D2.7 Holistic Impact Assessment of Demonstration Activities- updated version 1

30/09/2023

Aristotelis Ntafalias, Panagiotis Papadopoulos, Kyriakos Kentzoglanakis, Panagopoulou Fani- ***MOH,*** *Giorgos Papadopoulos, Katerina Vagena-* ***Suite5,*** *Jani Tartia, Joni Mäkinen-* ***ESP,*** *Aapo Huovila, Kalevi Piira, Tiina Vainio-Kaila, Mikaela Ranta-* ***VTT,*** *Elina Ekelund, Kimmo Hyttinen-* ***CIT,*** *Joona Töyräs-* ***PIT,*** *Saga-Sofia Santala, Merja Honkanen, Toni Tukia-* ***KONE,*** *Sami Laakso, Daniel Boldt-* ***SIE,*** *Timo Koljonen-* ***ADV,*** *Irene Müller, Nadja Riedel-* ***LPZ,*** *Sandra von Schirp-* ***CEN,*** *Patrizia Bolognesi, Heidi Marschner-* ***SEE,*** *Hendrik Kondziella-* ***ULEI,*** *Erik Jelinek , Simon Albrecht-* ***LSW,*** *Alexander Peitz-* ***WSL***

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

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SPARCS

Deliverable administration

No & name	**D2.7 Holistic Impact Assessment of Demonstration Activities- updated version 1**				
Status	Released	**Due**	M48	**Date**	2023-09-30
Author(s)	See cover page				
Description of the related task and the deliverable. Extract from DoA	**T2.4 Socio-economic, environmental, and technologic Impact Assessment (VERD) M18 – 60** The aim of this task is to step on the activities performed in the previous tasks of WP2 (T2.1, T2.2 and T2.3) to perform the holistic evaluation of the project activities and the assessment of the impact achieved by the project interventions in the lighthouse city demos. This will consist in a continuous process that will start with the launch of the demo deployment phase, to constantly provide up-to-date information about the demos progress, enable the identification of weak interventions and the definition of corrective actions, while supporting the dissemination and communication activities of the project on the basis of realistic data and impact achievements throughout the whole duration of the project. To this end a consolidated evaluation will take place for providing individual, aggregated and comparative (quantitative and qualitative) assessments of demo results, not only focusing on the energy-relevant impacts achieved, but addressing the smart city concept in a holistic manner, by considering associated economic, social and technological aspects. Evaluation will be performed in progressive phases following the distinct steps of the demo roll-out phase of the project and will involve all stakeholders engaged (directly or indirectly) in the demonstration activities in the lighthouse cities, to achieve the holistic assessment and collaborative devising of the SPARCs project interventions.				
Participants	MOH, VTT, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV, RIL, FHG, BABLE, SPI, NEW, CVUT, SUITE5, LCE,				
Comments					

V	Date	Authors	Description
0.1	05/04/2022	MOH	First draft of ToC and contribution to report
0.2	31/05/2022	ESP, LPZ, CEN, LSW, PIT, CIT, WSL, SEE, S5, SIE, KONE, VTT, ULEI, ADV	Contributing to report
0.3	10/006/2023	MOH	Review contributions and feedback to partners
0.4	02/09/2023	ESP, LPZ, CEN, LSW, PIT, CIT, WSL, SEE, S5, SIE, KONE, VTT, ULEI, ADV	Contributing to report
0.5	08/09/2023	MOH, S5	Internal Review and changes
0.6	11/09/2023	VTT, FHG	Peer review

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0.7	18/09/2023	MOH	Comments' incorporation
0.8	27/09/2023	S5, VTT	Deliverable checked by WP leader and released to the Coordinator and the Quality Manager for quality check and subsequent submission to the EC.
1	30/09/2023	VTT	Coordinator submits the deliverable to the EC

Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

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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 VirtualPositiveEnergy 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

VTT, Stadt Leipzig, Câmara Municipal da Maia, Kladno, Δήμος Κηφισιάς, Lviv, Espoo, KONE, SIEMENS, PLUGIT, CITYCON, ril, Adven, Fraunhofer, BABLE, WSL, Leipziger Stadtwerke, CENERO, verd, seecon Ingenieure, Universität Leipzig, spi Sociedade Portuguesa de Inovação, NEW, OR Reykjavík Energy, CTU Czech Technical University in Prague, Suite5 We Deliver Intelligence, ЛЬВІВАВТОДОР, MOTOR OIL, GOPA.com.

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ABBREVIATIONS

BEST	Building Energy Specification Table
BEv	Battery Electric vehicle
BL	Building Block Bevel
CDD	Cooling Degree Days
CHP	Combined Heat and Power
CO_2-eq	Equivalent CO_2
D.	Deliverable
DER	Distributed Energy Sources
DL	District Level
DoA	Description of Actions
DPBP	Discounted Payback Period
DR	Demand Response
DSCR	Debt Service Coverage Ratio
DSM	Demand Side Management
EC	European Commission
EU	European Union
Ev	Electric vehicle
FC	Fellow City
GA	Grant Agreement
GHG	Green House Gas
GoO	Guarantees of Origin
GSHP	Ground Source Heat Pump
HDD	Heating Degree Days
HEv	Hybrid Electric vehicle
ICT	Information and Communication Technologies
IRR	Internal Rate Return
KPI	Key Performance Indicator
kW	Kilo Watt
kWh	Kilo watt hours
LHC	Light House City
LLCR	Loan life coverage ratio
LoraWan	Long range wide area network
MaaS	Mobility as a Service
ML	Macro Level
MW	Mega Watt
NZEB	Nearly Zero Energy Building
P2H	Power to Heat
PED	Positive Energy District
PEC	Positive Energy Community
PV	Photovoltaic
RES	Renewable Energy Sources
ROI	Return of Investment
SPARCS	Sustainable Positive and zero cARbon CommunitieS
T.	Task
VPP	Virtual Power Plant
WP	Work Package

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EXECUTIVE SUMMARY

The overall goal of SPARCS is to demonstrate and validate innovative solutions for planning, deploying, and rolling out smart and integrated energy solutions that will transform cities into sustainable, citizen-centred, zero-carbon ecosystems.

The scope of T2.4 is to conduct an impact assessment of the interventions deployed in the Lighthouse Cities (LHCs) of the project -namely Espoo and Leipzig- based on the methodology and Key Performance Indicators (KPIs) defined in Task 2.1 of WP2. These KPIs cover both quantitative and qualitative aspects and address various aspects of smart city concept.

To conduct the assessment, specific targets were set for each intervention. These targets were either derived from the project's objectives or the cities' goals and Building Energy Specification Tables (BEST) or were established based on estimates according to the technical specifications. It is important to note that the intervention targets are meant to be achieved by the end of the project and not necessarily during the interim monitoring periods.

The current deliverable provides an update on the impact monitoring of the cities at the end of the second monitoring period of the project, which is set for September 2023. The final version of this deliverable will be available in September 2024. Through the assessment of the implemented interventions, the progress of the LHCs is measured, by monitoring the impact achieved in the demonstration areas, considering a wider smart city concept as presented in Figure 1 below.

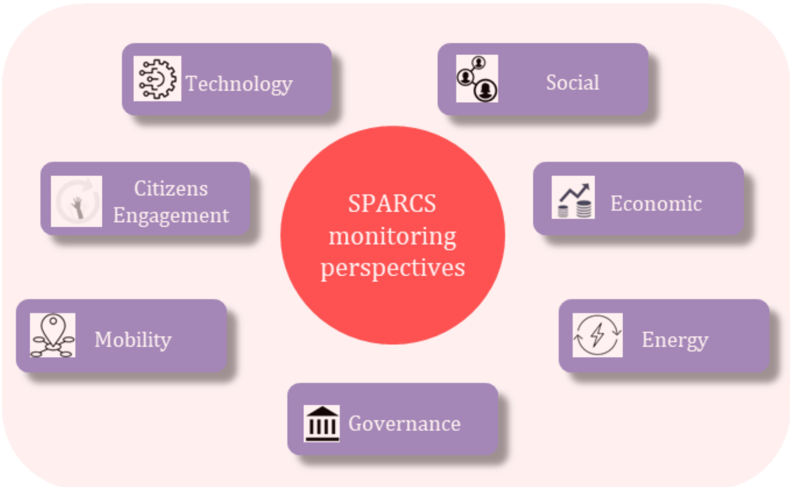

Figure 1. SPARCS evaluation perspectives

Furthermore, valuable lessons are offered from the entire process of implementing the interventions in the two LHCs, providing useful information, such as obstacles encountered and best practises followed, to be used by cities planning to replicate the solutions developed. This holistic evaluation of the interventions includes - in both LHCs - the individual presentation of the KPIs related to the intervention and the aggregated presentation of the KPIs related to the city.

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Figure 2 presents the aggregated results of KPIs monitoring in the two LHCs during the second monitoring period, both for the intervention and the city KPIs.

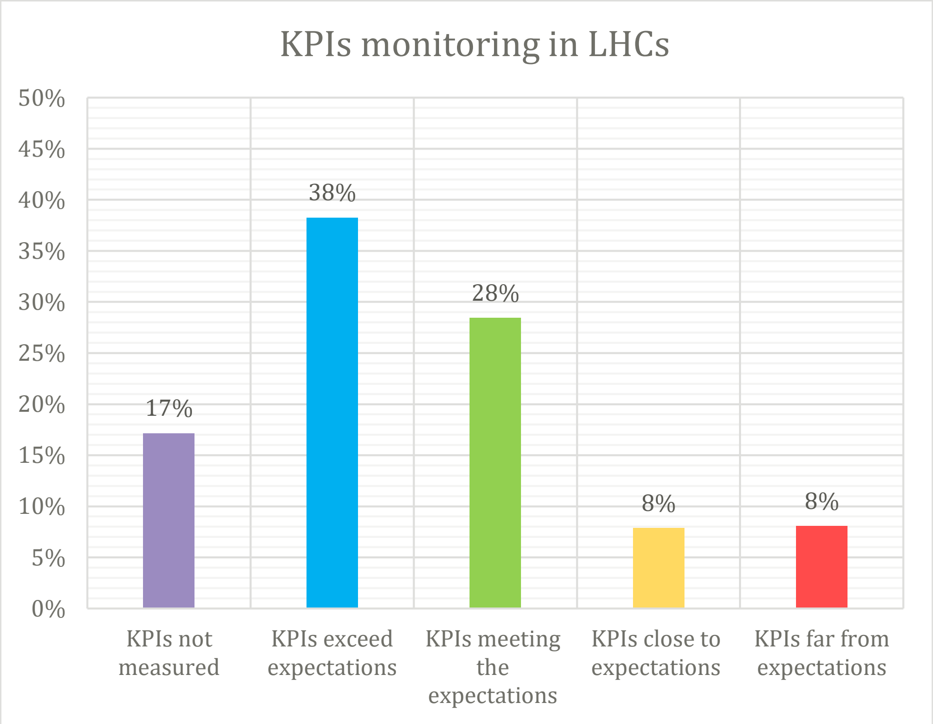

Figure 2. Overview of impact assessment in LHCs

This diagram shows nearly 40% of the KPIs (blue column) exceeded expectations meaning that the targets for these indicators were surpassed. For example, the KPI for "Total CO2 reduction based on charged electricity" in Espoo was targeted at 720 tonnes but the actual reduction on the current period was 1298 tonnes. The fact that 38% of the KPIs in both cities exceed the expectations is a very positive sign, indicating that the sustainable interventions are having a significant impact in these cities.

The green column indicates that 28% of the KPIs met expectations, which means that they achieved their set targets. This is a positive result, indicating that the sustainable interventions are on track to achieve their goals. The yellow column shows that 8% of the KPIs were close to meeting expectations, which means that interventions had some positive impact but still there is room for improvement. The red column shows that 8% of the KPIs were not very close to meeting expectations, indicating that the sustainable interventions are not having yet the desired impact. Finally, 17% of the KPIs were not monitored due to data-related issues, which means that in the current monitoring period we cannot assess the impact of the sustainable interventions in these areas.

Overall, the results are positive, with the majority of the KPIs meeting or exceeding expectations. However, there are some areas where improvement is needed. It is important to continue monitoring the impact of the sustainable interventions and to address any areas where they are not having the desired impact.

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1. INTRODUCTION

The SPARCS project aims to create zero-carbon urban communities through the integration of positive energy and optimised consumption technologies in both buildings and districts. In addition, the project promotes the participation of citizens and stakeholders in urban planning processes through the co-design of ecosystems to increase the quality of life of citizens.

To this end, a vast number of interventions were carried out in the LHCs of Espoo in Finland and Leipzig in Germany, focusing on the interconnection between buildings and districts that will pave the way for positive energy districts (PEDs), advanced management and efficiency of energy produced from renewable energy sources (RES), storage of surplus energy, transition to E-mobility as well as on the development of new business models (Figure 3).

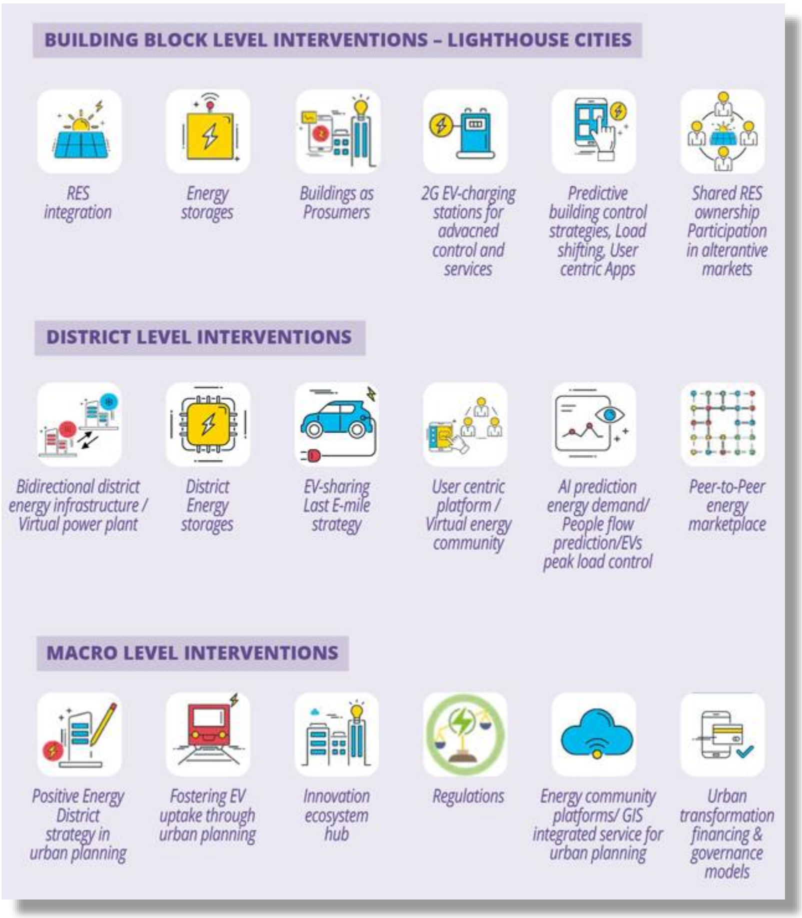

Figure 3. SPARCS interventions mapping

This document focuses on assessing the impact of the interventions implemented and uses the tools developed in the previous Work Package (WP) 2 tasks. KPIs, as defined for each demonstration area in D2.2, are continuously monitored and evaluated in an individual, aggregated, and comparative manner to provide updated information from a qualitative and quantitative perspective, while identifying potential weak interventions and triggering the proposal of corrective actions.

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1.1 Scope of the document

The main objective of T2.4 is to perform a comprehensive evaluation of the project's activities and to evaluate the impact obtained from the implementation of the LHC interventions. This evaluation is a continuous process that covers both qualitative and quantitative aspects and is divided into three distinguished monitoring periods as presented below:

- 1st period: March 2022-March 2023[M30-M42] (results published in D2.6)
- 2nd period: April 2023-September 2023 [M43-48] (covered in current deliverable)
- 3rd period: October 2023-September 2024 [M49- M60] (this will be covered in the final version of this deliverable- D2.8)

The second monitoring period, which began in April 2023 is presented in this report, and the evaluation is based on the impact assessment framework as developed and presented D2.2[1], in which the necessary KPIs with the relevant data for their calculation were thoroughly presented. In addition, the LHCs baseline establishment -presented in D2.3- is used as basis for the needs of the assessment indicating the improvement achieved in the different demo areas of each LHC.

Comparing the target values of the KPIs with their current values shows whether the interventions have been successful, measuring the impact they have had on various development sectors, such as energy, mobility, and governance. In cases where the intervention did not have the expected impact, corrective actions are proposed so that the goals are achieved in the final monitoring period. At the same time, the lessons learnt so far, either for successful interventions or for not yet successful ones, are reported, so that the knowledge gained from the whole process can be incorporated into the context of this report and used as a reference for future replication actions.

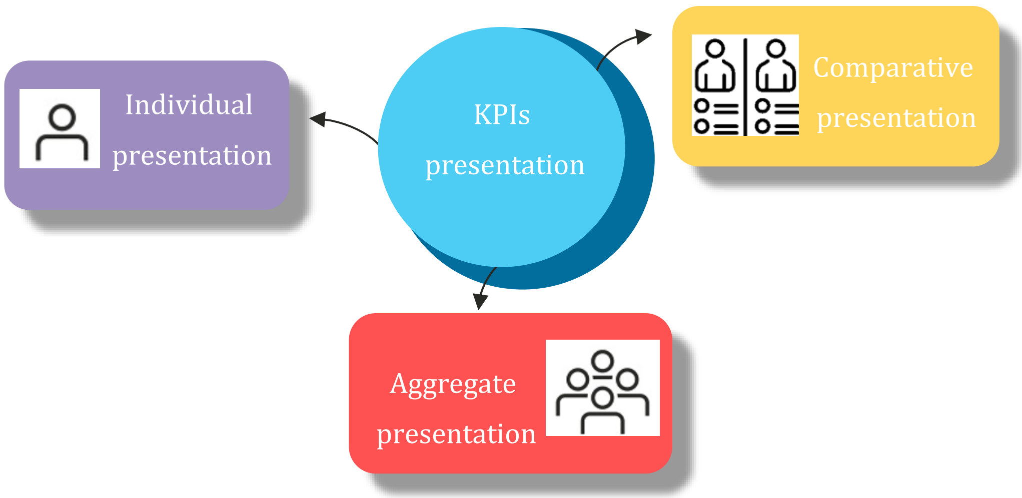

Figure 4. Demonstration categories of KPIs

[1] https://sparcs.info/en/deliverables/d2-02-definition-of-sparcs-holistic-impact-assessment-methodology-and-key-performance-indicators-updated-version/

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For the purposes of T2.4 the measured KPIs are planned to be presented in three ways (Figure 4):

1. Individually, so that the impact in each different intervention is easily visible and linked to the specific intervention
2. Aggregate, where KPIs belonging to a certain domain of a LHC e.g., Energy, to group together and see how SPARCS interventions affect specific areas of interest
3. Comparative, so that it is possible to compare between different areas of a city or between different LHCs.

1.2 Link to other deliverables

This deliverable presents the results of the continuous monitoring of interventions in demo sites and the impact that have been achieved. This document has strong relations and receives input from the following SPARCS tasks and associated deliverables:

- T2.1 "Demo Evaluation, Impact Assessment and Cost-Benefit Analysis Framework and Associated Key Performance Indicators", where the framework for the holistic assessment of the project's interventions in the LHCs, as well as the KPIs to serve the scope of evaluation have been defined and documented in D2.1 and D2.2. These KPIs allow for continuous monitoring of project progress and the overall evaluation of the impact achieved by the interventions planned and used.
- T2.3 "Data gathering from demonstration activities for evaluation", with the main objective of developing a standard process for collecting the various types of data derived from the demonstration activities, allowing the continuous monitoring of the project's progress and the overall evaluation of the impact achieved by these interventions. D2.4 and D2.5 provide a comprehensive overview and a documentation report of the various components and services of the SPARCS ICT ecosystem, responsible for collecting, handling, storing, and sharing the various datasets derived from the SPARCS LHCs and Fellow Cities (FCs).

1.3 Structure of the document

This document contains six chapters including this introduction. Chapter 2 gives the background of the demo sites and briefly describes the interventions developed while in parallel providing the context of the SPARCS impact assessment framework and the preparatory work of T2.4 for its achievement. Chapter 3 presents the progress and evaluation of Espoo LHC through the monitoring of the defined in T2.1 KPIs as well as the conclusions and valuable lessons learnt so far from the second monitoring phase; the same information is presented for Leipzig in Chapter 4. Chapter 5 presents the initial context for the comparative assessment of the demo areas while Chapter 6 presents the conclusions of this report and the future work on the impact assessment. The appendix at the end of the document contains the data and calculation forms for the LHCs KPIs presented in related chapters.

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2. Demonstration Sites, Assessment Framework and Challenges Faced

This chapter provides background information on the LHC demonstration sites and applied interventions related to SPARCS. In addition, the impact assessment framework established in T2.1 is presented to evaluate these interventions, to understand the landscape considered and to provide a better picture of the evaluation areas assessed in the following chapters of this document. In parallel, some issues that emerged from the preparatory work for the evaluation are presented in this section.

2.1 Espoo demo sites and interventions

Espoo is the second largest city in Finland, with approximately 300,000 residents, and is an integral part of the Helsinki capital metropolitan area. The city is growing rapidly and is expected to reach 400,000 residents by 2050. One special characteristic of Espoo is its urban structure. Instead of having one city centre, as commonly found in most cities, it contains five city centres that can be seen as smaller cities within the city, providing all necessary services close to its residents.

The SPARCS goals support the overarching sustainability objective of Espoo that is to reach carbon neutrality by 2030, including fossil-free district heating, and emissions reduction by 80 % by 2030, compared to 1990.

Through the project, Espoo develops its SPARCS 2050 City Vision that focuses on examining the possibilities of future sustainable urban energy and (e-)mobility solutions based on the learnings from the project. Figure 5 below briefly presents some of the key long-term sustainability targets of Espoo.

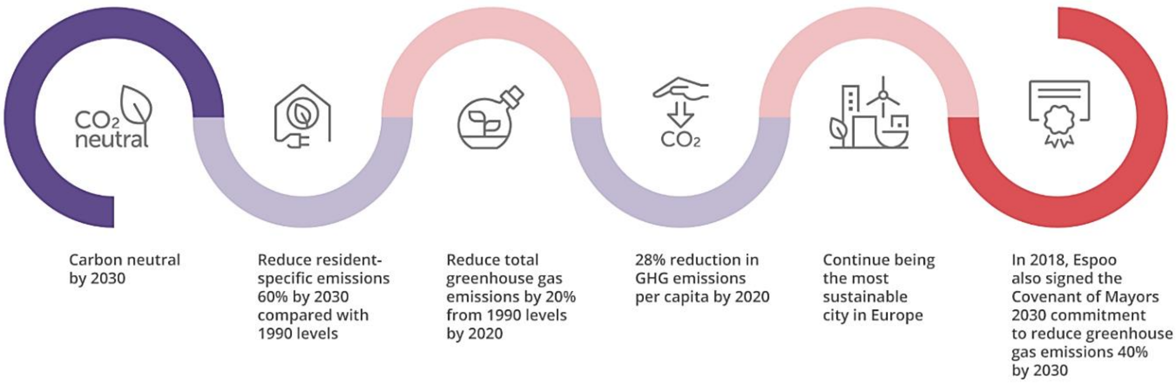

Figure 5. Espoo long-term sustainability goals

In the Espoo Lighthouse City, the demonstrations take place in three districts that are in different phases of development and construction; Kera is in the planning and very early construction phase, Espoonlahti district is in a redevelopment phase, and Leppävaara district is an already built-up area experiencing infill construction. In these demonstration areas 14 interventions were implemented within the SPARCS project; in addition, 9

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interventions, related to studies and analyses on energy, mobility, co-creation and citizen engagement and carbon neutrality in the near future, were implemented at the macro level of the city.

Espoonlahti district

The Espoonlahti district is one of Espoo's multiple city centres with 56,000 residents. The area is partially redeveloped and is expected to grow in the future. The main objectives of the district demonstrations include integrated RES solutions using PV panels, geothermal and waste solutions, e-mobility activities, and citizen engagement actions.

The SPARCS demonstration area within the district, the Lippulaiva block, uses a large ground source heat pump (GSHP) unit of 4MW in commercial buildings, producing at least 90% of the district's heating and cooling demand. The newly opened shopping centre has a gross floor area of nearly 190,000 square metres, while the leasable area is approximately 44,000 square meters, housing around 100 retailers and services. It is estimated to be visited by eight million customers annually as it is a large traffic hub, directly connected to public transport. The heating and cooling demand of the Lippulaiva shopping centre is mostly covered with the heat pump plant and the RES production includes a PV system with peak power of approximately 634 kWp and a 1,5 MWh capacity battery. Table 1 below presents in brief the interventions related to Espoonlahti district.

Table 1. Espoonlahti district interventios

Intervention	Description	Actions
E1	Solutions for Positive Energy Blocks	- Nearly zero energy building (NZEB) & PV optimisation - Battery as emergency power and electricity cost reduction factor - Self-sufficiency improvement of surrounding blocks
E2	Boosting E-mobility uptake	- EV charging infrastructures and their integration into the smart grid - Mobility and accessibility through sustainable transportation options
E3	Engaging users	- Piloting ways to engage and encourage citizens' energy positive ways of behaviour
E4	Smart Business Models	- Engaging users in co-creating energy positive business models in Lippulaiva and Espoonlahti district

Leppävaara district

The Leppävaara district is the largest and most active of Espoo's five city centres. As an already built area, the centre of Leppävaara, with over 65,000 residents and the Sello shopping centre - a key demonstration site of the SPARCS project - is a major urban activity and transport node. The area is expected to grow significantly in the near future and the population is estimated to reach 100,000 by 2040.

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The Sello shopping centre is the second largest of its kind in Finland, with approximately 23 million visitors per year. Its electricity needs are covered by renewable energy produced locally by a 750 kW PV plant in the summer and transitional months. During days with low solar irradiance, a virtual power plant supplies green electricity based on a Guarantees of Origins (GoOs) scheme, an instrument defined by European legislation[2] that tracks electricity from renewable energy sources and provides customers with information on the source of their energy. Table 2 summarises the interventions in Leppävaara district.

