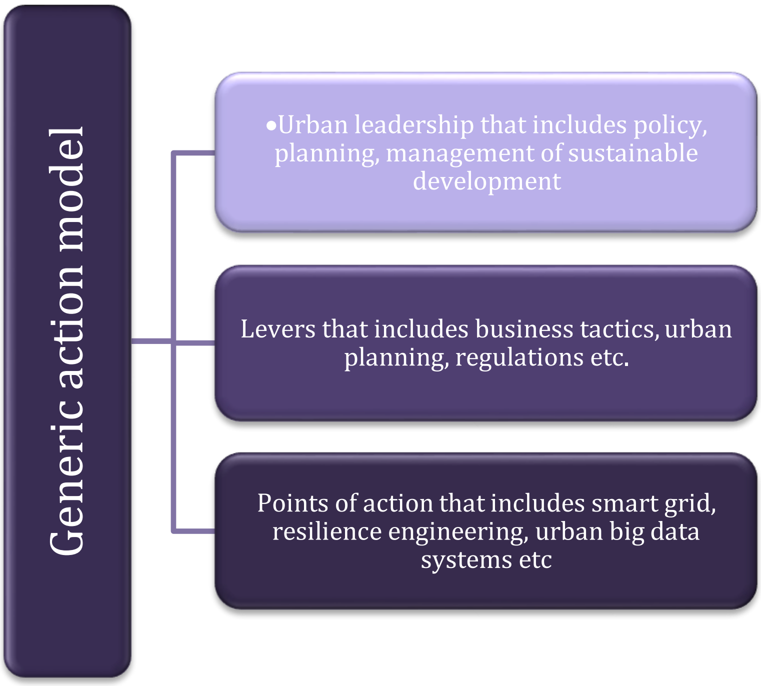

Figure 10: Morgenstadt's generic action model

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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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).

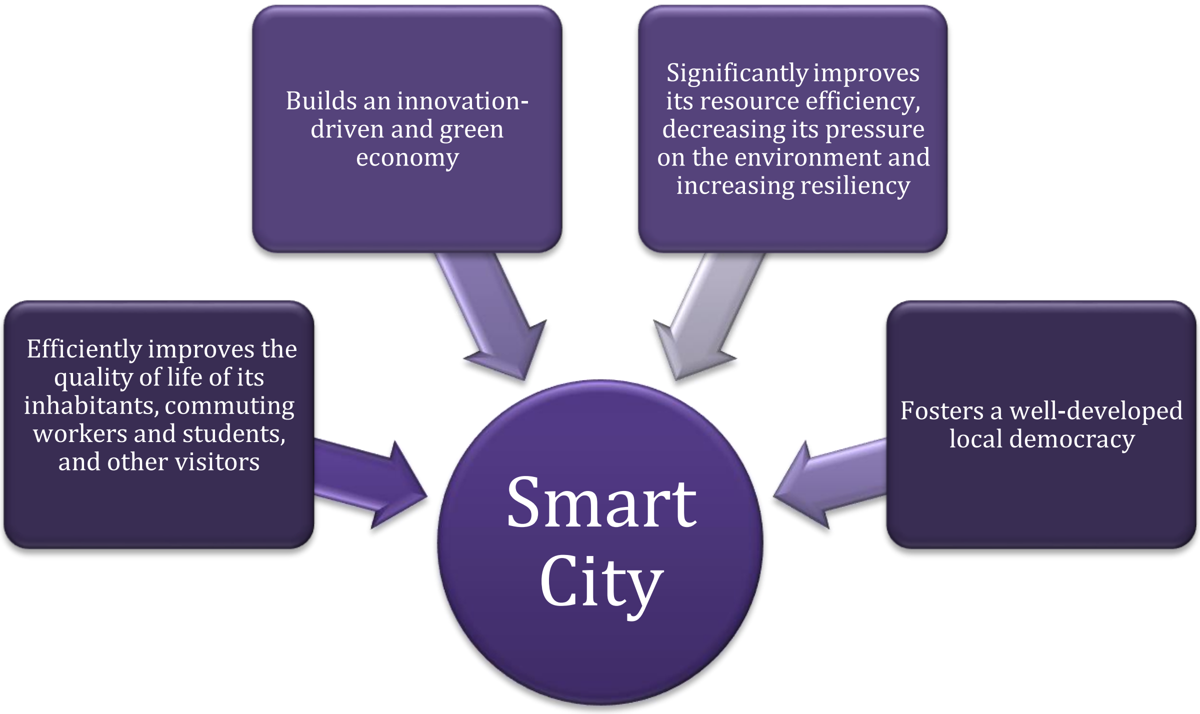

Figure 11: Smart City in the context of CITYkeys

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 analyzed 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

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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 follow Figure 12:

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

Apart from the three aforementioned categories, there are two more used for the evaluation of smart cities and are visualized in the follow Figure 12; Governance, assessing the importance of a city's internal and external factors, and the Propagation for assessing the up-scaling potential of the implementations:

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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.

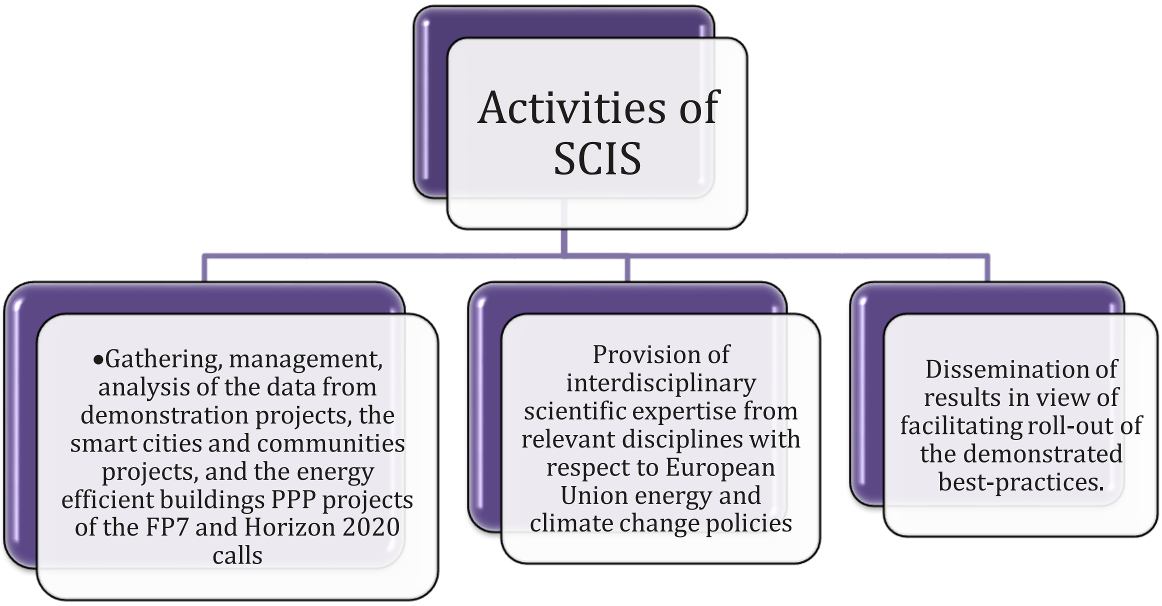

Figure 14 SCIS activities

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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

In the 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.

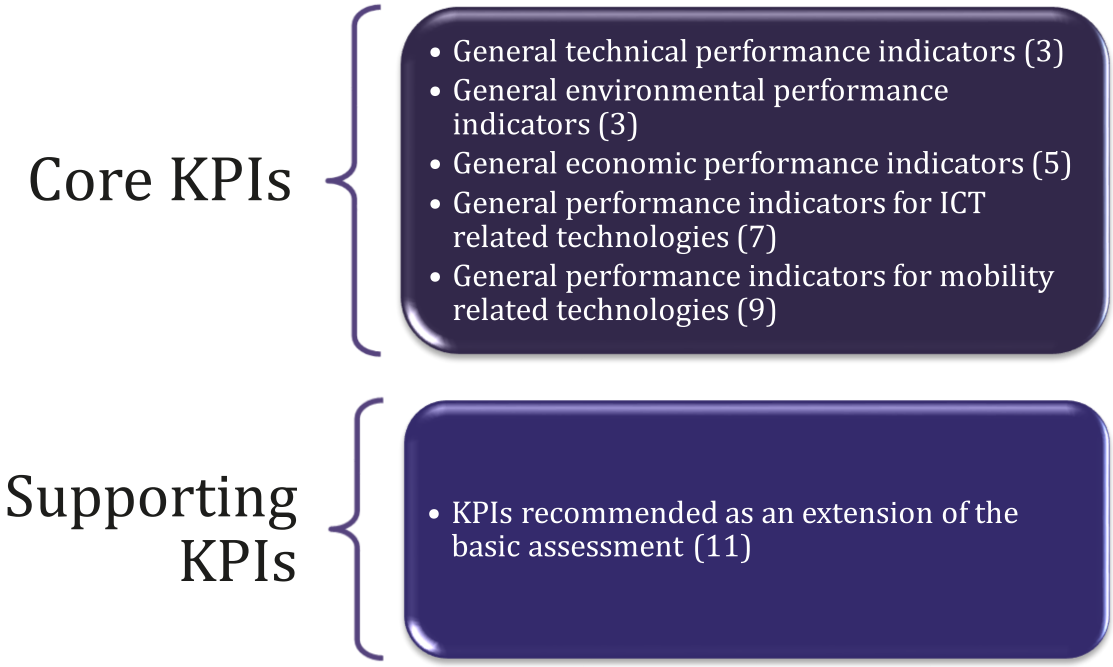

Figure 15: SCIS KPIs list

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.