Table 2. Leppävaara district interventions

Intervention	Description	Actions
E5	Solutions for Positive Energy Blocks	- Modelling of thermal energy processes to increase energy efficiency, self-sufficiency, and thermal flexibility - Simulation of on-site heat production with renewable energy
E6	ICT for Positive energy blocks	- Integration of electricity storage with onsite electricity production (PV), power backup generators and HVAC loads - Studying feasibility of connecting blockhouses with a centralised electricity storage to virtual power plant in a blockhouse environment
E7	New E-mobility hub	- Development existing mobility hub in Leppävaara - Development of electric vehicle (EV) charging for customers of the shopping centre - Research on current and future scenarios of this e-mobility hub
E8	Engaging users	- Study citizens energy positive mobility behaviours - Experiment concepts for encouraging people to use e-mobility solutions for their daily mobility habits
E9	Smart Business models	- Engaging users in co-creating energy positive business models in Sello

Kera district

Kera is an underdeveloped industrial area that will be rebuilt into a new residential district with 14,000 residents and 10,000 workplaces over the next decades. The urban development of Kera focuses on implementing advanced sustainable district energy solutions and sustainable mobility solutions focusing on public transportation, walking and bicycling. The main objective of SPARCS is to develop and pilot new models for co-creation, energy communities and stakeholder engagement to bring the residents and the local stakeholders of the developing Kera district to the centre of the energy ecosystem, maximising local production and encouraging prosumer models to enhance the utilisation of distributed generation. The current district heating network in Kera will be replaced with a local bi-directional low-temperature heating network connected to the larger grid. The local heating network will serve as a basis for the further development of local energy

[2] DIRECTIVE 2009/28/EC30 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources

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solutions. A new heat pump station will produce heat not only for the entire Kera district, but also for other districts in Espoo. Kera also has competitive transport links, as a railway already connects the district to the rest of the capital's metropolitan area. The traffic planning will favour pedestrian and bicycle accesses and lanes. In Table 3 the interventions in Kera district are presented briefly.

Table 3. Kera district interventions

Intervention	Description	Actions
E10	Solutions for Positive Energy Blocks	- City planning for PEDs - Energy infrastructure for PEDs - Energy system planning
E11	Engaging users	- Research insights to city planning authorities in Kera on citizens' preferable future multimodal mobility habits
E12	ICT for Positive energy blocks	- Smart 5G infrastructure - Developing new service models for autonomous transport and e-mobility solutions linked to the local 5G network - Blockchain technology as enabler
E13	E-mobility in Kera	- Multimodal transport solutions focusing on last mile - Replication of e-mobility solutions
E14	New economy/ Smart Governance models	- Development of solutions for smart and energy efficient future living through a co-creation process between the City of Espoo and the local consortia of stakeholders

Macro level

Urban Energy Planning in Espoo is looking for efficient applications to achieve the goal of carbon neutrality. Low-emission lifestyles are supported through incentives for RES penetration and through the growth of electrification solutions (private cars, work machines and especially public transport), autonomous transport and Mobility as a Service (MaaS). At the same time, through strategic planning with local energy providers to establish district heating systems in dense areas of Espoo and with the local distribution system operator (DSO) to facilitate the further development of the network to meet the increased needs of the city, Espoo supports its goals for sustainable development and carbon neutrality.

In addition, virtual power plant (VPP) solutions are implemented to monitor, forecast, and optimise distributed energy resources (DERs), such as solar farms and Combined Heat and Power (CHP) units, in the districts. In some cases – like Sello – VPPs are already operational and through SPARCS's macro level interventions the feasibility analysis for their replication in public buildings will be studied. In Table 4 the interventions and actions at the macro level are summarised.

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Table 4. Espoo Macro level interventions

Intervention	Description	Actions
E15	Virtual Power Plant	- Demonstration of a VPP solution for public buildings using the Espoo building stock as a pilot platform - Blockchain to support demand response (DR) events in PEDs
E16	Smart heating	- Buildings demand side management (DSM) and demand flexibility.
E17	Virtual twin	- Sello Virtual Twin predicting energy demands - Simulate solutions for energy positive blocks through Espoo's 3D City model
E18	EV charging effects to grid	- Mapping the optimal integration of EV chargers
E19	Sustainable lifestyle	- Definition and validation of solutions for optimizing urban people flow from energy
E20	District development	- Identification of requirements related to integrate buildings in the energy infrastructure
E21	Air quality	- Follow up of air quality development in Espoo
E22	Co-creation for Positive Energy District	- Co-creation for smart city development - Development and dissemination for smart city solutions

2.2 Leipzig demo sites and interventions

Leipzig is the eighth largest city in Germany and the largest city of Saxony and is inhabited by approximately 625,000 residents; it forms a metropolitan area with Halle and is within reach of Dresden and Berlin.

Leipzig aims to reduce its per capita CO_2 emissions by 10% per year to reach a sustainable level of 2.5 t by 2050. To fulfil this goal, it has drawn up an Energy and Climate Protection Work Programme, outlining priority measures and projects to be implemented by the municipality, public transport association, and municipal utilities. The long-term vision for 2050 aims at improving consumption of renewable energy produced in the city and virtually connecting all participating generation, storage, and consumption entities to balance energy consumption and production and enable new services. The goal of the city is to develop a 2050 strategy that can be replicated in districts not only in Leipzig, but in other cities across Europe. Figure 6 summarises the long-term sustainability targets of Leipzig. There are three demonstration areas in Leipzig within the scope of SPARCS project, namely Baumwollspinnerei, Leipzig West and Virtual positive energy community, in which 22 interventions are taking place.

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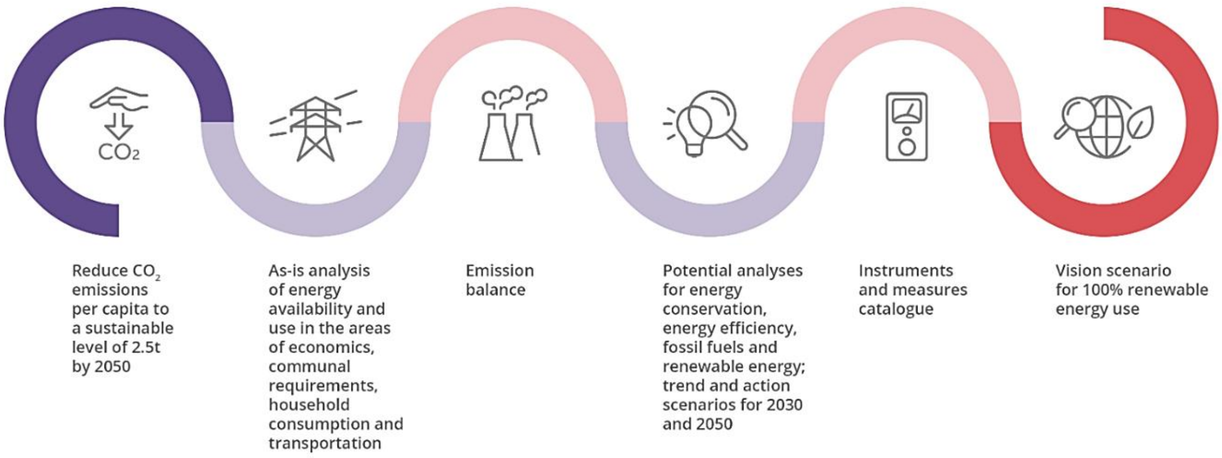

Figure 6. Leipzig long-term sustainability targets

Baumwollspinnerei

The premises of the Baumwollspinnerei (a former cotton mill) are protected as heritage buildings and were originally constructed in 1884. Nowadays, the site houses a diverse set of facilities combining living and working in a historical environment. For the needs of SPARCS two central buildings are used as demo-cases. These two buildings claim together a demand of appr. 689 MWh electricity and appr. 1.282 MWh of heat in 2020. Table 5 below presents the interventions and actions of the district.

Table 5. Baumwollspinnerei district interventions

Intervention	Description	Actions
L1	Intelligent EV charging and storage	- Development, demonstration, and implementation of bi-directional charging - Analysis of e-mobility effect on micro grid stabilisation - Extension of charging optimisation algorithms for EVs bidirectional charging
L2	Micro grid inside the public grid	- Installation and efficient integration of a 40 kWp PV-power-plant with storage in addition to the existing CHP-capacities - Balancing the micro grid against the city-wide virtual power plant
L3	Heating demand control	- Coupling heating needs with load profile of the micro grid - User interface with air quality info

The present renewable energy source consists of a CHP-Plant with a power of 50kWel contributing nearly 301 MWh electricity in the same year. Another CHP-Plant with an additional power level of 100kWel is currently implemented, outside the SPARCS-Project. CEN will install a solar power plant, supplying a maximum power of 40kWp. For increasing the flexibility in power usage, a bulk battery will be implemented, and a load-management software will be installed for efficiently steer the power streams. Near Hall

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18 there is a parking space equipped with an electrical charging column, used by a local carsharing company that will be enhanced by three bi-directional ready charging stations. In Hall 14, the heat generation infrastructure will be digitally networked to achieve automated coupling of demand and consumption.

Leipzig West

The district encompasses 31 buildings with a living space of 65.000 m2 and includes multiple units, which are priced for social housing needs. With its active and involved tenants, the district is the ideal testing ground for the proposed user-centric control, through a dedicated platform that promotes active involvement of citizens, to optimise the flow of energy. Within the district, there are seven buildings with 300 apartments that will be used as demonstration areas. The interventions in Leipzig West are presented in Table 6.

All apartments are equipped with net (smart) metering technology for thermal energy. In addition, a novel solution for optimising thermal energy consumption through the implementation of human-centric thermal demand response (DR) events is demonstrated. Moreover, the heat generation of the solar installation is examined and compared with the usual heat consumption buildings by providing different tariffs from a district heating supplier. The long-term goal is to configure and deploy an innovative solution for optimising thermal energy consumption through innovative human-centric thermal DR programs.

Table 6. Leipzig West district interventions

Intervention	Description	Actions
L4	Personalised Informative Billing	- Personalised informative billing based on real-time energy prices - Demonstration of dynamic thermal energy tariff schemes - Implementation of appropriate normative comparison mechanisms
L5	Human-Centric Energy Management and Control Decision	- Definition of detailed and accurate comfort profiles, to be able to identify context-aware thermal demand flexibility profiles
L6	Decarbonisation of district heating	-
L7	Heat storage (power to heat-P2H)	- Integration of P2H in the seasonal heat storage
L8	ICT integration	- Linking of the existing and newly constructed heat storage solutions with the DSM

It should be noted here that due to delays on the implementation of the solar thermal plant, interventions L6-L8 are not monitored and consequently, no impact assessment is performed in the current deliverable.

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Virtual Positive Energy Community

The Virtual Positive Energy Community represents the creation of a future regenerative energy system based on the orchestration of consumers, producers, and energy storage capabilities in virtually connected environments and systems. The goal of this ecosystem is the optimisation of energy generation and consumption through integration, analysis and control of assets and devices and the implemented interventions are presented in Table 7.

Table 7. Virtual PEC's interventions

Intervention	Description	Actions
L9	Implementation and installation of an open standard based ICT platform that we call the "L-Box".	- Interaction and integration between energy generating, storing and consuming entities into a virtual connected community
L10	Economically reasonable integration of open and standardised Sensors and Systems	- Sensor and metering transmission infrastructure based on the long-range wide area network (LoRaWAN) standard
L11	Establishment of a distributed cloud-centric ICT System which enables an intelligent energy management system.	- Development, implementation and distribution of green plugs for the L-Zero initiative - Real-time simulation of the integration of an existing 10 MW battery storage
L12	Implementation of a human-centric interface/application	- Demonstration of an application that offers the capability to monitor and control of end-users' individual energy consumption
L13	Visual metaphors and constructs/ dashboards for energy footprint analysis	- Demonstration of energy behavioural profiles, allowing through the self-evaluation and normative comparisons of energy behavioural patterns
L14	Commissioning on specific energy savings targets	- Maximisation of energy savings at the community level, by triggering individual consumers to achieve specific energy savings over specific timeframes
L15	Integration of 2G e-bus charging	- Integration, balancing and optimisation of load-depending electric busses charging stations into the Positive Energy Community (PEC)
L16	Load-balanced fleet management	- Demonstration of load-balanced fleet management and charging based upon users' specific inputs to the platform
L17	Conceptualisation and application of a public Blockchain for transactions between energy consumers, producers, service providers and grid system operators in a microgrid	- Feasibility study on the coordinating role of blockchain in local market dynamics - Development of potential blockchain-based solutions to enable prosumers to sell their surplus electricity

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L18	Integration of the planned community energy storage and community demand response	- Defining and developing the interface to the municipal data platform - Extending the virtual community to Leipzig

Macro level

Actions grouped as macro-level interventions in Leipzig (Table 8) aim to make more data available for integrated climate planning. To facilitate municipal planning, all available district energy data are stored centrally on an urban data platform; data available from SPARCS sites are uploaded as demonstration metrics and are being evaluated.

In addition, citizen engagement activities such as workshops, information days, postcard placements and other things are carried out to raise awareness among citizens about climate-friendly behaviours, involve them where possible in ongoing planning and enable them to be part of positive energy community.

Table 8. Interventions in Macro-level

Intervention	Description	Actions
L19	Energy positive district planning	- Integration of energy and building data from SPARCS for advanced and integrated district and building planning
L20	Standard model for smart cities	- Assessment of a standard model for the Leipzig replication districts
L21	Community empowerment support activities through dialogues, transferring ownership, knowledge-transfer etc.	- Establishing community management/energy advisor - Desk support for citizens with the cost-efficient installation of RES - Methodological approach for developing positive energy building blocks user centric solutions in the urban context

2.3 Impact assessment framework

To continuously monitor and evaluate the impact achieved by the implementation of SPARCS interventions in the demo areas, an assessment framework was defined in D2.2. The monitoring process ensures that SPARCS goals and long-term strategy of LHCs are reviewed on a regular basis; it measures and keeps track of their progress, and it reveals potential shortcomings and deviations related to the defined goals.

To define the SPARCS Holistic Impact Assessment Methodology and the related Key Performance Indicators, a seven-step approach was introduced as presented in Figure 7 below.

In the first step of the methodology the detailed analysis of the “Morgenstadt assessment framework” was introduced as well as the evaluation of 4 Smart City projects related methodologies. This step served as a basis for the subsequent actions, providing guidance, best practices and lessons learned from similar efforts.

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The methodology, in Step 2, adopted 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 was based on the interventions and the impact that the planned actions will deliver.

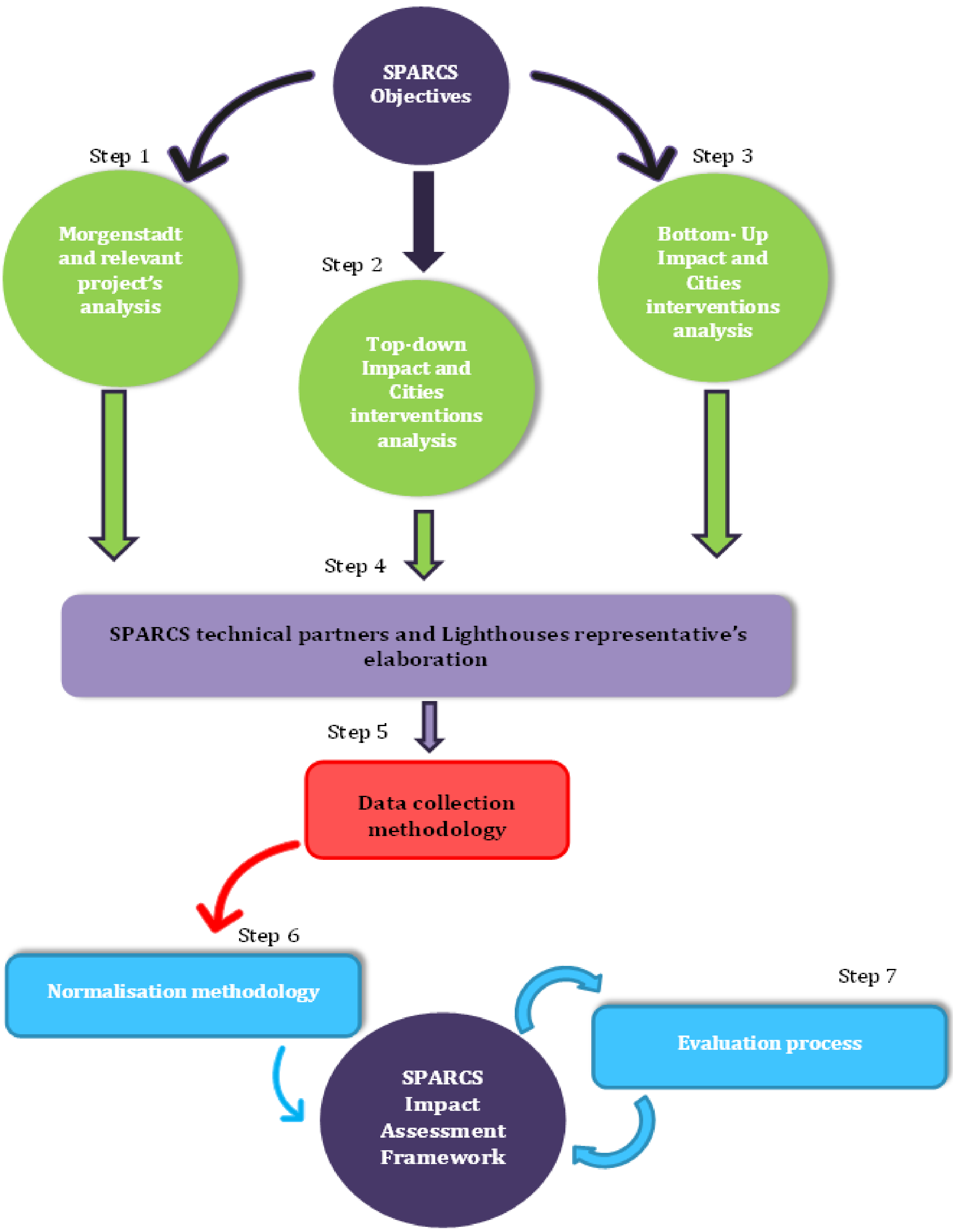

Figure 7. SPARCS Impact assesssment framework as defined in D2.2

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In Step 3, a complementing bottom-up method was followed; working with the city stakeholders to co-produce and enhance the list of KPIs, by analysing in detail all planned city interventions and identifying the resultant impacts.

Step 4 of the methodology involves the required assessment of the final list of indicators that are used for the needs of the SPARCS project, from the SPARCS technical partners as well as from the City representatives of Leipzig and Espoo. This assessment aims to enhance or modify the list as required, clarify any open points, and build a common understanding on the purpose of each indicator in the context of the planned city actions.

With the KPIs in place, a thorough data requirements analysis was conducted to determine how the indicators would be calculated. This was followed by a verification of the availability of the necessary data from the city partners, which was part of Step 5 of the methodology.

In Step 6, the normalization methodology was introduced, which involved the use of a tool for comparative assessment of the KPIs. This allowed for the objective evaluation of the SPARCS interventions and made it easier to adopt them across different cities.

Finally, in Step 7, the SPARCS process evaluation approach and its corresponding activities were introduced. This enabled a comprehensive impact assessment to be conducted, evaluating the efficiency and effectiveness of the results achieved.

2.4 Challenges faced during impact monitoring

Impact assessment is a complex and multidimensional process, and several difficulties arise in its implementation. In this sub-chapter, the three main challenging-categories are presented, and special emphasis will be given in the following periods for their successful handling.

Data gathering

The starting point for monitoring the transformation process of LHCs is the use and analysis of the collected data sets that provide meaningful content and useful information for various key stakeholders of the city. This in turn can support them in formulating more informed and evidence-based strategies to achieve the desired zero-carbon energy transformation, based on the impact assessment of the interventions carried out.

It is therefore clear that cities should be able to collect the vast amount of data that comes from both their operations and their partners activities. However, using and exploiting such data comes with its own challenges, mainly due to the heterogeneity of available data sources and formats. Though, the shared approach reveals the lack of a central storage location, where city-wide data is often distributed across multiple organisations or kept in private silos (i.e., storage solutions) with most of the information not accessible to all relevant stakeholders. This indicates an additional significant challenge that should be considered when conducting impact assessment of interventions.

In this deliverable some interventions were not possible to be evaluated as the necessary data was not available, such as those related to Leipzig's energy consumption that come with a 2- year delay, as the energy providers must go through an internal audit before they release them publicly.

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Target setting

Another key point for the evaluation is the interventions' target setting. Targets are necessary for assessing the KPIs as they provide a basis for measuring progress towards achieving the desired outcome. Targets represent specific, measurable, and time-bound goals that a city has set either on its own or by committing to initiatives and projects and provide a benchmark against which performance can be measured. By setting KPI targets, cities can establish clear goals for their performance, and they can use these targets to assess their progress and adjust their strategies as needed. Additionally, having clear targets can help motivate partners and stakeholders to work toward achieving the desired outcomes, and it can provide a sense of accountability for the city.

However, as sustainable development is a complex and multidimensional issue involving many different sectors, stakeholders, and interdependencies, setting sustainability goals can be difficult considering that this process requires resources such as personnel and expertise. In addition, it is worth mentioning that many of the proposed KPIs are new and no benchmarks are available in the literature for setting targets for them.

KPI related issues

In some cases, the KPIs defined in D2.2 were deemed irrelevant during the actual impact evaluation and were replaced by new ones more suitable for this purpose; in the interventions where this change was made, the relevant rationale was analysed and provided in the text.

Another issue LHCs had to overcome was the calculation of the financial KPIs. The main problem cities had so far, was the lack of data provision to calculate the required city-level KPIs. SECAP measures were proposed to be used as a basis of calculating investment costs in the analysis, however these reports provide investment data at a general level and not at a sufficiently detailed level to measure the defined financial KPIs. Therefore, two different approaches were proposed for the calculation of the KPIs:

- Identify and obtain more detailed data on investment costs, operating costs and revenues related to selected SECAP measures (linked to SPARCS actions) or
- Obtain approximate data for these KPIs from similar solutions in the past.

Both solutions proved to be difficult to achieve. The main issues that cause this are as follows:

SECAP -or similar- measures include entities not controlled by the city and that do not provide sufficient public financial data or provide it at a level where costs or revenues to the city cannot be calculated. Many of these entities come from the private sector and they are reluctant to provide this kind of information.

Large-scale infrastructure projects, usually have many revisions to financial estimates and statements, making it difficult to discover the accurate financial data.

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The approximate definition of the values for the selected KPIs is difficult to calculate from the literature, due to the novelty of the implemented solutions and the differences in the financial indicators between the sectors. This approach would lead to redefining the financial KPIs that were introduced in D2.2 and are outside the scope of this deliverable.

Determining the relationship between costs and benefits has proven more difficult for municipal projects. This is because all the positive effects are not measured in revenue streams as such, but in the transformation of urban landscape, reduced emissions, and increased wellbeing.

To mitigate the problems identified above, the LHCs had provided some proposals focusing on the calculation of city-level investment values and the calculation of additional demonstration-level KPIs for solutions where data is available. This approach includes as well indirect calculation of financial KPIs. This approach will be carried out during the final monitoring period to assess whether the replacement of the specific KPIs would be useful to measure the impact achieved from a financial point of view.

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3. PROGRESS AND EVALUATION OF ESPOO ACTIVITIES

This section presents the monitoring results during the current monitoring period and includes both the individual monitoring of the KPIs at the intervention level and the aggregated monitoring at the city level. As mentioned earlier, the KPIs are aligned with the project objectives, but they are designed to measure progress towards the end goal of the project, not necessarily to be achieved during each individual monitoring period.

To easily categorise impact monitoring, the following colour mapping is considered as Table 9 presents. It should be noted that the purpose of colour mapping is to provide a quick and easy way to understand the performance of a KPI. It is a tool that helps stakeholders identify areas for improvement, but it is not intended to be used to judge the solutions implemented. It simply shows whether the expected impact of each intervention has been achieved.

Table 9 Colour mapping classification legend

Legend		
KPIs exceed expectations	The monitored values exceed the set target	(blue)
KPIs meeting the expectations	The monitored values have less than 10% deviation from the set target	(green)
KPIs close to expectations	The monitored values deviate between 10%-50% from the set target	(yellow)
KPIs far from expectations	The monitored values deviate more than 50% from the set target	(red)
KPIs not measured	No data were available in the reference time window of the first monitoring period	(purple)

3.1 Intervention level - Individual assessment

Intervention E1- Solutions for Positive energy blocks

Intervention E1 is about solutions for Positive Energy Blocks in Lippulaiva. The intervention includes actions about NZEB and PV optimisation, battery storage, utilizing the ground source heat pump in heating and cooling of surrounding residential building blocks as well as calculating the profitability of the NZEB solution. Please note that in Table 10 the KPIs with an annual measuring unit apply a measuring period from August 2022 to July 2023.

Due to acquisition of Guarantees of Origin (GoOs), the share of RES is at the target level in Lippulaiva. However, the total energy demand continues to be slightly higher compared to the target, especially with heating demand. As the shopping centre opened roughly a year ago, the building is continuously seeking measures to improve the energy efficiency and go to the target level. During the current monitoring period, there was a discharge period ongoing which caused higher energy demand. In addition, during the first year of operation, we were still developing our aftercare program and making frequent adjustments. After the discharge period was completed, we were able to refine our settings and saw improvements in our KPI results. Energy storage solutions were

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implemented as planned, and there was no need for the back-up district heating. Due to the extensive usage of RES, CO_{2eq} emissions of the building are well below the target level.

Table 10. E1 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Share of RES (electricity)	100 %	100 %	100 %	0%
Share of RES (thermal, including heating and cooling)	100%	100 %	100 %	0%
Excess Heat Recovery Ratio	n/a	100 %	100 %	0%
Total building energy efficiency measurement (kwh/m2/a)	275	108	117	8%
Energy Storage (number of equipment)	n/a	2	2	0%
Energy Storage capacity (battery)	n/a	1,5 MW / 1,5 MWh	1,5 MW / 1,5 MWh	0%
Energy Storage capacity (thermal- MWh)	n/a	5000	5000	0%
Onsite energy ratio OER	n/a	100 %	100 %	0%
Annual Mismatch Ratio (AMRx) heating	n/a	5%	n/a	n/a
CO2 emissions reduction (tCO2/a)	n/a	670	1391	107%

Intervention E2- Boosting E-mobility uptake

Boosting E-mobility in Lippulaiva and Espoonlahti district means boosting electric mobility focusing especially on mobility hubs, EV charging infrastructures and their integration to the smart grid, and mobility and accessibility through sustainable transportation options. E-mobility solutions are developed in the Lippulaiva district by offering EV parking and charging capacity, as well as facilities for e-bicycles.

During the current monitoring period, the number of bicycle parking and EV charging stations were beyond the targeted level. Generally, demand ratios appeared to be at the target levels. The level of utilisation of EV charging stations and the utilisation of the charging system were slightly lower compared to the targets. It is assumed that the utilisation of EV charging will increase in 2023 when number of customers will rise as the new Espoonlahti metro station opened in December 2022 and the bus terminal opened in February 2023. The defined KPIs for this intervention as well as their values during the current monitoring period are presented in Table 11.

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SPARCS

Table 11. E2 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Bicycle parking	1100	1302	1388	7%
Charging cabinets for e-bikes	2	1	2	100%
EV charging stations	134	140	134	4%
Demand from all EV mobility modes; impact on the grid	n/a	2	10	400%
Ratio of peak demand from EV mobility modes to local transformer capacity	n/a	20%	13%	7%
Ratio of average demand from EV mobility modes to local transformer capacity	n/a	0,8%	0,8%	0%
Level of utilisation of EV charging stations	n/a	75	n/a	n/a
District EV parking/charging places (car and bicycle)	n/a	EV Car: 140 EV Bicycle: 5	EV Car: 134 EV Bicycle: 10	1%
Utilisation of the charging system	n/a	5 %	4 %	1%

Intervention E3– Engaging users

The implementation activities of this intervention focus on community engagement activities in the Espoonlahti demonstration area. The KPIs, presented in Table 12, and the impact assessment aims to describe the quality of community engagement and the number of citizens reached and contributed to the co-creation of solutions. It should be noted that this intervention has been completed during the 1st reporting period, and the data remains static due to the nature of the measured KPIs.

The impact assessment of citizen engagement activities is based on the collected qualitative and quantitative data of the citizen engagement activities. We can claim that the activities succeeded to reach a significant number of people in the Espoonlahti area, over 60 000 people more than the targeted (14 350) and exceed the targeted number of citizens who contributed to co-created solutions, 147 more than the targeted (200). There were 57 400 residents in Greater Espoonlahti area in 2021. The activities in Espoonlahti were targeted to reach 25% of the residents, however, a precise estimation of the people reached cannot be made, due to the social media KPI data collection method. The reach data is collected based on the followers in specific social media channels, where the invitation to engagement activities were posted, however it is not possible to evaluate how many people saw the posts in the feed. The number of co-created solutions covers all kind of novel co-design tools/methods for citizen engagement facilitated in Espoonlahti area. The number of new solutions doubled from the target value (from 3 to 6).

Total average of engagement of all citizens and improving awareness Likert scales are based on the number of actual respondents to the feedback survey and it includes both respondents: young people and other citizens. The feedback was collected from four activities conducted by KONE in Espoonlahti and includes 40 respondents out of 48

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participants. Feedback data shows that overall, most of the respondents feel that they were able to contribute to the activities to a significant extent (Average = 4.44 with a target of 4) and the activities improved their awareness (Average = 4.41 with a target of 4).

Table 12. E3 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of people reached in total	n/a	14350	81820	470%
Number of young people contributed to co-created solutions	n/a	100	100	0%
Number of citizens contributed to co-created solutions	n/a	200	347	74%
Engagement level of all citizens	n/a	Average above 4	4.4	10%
Number of co-created solutions	n/a	3	6	100%
Number of validated solutions	n/a	3	6	100%
Improving awareness of energy positive district solutions	n/a	Average above 4	4.4	10%

Intervention E4– Smart business models

The implementation activities of this intervention are focusing on business model co-creation activities in Espoonlahti and Leppävaara demonstration areas. The KPI data and the impact assessment aims to describe the quality of stakeholder engagement and number of stakeholders reached and contributed to the co-creation of solutions. The KPIs of intervention E4 (Table 13) are associated with the outcome of deliverable D3.6 which has been submitted as part of concluding the work of T3.6. Hence, the KPIs are static, and no changes are performed from D2.6.

The impact assessment of business model o-creation activities is based on the qualitative and quantitative data collected from the stakeholder engagement activities. We can claim that the activities performed above expectations due to the active social media marketing method (over 300 000 people more than targeted were reached). The number of stakeholders reached is based on the number of companies that were contacted and invited to the co-creation activities and co-innovation challenge competition. Social media marketing was done through LinkedIn and posted by several companies: KONE (335074 followers), Gaia (4768 followers), SPARCSeu (232 followers), Sweco (205180 followers).

The number of stakeholders contributed to the co-created solutions includes participants of business model workshops (1-2 people representing each organisation) and eight start-ups besides organisers and facilitators. The activities managed to engage the targeted number of stakeholders. Total average of engagement of stakeholders is based on the number of actual respondents to the feedback survey and it includes both public and private sector actors. The feedback was collected from three workshops conducted by KONE and Embassy of Design and includes 24 respondents out of 35 participants.

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Feedback data shows that most of the respondents feel that they were able to contribute to the activities to a significant extent (Average = 4.25 with a target of 4).

Table 13. E4 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Stakeholders reached by business model / solution co-creation activities	n/a	200 000	545 308	270%
Stakeholders contributing to the business model / solution co-creation activities	n/a	60	64	7%
Engagement level of stakeholders	n/a	Average above 4	4.3	6%
Number of co-creation sessions for (energy positive) business models	n/a	6	9	50%

The KPI assessment in E4 and E9 is based on the same data as the business model activities did not target specific demonstration area but were arranged on Espoo level. The premise was to engage relevant experts (such as mobility actors) outside the demonstration areas.

Intervention E5- Solutions for Positive Energy Blocks

This intervention was aimed at making Sello's energy use more efficient by implementing smart control tools to reduce peak power as well using a simulation to see how a deep heat energy system would impact the self-sufficiency of Sello. The KPIs in Table 14 display the improvements in energy use during the current monitoring period where many of the indicators have performed better than expected.

The share of renewable energy sources turned out to be 100 % already from the start as Sello purchases only 100% certified renewable energy for both electricity and district heating. During the project the electricity demand decreased even though 22 EV chargers were installed. Also, the heating demand decreased due to the limitation of the peak powers.

We created a simulation to determine how Sello's self-sufficiency would improve if we built a deep heat energy system under the shopping centre. The simulation was made using Siemens' own tool called PSS DE. In the simulation we used four deep heat energy wells that were 1500 meters deep. Each well produces heat approximately 110 kWh/m/a. Because this was a simulation, we can't get actual values for the 1st reporting period. But we can see that with these values the need for district heating reduces drastically (81.4 %) in ideal conditions. The reduced heating demand also increases net positivity of the district.

The thermal flexibility was increased by implementing an interface between district heating provider Fortum and Sello building management system (BMS)- Desigo- by Siemens. Fortum sends a request to Sello to decrease the consumption on certain hours and the BMS lowers the heating demand for those periods of time. The indoor

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temperature is monitored constantly to make sure sufficient, pre-determined indoor conditions are always preserved.

Table 14. E5 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Share of on-site electricity production	n/a	6 %	2.5 %	3.5 %
Total thermal energy consumption reduction (MWh/a)	12040	11500	10418	9 %
Onsite Thermal energy ratio OER (%)	0	100 %	154 %	54 %
Potential thermal flexibility (MW)	0	1.5	2.0	33 %
Thermal peak power demand (MWh/h)	9.5	8.0	6.5	19 %
Share of monitored thermal energy sub-systems	0	50 %	90 %	40 %

This affects the peak power need significantly since the peaks take place typically during the hours of the requests. The same concept can then also be used to limit the peak power without external request from district heating provider for example by defining the wanted peak power level.

To succeed with peak power limitation, it was needed to know where the heat is needed more precisely. Therefore, the heating sub-systems needed to be monitored and metered so new metering systems were added to the BMS.

Intervention E6– ICT for positive energy blocks

Similarly, to intervention E5, intervention E6 also focuses on improving energy use in Sello, but the KPIs highlight the reductions in CO_2 emissions (Table 15). Implementing a prediction model to achieve these results in flexibility is important, which is why the KPIs also highlight the benefits of using the prediction model in this intervention.

The EV chargers, 22 pieces, are added as a part of the smart flexibility platform. The CO2 reduction of flexibility can be calculated by comparing what it would take to gain similar flexibility with conventional power plants. In this calculation the average emission factor of 77 kgCO2 /MWh in Finland is used. The plant is assumed to operate with 100 kW power for 40 % of the time. The addition of this charging station to Sello has brought a reduction of 27.0 CO2 equivalent with the increased flexibility in energy demand. The difference is mainly due to lower emission factor which is a sign of transition towards cleaner energy system.

An increase in the integrated systems share KPI was seen due to the addition of 22x22kW EV chargers. Virtual monitoring of elevators and escalators was not a technically viable option due to the age of the demo site equipment. Thus, the associated ratio KPIs are also not needed. Nonetheless, two elevators were tested for virtual power and energy monitoring, but the actual connection to the VPP was established with physical meters. VPP peak load reduction potential and Flexibility up and down for elevator power

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demand was done more as a technical feasibility study, as the elevator power demands at the demo site were not high enough for concrete benefit analyses. Business models for the case are under development. Solar panels have natural degradation of about 0.5% per year. So, the production was expected to be around 580 MWh in 2022 based on the starting level. However, for RES the climate and weather variations can cause significant variation between the years.

Table 15. E6 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Annual Mismatch Ratio (AMRx)	90%	98%	95%	3%
Total available (RES, storage, HVAC, EV Charging. etc) Number.	162	184	184	0%
Number of equipment integrated	125	150	147	0%
Number of elevators/escalators units with physical power meters monitored by VPP	13	15	15	0%
Increased working efficiency due to prediction model (saved hours per day)	n/a	0.5	1	50%
CO2 equivalent reduction (tonnes)	0	30	27	10%

One important cornerstone for successful participation in the net stabilisation market is to have a reliable forecast model for the own flexibility. As exemplary input we worked with recorded timeseries measurements from the Sello shopping mall and verified the viability of several modelling approaches. In the end we settled on a robust and easily transferrable neural network-based approach. The network was then used to infer parameters for a probability distribution that represents the model prediction about the flexibilities of the next 36 hours. The actual, measured flexibility values were in a +/- 2 Sigma band around the expectation value of that distribution for an unassuming MLP-based neural network architecture – which was considered sufficiently accurate.

We then integrated and deployed this model into the existing system infrastructure, so it is automatically applied to current data to provide 36-hour predictions with uncertainty information to a human expert who can consider these forecasts as one cornerstone for viable bidding prices. The increased working efficiency is based on the time saved on manual forecasting labour per day. This allows the humans to take up more demanding and more productive tasks instead of repetitive, time-consuming exercises.

Intervention E7– New e-mobility hub

Leppävaara e-mobility hub intervention includes e-bus charging system, charging strategy simulations, and integrating chargers into shopping centre flexibility pool and the defined KPIs are presented in Table 16. VTT and PIT built a simulation model for charging strategies, and results from this task are included in E17.

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The KPI 'Increase of citizens using EV modes' was removed as there is no suitable data to measure the impact of the SPARCS activities in relation to this increase (or decrease). The modal share for different types of trips for Espoo is calculated by the Helsinki Regional Transportation Authority (HSL) for the whole Espoo municipality level.

Table 16. E7 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
A peak demand from all EV mobility modes (kW)	n/a	1000	1389	39%
CO2 reduction based on charged electricity (tonnes)	n/a	720	1298	80%
Average charging time /day (h/d)	n/a	23,3	26.28	13%
Average charging time /month (h/mth)	n/a	700	770	10%
Charged energy/ day (kWh/d)	n/a	2000	2952	47%
Charged energy/ month (kWh/mth)	n/a	60000	86546	44%
Peak demand from all EV mobility modes / Transformer capacity (hourly average)	n/a	33%	46.3%	13.3%
Average demand from all EV mobility modes / Transformer capacity	n/a	2.7%	4.1 %	1.4%
Peak demand reduction (KW)	n/a	100	100	0%
Flexibility % of normal load. Buildings/Prosumers	n/a	50%	93%	43%
Utilisation of chargers in the system after charging strategy	n/a	30%	35%	5%
Peak demand reduction using the charging strategy (kW)	n/a	300	280	7%
Number of charging strategies simulated	n/a	5	9	80%

There is no data about specific areas/districts (Leppävaara in this case) on modal share utilisation for different types of trips. Data about different powertrain types for private vehicles use for commutes are not calculated either, even on the whole Espoo municipality level. Due to this, the KPIs about the increase of citizens using EV modes cannot be measured properly and does not really serve the intended purpose (which is not measurable with the tools currently available).

Intervention E8– Engaging users

The implementation activities of this intervention were focused on community engagement activities in Leppävaara demonstration area. Table 17 presents the values of the KPIs in the current monitoring period. The KPI data and the impact assessment aims to describe the quality of community engagement and number of citizens reached and contributed to the co-creation of solutions. The impact assessment of citizen engagement activities until M36 are based on the collected qualitative and quantitative data of the

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citizen engagement activities. We can claim that the activities succeeded to reach a significant number of people in the Leppävaara area (over 50 000 people more than targeted), however fell below the targeted number of citizens who contributed to co-created solutions (58 less than targeted). There were 74 600 residents in Greater Leppävaara area in 2021.

Table 17. E8 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of engaged individuals in total	n/a	18650	72483	289%
Number of citizens contributed to co-created solutions	n/a	100	42	58%
Engagement level of all citizens	n/a	Average above 4	4.4	10%
Number of co-created solutions	n/a	3	4	33%
Improving awareness of energy positive district solutions	n/a	Average above 4	4.4	10%

The activities in Leppävaara targeted to reach 25% of the residents, however a precise estimation of the people reached cannot be made, due to the social media KPI data collection method. The reach data is collected based on the followers in specific social media channels, where the invitation to engagement activities was posted, and doesn't tell how many people saw the posts in the feed.

In the target value, Covid19 restrictions were considered as lowering the number of participants aimed to be targeted. The limitations for participation were for example that all actions were arranged online and required digital platforms and tools for participation. In Leppävaara activities, the targeted number of people was smaller because Leppävaara is already developed area in contrast to Espoonlahti, which is under development. In Leppävaara, there were no activities targeting schools and young people, reducing the overall reach of people and number of participants.

The number of co-created solutions covers all kinds of novel co-design tools/methods for citizen engagement facilitated in Leppävaara area. The number of new solutions exceeded slightly the target value (From 3 to 4).

Total average of engagement of all citizens and improving awareness Likert scales are based on the number of actual respondents to the feedback survey. The feedback was collected from three activities conducted by KONE in Leppävaara and includes 25 respondents out of 39 participants. Feedback data shows that overall, most of the respondents feel that they were able to contribute to the activities to a significant extent (Average = 4.4 with a target of 4) and the activities improved their awareness (Average = 4.36 with a target of 4). It should be noted that this intervention has been completed (in T3.6) during the 1st reporting period, and the data remains static due to the nature of the measured KPIs.

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Intervention E9– Smart business models

The KPI assessment in E4 and E9 is based on the same data. See the impact assessment of both interventions in section E4.

Intervention E10– Solutions for positive energy blocks

The aim of this intervention is to explore the benefits of using 3D city models in PEDs. In Table 18, the defined KPIs are presented. The KPI for monitoring the 3D city model utilisation rate is the number of yearly users. However, the city only collects data on downloads and API users, so the actual number of users is unknown. As of August 2023, the 3D model has been used by 223 individuals but the number of online views of the 3D model is not monitored. Yearly downloads, however, have dropped significantly between 2022 and 2023 according to the data received so far. Under 50 000 downloads have been accumulated during the first and second monitoring periods.

Table 18. E10 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Increased number of persons using Espoo 3D city model	104	200	223	11.5%
Increased number of downloads of the Espoo 3D city model	21187	120000	46965	61%
Number of promising technical and infrastructure solutions for PEDs	n/a	10	16	60%
Utilisation level of energy system planning solutions, roadmaps and reports produced in SPARCS	n/a	>3	n/a	n/a
Expected on-site Energy Ratio [%] for Kera	0	Over 1	n/a	n/a

The distance to the target (set as an average of downloads identified between 2018 and 2022, for two monitoring years) is still plentiful, but large variation between years has been seen previously. In addition, the Espoo 3D model has been made available online on the Espoo map service between the first and second monitoring periods, possibly reducing download numbers.

During the second monitoring period, a booklet of SPARCS energy solutions was devised for the aid of Kera development work. The number of solutions within this booklet was set as the measured value for KPI 'Number of promising technical and infrastructure solutions for PEDs'. At this moment, the number of promising solutions based on SPARCS actions exceeds the set target. A survey will be implemented as a part of this booklet to measure the utilization level and interest on SPARCS solutions and reports. For the last KPI, values will be provided once at the end of the project.

Intervention E11– Engaging users

This intervention aims to provide information to city planning authorities on the preferred future multimodal mobility habits, schedules, and routes of citizens to optimise the people flow from energy and user experience. Two KPIs have been developed to measure the impact of this intervention and are presented in Table 19.

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Table 19. E11 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of stakeholders reached	n/a	>25	13	48%
Were the mobility insights useful for the city planning authorities?	n/a	>4	n/a (to be collected once in the end of the project)	n/a

ESP has supported KONE and organized multiple meetings with Kera planning and development authorities and stakeholders to introduce the results of work done in the project's other demonstration areas Espoonlahti and Leppävaara.

Intervention E12– ICT for positive energy blocks

Intervention E12 is about ICT for Positive Energy Blocks. The aim is to develop new potential smart energy services using e.g., 5G and blockchain technologies. This intervention was completed as a collection of two studies, and thus the chosen KPIs (Table 20) will only assess the number of identified solutions within the final reports.

Table 20. E12 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of potential 5G solutions identified	n/a	5	30	500%
Number of potential stakeholders identified in a 5G ecosystem (mobility)	n/a	n/a	23	n/a
Number of potential stakeholders identified in a 5G ecosystem (energy)	n/a	n/a	15	n/a
Number of connections identified between 5G solution development and the Espoo Story	n/a	n/a	10	n/a
Number of potential blockchain solutions identified	n/a	5	7	40%
Number of potential blockchain solutions with direct links to either the Kera development activities or the Espoo story	n/a	n/a	4	n/a
Number of connections identified between blockchain solution development and the Espoo Story	n/a	n/a	7	n/a

As the city does not have an official position on how many solutions should be identified during the project, a general target of identifying 5 or more solutions for future project ideas was set. For blockchain, this target was met, as the final report identified 7 solutions (known as 'opportunities' within the report) for further study. The number of identified solutions for 5G has also exceeded the provided target, with a total of 30 solutions identified.

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The difference in the number of identified solutions can be explained by different scopes within the services themselves, and previous experience from projects and assessments regarding 5G in Espoo. The LuxTurrim5G project[3] has previously completed assessments on possible 5G services in Espoo, thus providing a basis for a more detailed analysis on these services and their potential for energy and mobility within SPARCS. In turn, the analysis of blockchain is still rather new within the city, and thus the report was kept at a rather broad level, leading to less identified solutions. There have been no updates to the completed reports between the first and second monitoring periods. Thus, there are no updates to the provided values either, or the previous impact assessment remains relevant.

During the first monitoring period, it was seen that the single KPI for both themes was insufficient to fully assess how well the activities within this intervention achieved their goals. Thus, new KPIs were added during the second monitoring period, focusing on the identification of stakeholders and the connections between the assessed technologies, Kera development and the city strategy. As the final values of these KPIs are already known, a decision to not set quantifiable targets was made. Still, these KPIs provide important information on ICT ecosystems and connections to strategy development.

Intervention E13 – E-mobility in Kera

The aim of this intervention is to support the development of future e-mobility solutions in the Kera area, and to provide insight for how to develop the existing Kera commuter train station area into a multimodal e-mobility hub. As the Kera area construction is yet to begin, the work on this intervention has focused on supporting the planning and design practices and processes, knowledge building, dialogue exchange between different stakeholders, and introducing solutions demonstrated in the Leppävaara and Espoonlahti areas in SPARCS for the Kera development process. In Table 21, are presented the KPIs used for the impact assessment.

One of the keyways this work has been carried out has been the organisation of dedicated meetings on the topic of mobility between relevant SPARCS partners and Kera area developers from the City of Espoo. Since late 2020, the group has met in total seven times so far. The meetings have included presentations and joint working sessions on the topics related to Kera area development, sustainable mobility development in general, and the mobility solutions developed in SPARCS. So far, seven different solutions from the SPARCS project activities have been presented and/or co-created in these meetings as possible concepts for Kera: insights of current mobility trends from expert interviews, mobile probing study insights, e-bus and EV-charging infrastructure, e-mobility hub concept creation, Kera e-charging simulation, 5G possibilities in automated e-mobility, and EV-car sharing services.

These activities have been reported in more detail in the D3.5 deliverable[4]. The relevance of the presented and co-created solutions and concepts for utilisation in Kera (as KPI "Value of the developed solutions for the development of a future district") will be

[3] https://www.luxturrim5g.com/

[4] https://sparcs.info/en/deliverables/d3-05-ev-mobility-integration-and-its-impacts-in-espoo/

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gathered through an online survey in a later date during the final year of the project to align with the general Kera development process. The charging demand for the Kera district has been studied on multiple levels. Simple charging patterns have been applied to the planned residential buildings in Kera. In addition to that, in E18-1 there has been effort to simulate larger areas of the city and the city of Espoo as a whole. Those results are useful to understand potential future charging behaviours in Kera district and are part of the D3.5 deliverable.

Table 21. E13 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Value of the developed solutions for the development of a future district	n/a	>4	n/a	n/a
Number of e-mobility solutions introduced for replication in Kera planning phase	n/a	5	7	40%
Simulated demand for charging stations in Kera area	n/a	Simulation complete	Simulation complete	0%

Intervention E14– New economy/Smart governance models

This intervention aims to develop a co-creation model for sustainable city development. The model will support the utilisation and implementation of novel smart city and PED solutions in urban areas. The model is being developed in Kera, but it will be generalised to be applicable in any city or urban area development. The City of Espoo has subcontracted a third party to create the model. The third party is using design sprints, questionnaires, interviews, and other workshops to gather input from different stakeholders. The KPIs for the model development process (Table 22) are shared between this intervention and intervention E22, which is developing the generalised model.

Table 22. E14 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of stakeholders involved in co-creation of the co-creation model	n/a	70	116	51%
Number of citizens involved in co-creation of the co-creation model	n/a	100	137	37%
Visitors on the co-creation model website (calculated monthly) (toolbox)	n/a	1500	3534	133%

As the co-creation model is developed in SPARCS, there is no baseline data available. A target of 70 stakeholders (representatives of companies, organisations, landowners, research institutions, cities, city departments etc.) and 100 citizens was set for the co-creation engagement process. The process was conducted between late 2021 and the end of 2022. Engagement here means active participation in some of the activities through

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which the model was created collaboratively, such as workshops and Design Sprints, webinars, questionnaires and interviews. These set targets have been met: 116 different persons representing 40 different organisations, and 137 citizens (of which 118 through an online questionnaire) participated in the co-creation model development process. The active development phase of the model ended in 2022 so there is no change to these numbers in this report update, and there is no expected increase therefore in the future as well. The model has been further examined and adjusted in different smaller workshops and based on feedback gained from its presentation in different events, but these activities are not considered as the active development phase of the model to which the KPIs refer to. The KPI "Satisfaction of the participants in the co-creation process" – set before the start of the monitoring phase – was removed as there was no sufficient data available. The co-creation process to develop the model was done in progressive steps that spanned a timeline of multiple months with different stakeholders. As the process followed the basic principles of *design thinking*, where the outcome is the product of multiple intertwining development processes, the positioning of this KPI (defined before the process for the model development was known) was not suitable in the end to cover the intended issue.

Instead, a new KPI "Visitors to the co-creation model website (toolbox)" was added in D2.7 to measure the reach of the created model. The model is presented as an open online toolbox (as a WordPress website: www.co-creatingsparcs.fi/en) which provides the possibility to measure the number of visitors on the page. The website was first launched during the first Design Sprint February 14th, 2022, and it acted as an open access project bank during the model development process. The site was re-launched in the model's launch event on November 31st, 2022, to host the final version of the finished generalised model. So far, there has been 3,534 unique visitors to the website since February 2022 (monthly visitors added into a total sum, visitors re-calculated monthly). The number was 1,568 during the 1st monitoring reporting period in the end of 2022. The model has been actively disseminated during the spring 2023 after its completion, which is probably the reason for the increase of almost 2,000 unique monthly visitors to the site. The aim is to keep the website up and running until the end of the project (M60), and the number of visitors is expected to grow also in the future through additional dissemination and small workshop events. (The model is also available in text format for more traditional use and dissemination – the reach of the 'offline' format of the model is not reflected in the KPI.)

Intervention E15– Virtual power plant

This intervention focused on creating new demand response functions in public buildings and investigating the role of blockchain within the energy sector. The KPIs (Table 23) highlight the successful implementation of loads connected to the demand response as well as new business models and blockchain solutions related to the intervention.

The original plan was to make VPPs based on building loads. As a part of this plan, an analysis of approximately a hundred buildings owned by the City of Espoo was completed, with a focus on their demand response potential. This analysis was continued via a further analysis and site visits to 13 buildings. In the end, the chosen pilot site was not one of the analysed buildings, due to issues in finding a suitable pilot site. Instead, Ilmatar Areena, an ice hall, was chosen as a pilot site. As the building loads were identified to be too small to be financially viable investments, five EV charging units were installed and used as flexible loads successfully. Communication between the main electric meters and the

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charging stations was created via Siemens control logic. Based on the meter readings in real time, the control logic sends commands to the charging units to decrease or increase power output. The power response from the charging units was achieved in around 5 seconds after sending the command. The commands can be sent as dynamic requests from the occurring status between –100 and +100%.

Table 23. E15 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of smart business models created	n/a	1	1	0%
Loads connected to demand response	0	4	5	25%
Number of blockchain solutions identified	n/a	1	1	0%
Number of smart business models identified in relation to blockchain solutions	n/a	1	2	100%

Identification of possible business models include peak load management and ancillary services for electric power markets. The blockchain could be used for recording the deliveries and actions on the markets. In addition, blockchain services and opportunities were identified in a report completed within the City of Espoo, with discussions between relevant SPARCS partners to help in the reporting process. The number of identified solutions in relation to this report are provided in the KPIs of intervention E12.