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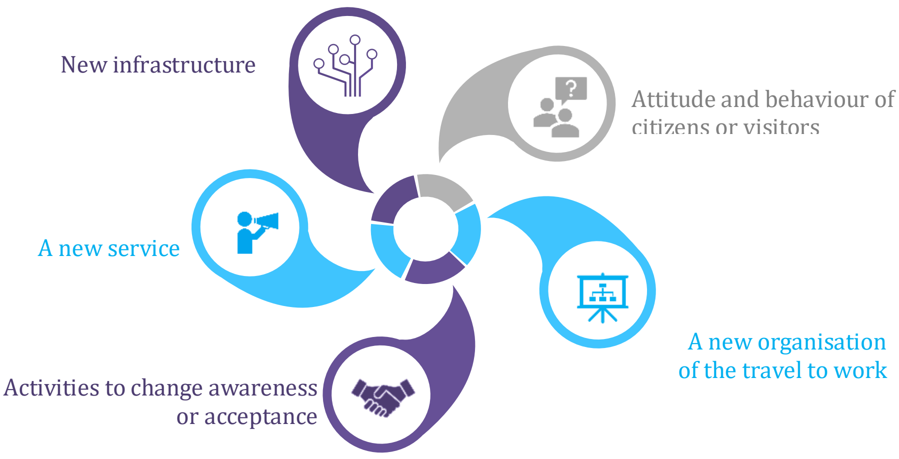

Figure 16: Civitas measures

In the latest issue of CIVITAS (CIVITAS2020) 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.

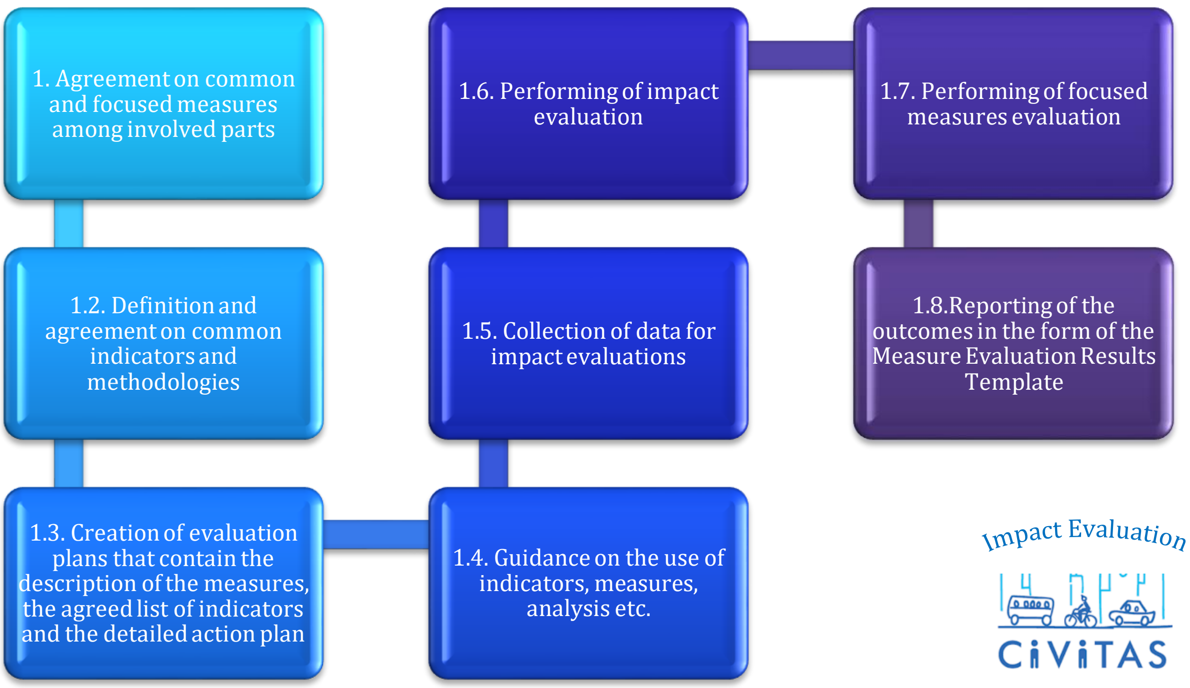

Figure 17: CIVITAS' impact evaluation

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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 the following Figure18.

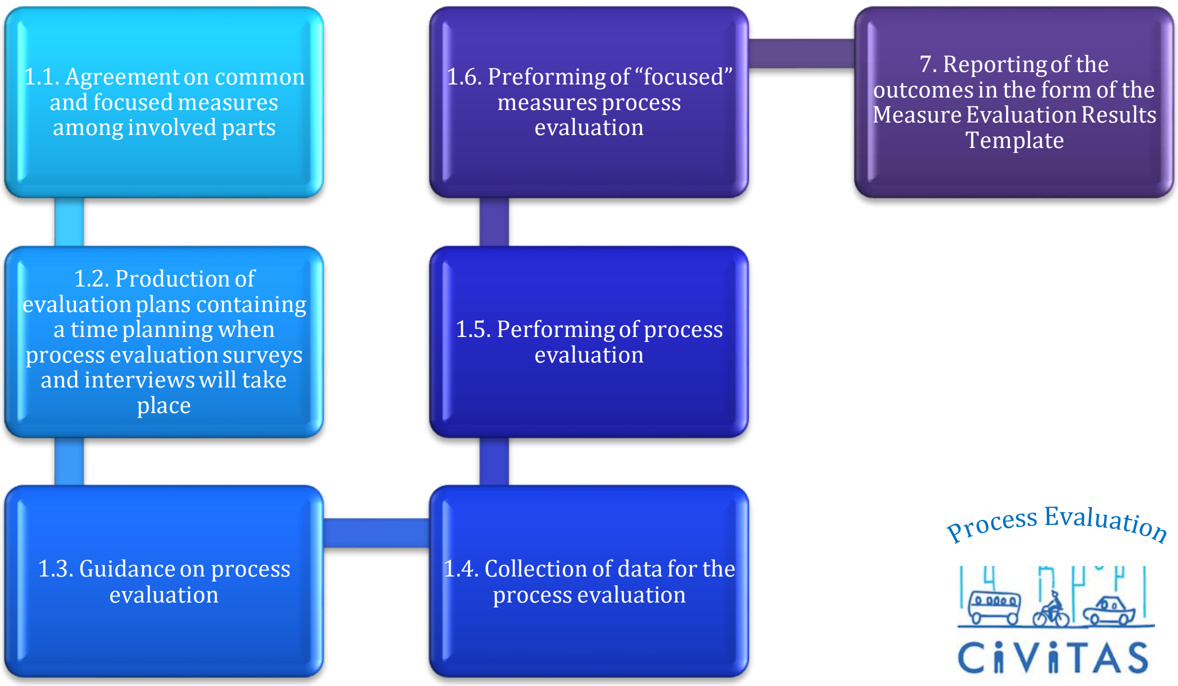

Figure 18: CIVITAS' process evaluation

3.5 Review of Triangulum impact assessment methodology

The Triangulum project (2015-2020) was a H2020 EU funded project, 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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

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.