Intervention E16- Smart heating

Intervention E16 focuses on new smart heating solutions to provide flexibility for the whole energy system. Within SPARCS, the aim is to develop further the current demand-side management (DSM) solutions implemented within the local social housing company, Espoon Asunnot OY, while assessing additional potential for energy efficiency improvements. To assess the improvements that DSM solutions have brought to Espoon Asunnot, flexibility as a percentage of consumption and emission savings derived from this flexibility portion were calculated.

When discussing possible targets for these KPIs, presented in Table 24, with researchers from VTT, it was noted that the main aim of the DSM scheme utilised within the Espoon Asunnot buildings is not to reduce energy consumption in certain buildings, and instead to optimise the whole district heating grid to reduce peak generation. Thus, it is possible that separate buildings have very different roles in the operation of the DSM scheme, and because of this even higher energy consumption values than normal should not be deemed to be bad in a broader outlook. However, it was still decided that identifying reductions in energy consumption and emissions should be a target for this analysis. The calculation of savings beyond 2021 has temporarily fallen beyond schedule due to delays in procuring needed data, and new calculations were not finished by the D2.7 deadline. Data from 2022 until May of 2023 has now been collected and values will be provided in the next monitoring report. Due to the delays in calculations, potential heat load has not been updated for D2.7. Espoon Asunnot OY has completed 554 new apartments compared

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to the values available during the first reporting period. We assume that all new apartments are included in the DSM scheme to correlate with assessments made in D2.6. Currently, the number of apartments is 3.9% over the set target.

Table 24. E16 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Heating flexibility increase as a percentage of normal load	n/a	at least -1%	-1.74	74%
Total potential heat load under DSM (kWh)	n/a	600	636	6%
Current and potential emission savings	n/a	n/a	4.47	n/a
Number of buildings or apartments participating in DSM scheme	15 724	15800	16170	4%

Intervention E17- Virtual twin

Intervention E17 focuses on Sello Virtual Twin predicting energy demands (electricity, district heating) and on-site electricity production from PV. Sello virtual twin is a real demo of the positive energy building block providing the same visual and operational characteristics as the real buildings and the energy system. The virtual twin predicts online the electricity and heating demand, as well as PV production in Sello for the next 24 hours (with as small difference to monitored data as possible). It can support the virtual power plant to operate in the electricity reserve markets. The monitored data and results of virtual twin can be visualised in a building model. The Espoo 3D city model is described under intervention E10.

Five technologies have been incorporated into the virtual twin for simulation purposes which is also above the target level (2). The virtual twin forecasting is performing accurately with the normalised root mean squared error with the measured data being under the error 0,1 for electricity and district heat. For PV production forecasts, the error is slightly higher (0,19). This error is mainly caused by the errors in the radiation forecast of the Finnish Meteorological Institute and thus cannot be much affected by SPARCS.

During the 2nd monitoring period, the number of simulations through the virtual twin has increased as compared to the 1st period but not as fast as in the 1st period. The reason for that is a period when the data collection and related forecasting procedure was changed. However, the number of simulations (now 2000) is above the target value (1550) also in 2nd period. The virtual twin forecasting accuracy has not changed for Sello's main electricity and district heating power and NRMSE values are good (0,1) for electricity and excellent (0,05) for district heating.

Another part of the intervention carried out as part of task E17-2 focused on the use of city data of the Espoo 3D city model for energy simulation. In the task, simplified building modelling was used to simulate and evaluate several energy improvement scenarios towards energy positiveness of selected urban block. The proposed new key performance indicators mainly describe the progress of the task in terms of number of simulation scenarios for the entire block as well as number of technologies evaluated. The new indicators are summarised in Table 25.

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Table 25. E17 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Increase of simulations executed via the Virtual Twins concept	n/a	1550	2000	29%
Number of innovative energy technologies incorporated in virtual twin for simulation purposes	n/a	2	5	150%
Accuracy of building heating and electricity load forecasting electricity (NRMSE*)	n/a	0.1	0.1	0%
Accuracy of building heating and electricity load forecasting District heating (NRMSE)	n/a	0.1	0.05	50%
Accuracy of building heating and electricity load forecasting PV (NRMSE)	n/a	0.1	0.18	80%
Number of scenarios for positive energy block evaluated	n/a	6	6	0%
Number of technologies utilised in the scenarios for positive energy block	n/a	3	3	0%

*NRMSE = normalised root mean squared error

The main technologies where thermal insulation of building envelope (windows), rooftop and standalone PV installations, medium-depth ground heat collection field coupled with heat pumps. In several scenario the block was estimated as energy positive on annual scale in terms of both heating and electricity. However, in no single one could it achieve complete energy (electricity) independence throughout the whole year with the selected technologies.

Intervention E18– EV charging effects to grid

Intervention E18 focuses on the optimal integration of EV charging in the electricity grid. The purpose is to analyse the charging need of all mobility modes (private and commercial vehicles) and develop strategies to manage the peak power demand.

Table 26. E18 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Increase of integrated public EV charging units	24	n/a	177	n/a
Peak load (electricity) reduction (MWh)	n/a	n/a	10.6	n/a
Demand from all EV mobility modes; impact on the grid (GWh)	n/a	n/a	106	n/a
Developed recommendations for future urban planning/new districts (y/n).	n/a	yes	yes	100%

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To that end, four KPIs have been selected (Table 26) to measure and analyse the impact of the intervention. In addition, the future needs are evaluated to provide recommendations for urban planning. As the number of EVs still is low but rising quickly, the optimisation strategies and the future demand are based on simulations of the EVs and their anticipated charging behaviour.

During the 2nd monitoring period the number of charging units has not changed as compared to the 1st period. In Sello, there are currently 47 chargers and in Lippulaiva about 130 chargers. However, as the number of electric vehicles is constantly increasing, the peak load and the demand from all EV modes have increased. The peak load is about 10.6 MWh and the peak electricity demand for all EV modes for one day is 106 GWh. The peak loads are not based directly on measurements as that kind of data is not possible to get on a city level. Instead, the figures are based on data on the number of vehicles in operation, statistics on energy consumption and driven distances and assumptions on the typical charging behaviour. Hence, the reported impact on the grid should be interpreted as an average value representing a typical working day.

Intervention E19– Sustainable lifestyle

The implementation activities of this intervention were focused on community engagement activities in the Espoo macro level. The KPIs, presented in Table 27, and the impact assessment aims to describe the quality of community engagement and number of citizens and other stakeholders reached and contributed to the co-creation of solutions.

The impact assessment of citizen engagement activities until M36 is based on the collected qualitative and quantitative data of the citizen engagement activities. We can claim that the activities succeeded to reach a significant number of people in the Espoo macro level (over 20 000 people more than targeted) and exceed the targeted number of citizens (141 more than targeted) and stakeholders (22 more than targeted) who contributed to co-created solutions. There were approx. 300 000 citizens in Espoo 2022. The activities targeted to reach 10% of the residents, however a precise estimation of the people reached cannot be made, due to the social media KPI data collection method. The data is collected based on the followers in specific social media channels and web pages, where the invitation to engagement activities was posted, and doesn't tell how many people saw the posts in the feed.

The number of co-created solutions cover 11 preliminary sustainable urban mobility concepts and all kind of novel co-design tools/methods for citizen engagement facilitated in Espoo macro level area. The number of validated solutions cover 8 sustainable urban mobility concepts and 2 co-design tools/methods for citizen engagement. The number of co-created solutions exceeded the target value (From 10 to 16). The number of validated solutions exceeded the target value (From 5 to 10).

The total average of engagement of all citizens and stakeholders, as well as improving awareness, Likert scales are based on the number of actual respondents to the feedback survey. The feedback was collected from three activities conducted e.g., by KONE and City of Espoo, on Espoo macro level, and includes 26 respondents out of 54 participants. Feedback data shows that overall, the respondents feel that they were able to contribute to the activities to some extent (Average = 3.78 with a target of 4) and the activities improved their awareness (Average = 3.86 with a target of 4). Data from Smart Otaniemi events is provided separately to the E19 data, in intervention E23.

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Table 27. E19 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of engaged individuals in total	n/a	30000	50461	68%
Number of citizens contributed to co-created solutions	n/a	400	541	35%
Number of other stakeholders contributed to co-created solutions	n/a	100	122	22%
Engagement level of participants	n/a	Average above 4	3.78	6%
Number of co-created solutions	n/a	10	16	60%
Number of validated co-created solutions	n/a	5	10	100%
Improving awareness of energy positive district solutions	n/a	Average above 4	3.86	3.5%

Intervention E20– district development

This intervention is about the replication of SPARCS solutions in the Finnoo district and beyond. No KPIs were assigned for this intervention during the baseline phase.

Intervention E21– Air quality

The baseline data presented in Table 28 from both Leppävaara and Matinkylä areas shows that the air quality in both areas was very good during the measurement period. The Helsinki Region Environmental Services Authority (HSY) has published limit values for different categories, from very poor air quality to good air quality[5].

Table 28. E21 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Leppävaara PM 2.5	6,14	≤10	6,42	36%
Leppävaara PM 10	17,08	≤20	24,27	12%
Leppävaara NO	10,47	≤15	3,22	79%
Leppävaara NO2	19,62	≤40	12,38	69%
Lippulaiva PM 2.5	6,11	≤10	2,93	71%
Lippulaiva PM 10	14,93	≤20	14,62	28%
Lippulaiva NO	6,54	≤15	12,31	19%
Lippulaiva NO2	13,70	≤40	8,19	80%

The measured values are all under the limit values for good air quality, except for the PM10 value for Leppävaara. This might be due to either errors in data as HSY has not validated that yet, or the spring season with lot of particles in the air. Other than PM10

[5] https://www.hsy.fi/ilmanlaatu-ja-ilmasto/mika-on-ilmanlaatuindeksi/

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values the values in reporting period two were very similar to values in reporting period one.

Intervention E22– Co-creation for positive energy district

This intervention is about the development of a co-creation model for smart city development. This intervention is closely linked to E14, where the model is created to support Kera development. In this intervention, the model is generalised to support the development of any sustainable and smart urban area, which includes land use planning, area development and the integration of smart urban solutions in collaboration with different stakeholders. As the model development process both for the Kera model and the generalised version are closely interlinked, the KPIs (Table 29) are shared between this intervention (generalised model) and intervention E14 (Kera model).

As stated above in the section describing the intervention E14, the set targets on citizen and stakeholder engagement during the active model development process in 2022 have been met, and there is no update to those numbers as the activity is completed. The original KPI – set before the monitoring phase – on the satisfaction about the process was removed for D2.6 and was replaced by a KPI presenting the interest towards the model as several site visitors. Please see the intervention E14 for more detailed description about these KPIs and the results.

Table 29. E22 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of stakeholders involved in co-creation of the co-creation model	n/a	70	116	66%
Number of citizens involved in co-creation of the co-creation model	n/a	100	137	37%
Visitors on the co-creation model website (calculated monthly) (toolbox)	n/a	1500	3534	136%

Intervention E23– New economy/ Smart business models

This intervention is about the generation of new economy and smart business models from the Espoo Lighthouse activities and Table 30 presents the related KPIs. Smart Otaniemi pilot platform and the local Espoo networks act as main elements of generating support for smart business model development. The action has included, among other things, the mapping of Espoo as an environment for new business and organizing events together with the Smart Otaniemi pilot platform.

The number of new innovative projects leveraged beyond SPARCS and the total volume of additional funding will be calculated only in the end of the project.

The KPI on the number of smart business models created – as defined before the beginning of the monitoring phase – in Espoo was removed as it does not properly describe the work done in the intervention. Instead, it has been replaced with two additional KPIs that are directly related with the work in the intervention for D2.7.

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Table 30. E23 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of new innovative projects leveraged beyond SPARCS	n/a	1	n/a	n/a
The total volume of additional funding	n/a	n/a	n/a	n/a
Active collaboration with ecosystems developing sustainable solutions in smart city sector	n/a	>5	6	20%
Participants in the Smart Otaniemi stakeholder events	n/a	100	93	7%

The first one on active ecosystem collaboration (KPI as "Active collaboration with ecosystems developing sustainable solutions in smart city sector") describes the role of ESP in collaborating with multi-stakeholder ecosystems in SPARCS themes. So far, ESP has actively contributed to multiple ecosystem work groups, and introduced SPARCS actions and solutions, as well as led the work in part of the groups. These include the Kera area energy group, the Kera area mobility and logistics group, the overall Kera development ecosystem, the energy partner meetings, and collaborating actively with RAKKE (a solution path to sustainable growth ecosystems) and KETO (the Implementation Pathway for Environments that Accelerate Sustainable Growth) projects. There are no additional groups since the previous monitoring period reported in D2.6. The other added KPI indicates the number of stakeholder participants in the Smart Otaniemi ecosystem events, arranged by VTT and ESP, which are aimed for different organisations and stakeholders to develop smart city solutions. There has been a new event organised since the last report, which adds to the total number of participants reached through the seminars.

3.2 City level - aggregated assessment

This section investigates the impact of SPARCS within Espoo on a more general city-wide level. This impact assessment is divided into four sections, based on different themes within the project. These are energy, mobility, and citizen engagement, with a separate table reserved for more general KPIs. Table 31 below presents the city-level KPIs focused on energy.

Compared to the first monitoring period, an increase in CO_2 emissions and a decrease in the use of renewables in district heating can be observed. The increase in emissions and decrease in renewable percentage can be explained by the Russian invasion of Ukraine, and the subsequent energy crisis. A reduction in the use of Russian natural gas has led to an increased use of oil and coal in district heating, increasing emissions from district heating by 30 % compared to 2021. The amount of renewable production within the heating and electricity sectors are already nearly at the target levels provided within the SPARCS Grant Agreement but did not surpass the target as was predicted in D2.6. It must be noted that the percentage of renewable electricity production is provided on a national level, as data is not provided on the city level by the Helsinki Region Environmental

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Services Authority (HSY). In Finland, consumers can buy electricity from any retailer and the agreements are not public. Calculating local renewable percentage for electricity use would require knowledge of these contracts in terms of the share of contracts requiring certified renewable production.

Table 31. Espoo city -level, energy KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Equivalent CO2 (%) reduction	n/a	14.8 %	15.4 %	0.6%
Share of RES increase-heating	41%	55%	48%	7%
Share of RES increase-electricity	52%	55%	54%	1%
Total electricity demand reduction compared to 2015 (%)	n/a	7.5%	-15%	200%
Total heating demand reduction compared to 2015 (%)	n/a	7.5%	-7.6%	100%

Regarding energy consumption, the City of Espoo has signed the Energy Efficiency Agreement for the Municipal Sector, thus pledging to reduce energy consumption by 7,5% between 2017 and 2025 (compared to 2015 levels). Espoon Asunnot OY, the city-owned social housing provider, has signed the same agreement for the property sector, pledging to the same goals as the city. However, this only affects the facilities owned by the city or Espoon Asunnot and is not an official target for the city. Still, this target was used to facilitate the impact assessment. Both heating and electricity consumption have increased compared to the 2015 levels. This is most probably due to an increase in the population of the city, and new constructions causing additional consumption sources. When looking at consumption divided by population, a decrease can be observed in both heating and electricity consumption during the second monitoring period. Table 32 below presents the general mobility related KPIs on a city-wide level.

The number of electric cars has increased rapidly since the start of the project in Espoo, which is probably at least partly due to the general increase of e-car popularity and visibility in media coverage in recent times. The increase of local EV chargers for general use supports the further increase of the number of electric cars in Espoo, and its role in the development is important (as access to charging). The number of electric cars still is very low compared to the total number of registered vehicles in Espoo, but direction of the development is becoming clearer. The relevant EU legislation will surely further accelerate this development, although the pace of the turnover of the general car fleet is slow to change amongst the whole population (the current average age of a registered car in use is around 12 years). In addition, e-car sharing services are entering the market: there is currently one private operator in the Helsinki Metropolitan area, including Espoo, operating with a fleet of around 150 vehicles.

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The KPI from D2.6 called "Utilisation of charging stations" was removed from D2.7 because it refers and provides data only about the SPARCS demo areas. The demo site specific KPIs are examined in the tables of relevant Interventions (E2 and E7). The presentation of the KPI "Increase of EVs share in local transportation" was edited to present the %-share rather than the numbers. The data remains unchanged from D2.6. The KPI "Transport infrastructure (rail-based)" was slightly edited to clearly highlight the focus on rail-based public transportation (rather than public transportation in general).

Table 32. Espoo city -level, mobility KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
EV car sharing rate increase	0	n/a	150	n/a
Increase of EVs share in local transportation	0,2%	n/a	2%	n/a
Transport infrastructure (metro and train stations)	13	18	18	0%
Increase of EV charging points (number)	270	n/a	404	n/a

The City of Espoo has recently made major investments to rail-based public transportation to form the backbone for sustainable urban development. Espoo's first metro line, with six (6) in the Espoo municipality area (the metro line connects directly to the long-existing metro line of Helsinki municipality) stations was opened a few years before the start of the project in 2017, and the extension of five (5) new stations, opened in December 2022, has brough the total number up of metro stations to eleven (11) (including Espoonlahti metro station, located under the new Lippulaiva centre, and Finnoo [replication site] metro station).

Table 33. Espoo city-level, general KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Job creation by SPARCS	n/a	550	70	88%
Annual number of new patents	n/a	n/a	0	n/a
Annual number of contributions to European Standardisation Organisations	n/a	n/a	0	n/a
Successful completion of the SPARCS interventions	n/a	Successfully completed	n/a	n/a
Relation of project to city strategy	n/a	n/a	n/a	n/a

These station areas act also as important public transportation and shared mobility hubs, including the existing shared (public) city bike system (with currently 4.600 bicycles in Espoo and Helsinki), organised by the joint local authority Helsinki Region Transport (HSL). They also provide a platform for possible (private) shared mobility services, such as micro mobility and EV sharing services. The existing commuter train connections are also currently actively developed as the Espoo City Rail Link. Additionally, the city's first

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fast tramline connection (Jokeri Light Rail) will open in autumn 2023 (ahead of the previously expected early 2024 timeline) with 11 tram stops, which will also include the SPARCS demonstration site Leppävaara. These investments can – by improving public transportation service, connectivity and travel experience – have a major impact to the modal share in Espoo in the long run and also affect the SPARCS demonstration areas and their future development. Table 33 contains general information that doesn't fit under any of the other city level KPI tables. SPARCS has created approximately 70 jobs in Espoo so far, which is below the targets set before the project. It must be noted that this does not contain all information of new jobs created, as only jobs connected to SPARCS actions are included. In total, the opening of the Lippulaiva demonstration site has created approximately 500 new jobs within Espoo.

Table 34. Espoo city-level, citizen engagement KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of engaged stakeholders	n/a	63000	204763	225%
Number of citizens contributed to co-created solutions	n/a	700	821	17%
Number of other stakeholders contributed to co-created solutions	n/a	100	122	22%
Engagement of stakeholder	n/a	> 4	4.27	7%
Number of co-created solutions	n/a	16	26	63%
Number of validated solutions	n/a	11	20	8%
Improving awareness of energy positive district solutions	n/a	> 4	4.22	%
Number of co-creation sessions for (energy positive) business models	n/a	6	9	50%
Stakeholders reached to contribute to business model co-creation	n/a	200000	545318	173%
Number of stakeholders contributed to business model co-creation	n/a	60	75	25%
Were the mobility insights useful for the city planning authorities?	n/a	n/a	n/a	n/a
Number of city planning stakeholders reached	n/a	n/a	n/a	n/a

The city doesn't apply for patents or contribute to standardisation organisations. Thus, the city suggests transferring this KPI to the intervention levels in future reports to better learn if these contributions have happened through demonstration actions. Two KPIs were moved to the city level sections from the intervention level, being the completion of SPARCS tasks and the relation of SPARCS actions to the city strategy. These will be assessed at the end of the project. The latter KPI was altered to focus on the new city strategy accepted during the project, to assess the connection of SPARCS with the latest strategic documents.

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City level values for the SPARCS citizen engagement actions are provided in the Table 34 below. These values are totals and averages of the values provided within the intervention sections, so more information will be provided in the updated versions of the document. Still, this table provides a brief overlook on how citizen engagement activities have fared during the project.

3.3 Partner level – Financial assessment

City of Espoo

The work during the implementation (and monitoring) phase of the project from the ESP part has actively aimed to contribute to the development of learnings for urban planning and development processes of Kera district and other replicable areas, such as Finnoo. The project has supported the climate neutrality target 2030 and the achievement of the goals for SDGs by 2025 - providing new information, knowledge exchange and capacity building on urban energy transformation. The SPARCS work has also contributed to the development of new citizen engagement tools and methods (the Buddy Class concept in specific). To achieve these goals, EU contributions have been integral in providing funding for personnel, communication & dissemination and organisation of events and activities. The EU contribution has also provided means for travel and networking.

Major emphasis in ESP work during SPARCS demonstration phase has been the creation of the Co-creation model for sustainable and smart urban areas. The model, presented as an open toolbox for the development of districts and their sustainable smart city solutions, available at www.co-creatingsparcs.fi, has been developed through design thinking and co-creation methods. A subcontracted party WSP (with Korkia Consulting) were utilised in to create the model. EU contribution provided the needed funds to subcontract the necessary work to complete the model. Other actions completed during the SPARCS project include the assessment of public buildings as a VPP, completed in collaboration with Siemens, and the assessment of the Espoo 3D city model as a tool for district-level energy planning, completed in collaboration with VTT. EU funding was also integral in the completion of these assessments.

Payback times for municipal energy efficiency investments and amount of public funding linked to the SPARCS themes are presented in Table 36. It must be noted that the values presented here are not the full picture on the investments made and to be made to aid sustainable development in Espoo, but are a small collection focused on SPARCS-related themes collected from public sources. Within the investment funds presented in Table 36, only public funding contained in the following sections is included. Within the city rail link and west metro extension projects, only investment costs related to SPARCS demonstration areas are included.

Energy investments

Fortum and the City of Espoo have committed to carbon-neutral district heating during the 2020s in the network that operates in the Espoo, Kauniainen and Kirkkonummi regions. The development work has since been accelerated with an intermediate goal of stopping the use of coal in 2025. The accelerated project for carbon-neutrality in 2020's is called Espoo Clean Heat.

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The Ministry of Economic Affairs and Employment of Finland (TEM) has provided investment aid for projects that rapidly phase out the use of coal energy. In 2021, Fortum Power and Heat Oy received 6,2 million euros to construct a 20 MW air to water heat pump plant in Kera, Espoo[6]. The plant will be connected to a low temperature heat network in the Kera area and the Espoo district heating network. A similar solution connected to the district heating network is under construction in Vermo, Espoo. Fortum Power and Heat Oy has received 3 million euros in aid for this investment.[7]

Within the City of Espoo, municipal investments into energy efficiency have totalled over 20 million euros between 2017 and 2021. However, achieving carbon neutrality will also include significant private investment, as the city owns and operates only a small portion of the local building stock.

Mobility investments

Extending the Helsinki subway system west to Espoo is a major investment that brings vitality to communities and enables new housing and jobs in an eco-friendly way. The second phase of the West Metro project, Matinkylä–Kivenlahti, involves the construction of seven kilometres of rail line and five new stations, and the construction of an underground metro depot in Sammalvuori. The adjusted cost estimate for phase two is EUR 1,159 million. Final construction costs in Espoonlahti and Finnoo (SPARCS demonstration and replication areas respectively) were estimated to be 292 million, with 90% of the project completed[8].

The Jokeri Light Rail line will be built between Itäkeskus in Helsinki and Keilaniemi in Espoo. The SPARCS demonstration area Leppävaara is one of the key mobility hubs on the line. The cost estimate for the light rail infrastructure is 386 million euros. Jokeri Light Rail receives government subsidies for 30 per cent of the construction costs[9]. The maximum amount of the government subsidies is 84 million euros. Espoo and Helsinki will share the remaining costs based on the border of the cities. As specified in the project plan, the shares of the costs are 35% (Espoo) and 65% (Helsinki)[10].

The Espoo City Rail Link is a joint project of Espoo, Kauniainen and the Finnish Transport Infrastructure Agency to build two new tracks between Leppävaara (SPARCS demonstration site) and Kauklahti. The construction planning of the City Rail Link started in the spring of 2021 and will continue until 2023. Construction work will start in 2022 and the rail link will be completed in 2028. The total cost of the rail link is EUR 275 million. while the estimated cost of the Leppävaara-Kera section amounts to 115 million euros[11]. In addition, the City of Espoo will carry out its own separate projects in connection with the rail link project, including a cycle and pedestrian path along the railway line

[6] Fortumin hiilen energiakäyttöä korvaaville hankkeille työ- ja elinkeinoministeriön investointitukea | fortum.fi

[7] Fortum suunnittelee Suomen suurinta kaukolämpöverkkoon liitettävää ilma-vesilämpöpumppulaitosta – hankkeelle TEM:in tukea | fortum.fi

[8] Matinkylä-Kivenlahti | Länsimetro (lansimetro.fi)

[9] Raide-Jokerin toteutus etenee kaupunkien päätöksentekoon | Raide-Jokeri (raidejokeri.info)

[10] Paljonko Raide-Jokerin rakentaminen maksaa? | Raide-Jokeri (raidejokeri.info)

[11] Microsoft PowerPoint - ESKA Markkinainfo 20230620.pptx (vayla.fi)

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(Rantaradanbaana, investment 15 million EUR) and new underpasses and overpasses (investment 40 million EUR)[12].

Table 35Espoo financial KPIs (mobility)

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Payback time (municipal energy efficiency investments)	n/a	2-13 years	0.56	72%
Investments (city-level)	n/a	n/a	607	n/a

City of Espoo has prepared an investment plan to improve the cycling infrastructure in main cycle routes. The investments needed to put the program into practice amount to approximately 10 million euros during the next ten years. The number and share of electric buses are growing quickly in the public transport system in Espoo operated by the Helsinki Regional Transport Authority (HSL), a joint manager of public transport systems in the metropolitan cities of Helsinki, Espoo, Vantaa, Kauniainen, Kerava, Kirkkonummi and Sipoo. HSL intends to increase the number of electric buses so that by 2025 about half of the buses used on HSL's services are electric. This means roughly an additional 330 buses to current fleet of 316 electric buses (2023)[13] ,with an investment cost running up to approximately double the investment needed for diesel buses (totalling up to half a million per bus), but with lower operational costs. In addition, the required charging infrastructure will require further investments not accounted for in this report, to accommodate the increase in vehicles.