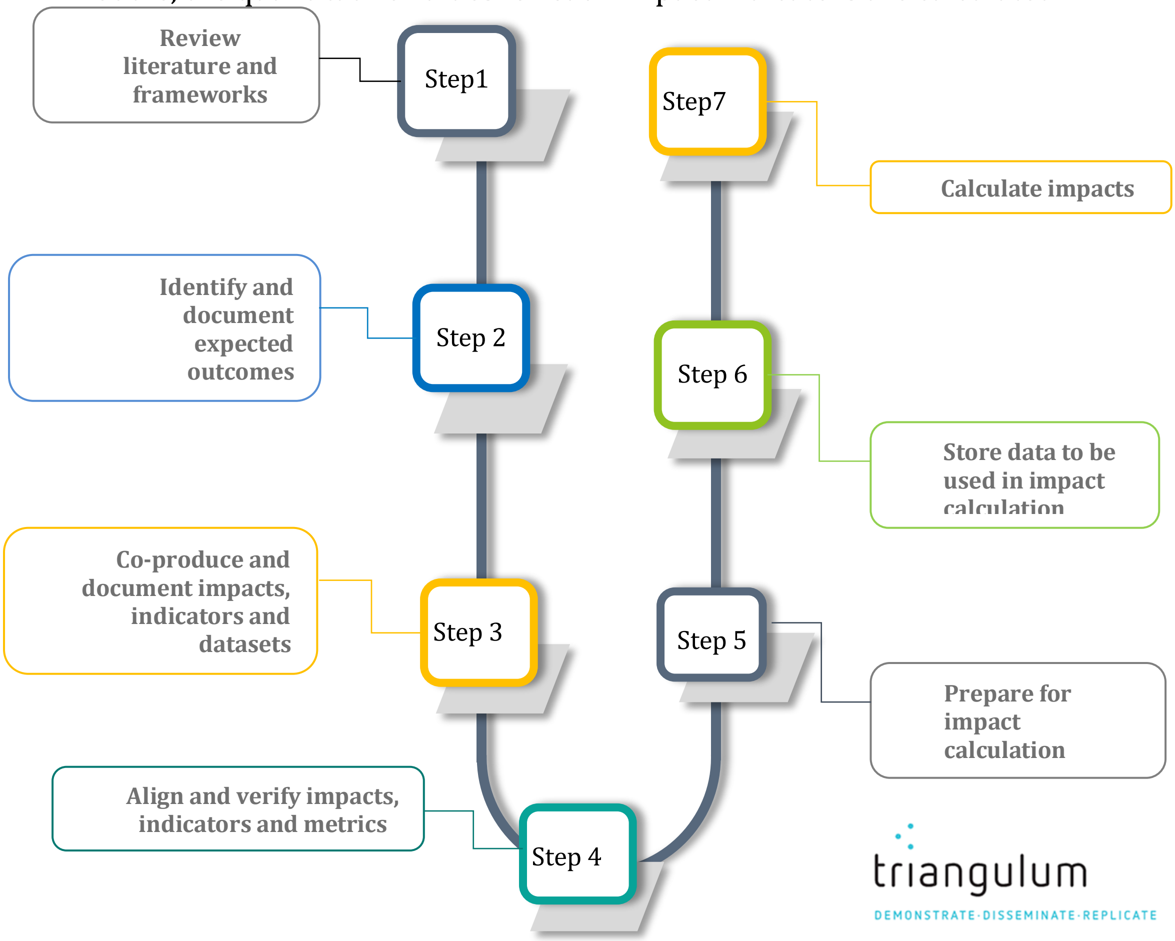

Figure 19: Triangulum's' seven steps methodology

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

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

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 critically 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. Although 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, supporting the targeted "Packaged Solutions" creation based on the identified city needs and knowledge gaps, the pool of Key Performance Indicators split into pressure, state and impact areas, present an excellent foundation for the identification of the indicators for the impact assessment methodology that will be defined in this deliverable.

In addition, 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.

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 waste, 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 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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

4. SPARCS IMPACT ASSESSMENT METHODOLOGY

The user-driven and demand-oriented smart energy solutions, integrated into cities infrastructure, innovative governance and citizens' inclusion action, 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 endeavors.

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 analyzed 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 analyzing 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, posing as **step 5** of the methodology.

The following step, namely the normalization 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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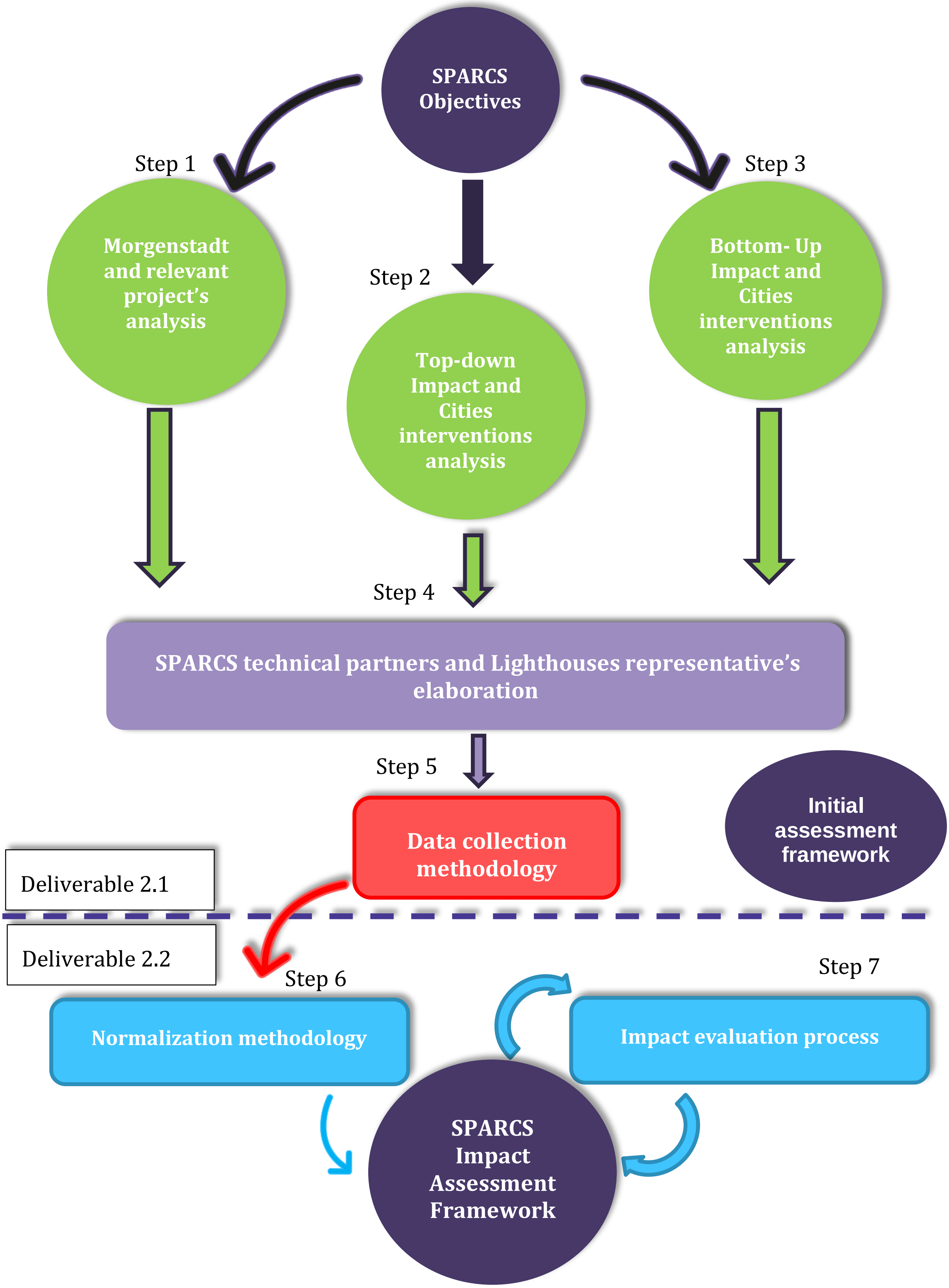

Figure 20: SPARCS seven steps Holistic Impact Assessment Methodology

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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 at their disposal an integrated strategy 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 waste heat management method,

(iii) the optimization of the local energy systems in presence of distributed renewable, 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 concretized into economic, environmental, social and technological aspects, captured in 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 analyzing 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, along with the impact number and a short description for each impact, the corresponding initial set of Specific, Measurable, Attainable, Relevant and Timely Key Performance Indicators is listed, based on the analysis performed.

Table 4: Top – Down analysis' KPIs

Impacts	Impact Description	Key Performance Indicators
General impacts	ROI, Payback Time, Debt Service Coverage Ratio, Carbon emission reduction, RES share, Energy savings	ROI, Payback time, DSCR, CO2 reduction, RES share, Total energy demand reduction
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	Greenhouse gas emissions reduction, CO2 reduction
Impact 2	SPARCS increases significantly the share of renewable energy, waste heat recovery, appropriate storage solutions and their integration into the	Share of RES, Use of waste heat, Share of integrated systems (smart control/ VPP/ storage), Energy Storage

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

	energy system; and reduces greenhouse gas emissions	
Impact 3	SPARCS leads the way towards wide scale roll out of Positive Energy Districts (PED)	Share of energy import
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	Total generation curtailment, Self-consumption rate, Flexible Loads: # of smart meters, Energy Market: Ancillary services Availability, Energy Market: participation in market type, Peak Demand, Total energy generation, Open District Heating increase rate
Impact 5	SPARCS increases the uptake of E-mobility solutions	Utilization of charging stations, EV car sharing rate, share of electric vehicles in local transportation (%), Engagement, modal split, mobility habits (car, EV car, bicycle, walking, transport, (Smart) EV charging services (car and BUS), V2G Parking places (car and bicycle)
Impact 6	SPARCS improves air quality	Reduction of CO2, NOx, small particulates, tHC
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	Employment rate
Impact 10	Increase citizens quality of life, health and well-being	Increase citizens quality of life, health and well-being
Impact 11	SPARCS contributes to the European policies and supports the development of standards	Annual number of contributions to European Standardization Organizations

As analysed in chapter 2.3, interventions and corresponding planned 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** interventions and **District level interventions** are complemented with **Macro level intervention** 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.

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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Table 5: : KPIs derived from Impact Analysis

#	KPIs	Impacts	Level
1	CO2 reduction	General Impacts, Impact 1	Macro/District/BB
2	Greenhouse gas emissions reduction	Impact 1	Macro /District/BB
3	Share of RES	General Impacts, Impact 2	Macro /District/BB
4	Use of waste heat	Impact 2	Macro /District/BB
5	Share of integrated systems (smart control/ VPP/ storage)	Impact 2	Macro /District/BB
6	Share of energy import	Impact 3	District
7	Total energy demand reduction	General Impacts	Macro /District/BB
8	Total generation curtailment	Impact 4	District/BB
9	Self-consumption rate	Impact 4	District/BB
10	EV car sharing rate	Impact 5	Macro /District
11	Share of electric vehicles in local transportation	Impact 5	Macro /District/BB
12	Engagement, modal split, mobility habits (car, EV car, bicycle, walking, transport)	Impact 5	Macro /District/BB
13	(Smart) EV charging services (car and BUS), V2G	Impact 5	Macro /District/BB
14	Parking places (car and bicycle)	Impact 5	District/BB
15	Energy Storage	Impact 2	District/BB
16	Flexible Loads: # of smart meters	Impact 4	District/BB
17	Energy Market: Ancillary services Availability	Impact 4	District/BB
18	Energy Market: participation in market type	Impact 4	District/BB
19	Peak Demand	Impact 4	District/BB
20	Total energy generation	Impact 4	Macro /District/BB
21	Open District Heating increase rate	Impact 4	District
22	Utilization of charging stations	Impact 5	Macro /District
23	Reduction of CO2, NOx, small particulates, tHC	Impact 6	District
24	Increase citizens quality of life, health and well-being	Impact 10	Macro /District/BB
25	ROI, Payback time, DSCR	Overall Impact	Macro /District
26	Replication strategy	Impact 7	City
27	Employment rate	Impact 9	Macro /District
28	Annual number of new patents	Impact 8	Macro
29	Annual number of contributions to European Standardization Organizations	Impact 11	Macro

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

An initial categorization, based on analysis performed in section 2.2, of the 29 identified KPIs into Energy, Economic, Social and technology areas is presented in the table 6 below. Further study, to introduce additional dimensions covering all aspects of smart city needs and more specifically the needs of the SPARCS project, will be handled in the updated version of this document.