Citycon

Lippulaiva shopping centre was built during the SPARCS implementation and opened in April 2022.

Table 36 Cost comparison in Lippulaiva shopping centre (heating)

	BASE CASE: District heating and cooling	LIPPULAIVA CASE: Geothermal energy
Initial investment	1 950 000 €	125 000 €
Operational expenditures	2 871 675 €	938 378 €
TOTAL	4 821 675 €	1 063 378 €

Intervention E1 is about solutions for Positive Energy Blocks, and with the leverage of the project Citycon was able to invest in energy solutions that in long term offer cost savings, provide energy to other buildings in the area and decrease carbon emissions from energy consumption. In addition, intervention E2 enables Lippulaiva to provide E-mobility

[12] Espoon kaupunkirata - Väylävirasto (vayla.fi)

[13] Electric buses | HSL | HSL.fi

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solutions to its neighbourhood via offering EV parking and charging capacity, as well as facilities for e-bicycles.

Table 36 and Table 37 demonstrate an overview on the financial implications of a base case of no SPARCS intervention and a use case with intervention. Due to confidentiality of pricing and agreements between Citycon and service providers Adven and Schneider Electric the background data of the financial assessments are not disclosed. The financial implications of the SPARCS are expected to change over time as uncertainty in energy and material prices continue to exist. The rising energy prices have increased the profitability of the geothermal energy installation.

Table 37 Cost comparison in Lippulaiva shopping centre (electricity)

	Cost comparison in Lippulaiva shopping centre		
	BASE CASE:	LIPPULAIVA CASE:	
	Electricity mix from grid	PV panels	Payback time
Operational expenditures	290 452 €	1 333 €	8 years

The expected payback time of the PV panel installation was 8 years prior to the investment decision. During the first year of operation, panels produced less electricity than expected. Volatility in electricity production may affect the final payback time. Installation of battery reserve system FCR-N has provided Lippulaiva operational revenue of roughly 430 000 €, as electricity is reserved in the battery and then sold back to grid when overall demand is high.

KONE

KONE has invested research and development resources on improving the power demand modelling of escalators and, especially, elevators to enable scalability of the solutions created in intervention E6. Furthermore, the connectivity and data sharing capabilities related to these solutions have been enhanced and tested with Siemens.

The developed power demand forecasting solution for elevators is currently viewed to serve specific customer needs in emergency power conditions, potentially helping to reduce the capacity required by the emergency power system. The decreased size of the backup power device and related components reduces the investment costs as well and running expenses, such as maintenance fees of the emergency power system. Additionally, the freed space can be potentially utilised for other purposes. The level of savings, thus, depends on the building type and the type of construction (new or modernisation).

There is also another interesting perspective emergency power systems. A smart and robust emergency power system brings considerable cost savings due to avoidance of loss of operations during outage (Zhang et al., 2022). The elevator power demand forecasting solution can support this outcome either by enabling more elevators connected to the same emergency power circuit, or by freeing backup capacity for other building

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operations, helping to the reduce the negative impact of power grid outage on the building operations and occupants.

SIEMENS

The investments of the project have focused on the technological development of the energy system. The focus has been on digitalisation, energy self-sufficiency and creating new smart energy models. E5 is concentrated on the energy self-sufficiency and utilizing buildings as thermal energy storages. E6 has the focus on the digitalisation, energy system modelling and using artificial intelligence for energy market predictions. This simultaneously automates manual labour. Financing provided by EU has helped greatly in the execution of the projects and added depth to them. An estimated 50% of the tasks might have not been completed or started without EU support. The other 50 % was executed with faster pace and the investments were made upfront.

*ROI = Operating profit / Investment cost * 100%, yearly figure*
Payback Time = Investment cost / Operating profit, lifetime figure

The chosen financial KPIs best represent the focal intervention's results (Table 38). The ROI and the payback period give valuable information about the feasibility and profitability of the interventions and what timeframe to expect for their successful execution. The last KPI of saved cost per year reflects on the potential increased productivity that can be gotten from the intervention. It grows well with respect to increased scale of the operations. To be able to present meaningful figures related to the interventions we are looking at the ROIs in 2027 by extrapolating the financial data and making financial predictions. Investment costs are based on the actual status as in M42 and estimations of additional investments before end of M60.

Table 38 Siemens financial KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
E5 ROI in 2027	0	n/a	0	n/a
E5 Payback time	n/a	n/a	n/a	n/a
E6 ROI in 2027	0	n/a	0	n/a
E6 Payback time	n/a -	n/a	n/a	n/a
Saved cost per year 2024 (increased productivity)	0	10000 €	15 000 €	n/a

VTT

VTT's main interest in the SPARCS project is to support cities and companies to develop positive energy district solutions for decarbonising cities by doing advanced applied research. In Espoo's lighthouse demonstrations, VTT's main role has been to support local partners in their work to implement PED solutions. VTT also leads a few interventions E17 and E18, which are also the topics that have been selected to be part of this financial impact assessment. As a technical research organisation, the investments of VTT's research work in Espoo's LHC interventions in SPARCS have been mostly about personnel costs, funded both with EU contributions and VTT's own funding.

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Espoo intervention E17 focuses on Sello Virtual Twin predicting energy demands (electricity, district heating) and on-site electricity production from PV, and Espoo 3D city model.

As mentioned in SPARCs D7.7 on exploitation plan, the knowledge gained in the research and solution development during SPARCs will help VTT to get funding for further public and industrial projects on national and international level, applying the developed solutions into different contexts. The first target is to undertake further research to improve, and update developed CityGML models-based energy simulation for energy positive blocks. Another target is to undertake further research to improve, and update developed digital twins for PEDs related solutions including digital twin-based forecasting models for building energy demands (electricity, district heating), PV based on-site electricity production, EV charging power, heat energy storing to building structures and how to visualise the results in 3D building model (BIM).

More importantly, the E17 virtual twin forecasting solutions (electricity, district heating, PV production, eV charging) can be easily scaled up to different types of buildings. They also can be easily used through APIs in VPPs and in building energy optimisation applications. In the long run these capabilities are expected to improve the ROI of the solutions for different stakeholders. The BIM solution can help to detect and locate faults in building energy related behaviour. The CityGML based building energy block analysis helps to analyse different scenarios towards energy positiveness.

The Espoo intervention E18 focuses on e-mobility and its impact on the grid. As part of the intervention, VTT has expanded the simulation capabilities from the analysis of specific vehicle types with known duty cycles to analysis of all vehicles arriving and departing at a given location without exact information about their duty cycles. The simulation methodology is based on statistical data and the approach can be used to study future scenarios for which actual data is not yet available. One of the main motivations behind the chosen approach was the costs caused by high power peaks. The price for charging at a public charger is typically fixed and based on either the charging duration or the amount of energy received. The charging service provider covers the difference between the charging price and the actual electricity costs. The developed simulation methodology can be used to investigate the impact of various pricing schemes on the daily power consumption and provide support in finding pricing schemes that optimises the charging behaviour. Hence, notable savings in the operation of the charging infrastructure can be achieved. Simulations can also act as a support in the dimensioning of new charging infrastructure. Further activities could focus on the improvement of the usability of the simulations and potential integration into other simulation platforms.

3.4 Conclusions and lessons learnt in Espoo

Impact monitoring of city interventions (Figure 9) has shown that the most KPIs are meeting or exceeding expectations. Specifically, 48% of the KPIs have exceeded expectations, indicating significant improvement over set targets. This is a positive sign that the interventions are having a meaningful impact on the city. Additionally, 34% of the KPIs have met their set targets, demonstrating consistent performance. This suggests that the interventions are working as intended and are having a positive impact on the city. However, 6% of the KPIs are close to but not quite meeting their set targets.

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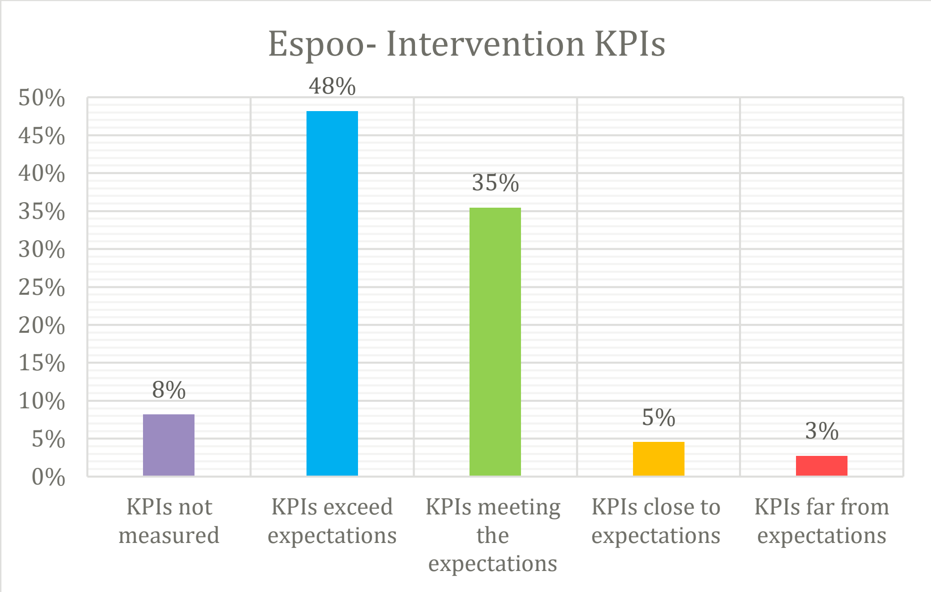

Figure 9. Overview of interventions impact assessment- Espoo

This suggests that there is still room for improvement in these areas. By making slight adjustments to the interventions, it is likely that these KPIs can be brought up to meet or exceed expectations. Finally, only 3% of the KPIs are far from meeting expectations. This highlights areas where corrective action is needed to enhance performance. By taking corrective action, it is possible to improve the performance of these KPIs and ensure that the interventions are having the desired impact on the city.

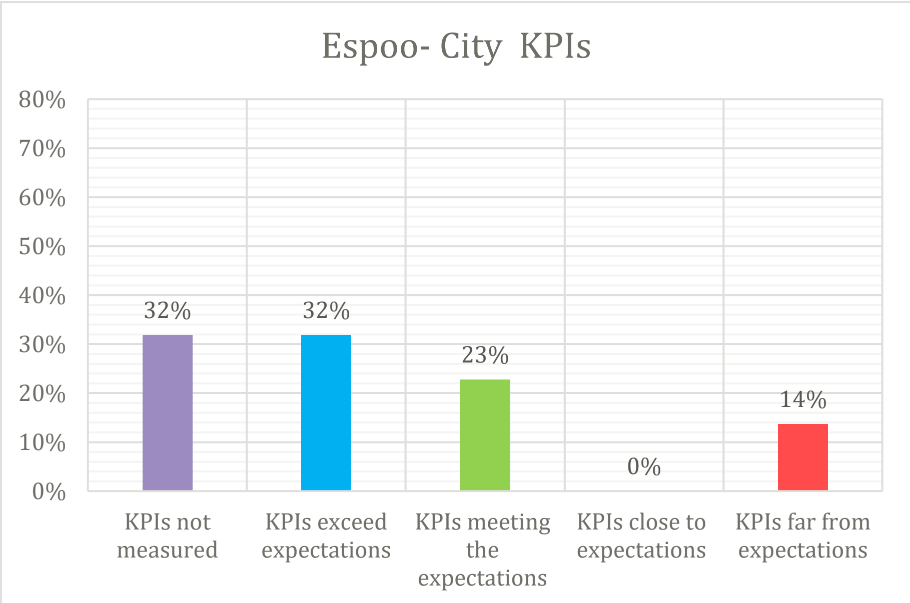

Figure 8. Overview of city-wide KPIs impact assessment- Espoo

Respectively referring to the city level KPIs at the current monitoring period (Figure 8) approximately 32% of KPIs (22 in total) were not measured due to lack of data. Meaning that there were not sufficient data available to measure them accurately. As analysed in the chapter above, this was due to various reasons such as missing data sources or other

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technical issues. KPIs that exceed or met the expectations were close to 55% which implies that the remaining KPIs had metrics that surpassed or matched the predefined goals. This suggests that the city's efforts towards improving its performance across different aspects are showing promising results.

Lastly, roughly 14% of the KPIs fell short of the established objectives, indicating areas where further improvements are necessary.

Lessons learned during impact monitoring in Espoo

Lippulaiva

In general, the situation of the Lippulaiva demo site is good. The shopping centre opened in March 2022 on time. Six residential buildings in the block have also been completed in 2022-2023.

The geo-energy plant was already up and running during the construction period. Its operation after the opening of the shopping centre has been flawless. So far there has been no need to use district heating, but instead the need for heat and cooling has been covered by local renewable energy. The solutions chosen to seem profitable also from an economic point of view. From the property owner's point of view, the energy as a service concept for the geo-energy solution also appears successful. During the first year of operation, it has been important to pay attention to adjustments and proper use of the building. This optimisation work will be continued during 2023.

The solutions for electric mobility were implemented according to plan and mostly on schedule. Electric car charging has been in use since opening. No technical problems have been detected. One negative observation related to the use has been that non-rechargeable cars are also parked at the charging points for electric cars. However, this can be limited through better communication. The lesson for future projects is that it is good to plan charging solutions as early as possible in a new project or renovation.

The bicycle spaces were implemented as planned. E-bike charging cabinets were delayed due to delivery problems. In the future, it would be good to consider how the use and adequate bicycle spaces are efficient.

As a real estate developer, owner, and manager of Lippulaiva, Citycon can learn from the observations of Lippulaiva presented above and take them into account in your future projects.

Sello

Shopping centre Sello is the main local city centre for Leppävaara area since its construction. Therefore, throughout the project so far, it was significant to consider that all the changes are done so that the user experience isn’t endangered significantly or for a longer time. This was especially important for heating demand response tasks as the indoor temperature would be affected almost directly.

Also, the EV charging tasks have a direct affect to the EV users. Therefore, the follow-up period is very important and gathering user feedback is needed. This way the limitations on charging power can be adjusted based on the feedback and the user experience is improved. This also gives valuable information for future projects and reduces optimisation time when the similar solutions are used.

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Otherwise, many tasks were based on digital platforms and changes in the programs. For example, creating the digital twin of the building doesn't have any immediate direct consequence to the users, but increased efficiency in long run can help optimizing the maintenance and consequently reduce cost for the building and tenants. For this type of tasks, the quality of acquired data is critical and there must be multiple datapoints and long enough history to achieve sufficient results.

Kera

Kera area is in an active development phase, with construction projects to begin soon, and the key learnings and insights from SPARCS can support the development of the area towards a sustainable and smart urban area according to the visions and goals set for the area's development.

The Kera focused Interventions in the project have focused on examining the potentials and limitations, the specific context and the possible approaches and solutions in terms of the overall picture on energy and e-mobility, mostly from an urban development and urban planning perspective. The long timeline of Kera development – spanning multiple decades in the future – will present interesting temporal challenges for the development, utilisation and renewal of such urban solutions, as the area will be built in multiple different phases and by multiple different stakeholders. The different phases and individual selected solutions in different buildings will all contribute (directly and indirectly) to the Kera area. The 'co-creation model for sustainable and smart urban areas', developed in the project for both Kera (E14) and for a general level (E21) has been one practical example of trying to tie this complex and system-level view into a manageable tool, and has also, as a co-creative process, acted as an example of this collaborative approach between different stakeholders and as facilitated and managed by the city.

Citizen engagement

The community engagement approach and its replicability has been reflected in the 'D3.6 Optimizing people flow and user experience for energy positive districts' under sections '5.1 Added value and replicability potential of selected community engagement methods and activities' and '5.2 Added value and replicability potential of the community engagement approach in general'. Here, we point out some highlights from this reflection.

The reflection points out that community engagement is time consuming and highly dependent on participation. One does not know beforehand where the process will lead and there are risks involved, such as participants quitting in the middle of the process.

Simultaneously, the community engagement approach enables more democratic approach to urban development, where diverse citizens have an opportunity to participate in the planning and decision-making related to matters affecting them. This provides citizens a more active role in city development. Potential positive outcomes can be, e.g., improved wellbeing and feeling of belongingness. This again can be seen to contribute to building flourishing neighbourhoods and city districts.

One of the biggest challenges in community engagement is to identify and engage the diversity of citizens. As every individual is different, all aspects can never be covered. However, a great variety of diverse needs can be considered through thorough

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understanding of district demographics and including people with diverse backgrounds and abilities in the planning and decision-making processes.

Finally, it is relevant to ask, 'on whose premises is community engagement conducted'. In the Espoo case, the engagement activities were strongly led by companies and city representatives. This creates a specific power dynamic, where citizens are easily seen as targets of change and design instead of active participants affecting matters relevant for them. In an optimal situation, we could get the best of both worlds: citizens actively leading matters important for them, and official partners effectively enabling change created by citizens.

Overall recap and general observations

On the more general level, issues can still be seen in the collection and identification of relevant data, while also taking into consideration the fact that SPARCS represents a small part of the overall development taking place in Espoo. Especially in the city level KPIs, the effect of SPARCS might not be identifiable from the broad data that is available, as the work focuses on certain demonstration sites on certain parts of the city. Some of the city level KPIs have also been observed to be measurable only on the level of the demonstration district in question, while targets have been presented for the city level as well. As an example, the utilisation level of excess heat and the number of integrated smart systems are KPIs that do not have available data on the city level.

In several interventions, KPIs proposed in D2.2 were suggested to be replaced. This has been done as more information on the work done during the intervention, available data, and knowledge on monitoring arises. In the end, this is not a negative aspect or issue as the work done during the project evolves and in relation, also the monitoring needs to change to reflect the results of the taken actions.

Another key question concerns the transfer of targets set by the city to the project level. Targets provided by the city may only concern city operations and are quite large in scope compared to what the project can achieve. As many of the city-level KPIs within this report are broader in scope than the project itself, many of the targets were used as-is. Thus, more work needs to be done to better focus monitoring on how a single project can affect the broader sustainability targets set by the city.

All three demonstration sites have proceeded as planned, from the Sello demonstration site, which was already in operation before the start of the Kera project, which will begin a long construction process this year. Data from Sello and Lippulaiva is constantly collected, which enables the dissemination and replication to the city planning demonstration of Kera, other replication areas in Espoo and beyond. This is most important as the impact of the project is considered. On the macro level, interventions have proceeded and yielded results that help in analysing the role of smart solutions, co-creation, and business models from a larger perspective. The macro level interventions have also led to pilot activities, that can provide additional data and information on top of the already expansive list of district specific interventions. This will give a good basis for the future monitoring and impact assessment work, and aid in the replication and dissemination activities.

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4. Progress and evaluation of Leipzig activities

This section provides an overview of the KPIs for Leipzig interventions and at the city-wide level during the second monitoring period. The presentation of Leipzig interventions includes both individual monitoring of KPIs at the intervention level and aggregated modelling at the city level. The colour mapping for the visual representation of the impact in the different KPIs was presented in Table 9.

As mentioned earlier the goal of colour mapping is to give an at-a-glance view of how well a KPI is performing. This tool helps stakeholders spot potential problem areas and track progress towards desired outcomes, and it shouldn't be used to pass judgment on the effectiveness of specific solutions. Instead, it provides insight into whether the anticipated benefits from those solutions have been realised. At the end of the chapter a summary of the results is presented as well as conclusions and important lessons learned from the city of Espoo.

4.1 Intervention level- Indiviual assessment

Intervention L1- Intelligence EV parking and storage

The L1 intervention at the Baumwollspinnerei demo site showcases the integration of e-mobility and bidirectional charging of electric vehicles within a microgrid. The primary objective is to enhance the stability of the microgrid network frequency and is achieved by utilising the car battery as an intermediate storage device, allowing electricity to be fed back into the grid during periods of high demand. Conversely, during times of high supply, electricity can be drawn from the grid and stored in the car battery. This process helps mitigate load peaks by utilising energy stored in EV batteries and feeding it back into the grid when deemed appropriate, following the Vehicle-to-Grid (V2G) concept. The KPIs related to L1 intervention are presented in Table 39.

CENERO implemented load management software to establish a connection between the e-mobility platform and actively monitors and analyses the outcomes of this integration.

The microgrid at Baumwollspinnerei has made significant progress in increasing energy storage capacity and implementing electric mobility solutions. Two on-site storage devices have been added, one in the form of a conventional bulk lithium-ion battery and the other a bidirectional EV equipped with a car battery. While the bidirectional EV storage is currently unpredictable and unreliable, its potential for storage benefits and the balancing of the grid frequency in the microgrid is recognised for the future.

The microgrid project aims to reduce the peak electrical load by 10%, and it has achieved a reduction slightly greater than the target. This reduction helps alleviate strain on the grid and reduces costs associated with sourcing electricity from the public grid. Peak load readings represent the highest amount of energy consumed or generated in each time frame. In this report, accumulative data is collected from the first reporting period in March 2022. In this case, the highest peak recorded (345 kW) was recorded in June 2022. Thereafter the peaks consistently reduced further to below 300 kW, however as we are reporting the entire reporting period, we cannot record a lower peak in this report.

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Table 39. L1 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Energy Storage Type (electrical)	n/a	2	2	0%
Energy Storage Increase (number)	0	2	2	0%
Energy Storage Increase (kWh)	0	48	48	0%
Peak Load Reduction (kW)	392	350	345	1%
Demand from all EV mobility modes; impact on the grid (kW)	0	33	11	34%
Monetary gains for user (charging costs vs flexibility revenues) (ct/kWh)	0	45	45	0%
Accuracy of Generation forecasting and storage utilisation (MWh/a)	0	30	0	n/a
Accuracy of storage utilisation	0	833	0	n/a
Increase in shared EVs availability	0	2	2	0%
Increase of integrated smart EV charging units	0	3	3	0%
Increased level of utilisation of EV charging units (kWh/a)	0	5000	2535	49%

The connection of the bulk battery to the grid has been delayed due to challenges in agreeing upon a favourable metering concept with the network operator. Despite this setback, efforts to reach a compromise are ongoing, and once the battery is connected, further reduction in peak load is expected.

The interruption index KPIs show no rise in interruptions, indicating successful implementation of the project's goal to eliminate interruptions in the grid network. The project also focuses on increasing the overall use of electric vehicles due to their environmental benefits and their potential to balance grid stability. The goal of increasing EV use has been met so far, with the installation of charging stations and the implementation of a fleet management system.

At Baumwollspinnerei, the target for the sum of peak charge demand from Kostal and Walter Werke wallboxes was not fully achieved due to technical errors and offline periods of the Kostal wallbox. The charging capacity of the wallboxes was not fully utilised, and cars were not consistently charged at maximum capacity or at the same time. Technical issues with the Kostal wallbox have affected the availability of charging stations, while the Walther Werke charging boxes have not caused any mobility restrictions. The accuracy of the storage utilisation forecast could not be evaluated as the storage integration into the load management system is pending.

The project has successfully increased the number of shared EVs and smart charging stations, although the charging output of the stations remains lower than the target due to technical issues with the wallbox. Efforts are ongoing to resolve these problems and increase EV usage in the future.

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In summary, this monitoring phase was relatively successful, however there is room for improvement. It is important to bear in mind, that this is an innovation project and the identification of possible risks or lessons learned are an important outcome of such a project. Here we achieved a very significant milestone within the context of the project regarding the adaptation of the grid operator's legislation regarding the connection of the battery to the grid. We expect these decisions to be finalised soon, and that the components will be connected for the next reporting period.

Intervention L2- Micro grid inside the public grid

The L2 intervention aims to integrate on-site electricity generation and storage facilities in the microgrid at Baumwollspinnerei. This enhances self-sufficiency and optimises energy utilisation. The intervention includes a 70.47-kWp PV plant, a large-scale battery storage, and the existing CHP plant. Additionally, bidirectionally capable electric vehicle batteries serve as intermediate storage. A digitised load management solution with smart meters, sensors, and energy monitoring ensures effective control of electricity flows and provides detailed information. An interface has been established for peer-to-peer energy trading with the public grid, enabling on-site demand balancing with grid supply. In Table 40 the two KPIs for this intervention are presented.

Table 40. L2 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
District self-consumption rate	42%	75%	35%	40%
Reduction of the customer energy cost (€/MWh)	22	27	29	7.4%

The calculation of the consumption rate is based on total energy generated compared with total energy consumed. Practical limitations of variable energy sources are not considered in this calculation. In practice, there will always be a percentage of PV energy that would be fed into the public grid as energy generated won't always be needed instantly on site. The commissioning of the PV plant with the Network Operator was delayed. As the district self-consumption rate only includes PV generation from August, this percentage is expected to increase considerably in the following reporting period.

The costs of energy production and customer prices increased more than expected, but since the PV plant is operational, positive effects are expected. It's important to note that individual results for specific areas of Baumwollspinnerei may be less precise due to prices being determined for all customers at the site.

Intervention L3- Demand oriented heating system and user information

The objective of this task is to customise the heat generation in Hall 14 according to the specific heating needs of chosen tenants and implement a tenant information concept. This will be achieved by installing intelligent radiator thermostats that utilise the LoRaWAN communication protocol to transmit individual heat requirements or lack thereof to compatible components in the heat distribution system. In instances where there is no need for heat, the electrically operated devices associated with the rental area,

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such as the pump and valve, will be deactivated. The aim is to enhance the efficiency of the technical system by reducing energy consumption in heat generation and electrical operations. Additionally, the concept includes providing digital information to the relevant tenants, which displays their past consumption patterns and enables them to identify opportunities for saving energy based on their demand. In Table 41 the intervention's KPIs are presented.

Table 41. L3 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total energy demand reduction (MWh/a)	2049	1945	2001	3%
Onsite energy ratio OER	0%	100%	1	99%
Peak Load Reduction MW	1442	1370	2737	100%

The total demand for energy decreased compared to the 2020 baseline. Although only a slight decrease, considering that the baseline value stems from a time with strict pandemic regulations, where most businesses were closed, this is quite a significant result. Partial utilisation of office space in 2022 and 2023 could impact these results, as there is still a strong presence of home office. It must also be noted that due to the war in Ukraine, energy prices increased drastically throughout the country and people are now more motivated to reduce consumption. During this reporting period, there were various phases where the bidirectional charging station was not working. If these problems are solved, a slight increase in consumption could be expected in the next report.

The onsite energy ratio could not be recorded as the PV plant has not been commissioned with the network operator yet. Concluding negotiations and exchange with the network operator are ongoing and the information should be available in the next reporting period.