Table 6: Initial SPARCS KPIs categorization

Energy	Economic	Social	Technology
CO2 reduction Greenhouse gas emissions reduction, Share of RES, Use of waste heat, Share of integrated systems (smart control/ VPP/ storage), Share of energy import, Total energy demand reduction, Total generation curtailment, Self-consumption rate, Share of electric vehicles in local transportation, (Smart) EV charging services (car and BUS), V2G, Energy Storage, Flexible Loads: # of smart meters, Peak Demand, Total energy generation, Open District Heating increase rate, Utilization of charging stations	Energy Market: Ancillary services Availability, Energy Market: participation in market type, ROI, Payback time, DSCR	EV car sharing rate, Engagement modal split, mobility habits (car, EV car, bicycle, walking, transport, Reduction of CO2, NOx, small particulates, tHC Increase citizens quality of life, health and well-being, Employment rate Parking places (car and bicycle)	Annual number of new patents, Annual number of contributions to European Standardization Organizations

The review of the Morgenstadt assessment methodology, as well as the study of CITYkeys, SCIS and Triangulum frameworks performed in chapter 3, served as an excellent pool for the identification of the 29 KPIs.

Out of the 29 KPIs identified for the SPARCS project and performing a sequential verification starting with the Morgenstadt framework,

- 11 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 are 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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Augmenting the table 3 created in section 3.6, the characteristics of KPIs identified via the Top-down impact analysis 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 7.

Table 7: KPIS overview from analyzed frameworks

	SPARCS	Morgenstadt	SCIS	CITYkeys	CIVITAS	Triangulum
Number of indicators	29 via the top-down analysis : (11 from Morgenstadt, 11 from the rest of the frameworks 7 newly introduced) 10 via the bottom-up analysis	107	38	101	30	79
Type of indicators	Process and Impact, Intervention, Replication	Pressure, State, Impact	Core and Supporting impact	Impact	Process, Impact	Impact
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 waste, 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

Performing a first comparison, and taking into account that the creation of a complete list of KPIs as well as the impact categories covered will be further enhanced, newly introduced KPIs, as well as the definition of explicit indicators covering the intervention

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

and the replication needs of the SPARCS project, are the enrichments that need to be taken into account to improve smart city monitoring and evaluation methodologies.

In Appendix C all KPIs identified in this step can be found, accompanied with the level of applicability, a clear definition, the calculation formulas, the related units and the references to the identified frameworks utilizing them, if any.

4.2 SPARCS Bottom-up and Technical interventions analysis

Analyzing the general impact targets of SPARCS pose as 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 is approached with two parallel activities:

- A bottom-up method that involves the city stakeholders, whereby the impact assessment for each action and intervention, together with corresponding indicators are co-produced, to document the impacts of activity in terms of the partner's own ambitions. Utilizing 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 analyzed 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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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

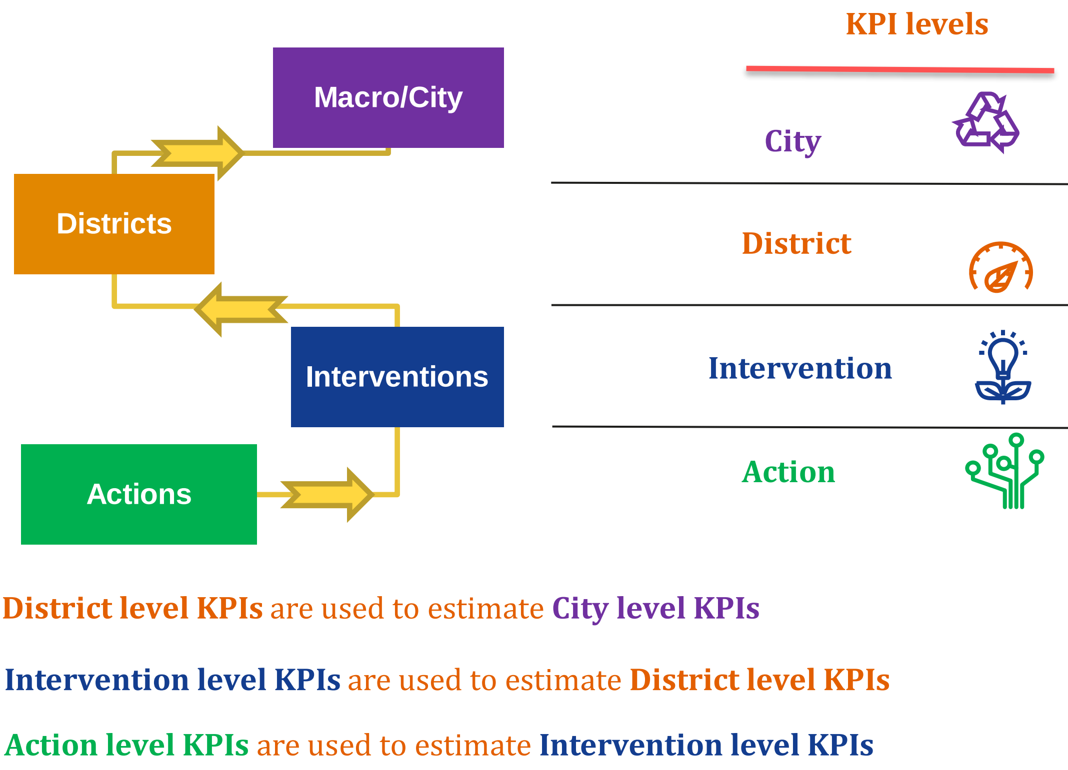

Figure 21: SPARCS' KPIs Levels

The table 8 below, 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 8: 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	% 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)
E4 - Smart Business Models	1	How well does the business model(s) cover the four lenses of innovation?
E5 - Solutions for Positive Energy Blocks	3	% of locally produced energy (heat, cool, electricity) compared to baseline % of onsite RES compared to demand

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

SPARCS

		% of onsite RES compared to max potential
E6 - ICT for Positive energy blocks	3	% of flexibility compared to baseline Prediction accuracy of flexibility
E7 - New E-mobility hub	3	% of flexibility compared to baseline Prediction accuracy of flexibility
E8 - Engaging users	3	% 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 (BHEV, BEV) excl. bicycles
E14 - New economy/ Smart governance models	1	# of stakeholders in cocreation % stakeholder satisfaction
E15 - Virtual Power Plant	2	Number of flexible load: 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 9 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 providing information about the number of interventions per district and the identified district KPIs respectively.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Table 9: 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 % 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 # Stakeholders involved in design and co-creation # 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 10 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 10: Espoo KPIs in Macro/City level

Macro/ City	# 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

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

It is important to note that the results presented on those tables are temporary, since at the time of preparing this deliverable, the bottom-up exercise on both cities was not yet finalized. A comprehensive version of this step will be presented in the updated version of this deliverable.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

SPARCS

4.2.2 Technical intervention Analysis

With the intension to avoid any limitations, that the familiarity with the planned actions of the implementation leaders might pose, and in order to perform an unrestricted analysis of the interventions, technical partners used as a foundation the detailed description of actions and interventions planned for each city, to identify the KPIs necessary to assess them.

In the following Table 11, similarly to table 8, 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.

Table 11: Espoo KPIs from technical analysis

Espoo Interventions	# of actions	Key Performance Indicators
E1 - Solutions for Positive Energy Blocks	6	Network quality improvement Potential energy resources Battery States (health, charge) Battery energy losses
E2 - Boosting E-mobility uptake	3	Network Quality improvement
E3 - Engaging users	3	Number of mobile broadband subscriptions (% of total) Internet penetration rate (%) Local community involvement in planning phase Local community involvement in implementation phase
E4 - Smart Business Models	1	# of energy positive Business models in Lippulaiva
E5 - Solutions for Positive Energy Blocks	3	Network quality improvement
E6 - ICT for Positive energy blocks	3	Potential energy resources # of new smart energy services developed Demand response utilization improvements
E7 - New E-mobility hub	3	Network quality improvement 5G utilization increase Demand response utilization improvements
E8 - Engaging users	3	Engagement improved # of new and improved existing positive district solutions # of experiments/pilots initiated
E9 - Smart Business models	1	# of energy positive Business models in Sello
E10 - Solutions for Positive Energy Blocks	3	Utilization of the Espoo 3D City model Flexibility availability
E11 - Engaging users	1	Improvement of the Modal Split towards non pollutant mobility habits
E12 - ICT for Positive energy blocks	3	5G utilization increase # of new and improved new services #of car batteries as reserve

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

		Utilization of blockchain technology
E13 - E-mobility in Kera	2	Improvement of the Modal Split towards non pollutant mobility habits #of private cars
E14 - New economy/ Smart governance models	1	-
E15 - Virtual Power Plant	2	Flexibility availability DR utilization Utilization of blockchain technology
E16 - Smart heating	1	Flexibility availability, DR utilization
E17 - Virtual twin	2	Utilization of the CityGML
E18 - EV charging effects to grid	1	Improvement of the Modal Split towards non pollutant mobility habits
E19 - Sustainable lifestyle	2	Engagement improved
E20 - District development	1	# of smart building requirements
E21 – Air Quality	1	Air quality improvement
E22 -Co-creation for Positive Energy District development	2	Engagement improved
E23 - New economy/ Smart business models	2	# of contributions involvement with the platform activities/updates

This table, and in order to make the presentation of KPIs related to interventions easier, 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.

An analogous table, depicting the technical analysis activity taking place in the city of Leipzig can be found in Appendix B.

Comparably to the bottom-up approach, the analysis of the interventions from the technical partners is not yet finalized and changes on the presented tables will possibly take place. A comprehensive version of this step will be presented in the updated version of this deliverable.

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.

Building upon the created lists of KPIs by focusing on the planned project and intervention impacts, an additional step 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, the Economic Perspective, the Social Perspective and the Technology Perspective is required. Special attention will be given to evaluating the replication

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

potential of the solutions, considering wider-scale deployments in lighthouse and Fellow cities, while assessing their deploy-ability in different city contexts.

Including all these parameters, defining a holistic approach requires, apart from adjusting the impact indicators already identified, to take in addition under consideration specific Interventions Indicators, as well as Replication Indicators. 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 as well as the City representatives of Leipzig and Espoo need to be consulted, contributing with specific know-how on the enhancement of available KPIs and with the identification of additional indicators. Several forms of feedback collection will be utilized to obtain the necessary information such as:

- Workshop sessions
- Live consultation/clarification sessions
- Offline reviews

It is crucial for the targets of the projects that all technical and city partners will contribute to the best of their abilities to cover all aspects of the holistic methodology, to clarify open points and to build a common understanding on the purpose of each indicator in the context of the planned city implementations.

Until the time of preparing this deliverable, offline review requests and online consultation and clarification sessions took place, on the basis of the impact related KPIs identified in step 2. Valuable feedback is collected and consolidated in the results presented in chapter 4.1.

Further consultation and clarification sessions, offline review requests as well as workshop sessions with specific targets will take place during the next months. Details about the proceeding as well as achieved outcomes will be part of the comprehensive version of this step, that will be presented in the updated version of this deliverable.

4.4 Data collection methodology

An important element of performance measurement is represented by the data collection capability, that 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.

Some of the most common challenges encountered are related to three main topics, namely:

- Accuracy of data
- Completeness of data
- Timeliness, Punctuality of data

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.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

In order 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, poses as the next challenge, which will be handled in this step.

The following table 12, lists the 29 KPIs identified in the top down approach in step 2 of the methodology, combined with the corresponding data needs for their calculation.

Table 12: Data related to KPIs from Impact analysis

#	KPIs	Data needs
1	CO2 reduction	Emitted CO2 measurements/calculations (Tonnes/year)
2	Greenhouse gas emissions reduction	Emitted greenhouse gases CH4, N2O, O3 measurements/calculations (ppm)
3	Share of RES	Total Energy Production (MWh/a), Energy production using RES (MWh/a)
4	Use of waste heat	Total waste heat (MWh/a), Utilization of waste heat (MWh/a)
5	Share of integrated systems (smart control/ VPP/ storage)	Total available (RES, storage)systems (#), Integrated systems (#), Energy from VPP(MWh), Energy to VPP(MWh)
6	Share of energy import	Energy import (MWh/a), Total Energy Production (MWh/a)
7	Total energy demand reduction	Total energy demand (MWh), Total Demand Electricity annual (MWh), Total Demand Electricity Maximum/Peak Demand (MW), Total Demand Heating annual (MWh), Total Demand Heating Maximum/Peak Demand [MW]
8	Total generation curtailment	Amount of involuntary and voluntary generation Curtailment (MWh)
9	Self consumption rate	Total energy demand (MWh), Total Energy Production (MWh/a)
10	EV car sharing rate	Total number of citizens (#), citizens sharing an EV (#)
11	Share of electric vehicles in local transportation	Total number of vehicles in local transportation (#), Electric vehicles in local transportation (#), EVs available for sharing (#), EV car charging stations (#), Bicycles in local transportation mode (#), EV bus charging stations (#)
12	Engagement, modal split, mobility habits (car, EV car, bicycle, walking, transport	Total number of citizens (#), citizens using bicycle to go to work, citizens going to work using a personal vehicle (#), citizens walking to work (#), citizens working remotely (#), citizens using public transportation to go to work (#), citizens going to work using a personal (EV) vehicle (#), citizens that do not own a personal automobile (#), Young people needs for customer experience and use of eco-friendly modes of transportation (Likert Scale 1-5), Consumers engaged (#)

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

13	(Smart) EV charging services (car and BUS), V2G	Quantity of energy supplied by EV charging stations (MWh/a)
14	Parking places (car and bicycle)	Car parking places (#), Bicycle parking places (#)
15	Energy Storage	Number of equipment (#), Storage type (type), Storage capacity (MWh)
16	Flexible Loads: # of smart meters	Smart meters available (#)
17	Energy Market: Ancillary services Availability	Ancillary services available (type)
18	Energy Market: participation in market type	Energy Market available (Yes/No), # of citizens participating in the Market
19	Peak Demand	Peak demand (MWh)
20	Total energy generation	Total Energy Production (MWh/a)
21	Open District Heating increase rate	Energy made available for District Heating (MWh)
22	Utilization of charging stations	Charging EV stations Utilization (hours used per day/month/year)
23	Reduction of CO2, NOx, small particulates, tHC	Emitted CO2 measurements/calculations (Tones/year), Values for Tropospheric NOx (ppm), Values for small particulates (ppm), Values for tHC Volatile hydrocarbons (ppm)
24	Increase citizens quality of life, health and well-being	Noise Level (dB), Life expectancy at birth (years), Green Area (ha/100,000 residents), Length of bicycle paths and lanes (Km), Budget spent on city management (Euros), Budget spent on green space management (Euros)
25	ROI, Payback time, DSCR	Return on Investment (%), Payback time (years), Debt Service Coverage Ratio (%)
26	Replication strategy	Social compatibility, Ease of use for professional stakeholders, Trialability, Technical compatibility, Visibility of Results, Advantages for end users, Ease of use for end users of the solution, Solution(s) to development issues, Advantages for stakeholders (Likert Scale 1-5 for all parameters)
27	Employment rate	Employment (%)
28	Annual number of new patents	Patents filed in the context of SPARCS (#/a)
29	Annual number of contributions to European Standardization Organizations	Contributions to European Standardization Organizations (#/a)

Similarly, the data required for the calculation of the Espoo KPIs identified via the bottom-up approach, as well as the ones identified via the technical analysis in step 3, are listed in the table 13 below. Each row covers one intervention with the second and the third column listing the KPIs proposed via the bottom-up and the technical analysis respectively, while the fourth column lists the data needs to calculate all intervention related KPIs.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Table 13: Interventions' KPIs and data needed for their calculation

Interventions Espoo	KPIs of Bottom-up analysis	KPIs of Technical analysis	Data needs
E1 - Solutions for Positive Energy Blocks	The sum of renewable energy and heat generated in the block plus certified green energy divided by consumed total energy in the block "OER"	Network quality improvement Potential energy resources Battery States (health, charge) Battery energy losses	Total RES energy generation, Total RES heat generation, Total of energy consumption Congestions, level of harmonics, voltage variations, SCADA availability, SAIDI, SAIFI, Network losses, Max penetration potential, degree of landscape impact (possible opposition) Peak Sun Hours, Average Sunshine hour per year, Average Rainy days per year, Heating Degree Days, Cooling Degree Days, Battery States (health, charge), Battery energy losses
E2 - Boosting E-mobility uptake	kWh charged to EVs Number of different EV charging stations	Network Quality improvement	Energy consumed in EV charging stations # of EV charging station Congestions, level of harmonics, voltage variations, SCADA availability, SAIDI, SAIFI, Network losses, Max penetration potential, degree of landscape impact (possible opposition)
E3 - Engaging users	% 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)	Number of mobile broadband subscriptions (% of total) Internet penetration rate (%) Local community involvement in planning phase Local community involvement in implementation phase	# of citizens # of citizens that are 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) Number of mobile broadband subscriptions (% of total), Internet penetration rate (%), Local community involvement in planning phase, Local community involvement in implementation phase
E4 - Smart Business Models	How well does the business model(s) cover the four lenses of innovation?	# of energy positive Business models in Lippulaiva	How well does the business model(s) cover the four lenses of innovation? # of energy positive Business models in Lippulaiva