After a thorough review of the key figures for heat storage potential, it was determined that monitoring this potential was not feasible due to the lack of a reliable method to measure and accurately represent the existing but dispersed heat storage potential. Therefore, it was decided to exclude heat storage potential from the monitoring process.

The values recorded and presented in this report represent accumulative data over the past reporting periods, starting in March 2022. The highest value, 2,7 MW, was recorded in February 2023. In this report structure, we will not be able to report a lower value than this, as the highest value of the entire reporting period needs to be considered. In practice, the value did decrease significantly in March and April, with May bringing an end to the heating season.

Intervention L4- Personalised Informative Billing

The Leipzig West district is working to reduce thermal energy consumption and increase the use of renewable energy for electricity. The district has 8 buildings with 314 apartments and one kindergarten. It is connected to the district heating grid and each building has its own heating station. To reduce thermal energy consumption, the district has installed 1363 smart heat cost allocators in the apartments and buildings. These devices collect data on temperature and consumption, which is then used to optimise the heating system. The district has also developed two mobile applications, Meine LWB App

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and SPARCs App, which allow tenants to monitor their energy consumption and compare it to their neighbours. The results of these measures have been significant. The yearly thermal consumption has been reduced by 13%, and the climatic adjusted data shows a reduction of 21%. This is due to a change in the behaviour of the tenants, who are now more aware of their energy consumption thanks to the information provided by the applications. Figure 10 presents the real consumption after the optimization and the calculated typical consumption as measured on April 2023.

The district is also working to increase the use of renewable energy for electricity. It has installed solar panels on the roofs of several buildings, and it is planning to install a battery storage system to store the excess energy. The Leipzig West district is a model for other districts that are looking to reduce their energy consumption and transition to renewable energy. The success of these measures will depend on the continued participation of the tenants, who need to be aware of their energy consumption and willing to make changes to their behaviour.

With the smart heating system energy savings, up to additional 16 % could be reached in the 2nd monitoring period calculated to the settings before optimisation. It is shown in the graphic below for the month April.

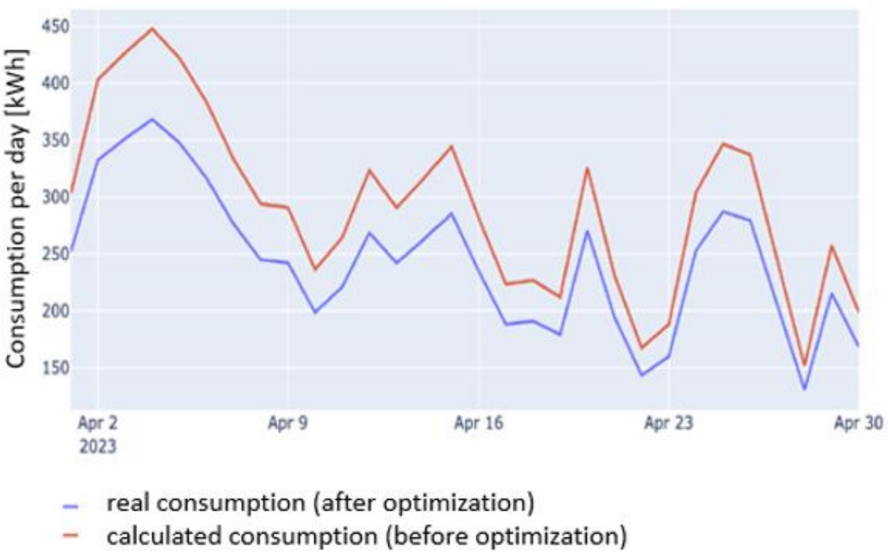

Figure 10. Calculated vs real consumption in April 2023

Finally, another goal is to increase the self-consumption, by combining an energy storage with a PV plant to use the energy within the building grid (L4-7). This will be monitored by the amount of energy produced by the PV plant, the amount of energy stored, and the increase of the self-consumption through the energy storage.

The Leipzig West district is also working to increase the self-consumption of renewable energy. They have installed a PV plant with a capacity of 30 kWp and a storage with 12 kWh capacity. This has allowed them to increase the self-consumption rate to almost 100%, which means that the energy produced by the PV plant is used within the building grid. This has resulted in CO2 neutral energy use and cost savings for the tenants. In total,

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there are 3 PV plants installed in the district, which will produce around 69,000 kWh per year. This means a total CO2 saving of 29 tonnes.

In the table below, all KPIs defined for this intervention / district are presented, accompanied with the needed datasets to calculate them and their respective baseline values. The target, the actual value and the difference between baseline and the reporting period value are presented as well.

Table 42. L4 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Reduction of thermal Energy consumption in the district (MWh/year)	1290	1161	1118	4%
Reduction of thermal Energy consumption in the district climate adjusted (MWh/year)	1450	1305	1125	14%
Reduction of CO2 emission (due to thermal reduction) in the district -thermal energy (tonnes)	268	241	210	13%
Real self-consumption rate in buildings -electricity (kWh/year)	0%	20%	100%	80%
Virtual self-consumption rate of district- electricity (kWh/year)	0%	20%	100%	80%
Reduction of CO2 emission (due to self-consumption) in the district -thermal energy (tonnes)	0	25	29	16%

Intervention L5- Human-Centric Energy Management and Control Decision

In this intervention, the same testbed is utilised, consisting of the 27 apartments designated in intervention L4. The data that for the calculation of the KPIs (Table 43) is collected via the streaming mechanism is used for the definition activities of accurate comfort profiles, to be able to identify context-aware thermal demand patterns, as described in action L5.1. Analysing the collected parameters, such as the energy behaviour patterns and the calculated comfort preferences, targeted guidance on control actions is provided to the building tenants as presented in L5.2, to manually perform shedding or shifting operations of their thermal loads. This functionality is offered via the SPARCS Application user-interface.

Taking under consideration the created comfort profiles of the tenants, the main goal of this intervention is to reduce the thermal energy total and peak demand of the building, while increasing the available flexibility and its utilisation. In the table below, the defined KPIS in D2.2 are listed, offering the baseline value of the total thermal demand of the apartments, namely the value 75.5 MWh. For the rest of the KPIs, values captured in the

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first reporting period will serve as the basis for evaluating the progress in the updated versions of this report. The Consumption reduction is about 25% to 60 MWh per year.

Facing the same conditions presented in L4, at the time of writing this deliverable, the effect of the SPARCS application on the reported values above cannot be assessed, since the installation of the application from the apartment tenants did not start yet. With the plan to engage the building tenants to install the SPARCS application during the next period, updated values of the KPIs presented above are expected, that will be captured and reported in the updated version of this deliverable.

Table 43. L5 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total thermal energy consumption reduction (MWh)	75	67.5	60	13%
Peak Load Reduction	n/a	10%	n/a	n/a

Facing the same conditions presented in L4, at the time of writing this deliverable, the effect of the SPARCS application on the reported values above cannot be assessed, since the installation of the application from the apartment tenants did not start yet. With the plan to engage the building tenants to install the SPARCS application during the next period, updated values of the KPIs presented above are expected, that will be captured and reported in the updated version of this deliverable.

Intervention L9- Integration of RES

The SPARCS virtual power plant in Leipzig, has been advancing during the 2nd monitoring period (March 2023 - August 2023), with various KPIs serving as benchmarks(Table 44). The generation of renewable electricity, primarily through photovoltaics has been increasing. The targeted capacity of 3070 kWp was exceeded through a finished installation of 3391 kWp. A final target of annually 2565 MWh generation has been set, and during this monitoring period, 3128 MWh has been generated. In the area of self-consumption from photovoltaic (PV) sources, the target was set at 30 MWh. The measurement for the 2nd monitoring period is 37 MWh, with this consumption predominantly by the WSL apartment houses.

One of the strategies of the virtual power plant is the optimisation of LSW heating stations. The process involves identifying stations and either replacing old ones with new ones or applying machine learning algorithms to locally optimise their operation. The aim is to optimise 400 heating stations, and 209 have been addressed so far. An aim to prevent the generation of 2500 kWh has been set, and a reduction of 2100 kWh has been achieved so far. The heating efficiency, measured by the load factor, currently stands at 65%, with the end goal being 70%.

In terms of digital infrastructure, six platforms are being utilised, surpassing the envisioned number of five. These platforms include both back-end infrastructure as well as user platforms. One instance is the Leipzig Digital Platform, which runs on Kubernetes and provides an environment for applications and services for both energy and e-mobility

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sectors. An instance for the latter is the VPP dashboard, a tool for utility operators to display and control assets, but also the smartphone apps (e.g., LeipzigZero App) running on the servers of LSW.

The virtual power plant has also surpassed its intended number of assets and devices. Currently, 7000 assets are in use, exceeding the envisioned number of 6000. These assets encompass a wide range of devices, including smart plugs, charging points, heat meters, electricity meters, PV panels, heating stations, L-Boxes, and cogeneration plants.

Table 44 L9 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Renewable electricity generation capacity (kW peak)	1927	3070	3391	10%
Annual renewable electricity generation (MWh)	1412	2565	3128	22%
Self-consumption PV (MWh)	30	68	102	50%
Number of heating stations in which inefficiencies were identified and optimised by VPP	0	400	209	47%
Reduced energy generation due to VPP heating station optimisation (kWh per month)	0	2500	2100	16%
Thermal efficiency in district (System Efficiency Ratio, %)	60%	70%	65%	5%
Number of digital platforms used	0	5	6	20%
Number of assets and devices in virtual power plant	500	6000	7000	16%
Virtual flexibility provided by Microgrid Trade (avg kWh per month)	0	2000	2500	20%
Virtual flexibility capacity provided by smart plugs (W)	0	1000	204	79%
Virtual flexibility provided by battery storage farm (MWh)	0	600	623	4%

Virtual flexibility is major aspect of the virtual power plant. It has been facilitating virtual Microgrid trade between LSW and the Cenero Microgrid at Baumwollspinnerei, with an average of 2500 kWh per month, which has exceeded the objective of 2000 kWh. The virtual flexibility capacity provided by smart plugs currently stands at 204 W, with the aim of reaching 1000 W. The battery storage farm, positioned at the BMW production site in Leipzig, has provided 623 MWh of virtual flexibility, which is in line with the goal of 600 MWh.

Intervention L10- LoRaWAN network

LSW aims to install 20 city sensors, utilizing both LoRaWAN and other transmission systems (Table 45). The use of LoRaWAN technology allows for the efficient connection of sensors and devices across districts, even in areas such as cellars, with minimal antennas.

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This enables the integration of various additional use cases, such as car parking spot sensors and intelligent waste disposal, throughout the demonstration district.

During the second monitoring period, 14 city sensors were active, showcasing the progress in deploying the sensor network. The ongoing efforts aim to expand the coverage and functionality of the smart city infrastructure, leveraging the flexibility and wide coverage provided by the LoRaWAN technology.

Table 45. L10 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of actively transmitting city sensors	0	20	14	30%

Intervention L11- Establishment of a distributed cloud-centric ICT System which enables an intelligent energy management system.

LeipzigZero is a smart plug prototype that focuses on IoT smart homes, demand response, and gamification incentives. It aims to incentivise users to change their electricity consumption behaviour through inquiries. The project plans to install 1000 smart plugs in 333 Leipzig apartments and send 20 inquiries per month (Table 46). By the second monitoring period, they had achieved 15 monthly inquiries and deployed 160 smart plugs. LeipzigZero combines smart technology and incentives to promote sustainability and energy efficiency.

Table 46. L11 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of smart plugs	0	1000	160	84%
Number of inquiries for smart plugs	0	20	17	15%

Intervention L12- Implementation of a human-centric interface/application

The Leipzig Virtual Energy Community consists of an additional testbed that includes 27 apartments in Leipzig West, as presented in interventions L4 and L5. Having real time electricity consumption measurements for each one of the apartments, the SPARCS App offers to the apartment tenants the capability to monitor and control their individual energy consumption, gaining a better understanding of the impact of everyday activities and behaviour on the building energy performance status.

In the list of KPIs (Table 47), as defined on deliverable D2.2, the focus is on the reduction of the total and per apartment energy demand, as well as the reduction of the peak load, displayed in the table below. The expected total electricity demand baseline is set to 40,5 MWh, while the measurements per apartment that will be captured by the individual smart meters, will allow for baselining the rest of the KPIs.

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Table 47. L12 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total energy demand reduction- electricity (MWh)	40,5	36	n/a	n/a
Energy demand reduction per apartment	n/a	10%	n/a	n/a
Peak Load Reduction	n/a	10%	n/a	n/a

To be able to capture the impact that the SPARCS application has on the listed KPIs, the installation of electricity smart meters is required, to deliver the necessary data to the application and enable the related functionalities described in this intervention. Without this precondition in place, the effect of the SPARCS application on the reported values above cannot be assessed. With a clear plan in place to perform the necessary installation of the electricity smart meters during the next period, accompanied with the plan to engage the building tenants to install the SPARCS application, updated values of the KPIs presented above are expected, that will be captured and reported in the updated version of this deliverable.

Intervention L13- Visual metaphors and constructs/ dashboards for energy footprint analysis

Complementing the activities of intervention L12, this intervention utilises the same environment to demonstrate the creation of Energy Behavioural Profiles, allowing through the utilisation of the application for self-evaluation and normative comparisons of energy behavioural patterns. Via comparison of normalised energy performance information against peer top-performing consumers with similar characteristics, energy savings, cost savings and CO_2 emission reduction are the main targets. With the same targets as in L12, identical KPIs and baselining data are defined and presented in Table 47.

Intervention L14- Commissioning on specific energy savings targets

Concluding the functionalities of the application as described in interventions L12 and L13, the target of this intervention is to maximise energy savings at the community level, by triggering individual consumers to achieve specific energy savings over specific timeframes. With the utilisation of a Social Engagement Loop, further engagement, and involvement of consumers in energy saving actions is established. Sharing identical KPIs with L12 and L13, the datasets needed, and the corresponding baselining data defined and presented in Table 47.

Intervention L15- E-bus charging

Leipzig is transforming bus lines 89/74/76 to e-buses, contributing to sustainable transportation. With 38 electric buses out of a total of 181 vehicles, the local transportation system has a 20% share of EVs at the time of the second monitoring period.

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Table 48. L15intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total number of vehicles in local transportation	164	181	170	6%
Electric vehicles in local transportation	1	38	37	3%
Share of EV in local transportation	0.1%	21%	22%	1%
Number of E-Bus charging stations	2	46	51	11%

Additionally, there are 51 charging stations dedicated to e-buses. The central bus garage at "Lindenauer Bushof" was modernised with a central charging system, enabling load shifting and better integration of renewable energy sources into the grid. Table 48 presents the KPIs for this intervention.

Intervention L16- Load-balanced fleet management

This intervention demonstrates load-balanced fleet management and charging based upon user specific inputs to the platform defining their flexibility. This includes the positioning of additional charging points (38 before project start, amounting to 85000 kWh) on the city surface. At the time of the second monitoring period, 455 charging stations are active, amounting to a net utilisation of 1.800 MWh. Additionally, LSW integrates 50 fleet-based electric vehicles in an instantly available load-shifting program. All these measurements are compiled in Table 49 below.

Table 49. L16 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of smart EV charging points	38	400	455	13%
Utilisation of EV charging stations (MWh)	85000	2000	1800	10%
Number of EVs in fleet management	0	50	50	0%

Intervention L17- Blockchain supported energy services

Blockchain technology helps to tackle the core challenge when it comes to energy distribution: the integration of millions of small-scale distributed energy resources in an energy system that is currently not designed for having a large amount of individual market participants. Focus of the demonstration activity is therefore on the conceptualisation and application of a public blockchain for transactions between energy consumers, producers, service providers and grid system operators in a microgrid.

Note: L17 provides no new monitoring data as the developed blockchain use cases remained in prototype state due to regulatory barriers.

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Intervention L18- Integration of Community Energy Storage (CES) and Community Demand Response (CDR)

This subtask projects the rational behaviour of the energy community when providing system flexibility. The reliable integration of the "community energy storage" (CES) and "community demand response" (CDR) based on assets of the virtual power plant (see L9) represent possible business cases for a successful system transformation at the municipal level. The evaluation is done by a modelling approach that also sets the target levels for the economic potential given the future roll-out of technical interventions. In addition, the behaviour of participants is measured with data from Smart Plugs.

The roll-out of the Smart Plugs (formerly: green sockets) as a means of accessing flexibility of household customers is still in progress, as can be derived from intervention L11. Therefore, the monitoring data regarding the households that will be a part of the CDR is not yet available. The modelling exercise is based on the toolbox IRPopt, which is applied to generate data based on realistic assumptions regarding the total residential load and load shifting parameters for the model year 2025.

The optimal customer behaviour is determined as reaction to flexible electricity tariffs. In addition, the customer-oriented CDR is evaluated in combination with a Virtual Power Plant (VPP) to show its impact on the design of positive energy districts (PED). The research question is divided into three parts, which illustrate the technical, economic, and environmental aspects of the potential of residential demand response. Regarding the methodology, a techno-economic energy system model is proposed that optimises both, the customer cost and the utility's margin. Three scenarios – namely "Reference", "Reluctance" and "Acceptance" were considered in total. Additionally, for each scenario four tariffs (FT, HD, VPP(TOU) and VPP(HD)) and three sensitivities (no RE curtailment, increased battery capacity and increased RE capacity) were modelled. The results presented in the KPIs "Total flexibility available increase" and "Flexibility increase (%) of normal load in kW" (see Table 51) focus on a flexible tariff that is designed to optimally support the generation-demand-ratio of the VPP at all timesteps (VPP(TOU)) and therewith provide a service for the VPP. The technical parameters for the 1000 households (hh) in 2025 under moderate assumptions are presented in Table 50 below.

Table 50. Technical parameters for households

Shifting parameters	Residential customer group 1 (900 hh)	Residential customer group 2 (100 hh)
Total load	2250 MWh	650 MWh
Load shift potential	10 %	35 %
Load shift horizon	1.5 h	1.5 h

Even though realistic data was used for parameters in the model, it must be noted, that the access to household flexibility is still far from a real case based on the Smart Plugs. Some reasons for this are mentioned in the following. We assumed, that large portions (>= 10%) of the total load of households can be shifted using CDR-measures (see Table 50). However, through the application of the Smart Plugs few household appliances (most likely with a relatively low power level), can be integrated into the LSWs Zero app. Larger

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electrical appliances may not work due to a lack of technical maturity (fridge, washing machine, etc.). Moreover, time variable electricity tariffs are available in the model that can be used by customers to minimise cost. However, the current mode of remuneration planned by LSW is made up of collecting points for a voucher program when switching on/off at distinct points in time. Consequently, the results generated with IRPopt and shown in Table 51 as target values must be viewed carefully and under consideration of the boundary conditions. They may be considered as a maximum technical potential of a Demand Response scheme, which can be accessed by innovative business models of LSW.

Increase of integrated systems share: this number used to indicate the amount of Smart Plugs distributed among Leipzig citizens. In the frame of the model computations, it denotes the number of entire households that were considered instead. Total flexibility available increase: The additional flexibility gained through the distribution of Smart Plugs. In terms of the model-based calculation, it is the maximal power that could have theoretically been shifted by all 1000 households in total under the conditions of table 50. The baseline is zero, as we assume no flexibility was present beforehand.

Table 51. L18 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total flexibility available increase	0	117	0	100%
Flexibility increase (%) of normal load in kW	0	15.6	0	100%
Number of models runs via the modelling framework IRPopt	0	20	36	80%
Number of scenarios evaluated	0	3	3	0%

Intervention L19- Integrating energy and building data into the Urban Data Platform

Table 52. L19 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of energy and building datasets for creating district refurbishment concepts integrated in the Urban Data Platform	8	10	12	20%
How much has the project benefitted from, contributed to, and follows the strategic documents of the city?	2	4	4	0%
How many city units have been involved in planning?	8	10	10	0%

L19 integrates energy and building data from SPARCS demo districts into the Urban Data Platform of the City of Leipzig, to allow for improved, data-based district and building planning. The related KPIs are presented in Table 52.

For the planning needs, energy and building data sets have been identified from various data owners such as on municipal, regional, and federal level. The quality of data sets has

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been assessed, and they have been brought into one platform. Currently the Leipzig team is investigating with workshops how these should be designed to be meaningful for energy planning of various stakeholders. Besides the City of Leipzig determines what is needed to integrate data into the urban data platform (data formats, API's, etc.).

Intervention L20- Standard model for smart cities

In L20, the city of Leipzig assesses a standard model for climate just district development - to be applied to further energetic refurbishment districts. In collaboration with partners, stakeholders and responsible city departments, this started with assessing what needs to be improved in the process when improving districts energetically. Smart city solutions are also considered. Currently the focus is on making data easily available in an Urban Data Platform (UDP), on providing a visual overview, and a standard content manual. Findings from actions T4.2, T4.3 and T4.4 are carefully reviewed to determine a standard approach for integrating relevant energy-related district and building data. The second KPI measures cooperation and how much effort is the project putting into creating support. Both KPIs are presented in Table 53.

Table 53. L20 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of relevant check lists or maps available	1	3	2	30%
Number of Workshops with city units	n/a	5	5	0%

Intervention L21- Community empowerment support activities through dialogues, transferring ownership, knowledge transfer

L21 will establish an Energy Advisor to provide support and information to residents on energy efficiency and the transformation of privately owned buildings, cost-effective installation of renewable energy sources, participation in the Positive Energy Community, and developing daily habits to reduce energy consumption. Table 54 presents the KPIs for this intervention.

To facilitate dialogue with citizens in the urban context, at least four workshops per year are planned in the model district. To reach the residents of social housing in the Duncker neighbourhood, various approaches of co-involvement were employed: informing, raising awareness, and involving the community. During the second reporting period, the events included a focus on presenting several times the SPARCS-App directly at the residences of the buildings in Beckerstrasse 52-56. The SPARCS-App is one of the two technological solutions developed by SPARCS to engage communities and individuals in energy-saving behaviours and data collection.

In the second reporting period was implemented SPARCS-Fete, a collaborative effort between all project partners in Leipzig to engage families and residents of the neighbourhood, with a specific focus on promoting the event to the inhabitants of Beckerstrasse, the target group for the SPARCS-App. The event aimed to intensify cooperation with LWB Social Management employees and establish the neighbourhood meeting as a well-known and popular gathering place.

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Table 54. L21 intervention KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Number of workshops, information and co-creation activities conducted	n/a	15	16	6%
Flyers distributed door-to-door in the neighbourhood	n/a	1000	1256	25%
Participants (on average per event)	n/a	50	26	48%
How many people have utilised the contact information provided on the flyer for desk support after the event, by asking questions or providing suggestions and comments?	n/a	25	2	92%

Additionally, cooperation with Caritas was established to organize regular "Energy Consultations." For each marketing action, personal contact information was provided on every flyer and poster, enabling individuals to seek further information or ask questions about the topics communicated while in parallel SPARCS-App was promoted.

Additionally, a local socio-psychological study is being carried out by the psychology department of the University of Leipzig, amongst other things to evaluate the effects of the implemented measures; the related KPIs are presented in Table 55.

Table 55. ULEI study KPIs

KPIs	Baseline	Target	2nd reporting period	Difference
Longitudinal socio-psychological evaluation study	0	3	2	33%

Monitoring via research program; results of research program will be presented via report; inference-statistical analysis and therefore robust conclusions are potentially limited due to low participation of residents in survey questionnaire waves.

The focus of our monitoring and impact assessment refers to the number of people involved, and the number of events realised as well as on the number of partners involved and networking that will be able to be replicated in the future. In 2022 the number of live events increased considerably compared to the Lockdowns years (2020-2021). In parallel with the development of new technical solutions we expect to be able to reach more people in 2023. The events in 2022 included among others the presentation of the LWB-App and the SPARCS-App, which are two of the key technological solutions to engage communities and individuals in energy saving behaviours and data collection. This shows that the challenges of the Covid-time were overcome and did not have any adverse impacts on the project. Seecon is now in the process of planning all its events for 2023, in accordance with its responsibilities. The events are tailored to the current context of Leipzig and will for example provide opportunities for residents in the Dunckerviertel to

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further engage with the SPARCS App as well as for children in the neighbourhood to learn about challenges like climate change that SPARCS is seeking solutions to.

In the monitored period we have achieved good results in terms of the number of live events organised, the increased participation and the increased networking connections. Family with children walked by. Interested citizens have given input and asked questions at, for instance, the DIPAS-table or at the Ökofete-booth. We have informed families about the possibilities of the developed Apps and gathered people with concrete topics of energy savings tips.

The development of good and strong networking was vital to us to increase the involvement of more people. In 2023, we plan to further enhance this cooperation. We however noticed that to involve citizens in the Duncker Quarter, it was very important to offer tangible activities as well as eyecatchers (Drawing Competition, Coffee & Cakes, DIPAS-Tisch, i.e.). beside that it was sometimes very difficult to find a concrete and appealing topic that got people involved at the right day on the right time. Moreover, as our target group are families, elderly people, refugees, and asylum seekers, it is difficult to involve them in the use of the Apps and modern technical solutions.

In general, it is difficult to give a quantitative evaluation with respect to the number of people we would expect at an event or with respect to the number of people most informed after a certain event. Regarding to this, in the first survey in August 2021, the University of Leipzig asked a question that read: "Would you participate in events on the SPARCS project? The question was answered by 55 people. Of these, 25 ticked 1 on a scale of 1 (definitely no) to 7 (definitely yes).

4.2 City level - aggregated assessment

Leipzig has a long history of population growth and decline. After a period of decline during and after the GDR, the city's population has been growing since 2000. This growth is still ongoing, but it has slowed down since the COVID-19 pandemic.

The growth in population has a significant impact on energy consumption. As the city grows, more homes and businesses are built, which requires more energy to heat and power. In addition, the growing population means more people are driving cars, which also increases energy consumption. The indicators are used to assess the impact of the SPARCS demo district measures on the city. However, it is difficult to isolate the effects of SPARCS from other factors, such as the overall growth of the city.

As presented in Table 56, energy consumption data is only available with a 2–3 year delay. This is because the data from energy providers must go through an internal audit before being published. The city of Leipzig then calculates its energy balances based on this data, and these balances are published later. The next balances are expected in summer 2024.

The reason why the city of Leipzig is not able to set a target for electricity consumption is because it is difficult to predict how the economy and population will develop in the future. The city also needs to make assumptions about the chosen energy transition technologies, their energy consumptions, and their roll-out speeds. This is a complex task that requires a lot of resources, and the city does not have the resources to do it currently. However, the city has set a target of climate neutrality by 2040. This means that the city aims to reduce its greenhouse gas emissions by 95% by 2040. The city is also participating

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in the EU programme 100 climate neutral and smart cities by 2030, which has a target of climate neutrality by 2030.

Table 56. Leipzig city-level, general energy KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total Heating Demand (MWh/a)	5.491.900	Reduction of 19% by 2030	Energy balance data earliest available with 2-3 years delay	n/a
Net installed renewable electricity (MWp)	103.33	135.12	146.53	8%
Net installed renewable heat (MWp)	0	To cover demand	0	n/a

The city of Leipzig is committed to reducing its energy consumption and greenhouse gas emissions. However, it is important to be realistic about what can be achieved in the short term. The city is working to develop its energy transition strategies, and it will continue to monitor its energy consumption and emissions. To monitor the development of renewable energies in the city, data from the official registry are given (Table 57). All renewables installed in the city since the start of the project period, limited to the municipal area, are provided.

Table 57. Leipzig city-level, specific energy indicators

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Electricity peak load (MW) on a day of the year	212	Less than grid capacity	226	0%
Heat peak load (MW)	878	Less than grid capacity	962	0%

While the air quality (Table 58is improved by the use of electric buses within the district area the renewable heat is related to district heating and thus the benefit of RES is not noticeable in district. This means that the air quality improvement is happening at the generation source, not at the Leipzig West where the air quality measurement station is installed. Improvements on air quality are also due to other trends, such as general improvements in combustion standards.

Table 58. Leipzig city-level, air quality indicators

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
O3 (µg/m^3 yearly average)	51	40	53	33%
NOx (µg/m^3 yearly average)	53	40	11	72%
Small particulates (pm10) (µg/m^3 yearly average)	41	23	13	48%

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While, some indicators are meeting their targets, one is not. This is because the air quality improvement is not being measured at the Leipzig West air quality measurement station. The station is in a residential area, and it is not representative of the city.

Not all the traffic indicators (Table 59) are impacted by SPARCS measures. The number of electric vehicles in public transport, and the number of smart charging points is influenced by SPARCS. Also, V2G charging was demonstrated in SPARCS and can be rolled out as soon as more compatible electric vehicles and compatible charging stations are available.

For electric vehicles (EVs) available for sharing, no statistical data were available for Leipzig, as sharing cars are mostly not registered in Leipzig. Therefore, the indicator is replaced by the number of EVs available for sharing at LSW, LAS & Netz. The latter counts all personal and light duty vehicles available for several people (excluding personal company EVs).

Table 59. Leipzig city-level, transportation KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Total number of motor vehicles registered in Leipzig	268 059	Decrease	271 218	7%
Number of shared EVs (increase)	20	40	41	5%
Total number of e-vehicles in local public transportation	434	n/a	n/a	n/a
Electric busses	0	20	38	90%
Bicycles counted past 12 months at counting stations	6 991 905	7 500 000	7 955 489	6%
Share of citizens using a personal vehicle (non-EV) for going to work (%)	43	decrease	46	7%
Share of citizens using public transport for going to work (%)	26	increase	21	20
Public or semi-public charging points	369	750	831	11%
Smart charging points	38	200	454	127%
Bidirectional charging points (V2G)	0	increase	1	0%

In this monitoring period, there was no update on the number of jobs created by SPARCS (Table 60). This is because the data is only available on a yearly basis. However, the target was set based on the assumption that there would be more replication districts, which would have created more jobs.

Table 60.Leipzig city-level, economic KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Jobs created by SPARCS	0	270	84	68%
Life expectancy as proxy for life quality	81	81	81	0%

The improvement of citizens' quality of life, health, and wellbeing is difficult to measure. Life expectancy is a good indicator for quality of life, health, and wellbeing, but it does not

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vary at the SPARCS time and regional scale. Life expectancy is stable in the SPARCS districts.

4.3 Partner level – Financial assessment

City of Leipzig

The municipality did not invest in energy assets itself, but rather through public utilities that are partners in the SPARCS project. The money spent by the municipality was on personnel and project management costs. The money spent without EU contribution reflects the money spent on SPARCS-related measures within the city, as reflected in the database of the European Energy Award.

On the city level, financial KPIs refer to all measures related to smart and climate-neutral city improvements that have a relationship to SPARCS measures, as tracked in the European Energy Award tool. However, no updates have been made to the database since then. The database only lists investments up to 2020. Investments from 2021-22 could not be tracked because there is no municipal database available yet. As mentioned, the city of Leipzig did not intend to generate revenue from the measures carried out. The work within SPARCS is better considered as provisional planning, mitigating, and adapting to climate change and the current energy crisis. Cost savings will occur through improved city planning due to streamlined processes. In addition, faster analysis of districts thanks to the data in the urban data platform will also create cost savings. As a result, more time can be dedicated to developing measures.

Cenero

While the environmental and social benefits of sustainable energy projects are evident, it is equally important to evaluate their financial viability and performance. As technical partners of the SPARCS project, CENERO implemented various innovative measures to promote sustainability at the Baumwollspinnerei in Leipzig. Among these are e-mobility measures, microgrid measures, intelligent heating solutions and decentralised energy production and storage solutions. Financial KPIs serve as essential tools for assessing the success and profitability of these innovations which plays a huge role on their replication potential by allowing stakeholders to make informed decisions, attract investors, and ensure the long-term sustainability of such ventures.

For the measures implemented at the Baumwollspinnerei, we considered the Return on Investment (ROI) and the Payback Time (Table 61). It is important to bear in mind, that as an innovative project, many of the expenses include research, initial programming, designing and testing. Many of these costs would be obsolete when replicating. In addition, the financial benefits of many of these measures are expected to be greater when rolled out in larger scale, especially in the case of bi-directional e-vehicles.

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Table 61 Cenero financial KPIs

KPIs	Baseline	Target	2nd monitoring period measurement	Distance from target
Return on Investment	0	n/a	7%	n/a
Payback Time	0	n/a	14.5 Years	n/a

After evaluating the financial aspects of CENERO measures at the Baumwollspinnerei, we found that the Return on Investment (ROI) is 7%, meeting the lower end of the target scale. However, it's important to consider that these measures are sustainable and have positive environmental impacts. Promoting such interventions is essential for a sustainable future, leading to lower costs and improved performance.

To achieve cost-effectiveness, testing innovative solutions on a small scale to identify risks and optimise them is crucial before replicating them on a larger scale. Many interventions at the Spinnerei focus on peak shaving, consumption reduction, and energy savings, especially with the microgrid concept using bidirectional EVs, storage, and PV plants. Scaling up the bidirectional EV fleet and renewable energy sources can enhance energy efficiency and cost savings.

Regarding the intelligent heat demand control intervention, the financial results were influenced by the approach of hardware purchasing rather than renting or selling. Replicating this concept with hardware sales at other sites showed considerably better financial KPIs. The replicability of projects is enhanced by transferable programming, which reduces costs and improves ROI and Payback Time. However, project timeframes are crucial, and external factors like the pandemic and political unrest can impact supply chain, hardware prices, delivery costs, and energy costs, making future cost predictions uncertain. As Baumwollspinnerei is privately owned, installing energy-efficient and sustainable measures improves the property's value and rental conditions, aligning with the increasing importance and requirements of sustainability measures for property investment companies.

In summary, the interventions at Baumwollspinnerei are beneficial or even required in some cases, irrespective of their financial feasibility, due to their positive impact on sustainability and property value.

LSW

In the pursuit of sustainable energy solutions and innovative technologies, LSW has undertaken a series of diverse initiatives within the scope of SPARCS aimed at enhancing energy management, optimizing resource utilisation, and driving new revenue streams.

The initial investments for these use cases range from 150,000 to 5,000,000 Euros. The funding sources are a combination of in-house investment, private sector investment, and European Union funding. The expected payback periods for these projects range from 5 to 10 years.

The revenue streams for these use cases are centred around data aggregation for energy management, value-added services offered on top of the sensor framework, remote monitoring and control of plants, energy flexibility and the avoidance of grid congestion,

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energy trading and reselling with local partners, and the establishment of green electricity contracts and citizen participation.

Table 62 summarises the key financial information for each use case.

Table 62 LSW financial KPIs

Use Case	Initial Investment (€)	Funding Sources	ROI Period (years)	Revenue Streams
Virtual Power Plant	150,000-300,000	In-house (75%), non-municipal public (25%)	5-10	Data aggregation for energy management
City Sensors and LoRaWAN	<40,000	Private sector (70%), European Union (30%)	5-10	Value-added services offered on top of the sensor framework
L-Box	500,000-1,000,000	Private sector (95%), municipal (5%)	5-10	Remote monitoring and control of plants
Blockchain Prototype for Local Energy Transactions	<30,000	Private sector (75%), European Union (25%)	n/a	Uncertain
Load-balancing Fleet Management	1,000,000-5,000,000	Private sector (99%), European Union (1%)	5-10	Energy flexibility and the avoidance of grid congestion
Baumwollspinnerei Microgrid Simulation	<50,000	In-house (95%), European Union (5%)	<5	Energy trading and reselling with local partners
L-Zero	50,000-250,000	Non-municipal public	5-10	Green electricity contracts and citizen participation

SEECON

SEECON has actively contributed to the community support for energy transformation in the district. To achieve these goals, EU contributions have been integral in providing funding for personnel, communication, and dissemination, renting the venue, conducting marketing activities, and purchasing giveaways for promotional purposes. EU contributions also supported the organisation of events and specific activities like film screenings sessions. The EU contribution has also provided means for travel and networking.

A cost-benefit analysis compares the costs of implementing the smart city interventions to the benefits they provide. The costs include the initial investment cost and ongoing maintenance costs, while the benefits include financial benefits such as cost savings and revenue generation, as well as non-financial benefits such as improved quality of life and environmental sustainability. The analysis weighs the costs against the benefits to determine if the smart city intervention is financially viable.

In our case, it is possible to affirm that we have contributed to social benefits in terms of social inclusion, citizen engagement, and the diffusion of sustainable practices. More generally, the long-term effects of SPARCS activities will lead to environmental benefits in

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terms of decreased energy consumption, reduced greenhouse gas emissions, and a decrease in external costs associated with the use of traditional energy sources. Citizen engagement does not have visible social and environmental costs, but we should consider the potential risks involved, such as the non-acceptance of the proposed offers. There is a possibility of investing money and resources without receiving positive feedback or the necessary participation.

A potential surplus of our activities could be the involvement of external local partners during local activities, who can offer regional products and derive profits from them. In this case, external benefits would be produced. Similarly, offering proposals that can save money for citizens is important. For instance, introducing initiatives like tenant electricity (Mieterstrom) or our consultant model, which can provide cost-saving opportunities for residents.

4.4 Conclusions and lessons learnt in Leipzig

Figure 11 depicts the intervention's KPIs achieved impact. he KPIs that exceeded expectations reached 35% of the overall KPIs, which is a significant sign that the intervention is having a very positive impact.

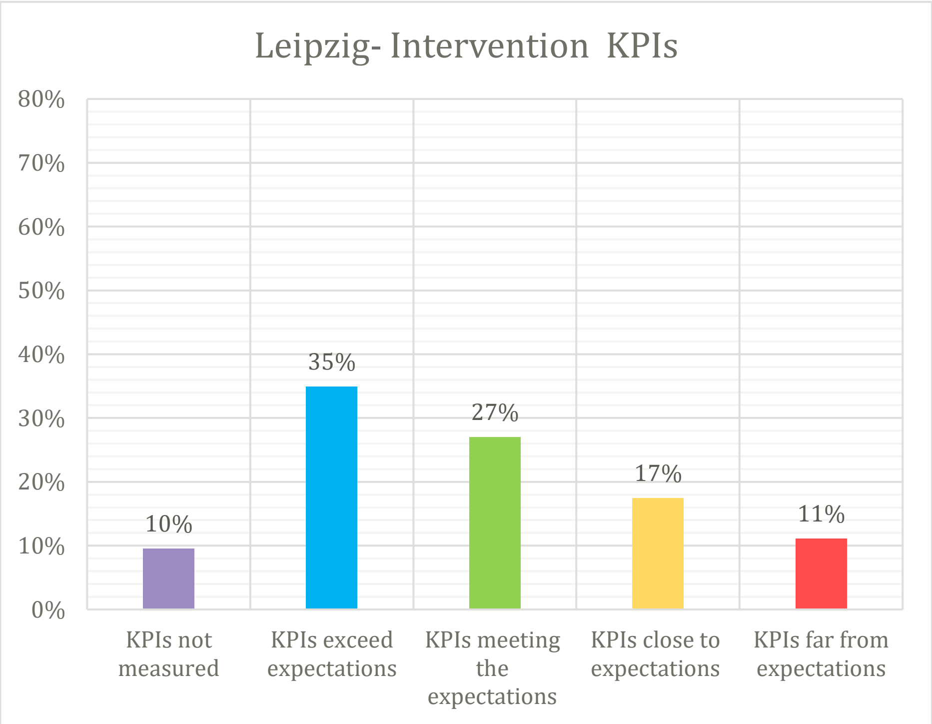

Figure 11. Overview of interventions impact assessment- Leipzig

Additionally, 27% of the KPIs met the set targets, which is also a positive sign as it shows that the intervention reached the planned targets. These results suggest that the sustainable interventions are effective in achieving their goals and making a positive impact. Based on the information provided, it appears that the rest sustainable interventions are making progress towards achieving their goals, with 17% of the KPIs being close to the set targets. This suggests that the interventions are on track to achieve their objectives by the end of the project. However, more effort will be required to achieve

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the remaining KPIs that are not as close to the targets, which make up 11% of the overall KPIs. Additionally, there were technical reasons for the non-achievement of some KPIs, as explained in the related interventions resulting 10% of non-measured KPIs.

Similarly, on the city KPIs results presented in Figure 12, it can be concluded that there is room for improvement in terms of measuring and achieving certain performance indicators. 38% of the KPIs exceeded expectations, 29% met their defined targets, and 10% came very close.

. However, 19% of the KPIs couldn't be evaluated due to insufficient data. Furthermore, 5% of the KPIs fell short of reaching their set targets, highlighting areas that require additional attention to achieve desired outcomes.

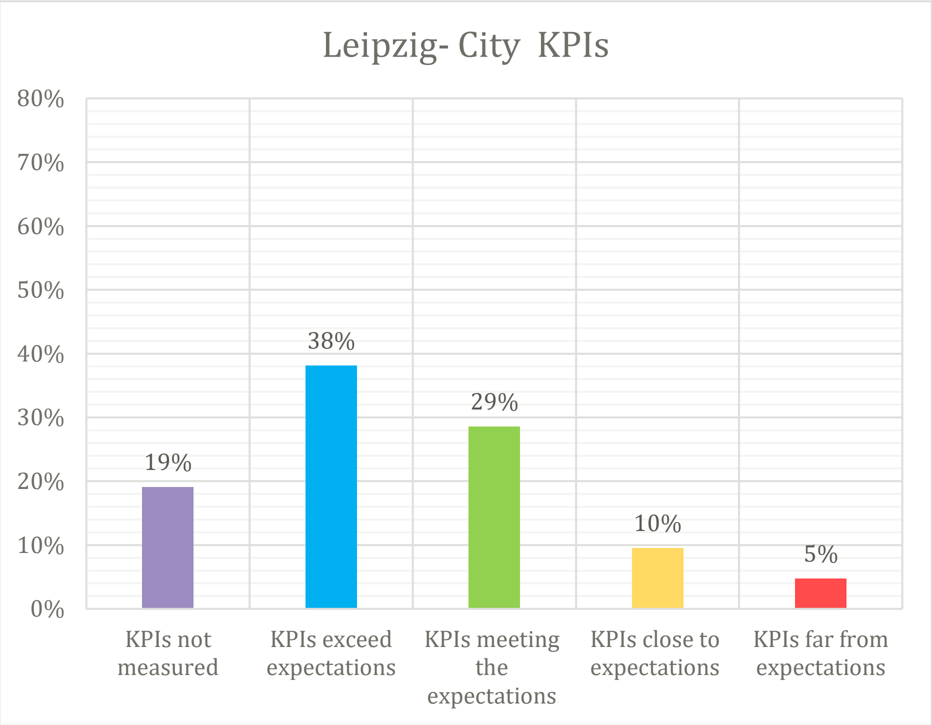

Figure 12. Overview of city-wide KPIs impact assessment- Leipzig

In summary, the current monitoring period has demonstrated a mix of successes and challenges in the implementation of the sustainable interventions. Most KPIs have shown successful implementation of interventions but still there are some challenges to address to improve results in the rest KPIs during the upcoming period.

Lessons learned during impact monitoring in Leipzig

Baumwollspinnerei District

Regarding the demo district Baumwollspinnerei (Spinnerei), the task leaders conclude that the importance of identifying an ideal site for the roll-out of the project deliverables should not be underestimated. All relevant parameters of the site and its surroundings must be considered. Factors such as heritage protection laws and certain protected plants,

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animals and their habitats can strongly influence the introduction of new infrastructure or equipment.

The existing infrastructure of the site and surrounding area should be thoroughly investigated to ensure that there are no operational constraints and to be aware of any limitations. At the same time, it is important to carry out such projects at sites that have comparable challenges to other common sites, so that the lessons learned here facilitate replication elsewhere. A balance must be found to maximise the impact of the project, not only during the project, but also in scalable real-life settings.

In most cases, external stakeholders must be involved to some degree. These can sometimes be unreliable and volatile, causing a ripple effect of delays. It is therefore important to inform all external stakeholders early on about the project schedule and the importance of adhering to it from the get-go.

During the onboarding phase of the project, when the KPIs are defined, it is important to consider an outsider's perspective on the KPIs. The KPIs should be clear, concise, and easy to interpret. It should be easy to draw meaningful conclusions from the data used to calculate the KPIs. They should be defined and presented in a way that is useful and insightful to the external audience, who often have little or no background information and are sometimes unwilling to read voluminous reports. If the interventions are successful, this will ensure a higher potential for replication and generate more interest among citizens, other projects, cities, and companies.

Effective documentation processes and well-organised structures play a crucial role. Ensuring each step, decision, agreement, and even minor amendment is accurately recorded and systematically archived holds significant importance. In projects of extensive duration and scope, staff transitions are bound to occur. Aspects that were settled and agreed upon during the project's initial phases might regain relevance in its concluding stages and thus need to be easily located. Hence, it is equally important to consistently document verbal agreements in written form.

One significant lesson we ‘ve learned revolves around the challenges posed by regulatory restrictions and the absence of consistent standards. This is particular apparent in Germany. According to Dena (*Publikationsdetailansicht – Deutsche Energie-Agentur (Dena)*, n.d.), Germany has not yet implemented the European framework for Citizen Energy Communities and Renewable Energy Communities. Navigating through various regulatory frameworks with inconsistencies has proven to be a hurdle. The lack of established norms often leads to uncertainty in decision-making and delays in implementation. The legal frameworks already in place to regulate certain activities of energy cooperatives, such as energy production or provision of energy efficiency services, are considered a good basis for further development in line with EU requirements. As we move forward, advocating for standardised guidelines and clearer regulations is crucial to fostering a more seamless and efficient progression of similar energy initiatives.

Duncker District

Regarding the Duncker district, the task leaders conclude that the challenge in the demo district, in addition to the participation of the tenants, was the selection of technical components, and the coordination of the components with the goals.

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The large number of manufacturers of meters and sensors for the large number of different cases makes uniform data use difficult. Each manufacturer has specific data protocol and transmission routines. Even with the use of the open metering standard (OMS) this is not easy, since in most cases interoperability does not work without considerable additional effort in the backend system. Changing the hardware or sensors to another manufacturer is consequently not easy to implement. Data transmission or even an application, such as the visualisation of consumption data, is therefore tailored to a special case. If the application is to be used in a different object or context, then either the basic conditions on the data acquisition side must be recreated exactly as they were in the original, or the backend system must be extensively adapted to the new conditions.

Hence, before implementation, it is necessary to know exactly what to measure and how and whether the corresponding hardware suits the requirement. For replicating the solutions, either standards must be developed further on higher levels; or it must be considered carefully beforehand, if possible, whether and where replication will actually be possible.

Virtual District

Regarding the Virtual district, the task leaders conclude that clear communication of virtual boundaries is central. As the district was realised via a VPP, and then all connectable assets were connected, monitoring always had to take a step back from all assets integrated to the VPP to include only those parts of the SPARCS virtual community. Here, it must be noted that the virtual character makes it even more important to communicate the (virtual) boundaries with all project managers and collaborators, so that monitoring refers to the project areas.

Furthermore, digitally networked assets are a crucial prerequisite for sector coupling at the neighbourhood level. E- mobility, energy efficiency, decentralised generation, connection of decentralised systems with large centralised systems and communication with users must be addressed. The first step to sector coupling is data collection and processing. For this, digital infrastructure is needed in every house that participates to the virtual district. A prerequisite for setting up supply models, visualizing data and operating energy management systems is that it collects consumption data and includes a control channel.

Building such a VPP practically is challenging. Cooperation between interests on the city level and the municipal companies, such as municipal utilities, as well as other companies representing economic interests is difficult due to partially diverging interests. Establishing data pipelines for continuous (data) communication in the Virtual Energy Quarter requires a legal and data protection basis. A VPP brings together generation data, consumption data and network data. In the context of the German sector unbundling requirement, this is challenging practically, especially for integrating network data.

Regarding blockchain use for peer-to-peer trading, it must be noted that the Leipzig VPP has been subject to numerous challenges and barriers. Among conventional and known issues (e.g., standardisation of interfaces, legacy system, data access rights, limitations of throughput), the use cases involving peer-to-peer energy (P2P) trade and blockchain were of specific concern. While all these cases have been tested, the business case extension is not viable due to regulatory and legal barriers.

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Citizen's engagement

Good technical achievements have been made in SPARCS interventions, including amongst other the implementation of heat meters and establishment of data flow, the design and distribution of the MeineLWB App and the SPARCS App. However, in the case of the MeineLWB App, the target group was questionable. The focus lays on a specific block of houses in the Duncker district, which has been chosen based mostly on technical criteria. This block of houses contains social housing and is accordingly inhabited by people in socially critical situations and partly with migration history. Here, the personal focus is typically less on climate protection issues and there is not necessarily time to get to grips with new apps whose language one may not understand properly. Furthermore, for some of the tenants, the heating bills are covered by the social system, so the incentive to lower consumption is lower than in other residents. This is reflected in a low level of participation and commitment of the residents.

Ideas for corrective actions that are suggested for replications include: target criteria for the districts under consideration should be carefully considered from the outset. Thus, in addition to the technical factors that led to the selection of the district, socio-economic factors should also be considered. A concrete way of doing this could be to look at the predominant milieu in a particular neighbourhood; this is offered, for example, by the SINUS Institute. This way, milieus that are more easily engaged could be targeted. Another possibility would be a more in-depth engagement of citizens, to generate engagement for a topic such as energy monitoring after all. If one decides nevertheless for other reasons for a specific area with a special target group, the envisioned technical actions might have to be adapted, and one will have to comprise with limitations of what is reachable.

Furthermore, regarding citizen engagement in product development, it must be noted that project induced engagement in shaping and developing the technical solutions highly depends on the openness of the technical, commercial partners. Herein, the responsible persons at the technical partners are not free but depend on their company policy. Whether or not to engage "outsiders" in the development of unfinished projects depends on the respective communications policy. Collaborating in this stage therefore is sometimes not desired and hence difficult. Projects aiming at citizen engagement therefore must carefully reflect when and where citizen engagement is likely to be possible. Regarding general support for developing renewable energies in a city, projects must consider where citizens could play a role. In a city as Leipzig, where most people are tenants and not house owners (only 11% live in self-owned apartments), their capacity to be part of the energy transition by building photovoltaic plants is limited. Tenant tariffs proved to be not marketable at the current legislator state.

General observations

Generally, it can be noted that capturing the effects in some cases can be difficult with available data and resources' constraints. Constraints comprise for instance the exact definition, the capturing interval, the amount of work needed to derive or to collect data, or the delay of availability of data. Furthermore, especially in big cities, it is not always expectable that effects from demo districts will be distinguishable from normal variation at city level. In these cases, it is difficult to argue to data holders why a certain indicator should be monitored, and the data flow digitalised at a scale where no variation is

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foreseeable. This can be done for some data as test cases to lay ground for digitalised data monitoring, but not for all.

Additionally, gathering data for some KPIs in a city is difficult within project timelines, if there are considerable availability delays due to internal checking procedures, as in the case of energy balances. This underlines the importance of digitalising data flows, which is exactly the content of one of the actions of this project.

A general observation is that there is understandably a tendency to be less vocal about weak interventions publicly and they are rather improved internally because there is a pressure to perform in towards external actors. This is especially true for all commercial actors. Within the monthly local consortium calls, weak interventions are being identified, and solutions to improve them are being discussed and brought on the way.

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5. COMPARATIVE ASSESSMENT OF DEMO RESULTS

Benchmarking the demonstration results is an important step in the evaluation process as, on the one hand, it allows stakeholders to use this information to monitor their progress compared to other cities (or regions), make improvements where necessary and update targets that have been set while on the other hand, gives citizens the opportunity to monitor the performance of their city/district towards sustainability. In addition, it is possible to identify best practices and successful strategies to be replicated by other districts within the city limits or by other cities to improve their performance and outcomes.

However, the comparison of the KPIs is a challenging process as they can interact in complex ways, and changes in one KPI may affect others. For example, improving transportation infrastructure may increase economic growth but also increase air pollution. In addition, KPIs are influenced by contextual factors such as demographics, geography, etc., which can vary across different entities.

To address these challenges, we set out the following steps to make a more informed comparison between Espoo and Leipzig.

Step 1- The first step is to identify the KPIs to be compared i.e., to determine which KPIs are relevant to both Espoo and Leipzig and are comparable in terms of their definition and measurement.

Step2- Collect data on the selected KPIs for both cities. Ensure that the data is collected using similar methods and definitions to ensure accuracy and comparability.

Step3- Normalize the data to account for any differences in the size and population of the two cities. For example, if comparing number of EVs, adjust the data by the number of people in each city to make the comparison more accurate**.**

Step4- Once the data is normalized, KPIs can be compared, analysed, and interpreted to identify any similarities or differences between Espoo and Leipzig.