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

SPARCS

E5 - Solutions for Positive Energy Blocks	% of locally produced energy (heat, cool, electricity) compared to baseline % of onsite RES compared to demand % of onsite RES compared to max potential	Network quality improvement	Total of energy produced locally Total of energy produced locally according to the baseline RES energy produced Total energy demand Total energy production potential Congestions, level of harmonics, voltage variations, SCADA availability, SAIDI, SAIFI, Network losses, Max penetration potential, degree of landscape impact (possible opposition)
E6 - ICT for Positive energy blocks	% of flexibility compared to baseline Prediction accuracy of flexibility	Potential energy resources # of new smart energy services developed Demand response utilization improvements	Total of energy available via flexibility Total of energy produced according to the baseline Accuracy of flexibility available Peak Sun Hours, Average Sunshine hour per year, Average Rainy days per year, Heating Degree Days, Cooling Degree Days, # of smart energy services? Flexibility available (KW), Flexibility provided (KWh), # of demand requests, # of demand responses, renumeration due to flexibility delivered (Euro), penalty due to flexibility refusal (Euro), # of requests that are initially accepted but declined afterwards; overwrites.
E7 - New E-mobility hub	% of flexibility compared to baseline Prediction accuracy of flexibility	Network quality improvement 5G utilization increase Demand response utilization improvements	Total of energy available via flexibility Total of energy produced according to the baseline Accuracy of flexibility available Congestions, level of harmonics, voltage variations, SCADA availability, SAIDI, SAIFI, Network losses, Max penetration potential, degree of landscape impact (possible opposition) # of equipment utilizing the 5G infrastructure, 5G coverage Flexibility available (KW), Flexibility provided (KWh), # of demand requests, # of demand responses, renumeration due to flexibility delivered (Euro),

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

			penalty due to flexibility refusal (Euro), # of requests that are initially accepted but declined afterwards; overwrites.
E8 - Engaging users	% of flexibility compared to baseline Prediction accuracy of flexibility	Engagement improved # of new and improved existing positive district solutions # of experiments/pilots initiated	Total of energy available via flexibility Total of energy produced according to the baseline Accuracy of flexibility available # of new and improved existing positive district solutions # of experiments/pilots initiated
E9 - Smart Business models	Customer/user interest in new business models	# of energy positive Business models in Sello	Customer/user interest in new business models # of energy positive Business models in Sello
E10 - Solutions for Positive Energy Blocks	On-site energy ratio Number of early stage solutions investigated	Utilization of the Espoo 3D City model Flexibility availability	On-site energy ratio Number of early stage solutions investigated Utilization of the Espoo 3D City model Flexibility available (KW), Flexibility provided (KWh), # of demand requests, # of demand responses, renumeration due to flexibility delivered (Euro), penalty due to flexibility refusal (Euro), # of requests that are initially accepted but declined afterwards; overwrites.
E11 - Engaging users	Targeted share of bicycle and pedestrian mobility mode	Improvement of the Modal Split towards non pollutant mobility habits	# of citizens # of citizens utilizing bicycles # of pedestrians Modal Split values
E12 - ICT for Positive energy blocks	Model developed and cost-benefit analysis completed for Blockchain	5G utilization increase # of new and improved new services #of car batteries as reserve Utilization of blockchain technology	Model developed and cost-benefit analysis completed for Blockchain # of equipment utilizing the 5G infrastructure, 5G coverage Model developed and cost-benefit analysis completed for Blockchain

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

E13 - E-mobility in Kera	Estimated share of vehicle- kms by chargeable vehicles (BHEV, BEV) excl. bicycles	Improvement of the Modal Split towards non pollutant mobility habits #of private cars	# of vehicles # of chargeable vehicles (BHEV, BEV) excl. bicycles Modal Split values
E14 - New economy/ Smart governance models	# of stakeholders in cocreation % stakeholder satisfaction	-	# of stakeholders in cocreation % stakeholder satisfaction
E15 - Virtual Power Plant	Number of flexible load: typology/type, capacity (kWh), response delay Number of blockchain platforms	Flexibility availability DR utilization Utilization of blockchain technology	Number of flexible load: typology/type, capacity (kWh), response delay Number of blockchain platforms Flexibility available (KW), Flexibility provided (KWh), # of demand requests, # of demand responses, renumeration due to flexibility delivered (Euro), penalty due to flexibility refusal (Euro), # of requests that are initially accepted but declined afterwards; overwrites.
E16 - Smart heating	Number of buildings connected to smart heating service	Flexibility availability, DR utilization	# of buildings connected to smart heating service Flexibility available (KW), Flexibility provided (KWh), # of demand requests, # of demand responses, renumeration due to flexibility delivered (Euro), penalty due to flexibility refusal (Euro), # of requests that are initially accepted but declined afterwards; overwrites.
E17 - Virtual twin	Usefulness of the tools to create new PEDs in the city	Utilization of the City GML	Usefulness of the tools to create new PEDs in the city
E18 - EV charging effects to grid	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	Improvement of the Modal Split towards non pollutant mobility habits	Peak demand values #of innovative energy technologies incorporated in virtual twin for simulation purposes Modal Split values

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

	virtual twin for simulation purposes		
E19 - Sustainable lifestyle	Number of residents responded to SPARCS activities Healthy lifestyle indicators	Engagement improved	Number of residents responded to SPARCS activities Healthy lifestyle indicators Number of relevant stakeholders engaged
E20 - District development	Energy infrastructure smart building requirements	# of smart building requirements	Energy infrastructure smart building requirements
E21 – Air Quality	PM10 NOx	Air quality improvement	PM10 NOx
E22 -Co-creation for Positive Energy District development	Number of relevant stakeholders engaged Acceptance of smart city Espoo concept	Engagement improved	Number of relevant stakeholders engaged Acceptance of smart city Espoo concept
E23 - New economy/ Smart business models	Number of new projects generated and volume of funding	# of contributions involvement with the platform activities/updates	Number of new projects generated and volume of funding # of contributions involvement with the platform activities/updates

With the step 3 activities and the list of intervention related KPIs not yet finalized, the data needs listed in this step as well as the limitations that the data gathering process will generate, need to be further analysed. Towards this direction and in order to identify data collection challenges and gaps and work on possible solutions, a data availability check request is initiated. Using the template which is illustrated as an example in the table 14 below, city partners were asked to provide feedback on the availability of the data needs identified in the previous tables.

Table 14: Data's availability template

Data needs to calculate the KPIs	Level	Units	Description	Level City/ District/ Building	Historical data available ? (Number of years?)	Granularity (Year, Month, Day, Minute, etc.)	Type (Excel, DB, Text, etc.)
Emitted CO2 measurements /calculations	City/ District/ Building Block	Tones/ year	Carbon dioxide (CO2) emissions classified by final use of products				
Emitted greenhouse gas CH4 measurements /calculations	City/ Building Block	ppm	Parts per million of air pollution for methane (CH4)				

In the used table, apart from the data identification, a short description and the unit of each request, in column 1, 4 and 3 respectively, column 2 identifies the different levels that the data is needed. In columns 5, 6, 7 and 8, the city partners are requested to provide the availability of data for each of the levels, the availability of the historical data, their granularity and the form in which the data is available, respectively.

4.5 Normalisation methodology definition

All steps followed up to this point, focus entirely on the assessment of the planned interventions implemented on the cities of Espoo and Leipzig. But in order to be able to obtain results that are detached from the specificities of cities and can be compared with similar findings of analogous projects, aspects of the key element of the implementation activities, namely the buildings, need to be examined, since different buildings require different benchmarks to identify their energy performance.

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 (kgCO2/m2/yr.) are also indicated, using representative CO2 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.):

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

- 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
- 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.

Using these benchmarks and with the support of the technical and city partners, all buildings in the cities of Espoo and Leipzig will be analyzed and adjustments for the location, affecting the weather region, for the hours of occupancy and for the size of each building will take place.

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

With the definition of the holistic framework not yet finalized and the data collection activities still under construction, valuable data about the actual energy performance of the buildings, districts and cities is not available and the normalization actions cannot start. A comprehensive version of this step, with details about the benchmarks, as well as about the adjustments that need to take place as part of the normalization methodology, will be presented in the updated version of this deliverable.

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 roles of information, communication and participation. 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 phase by analyzing all relevant information.

Taking under consideration the findings of the CIVITAS framework analysis performed in chapter 3.4, the proposed process evaluation framework will be utilized for the needs of the SPARCS project and its steps, together with relevant actors and activities are presented below.

The process evaluation will be performed by the lighthouse cities with support of the technical partners and consists of the following activities:

1. Agree on common measures and “focused” measures for impact and process evaluation (LH cities and technical partners);

2. Produce evaluation plans containing a time planning when process evaluation surveys and interviews will take place (LH cities);

3. Provide guidance on process evaluation (Technical partners to LH cities);

4. Collect data for the process evaluation (LH cities);

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

5. Perform process evaluation on preparation, implementation and operation phases (LH cities with the support of technical partners);

6. Perform "focused" measures process evaluation (LH cities with the support of technical partners);

7. Report to the technical partners in the form of the Measure Evaluation Results Template (LH cities to technical partners)

Process evaluation activities, together with enhancements or changes on the steps proposed from the CIVITAS evaluation framework, will be thoroughly presented in the updated version of the delivery.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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 transform cities into citizen-centered, environmentally friendly and resilient smart urban areas.

This deliverable of SPARCS, proposes a first version of a novel assessment framework for smart cities by gathering learnings from previous prominent Smart Cities related projects and enhancing this knowledge using their consortium's expertise. The deliverable focused 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 relevant projects; CITYkeys, SCIS, CIVITAS and Triangulum. This extensive review made available a range of possible KPIs, more than 350, 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, following two 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 out of those KPIs were matched with the pool of available indicators from analyzed 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, in order to enhance the core set of KPIs, analyzing in detail all planned city actions from a local perspective. This collaboration captured a preliminary set of 10 KPIs that will enhance the main set defined.

In the following critical step, with the consultation of technical experts and cities representatives of Leipzig and Espoo, contributing with specific know-how on the enhancement of available KPIs and the identification of additional indicators, a holistic method, taking into account the energy, economic, social and technology sectors will be established.

A data collection step, based on the KPI definitions and the calculation formulas covered already in the previous steps, targeting data and limitations needs, was introduced in this stage. A data availability check request towards cities is ongoing and will be finalized in the updated version of this report.

As next, a data normalization methodology which is introduced in step 6, will provide an objective assessment of the project results, so that dissimilar measurements can be effectively compared.

Finally, an evaluation process will be utilized in order to overcome possible barriers during the implementation phase.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

The work that the SPARCS team depicted in this deliverable is ongoing and an updated version will be made available in March 2021. In the updated version, a holistic list of KPIs, concrete data collection methods combined with normalization approaches and an established evaluation process necessary for the impact assessment implementation will be presented.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

7. Appendices

A. Leipzig Bottom-up approach table

Leipzig Interventions	# of actions	Key Performance Indicators
L1- Intelligent EV Charging and Storage	4	Energy Storage (kWh), Peak Demand, (Smart) EV charging services (car and BUS), V2G, Share of integrated systems (smart control/ VPP/ storage), EV car sharing rate
L2- Micro grid inside the public grid	3	Share of energy import or energy production self-sufficiency, Energy Storage (kWh), Energy Market: participation in market type, Peak Demand
L3- Heating Demand control	2	Share of integrated systems (smart control/ VPP/ storage),Increase citizens quality of life, health and well-being, Engagement, modal split, mobility habits (car, EV car, bicycle, walking, transport)
L4-Personalized informative billing	7	Energy Storage, self-consumption, number of buildings / or no KPIs needed, heat
L5- Human-Centric Energy Management and Control DecisionSupport	2	-
L6- Decarbonization of district heating.	4	On-site Energy Ratio,(OER) / relation between the annual energy supply from local renewable sources and the annual energy demand, Annual Mismatch Ratio (AMRx), Greenhouse gas emissions reduction
L7- Heat storage (P2H)	1	On-site Energy Ratio (OER)
L8- ICT integration	1	Energy Storage (kWh)
L9- Implementation and installation of an open standard based ICT platform that we call the “L-box”	2	-
L10- Economically reasonable integration of open and standardized sensors and systems	1	-
L11- Establishment of a distributed cloud centric ICT System which enables an intelligent energy management system	2	-
L12-Implementation of a human-centric interface/application	1	-

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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	-
L16- Load-balanced fleet management	4	-
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	Share of RES, Annual Mismatch Ratio (AMRx), Model run-time reduction, Data transfer rate, Time lag
L19- Energy Positive District Planning	2	No. of datasets ,No. of unique visitors, No. of integrated buildings
L20- Standard model for smart cities	1	No. 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 1: Leipzig bottom-up analysis' 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 CO2 Gas Emissions, Air quality indicator, Quantity of energy supplied by EV charging stations
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, Consumers 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 2: Leipzig districts KPIs

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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

Appendix table 3: Leipzig Macro level KPIs

B. Technical intervation analysis

Leipzig Interventions	# of actions	Key Performance Indicators
L1- Intelligent EV Charging and Storage	4	Quantity of energy supplied by EV charging stations, EV charging services (car and BUS)
L2- Micro grid inside the public grid	3	Number of apps developed in response to innovation challenges which use smart city module data and seek to change user behavior, utilization of blockchain technology
L3- Heating Demand control	2	Flexibility availability,Share of integrated systems (smart control/ VPP/ storage)
L4-Personalized informative billing	7	Reliability (Network Quality), Reduction of energy cost,
L5- Human-Centric Energy Management and Control DecisionSupport	2	Operational energy use/final energy demand, Self consumption rate
L6- Decarbonization of district heating.	4	Total heat supplied to the buildings connected to the district heating network
L7- Heat storage (P2H)	1	-
L8- ICT integration	1	Efficient control of the district heating
L9- Implementation and installation of an open standard based ICT platform that we call the "L-box"	2	-
L10- Economically reasonable integration of open and standardized sensors and systems	1	Improved interoperability
L11- Establishment of a distributed cloud centric ICT System which enables an	2	-

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

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intelligent energy management system		
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	-
L16- Load-balanced fleet management	4	-
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	-
L20- Standard model for smart cities	1	Replication strategy, Professional stakeholder involvement, Local community involvement in planning phase, Involvement of the city administration
L21- Community empowerment support activities through dialogues transferring ownership, Knowledge transfer	4	-

Appendix table 4: Technical intervention’s KPIs

C. KPIs description and calculation

KPI Name	Share of RES		
Level of Applicability	City ☑	District ☑	Building ☑
Description	The promotion of renewable energy sources is a high priority for sustainable development, for reasons such as the security and diversification of energy supply and for environmental protection. This indicator is the percentage of total energy derived from the renewable systems installed in the city as a share of the city’s total energy consumption		

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Calculation	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption. The share of renewable energy produced within the city is calculated as the total consumption of electricity generated from renewable sources (numerator) divided by total energy consumption (denominator). The result shall then be multiplied by 100 and expressed as a percentage. Consumption of renewable sources includes geothermal, solar, wind, hydro, tide and wave energy, and combustibles, such as biomass. (ISO/DIS 37120, 2013).
Units	[%]
References	• Morgenstadt framework • CITYkeys project

KPI Name	**Use of waste heat**
Level of Applicability	City ☑ District ☑ Building ☑
Description	Waste heat is the unused heat given to the surrounding environment by a heat engine in a thermodynamic process. Capturing waste heat enables it to be redirected to a function that would otherwise be using energy from the grid.
Calculation	The percentage of total reused waste heat, as a share of the total produced waste heat.
Units	[%]
References	-

KPI Name	**Share of integrated systems**
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.
Calculation	The percentage of integrated systems including storage devices, VPP and RES systems as a share of the individual systems installed.
Units	[%]
References	-

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

KPI Name	Energy savings/Reduce Demand consumption
Level of Applicability	City ✓ District ✓ Building ✓
Description	This KPI determines the reduction of the energy consumption to reach the same services (e.g. comfort levels) after the interventions, taking into consideration the energy consumption from the reference period. ES may be calculated separately determined for thermal (heating or cooling) energy and electricity, or as an addition of both to consider the whole savings.
Calculation	$ES_T = ER_T - TE_c$ ES_T Thermal energy savings ER_T Thermal energy reference demand or consumption (simulated or monitored) of demonstration-site [kWh/(m2 year); MWh/(year)]. TE_c Thermal energy consumption of the demonstration-site [kWh/(m2 year)MWh/(year)] $ES_E = ER_e - EE_C$ ES_E Electrical energy savings ER_e Electrical energy reference demand or consumption (simulated or monitored) of the demonstration-site [kWh/(m2 year) Wh/(year)] EE_C Electrical energy consumption of the demonstration-site kWh/(m_2 year) MWh/(year)]
Units	kWh/(m_2 year); MWh/(year)
References	• CITYkeys project
KPI Name	**Carbon dioxide Emission Reduction**
Level of Applicability	City ✓ District ✓ Building ✓
Description	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. CO2 accounts for a major share of Green House Gas emissions in urban areas. CO2 emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Calculation	The emitted mass of CO2 is calculated from the delivered and exported energy for each energy carrier: $mCO2=\Sigma(Edel,i\ K\ del,i)-\Sigma(Eexp,iKexp,i)$ Where $Edel,i$ *is the delivered energy for energy carrier i* ; *Eexp,i is the exported energy for energy carrier i* ; *Kdel,i is the CO2 emission coefficient for delivered energy carrier i*; *Kexp,i is the CO 2 emission coefficient for the exported energy carrier i*. The indicator is calculated as the direct (operational) reduction of the CO2 emissions over a period of time. The result may be expressed as a percentage when divided by the reference CO2 emissions. To calculate the direct CO2 emissions, the total energy reduced, can be translated to CO2 emission figures by using conversion factors for different energy forms as described in below tables: National and European emission factors for consumed electricity (source: Covenant of Mayors).
Units	Tones/year
References	• Morgenstadt framework • SCIS project • CITYkeys project

KPI Name	**Greenhouse Gas Emissions**
Level of Applicability	City ☑ District ☑ Building ☑
Description	The greenhouse gas, particulate matter, NOx and SO2 emissions of a system correspond to the emissions that are caused by different areas of application. In different variants of this indicator the emissions caused by the production of the system components are included or excluded. SCIS only excludes these emissions. To enable the comparability between systems, the emissions can be related to the size of the system (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. month, year). The greenhouse gases are considered as unit of mass (tones, kg.) of CO2 or CO2 equivalents.
Calculation	$GGE=TEc\cdot GEFT+EEc\cdot GEFE/Ab$ GGE Greenhouse gas emissions TEc Thermal energy consumption (monitored) of the demonstration site [kWh/ (month); kWh/ (year)] EEc Electrical energy consumption (monitored) of the demonstration site [kWh/ (month); kWh/ (year)]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