In D2.2. by analysing the context as well as the priorities and the objectives of the two LHCs, several KPIs were defined to measure the impact. In addition, it was stated that for KPIs to be meaningful and objectively comparable to each other, a normalisation approach should be considered, allowing data to be detached from the specificities and exogenous characteristics of cities and therefore considered as a useful tool for urban planners and stakeholders. Nevertheless, the normalisation process is a complex task that requires careful consideration of the specific KPIs being measured and the factors that may influence them in each city.

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The difficulties encountered by the municipalities in the collection and evaluation of data, make the comparative evaluation in the present version of the report unrealisable, since the individual KPIs could not be calculated in one or both cities. In the case of Leipzig, for example, data related to city's energy consumption is only available every two years, as energy providers must undergo an internal audit before making it publicly available. In the updated version of this deliverable, it is expected that both cities will have major improvement on their assessment as they identified the challenges of the process.

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6. CONCLUSIONS AND NEXT STEPS

SPARCS is a pioneering project that aims to help cities become more efficient, citizen-cantered, and environmentally friendly. This deliverable report from SPARCS, assesses the impact of the interventions during the second monitoring phase.

The LHCs' progress is measured by tracking KPIs at the intervention and city levels. Data from demonstration sites can provide valuable insights to stakeholders and be used for replication and dissemination. However, evaluating the LHCs' impact on cities' zero-carbon energy transformation is complex and challenging and some of the issues include a lack of available data and the heterogeneity of data sources.

As mentioned, KPIs are essential for assessing progress towards desired outcomes. However, setting targets for these KPIs can be challenging due to the complexity of sustainable development and the lack of proper benchmarks in the city context. Moreover, transferring targets set by cities’ sustainable plan to the project level can be challenging due to the targets' scope and the project's limited impact.

Despite these challenges, the report provides a thorough impact assessment of the interventions in SPARCS LHCs, highlighting successful cases and providing corrective actions to improve the interventions' impact in future SPARCS monitoring phases. The report also provides valuable lessons from the two LHCs that other cities can use when replicating the developed solutions.

Future work will focus on developing a more detailed data collection and analysis plan for KPI measurement and making data available in a timely manner and continuing to monitor and evaluate the LHCs' impact on cities' zero-carbon energy transformation.

The work described in this deliverable is ongoing, and an updated version will be available in September 2024. The updated final version will present the results of the third monitoring period, which aims to significantly improve the issues that were identified in the assessment of the first period.

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8. Appendices

Espoo KPIs calculation

Espoonlahti district

KPI	Share of RES [electricity]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total Energy consumption [electricity]	5 888	[MWh]
	Energy production using RES [electricity]	254	[MWh]
	Purchased Guarantees of Origin [electricity]	5 634	[MWh]
KPI Calculation	Energy production using RES / Total Energy consumption: (254+5634)/5888=1→ 100%		
KPI Units	[%]		

KPI	Share of RES [thermal, including heating and cooling]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total Energy consumption [thermal]	7 825	[MWh]
	Energy production using RES [thermal]	7 825	[MWh]
KPI Calculation	Energy production using RES / Total Energy consumption: 7825/7825=1→ 100%		
KPI Units	[%]		

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KPI	Excess Heat Recovery Ratio		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total excess heat [thermal]	2 117	[MWh]
	Utilisation of excess heat [thermal]	2 117	[MWh]
KPI Calculation	Utilisation of excess heat / Total excess heat: 2 117/2 117=1→ 100%		
KPI Units	[%]		

KPI	Building energy efficiency measurement		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total energy demand	130	[kWh/m2/a]
	Total Demand Electricity	50	[kWh/m2/a]
	Total Demand Heating annual	67	[kWh/m2/a]
	Total Demand Cooling annual	13	[kWh/m2/a]
KPI Calculation	(Total Demand value/Target value 1) *100		
KPI Units	[%]		

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KPI	Onsite energy ratio OER		
Data for calculation	Data	Measured Value	Units
	Energy production using RES	15 253	[MWh]
	Total energy demand	15 253	[MWh]
KPI Calculation	Energy production using RES / Total energy demand: 15 253/15 253=1→ 100%		
KPI Units	[%]		

KPI	Annual Mismatch Ratio (AMRx)		
Data for calculation	Data	Measured Value	Units
	District Energy import	0	[MWh]
	Energy production using RES	15 253	[MWh]
	Total energy demand	15 253	[MWh]
KPI Calculation	HMR= Hourly Mismatch Ratio If P>C, HMR=0 IF P<C, HMR= (C-P)/C Annual mismatch ratio is the average of HMRs over the year		
KPI Units	[%]		

KPI	CO2 emissions (Scope 2)		
Data for calculation	Data	Measured Value	Units
	Total CO2 emissions	1 391	[MWh]
KPI Calculation	Total CO2 emissions/Target emissions - 1 1391/-670 - 1 = -3,08 → -308%		
KPI Units	[%]		

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KPI	Bicycle parking		
Data for calculation	Data	Measured Value	Units
	Number of parking spaces	1 388	Number
KPI Calculation	Current value/Target value - 1 1388/1302 - 1 = 0,07 → 7%		
KPI Units	[%]		

KPI	Charging cabinets for e-bikes		
Data for calculation	Data	Measured Value	Units
	Number of cabinets	2	Number
KPI Calculation	Current value/Target value - 1 2/1 - 1 = 1 → 100%		
KPI Units	[%]		

KPI	EV charging stations		
Data for calculation	Data	Measured Value	Units
	Number of charging spaces	134	Number
KPI Calculation	Current value/Target value - 1 134/140 - 1 = 0,06 → 6%		
KPI Units	[%]		

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KPI	Demand from all EV mobility modes; impact on the grid		
Data for calculation	**Data**	**Measured Value**	**Units**
	Demand from all EV mobility modes (considering EV Smart chargers)	10	kW
KPI Calculation	Current value/Target value - 1 10/2 - 1 = 4 → 400%		
KPI Units	[%]		

KPI	Ratio of peak demand from EV mobility modes to local transformer capacity		
Data for calculation	**Data**	**Measured Value**	**Units**
	Local transformer capacity	Local transformer capacity: 5 MW Peak demand n/a MW Ratio 13%	kVA
	Peak demand from all EV mobility modes		kW
KPI Calculation	Current value/Target value - 1 0,13/0,20 - 1 = 0,35 → -35%		
KPI Units	[%]		

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KPI	Ratio of average demand from EV mobility modes to local transformer capacity		
Data for calculation	**Data**	**Measured Value**	**Units**
	Local transformer capacity	Local transformer capacity: 5 MW Average demand: 0,416 MW Ratio: 0,8%	kVA
	Average demand from all EV mobility modes MW		kW
KPI Calculation	Current value/Target value - 1 0,8/0,8 - 1 = 0 → 0%		
KPI Units	[%]		

KPI	Level of utilisation of EV charging stations		
Data for calculation	**Data**	**Measured Value**	**Units**
	Time	-	Minutes
KPI Calculation	Current value/Target value - 1 134/75 - 1 = 0,06 → 6%		
KPI Units	[%]		

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KPI	District EV parking/charging places (car and bicycle)		
Data for calculation	Data	Measured Value	Units
	EV Car parking/charging places (#)	EV Car: 134 EV Bicycle: 10 Total: 144	Number
	EV Bicycle parking/charging places (#)		Number
KPI Calculation	Current value/Target value - 1 144/145 - 1 = -0,01 → -1%		
KPI Units	[%]		

KPI	Utilisation of the charging system		
Data for calculation	Data	Measured Value	Units
	Percentage of chargers occupied	4 %	%
KPI Calculation	Current value/Target value - 1 4/5 - 1 = -0,14 → -14%		
KPI Units	[%]		

KPI	Number of people reached in total		
Data for calculation	Data	Measured Value	Units
	Social media reach	81141	[#]
	Email list recipients	400	[#]
	Survey respondents	279	[#]
KPI Calculation	Total sum		
KPI Units	[#]		

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KPI	Number of young people contributed in co-creation solutions		
Data for calculation	**Data**	**Measured Value**	**Units**
	Size of buddy classes	45	[#]
	Young workshop participants (micro-mobility & 1.5-degree lifestyle)	5	[#]
	Participants in co-creation with youth event in Lippulaiva	50	[#]
KPI Calculation	Total sum		
KPI Units	[#]		

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KPI	Number of citizens contributed in co-creation solutions		
Data for calculation	**Data**	**Measured Value**	**Units**
	Mobile probing study participants	5	[#]
	Thesis work contributors: Car sharing services	7	[#]
	Workshop participants and facilitators (micro-mobility & 1.5-degree lifestyle)	40	[#]
	Size of buddy classes and families	145	[#]
	Participants in co-creation with youth event in Lippulaiva	50	[#]
	EV test day	100	[#]
KPI Calculation	Total sum		
KPI Units	[#]		

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KPI	Engagement level of all citizens		
Data for calculation	**Data**	**Measured Value**	**Units**
	Grade of the citizens feeling that they were able to contribute to the activity and feel engaged (scale 1-5, 1=not at all, 2=to a little extent, 3=I don't know, 4=to some extent, 5= to a great extent) Mobile probing study	4.38	[Number, Likert scale]
	Espoonlahti micro-mobility workshop	4.5	
	1.5-degree lifestyle workshop	4.28	
	1.5-degree lifestyle follow-up study	4.75	
	Ratio of total responses: Mobile probing study	0.2222	[#]
	Espoonlahti micro-mobility workshop	0.1111	
	1.5-degree lifestyle workshop	0.5000	
	1.5-degree lifestyle follow-up study	0.1667	
KPI Calculation	Average of given grades = Σ (average grade of activity) × (ratio of the total responses)		
KPI Units	[Number, Likert scale]		

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Leppävaara district

KPI	Share of On-site RES [electricity]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total electricity consumption		[MWh]
	Onsite electricity production using RES		[MWh]
KPI Calculation	Energy production using RES / Total Energy consumption: 80/200=0.4→ 40%		
KPI Units	[%]		

KPI	Annual Mismatch Ratio (AMRx)		
Data for calculation	**Data**	**Measured Value**	**Units**
	Production (P)		kWh
	Consumption (C)		kWh
KPI Calculation	**HMR= Hourly Mismatch Ratio** **If P>C, HMR=0** **IF P<C, HMR= (C-P)/C** **Annual mismatch ratio is the average of HMRs over the year**		
KPI Units	%		

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KPI	CO2 equivalent change		
Data for calculation	**Data**	**Measured Value**	**Units**
	Power of the flexibility assets (P)		MW
	Emission factor (f)		kgCO2/MWh
	Uptime (t)		% x 8760 h
KPI Calculation	CO2 equivalent change = P x f x t		
KPI Units	kgCO2		

Kera district

KPI	Value of the developed solutions for the development of a future district		
Data for calculation	**Data**	**Measured Value**	**Units**
	How valuable the developed solutions are for the development of future districts by the relevant stakeholders (Likert scale 1-5)	n/a (counted only once during the final project year)	[Number, Likert scale]
KPI Calculation	Average of responses (numbers 1-5)		
KPI Units	[#]		

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KPI	Number of e-mobility solutions introduced for replication in Kera planning phase		
Data for calculation	Data	Measured Value	Units
	Number of e-mobility solutions introduced	7	[Number of solutions]
KPI Calculation	Added number of introduced solutions from SPARCS demonstration for Kera area development		
KPI Units	[#]		

KPI	Simulated demand for charging stations in Kera area		
Data for calculation	Data	Measured Value	Units
	Completion of simulation of demand for charging stations in Kera area	Simulation complete	[text value]
KPI Calculation	n/a		
KPI Units	[text value]		

Macro level

KPI	Number of smart business models created		
Data for calculation	Data	Measured Value	Units
	Number of smart business models created	1	[Number of models]
KPI Calculation	Added number of smart business models created during the intervention implementation		

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KPI Units	[#]

KPI	**Loads connected to demand response**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of loads connected to demand response	5	[Number of loads]
KPI Calculation	Added number of loads connected to demand response functions		
KPI Units	[#]		

KPI	**Number of blockchain solutions identified**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of identified blockchain solutions	1	[Number of solutions]
KPI Calculation	Added number of blockchain solutions identified during intervention implementation		
KPI Units	[#]		

KPI	**Number of smart business models identified in relation to blockchain solutions**		
Data for calculation	**Data**	**Measured Value**	**Units**

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	Number of identified smart business models	2	[Number of models]
KPI Calculation	Added number of smart business models identified in relation to blockchain solutions		
KPI Units	[#]		

KPI	**Heating flexibility increase as a percentage of normal load**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Reference load profile	-	[kWh]
	Flexible load profile	-	[kWh]
KPI Calculation	The deviation of the two resulting profiles		
KPI Units	[%]		

KPI	**Total potential heat load under DSM (kWh)**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Potential heat load	636	[kWh]
KPI Calculation	Identified hourly peak load of load profile of full assessed building stock without heating of water included		
KPI Units	[kWh]		

KPI	**Current and potential emission savings**

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Data for calculation	**Data**	**Measured Value**	**Units**
	Measured monthly flexibility compared to reference load	-	[MWh]
	Monthly emission coefficient	-	$kgCO_2/MWh$
KPI Calculation	Flexibility*emission coefficient calculated for each month and summed together		
KPI Units	[tCO_2]		

KPI	**Number of buildings or apartments participating in DSM scheme**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of participating apartments	16 170	[Number of apartments]
KPI Calculation	Added number of apartments participating in DSM scheme		
KPI Units	[#]		

KPI	**Increase of simulations executed via the Virtual Twins concept**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of executed simulations	2000	[Number of simulations]

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KPI Calculation	Added number of simulations executed via the Virtual Twin concept
KPI Units	[#]

KPI	**Number of innovative energy technologies incorporated in virtual twin for simulation purposes**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of innovative energy technologies	5	[Number of technologies]
KPI Calculation	Added number of innovative energy technologies incorporated in virtual twin		
KPI Units	[#]		

KPI	**Accuracy of building heating and electricity load forecasting electricity/district heating/PV (NRMSE)**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Building forecasting data	-	[-]
	Real energy data	-	[-]
KPI Calculation	Ratio of predicted / actual energy		
KPI Units	[%]		

KPI	**Number of scenarios for positive energy block evaluated**

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Data for calculation	**Data**	**Measured Value**	**Units**
	Number of evaluated scenarios	6	[Number of scenarios]
KPI Calculation	Added number of evaluated scenarios		
KPI Units	[#]		

KPI	**Number of technologies utilized in the scenarios for positive energy block**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of utilized technologies	3	[Number of technologies]
KPI Calculation	Added number of technologies utilized in positive energy block scenarios		
KPI Units	[#]		

KPI	**Developed recommendations for future urban planning/new districts (y/n).**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Were recommendations for future urban planning developed?	Yes	[Yes/No]
KPI Calculation	n/a		
KPI Units	[Yes/No]		

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KPI	Increase of integrated public EV charging units		
Data for calculation	Data	Measured Value	Units
	Number of integrated public EV charging units	177	[Number of units]
KPI Calculation	Added number of integrated public EV charging units		
KPI Units	[#]		

KPI	Air quality in Leppävaara/Lippulaiva		
Data for calculation	Data	Measured Value	Units
	Measured values of the different compounds	PM 2.5 (6.42, 2.93) PM 10 (24.27, 14.62) NO (3.22, 12.31) NO2 (12.38, 8.19)	[µg/m3]
	Limit of 'Good' values as provided by HSY	PM 2.5 (≤10) PM 10 (≤20) NO (≤15) NO2 (≤40)	[µg/m3]
KPI Calculation	Measured values compared to set limit		
KPI Units	[µg/m3]		

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Espoo city level

KPI	Reduction of heating demand [compared to 2015]		
Data for calculation	Data	Measured Value	Units
	Current heating consumption	897	GWh
	Heating consumption for 2015	1060	GWh
KPI Calculation	(CO_2-e (1990) – CO_2-e (current)) / CO_2-e (1990): (1060-897)/1060=0.154→ 15.4%		
KPI Units	[%]		

KPI	Reduction of electricity demand [compared to 2015]		
Data for calculation	Data	Measured Value	Units
	Current electricity consumption	897	GWh
	Electricity consumption for 2015	1060	GWh
KPI Calculation	(CO_2-e (1990) – CO_2-e (current)) / CO_2-e (1990): (1060-897)/1060=0.154→ 15.4%		

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KPI Units	[%]

KPI	Reduction of CO_2 equivalent emissions [compared to 1990]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Current CO_2 equivalent emissions	897	1000t CO_2-e
	CO_2 equivalent emissions for 1990	1060	1000t CO_2-e
KPI Calculation	(CO_2-e (1990) – CO_2-e (current)) / CO_2-e (1990): (1060-897)/1060=0.154→ 15.4%		
KPI Units	[%]		

KPI	Share of RES [electricity]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Share of RES as a percentage of Finnish electricity production	54	[%]
KPI Calculation	No calculation needed, as share of RES is provided as-is by Finnish Energy (ET).		
KPI Units	[%]		

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KPI	Share of RES [district heating]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total district heating production	2248	[GWh]
	District heating production using RES and carbon free means	1071	[GWh]
KPI Calculation	District heating production using RES / Total district heating production: 1071/2248=0.476→ 47.6%		
KPI Units	[%]		

KPI	Number of stakeholders involved in co-creation of the co-creation model		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of stakeholders	116	[number]
KPI Calculation	Counting the number of participating stakeholders in different events		
KPI Units	[#]		

KPI	Number of citizens involved in co-creation of the co-creation model

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Data for calculation	**Data**	**Measured Value**	**Units**
	Number of citizens	137	[number]
KPI Calculation	Counting the number of participating citizens in different events		
KPI Units	[#]		
KPI	**Visitors on the co-creation model website (calculated monthly) (toolbox)**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of unique visitors on the website (all months combined)	3534	[number]
KPI Calculation	Number of visitors on the co-creation model toolbox website, counted by the website; visitors from each month are combined for a total number		
KPI Units	[#]		

KPI	**Number of new innovative projects leveraged beyond SPARCS**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of projects	n/a (counted once during the final year of the project)	[number]
KPI Calculation	Number of projects		
KPI Units	[#]		

KPI	**The total volume of additional funding**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Volume of funding	n/a (counted once during the final year of the project)	[€]

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SPARCS

KPI Calculation	Volume of funding
KPI Units	[€]

KPI	**Active collaboration with ecosystems developing sustainable solutions in smart city sector**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of ecosystems	6	[number]
KPI Calculation	Added number of ecosystems		
KPI Units	[#]		

KPI	**Participants in the Smart Otaniemi stakeholder events**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of people	93	[number]
KPI Calculation	Added number of participants in all events		
KPI Units	[#]		

KPI	**Demand from all EV mobility modes; impact on the grid**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of private cars (BEV)	6067	#

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	Number of private cars (PHEV)	12008	#
	Number of vans (BEV)	168	#
	Number of vans (PHEV)	18	#
	Number of buses (BEV)	64	#
	Number of trucks (BEV)	3	#
	Number of trucks (PHEV)	0	#
	Daily mileage cars	41.1	km
	Daily mileage vans	49.3	km
	Daily mileage buses	173.3	km
	Daily mileage trucks	93.2	km
	Electric energy per km, cars BEV	0.16	kWh/km
	Electric energy per km, cars PHEV	0.11	kWh/km
	Electric energy per km, vans BEV	0.2	kWh/km
	Electric energy per km, vans PHEV	0.12	kWh/km
	Electric energy per km, buses BEV	1	kWh/km
	Electric energy per km, trucks BEV	1	kWh/km
	Electric energy per km, trucks PHEV	0.6	kWh/km
KPI Calculation	For each vehicle type: Number of vehicles * daily mileage * electric energy consumption per km Add the impact of all vehicle types 6067*41.1*0.16 + 12008*41.1*0.11 + 168*49.3*0.2 + 18*49.3*0.12 + 64*173.3*1 + 3*93.2*1 = 106 000 kWh -> 106 MWh		

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SPARCS

KPI Units	MWh

KPI	**EV car sharing rate increase**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of EVs. EVs available for sharing	28.17 full electric cars registered in Espoo area; approx. 150 full electric cars for shared use registered in Espoo area	[number]
KPI Calculation	n/a		
KPI Units	[#]		

KPI	**Increase of EVs share in local transportation**		
Data for calculation	**Data**	**Measured Value**	**Units**
	Share of full electric vehicles of the whole vehicle stock registered in Espoo area & Number of vehicles	2%	[percent]
KPI Calculation	2817 (number full electric cars registered in Espoo area) / 125293 (total number of vehicles registered in Espoo area)		
KPI Units	[%]		

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KPI	Transport infrastructure (km of roads for cars, bicycles)		
Data for calculation	Data	Measured Value	Units
	Amount of road and bicycle path infrastructure in Espoo	1213 km of roads; 1195 of (partially joint pedestrian paths) bicycle paths	[kilometres]
KPI Calculation	n/a		
KPI Units	[km]		

KPI	Transport infrastructure (rail-based)		
Data for calculation	Data	Measured Value	Units
	Number of rail-based public transportation stations/stops in Espoo area	6 metro stations, 7 commuter train stations in Espoo area (2020)	[number]
KPI Calculation	n/a		
KPI Units	[#]		

KPI	Stock of vehicles (Cars, Motorcycles, Buses, Trucks)		
Data for calculation	Data	Measured Value	Units

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	Vehicle per capita	568/1000	[number]
KPI Calculation	n/a		
KPI Units	[#]		

KPI	Transport behaviour (% of all trips)		
Data for calculation	**Data**	**Measured Value**	**Units**
	Share of the modal split in Espoo area	Public transportation trips: 33%; private car trips: 48% (in 2018)	[share]
KPI Calculation	n/a		
KPI Units	[%]		

KPI	Increase of EV charging points		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of EV charring points in Espoo	404	[number]
KPI Calculation	n/a		
KPI Units	[#]		

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Leipzig KPIs calculation

Baumwollspinnerei district

KPI	District self-consumption rate		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total district Energy Demand (Σ Jan 2022 to end May 2023)	2259	MWh
	Total Energy Production (Σ Jan 2022 to end May 2023)	1141	MWh
KPI Calculation	[(1141/17*12) / (2259/17*12)] * 100 = 50.5%		
KPI Units	50.5%		

KPI	Total energy demand reduction		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total Demand Electricity (Σ Jan 2022 to end May 2023) /17*12)	620	MWh/a
	Total Demand Heating (Σ Jan 2022 to end May 2023) /17*12)	1639	MWh/a
KPI Calculation	620+1639 = 2259		
KPI Units	MWh/a		

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KPI	Onsite energy ratio OER		
Data for calculation	**Data**	**Measured Value**	**Units**
	Energy Production using RES	0	MWh/a
	Total energy demand (Σ Jan 2022 to end May 2023) /17*12)	2259	MWh/a
KPI Calculation	0 / 2259 * 100=0		
KPI Units	%		

KPI	Return on Investment		
Data for calculation	**Data**	**Measured Value**	**Units**
	Savings p.a.	42400	€
	Costs	615000	€
KPI Calculation	42400/ 614292 *100 = 7%		
KPI Units	7%		

KPI	Payback Time		
Data for calculation	**Data**	**Measured Value**	**Units**
	Savings p.a.	42400	€
	Costs	615000	€
KPI Calculation	614292/42400 = 14.5 yrs.		
KPI Units	14.5 yrs.		

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Leipzig West

Example

KPI	Share of RES [electricity]		
Data for calculation	**Data**	**Measured Value**	**Units**
	Total Energy consumption [electricity]	200	[MWh]
	Energy production using RES [electricity]	80	[MWh]
KPI Calculation	Energy production using RES / Total Energy consumption: 80/200=0.4→ 40%		
KPI Units	[%]		

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Virtual Positive Energy Community

KPI	Increase of integrated systems share		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of Smart Plugs	See L11: 'Number of smart devices'	#
KPI Calculation	Counting the amount of distributed Smart Plugs		
KPI Units	Green sockets available (#)		

KPI	Total flexibility available increase		
Data for calculation	**Data**	**Measured Value**	**Units**
	Flexibility of customer group 1	8760 values	MWh/h
	Flexibility of customer group 2	8760 values	MWh/h
KPI Calculation	Max (Sum over customer groups (Flexibility of customer groups): 0.11705		
KPI Units	MWh/h		

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KPI	Flexibility increase (%) of normal load in kW		
Data for calculation	Data	Measured Value	Units
	Modelled Residential Load over one year for customer group 1	8760 values	MWh/h
	Modelled Residential Load over one year for customer group 2	8760 values	MWh/h
	Flexibility of customer group 1	8760 values	MWh/h
	Flexibility of customer group 2	8760 values	MWh/h
KPI Calculation	Sum over timesteps (Sum over customer groups (Flexibility of customer groups)) / (Sum over timesteps ((Sum over customer groups (Electricity demand of customer groups)))		
KPI Units			

Macro level

KPI	Number workshops, information and co-creation activities were conducted		
Data for calculation	Data	Measured Value	Units
	Number of workshops [PM M20-M48]	16	# NR.
	Project months taken into consideration	28	# NR.
KPI Calculation	Target: 28/12 months =2,33 2,33 * 4 =9,333 (Target: Nr. of events in the 28 months considered) Target in %: (16/100) * 9,33=171% Distance from the target: 0%		
KPI Units	[%]		

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KPI	Number of flyers distributed door-to-door in the neighbourhood		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of Flyer printed and distributed	20.100	# NR.
	Number of workshops	16	# NR.
KPI Calculation	20.100/16 = ca. **1.256** Average of Flyers printed and distributed pro event		
KPI Units	Nr.		

KPI	How many people attended the event?		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of participants	331	# NR.
	Number of workshops considered	16	# NR.
KPI Calculation	300/16 = ca. **21** participants pro events Target: 50 person's pro event. Target reached: (21/ 50) * 100 = 41% Distance from target: 59 %		
KPI Units	[%]		

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KPI	How many people have utilised the contact information provided on the flyer for desk support after the event, by asking questions or providing suggestions and comments?		
Data for calculation	**Data**	**Measured Value**	**Units**
	Number of participants [PM M20-M48]	331	# NR.
	Number of contacts after events	2	# NR.
	Target: Number of contacts	50	# NR.
KPI Calculation	Number of contacts after events / Target: Number of contacts: 2 / 50 = 0,04 = **4 %**		
KPI Units	[%]		

KPI	With the goal of creating a strong networking environment, how many events were organised in collaboration with non-SPARCS partners?		
Data for calculation	**Data**	**Measured Value**	**Units**
	number of workshops considered	16	# NR.
	number of Workshops with external partners	10	# NR.
KPI Calculation	Number of Workshops with external partners / number of workshops: 10 / 16 = 0,63 = **63 %**		
KPI Units	[%]		

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