	GEFT Greenhouse gas emission factor for thermal energy (weighted average based on thermal energy production source/fuel mix) (kg CO2eq/kWh consumed) *GEFE* Greenhouse gas emission factor for electrical energy (weighted average based on electricity production source/fuel mix) (kg CO2eq/kWh consumed) *Ab* Floor area of the building [m2]
Units	kWh/ (m2 month); kWh/(m2 year)
References	• Morgenstadt framework • SCIS project
KPI Name	**Share of energy import**
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.
Calculation	The percentage of energy imported as a share of the total energy consumed.
Units	[%]
References	-
KPI Name	**Reduced energy curtailment of RES and DER**
Level of Applicability	City ☐ District ☑ Building ☑
Description	Reduction of energy curtailment due to technical and operational problems. The integration of ICT will have an impact on producers, as the time for curtailment will be reduced, and the operative range will be wider. This indicator can be measured as the percentage of GWh electricity curtailment from DER reduction of R&I solution compared to BAU for a period of time, i.e. a year.
Calculation	Energy not-injected, is the total energy not injected in network due to MV/LV network conditions. Reduction of Energy injected= [(Energy not injected$_{baseline}$- Energy not injected$_{R\&I}$)/ Energy not injected$_{baseline}$]*100
Units	[%]
References	• SCIS project

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

KPI Name	Increase in Local Renewable Energy Generation
Level of Applicability	City ☑ District ☑ Building ☑
Description	The share of renewable energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator should account for the increase of the renewable energy generation due to the intervention.
Calculation	As input parameters, it should take into account the increase in local renewable energy production caused by the intervention calculated as the difference between the annual renewable energy generation related to the system before and after the intervention (or as the difference between the annual renewable energy generations related to the project compared to BAU). The result will be divided by the annual total energy consumption related to the project.
Units	[%]
References	• SCIS project

KPI Name	Utilization of local district heating
Level of Applicability	City ☐ District ☑ Building ☐
Description	Share of heat demand delivered by district heating systems.
Calculation	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)
Units	(Kwh/a)
References	• Morgenstadt framework

KPI Name	Small particulate emission
Level of Applicability	City ☐ District ☑ Building ☐
Description	Small particulate emission is defined as the annual average particulate matter (PM10 and PM2.5) emission.
Calculation	Small particulate emissions can be measured through many methods including field trials or modelling
Units	g/vkm, ppm
References	• CIVITAS project

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

KPI Name	NOx emissions
Level of Applicability	City ☐ District ☑ Building ☐
Description	NO_x emission is defined as the annual average NO_x emission per vehicle-km by vehicle and fuel type.
Calculation	NO_x emissions can be measured through many methods including field trials or modelling.
Units	g/vkm, ppm
References	• CIVITAS project
KPI Name	**Peak load reduction**
Level of Applicability	City ☐ District ☑ Building ☑
Description	Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power.
Calculation	$\%=(1-P_{peak,R\&I}/P_{BAU})*100$
Units	[%]
References	• SCIS project
KPI Name	**Smart meters**
Level of Applicability	City ☐ District ☑ Building ☑
Description	This indicator is the percentage of smart meters coverage on the energy distribution network; it could be distinguished for electric and methane or heat networks.
Calculation	Smart meters installed and used
Units	Number of meters, GWh/yr
References	• SCIS project
KPI Name	**Average annual unemployment rate**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Level of Applicability	City ☑ District ☑ Building ☐
Description	The total number of unemployed persons, divided by the total labor force. The unemployment rate is the percentage of the labor force that actively seeks work but is unable to find work at a given time.
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	Years
References	• Morgenstadt framework
KPI Name	**Payback period**
Level of Applicability	City ☑ District ☑ Building ☐
Description	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators.
Calculation	$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Net Cash Flow per Period}}$ When cash inflows are uneven, Payback Period = A + B/C Where A is the last period number with a negative cumulative cash flow B is the absolute value (i.e. value without negative sign) of cumulative net cash flow at the end of the period A C is the total cash inflow during the period following period A.
Units	Years

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

References	• SCIS project
KPI Name	**Diffusion to other locations**
Level of Applicability	City ☑ District ☐ Building ☐
Description	The extent to which the project is copied in other cities and regions
Calculation	The indicator provides a qualitative measure and is rated on a five point Likert scale: Not copied in other locations – 1 — 2 — 3 — 4 — 5 — Very much copied in other locations 1. The innovation is not copied in other locations. 2. The innovation has been copied once in another location within the same city/region. 3. The innovation has been copied several times within the same city/region. 4. The innovation has been copied in projects within the same city/region, as well as projects outside the original city/region. 5. The innovation has been copied in its country of origin, as well as internationally.
Units	
References	• CITYkeys project
KPI Name	**Employment rate**
Level of Applicability	City ☐ District ☑ Building ☑
Description	The total number of unemployed persons, divided by the total labour force. The unemployment rate is the percentage of the labour force that actively seeks work but is unable to find work at a given time.
Calculation	The number of working-age city residents who during the survey reference period were available for work and seeking work, but were not in paid employment or self-employment, is divided by the number of people above the age specified for measuring the labour force. Discouraged workers—persons who are not actively seeking work because they believe the prospects of finding it are extremely

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

	poor—are not counted as unemployed or as part of the labour force. (Based on GCIF indicator description for "City unemployment rate.")
Units	Number
References	• Morgenstadt framework
KPI Name	**Life expectancy at birth**
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. (CIA Fact Book and OECD definition, also used by GCIF.)
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	Years
References	• Morgenstadt framework
KPI Name	**Number of personal automobiles per 1000 inhabitants**
Level of Applicability	City ✓ District ✓ Building ✓
Description	Number of personal vehicles per capita (1000 inhabitants)
Calculation	The number of personal automobiles per capita shall be calculated as the total number of registered personal automobiles in a city (numerator) divided by the total city population (denominator). The result shall be expressed as the number of personal automobiles per capita. The total number of registered personal automobiles shall include automobiles used for personal use by commercial enterprises. This number shall not include automobiles, trucks and vans that are used for the delivery of goods and services by commercial enterprises.
Units	Number
References	• Morgenstadt framework
KPI Name	**Energy storage**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242
Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Level of Applicability	City ☐ District ☑ Building ☑
Description	Energy storage
Calculation	Energy storage capacity by energy type depending on storage type, e.g. the storage capacity, volume, mass, temperature, long or short-term storage
Units	Depending on the storage type, e.g. mass (kg or t),volume (m3),storage capacity (kWh or Ah or MW)
References	• CITYkeys project
KPI Name	**Smart meters**
Level of Applicability	City ☐ District ☑ Building ☑
Description	This indicator is the percentage of smart meters coverage on the energy distribution network; it could be distinguished for electric and methane or heat networks.
Calculation	Smart meters installed and used
Units	Number of meters, GWh/yr
References	• SCIS project
KPI Name	**Market orientation**
Level of Applicability	City ☐ District ☑ Building ☑
Definition	The extent to which the project was planned on the basis of a Market analysis
Calculation	Likert Scale: No market orientation – 1 – 2 – 3 – 4 – 5 - Extensive feasibility study
Units	-
References	• CITYkeys project
KPI Name	**Peak load reduction**
Level of Applicability	City ☐ District ☑ Building ☑
Definition	Compare the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). E.g. Peak load is the maximum power consumption of a building or a group of buildings to provide certain comfort levels. With the

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

	correct application of ICT systems, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In SCIS, the indicator is used to analyse the maximum power demand of a system in comparison with the average power.
Calculation	%=(1− Ppeak,R&I/PBAU)*100
Units	[%]
References	• SCIS project
KPI Name	**Quantity of energy supplied by EV charging stations**
Level of Applicability	City ☐ District ☑ Building ☐
Definition	Energy supplied to the grid by EVs connected to the charging stations
Calculation	Energy supplied to the grid by EVs connected to the charging stations
Units	kWh/yr
References	• Triangulum
KPI Name	**Return on Investment**
Level of Applicability	City ☑ District ☑ Building ☐
Definition	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 %.
Calculation	ROI= (Current Value of Investment−Cost of Investment) Cost of Investment
Units	
References	• SCIS project

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

KPI Name	Payback period
Level of Applicability	City ☑ District ☑ Building ☐
Definition	The payback period is the time it takes to cover investment costs. It can be calculated from the number of years elapsed between the initial investment and the time at which cumulative savings offset the investment. Simple payback takes real (non-discounted) values for future monies. Discounted payback uses present values. Payback in general ignores all costs and savings that occur after payback has been reached. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period. As the invested capital flows back slower, the risk that the market changes and the invested capital can only be recovered later or not at all increases. On the other hand, costs and savings that occur after the investment has paid back are not considered. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators.
Calculation	Payback Period = Initial Investment / Net Cash Flow per Period When cash inflows are uneven, Payback Period = A + B/C Where A is the last period number with a negative cumulative cash flow B is the absolute value (i.e. value without negative sign) of cumulative net cash flow at the end of the period A C is the total cash inflow during the period following period A.
Units	Years
References	• SCIS project

KPI Name	Diffusion to other locations
Level of Applicability	City ☑ District ☐ Building ☐
Definition	The extent to which the project is copied in other cities and regions

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities

Calculation	The indicator provides a qualitative measure and is rated on a five-point Likert scale: Not copied in other locations – 1 — 2 — 3 — 4 — 5 — Very much copied in other locations 1. The innovation is not copied in other locations. 2. The innovation has been copied once in another location within the same city/region. 3. The innovation has been copied several times within the same city/region. 4. The innovation has been copied in projects within the same city/region, as well as projects outside the original city/region. 5. The innovation has been copied in its country of origin, as well as internationally.
Units	
References	• CITYkeys project

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Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities