D2.6 Holistic Impact Assessment of Demonstration Activities

31/03/2023

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SPARCS

Deliverable administration

No & name	**D2.6 Holistic Impact Assessment of Demonstration Activities**				
Status	Released	**Due**	M42	**Date**	2023-03-31
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, in order 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, so as to achieve the holistic assessment and collaborative devising of the SPARCs project interventions.				
Participants	VERD, VTT, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV, RIL, FHG, BABLE, SPI, NEW, CVUT, SUITE5, LCE, CiviESCo, MOH				
Comments					

V	Date	Authors	Description
0.1	15/10/2022	VERD	First draft of ToC and contribution to report
0.2	31/12/2022	ESP, LPZ, CEN, LSW, PIT, CIT, WSL, SEE, S5, SIE, KONE, VTT, ULEI, ADV	Contributing to report
0.3	20/01/2023	MOH	Review contributions and feedback to partners
0.4	10/03/2023	ESP, LPZ, CEN, LSW, PIT, CIT, WSL, SEE, S5, SIE, KONE, VTT, ULEI, ADV	Contributing to report
0.5	15/03/2023	MOH	Internal Review and changes
0.6	15/03/2023	VTT, FHG	Peer review
0.7	28/03/2023	MOH	Final version prepared

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0.8	29/03/2023	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	31/03/2023	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

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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 systems that will transform cities into sustainable, citizen-cantered, zero-carbon ecosystems.

The scope of T2.4 is to perform the 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. In order for the assessment to be processed, specific targets were set for each intervention. These targets were either derived from project's objectives or cities' goals and Building Energy Specification Tables (BEST) or were set based on estimates according to interventions' technical specifications. The aim of T2.4 is intervention targets to be achieved by the end of the project and not during this first monitoring period.

In the current deliverable, the evaluation of the first - of the three - monitoring phase is carried out. For the city of Espoo, the first monitoring phase covers a period of 12 months, from March 2022 to February 2023. In contrast, for Leipzig, due to delays in the implementation of the planned interventions, the first phase covers a period of six months, instead of a 12-month period as originally planned, i.e., from September 2022 to February 2023.

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.

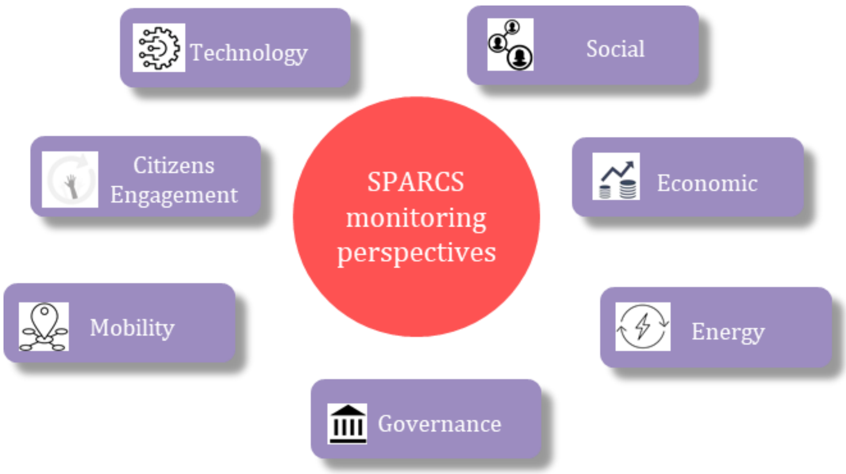

Figure 1. SPARCS evaluation perspectives

Moreover, in this report, 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 practices 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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The following figures (Figure 2 and Figure 3) summarise the impact assessment of the interventions at the two LHCs for the first monitoring period. It is noted that for the case of Leipzig, some data necessary for the evaluation could not be retrieved, resulting in a small number of monitored interventions. This is due to various reasons, such as the short time between the completion of the interventions and the initial collection of the necessary information for the first assessment, or the protection of personal data. Work towards the objectives of this task is ongoing by the SPARCS team, and an updated version of the deliverable will be available in September 2023.

To easily categorize impact monitoring, the following colour mapping is considered as Table 1 presents:

Table 1 Colour mapping classification legend

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

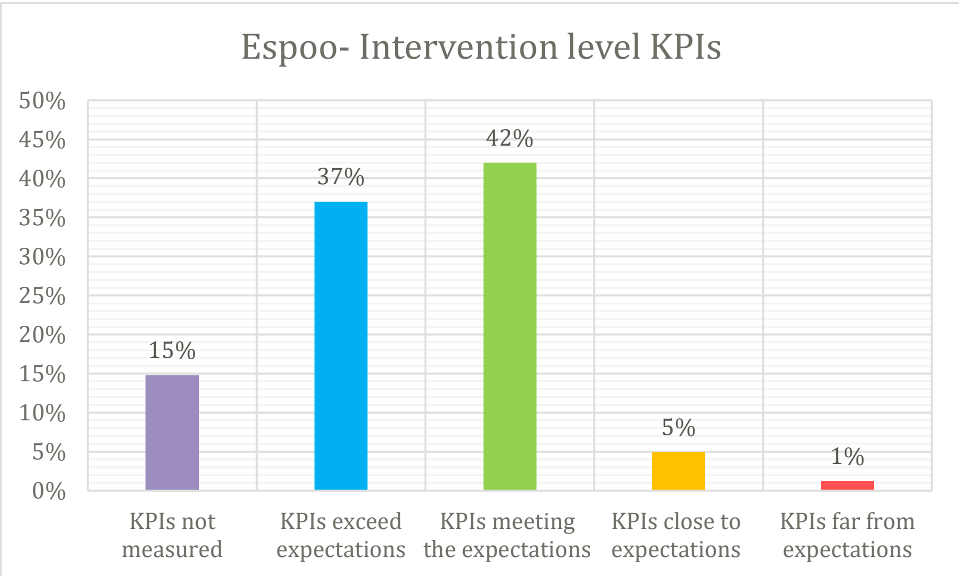

Figure 2. Overview of impact assessment- Espoo

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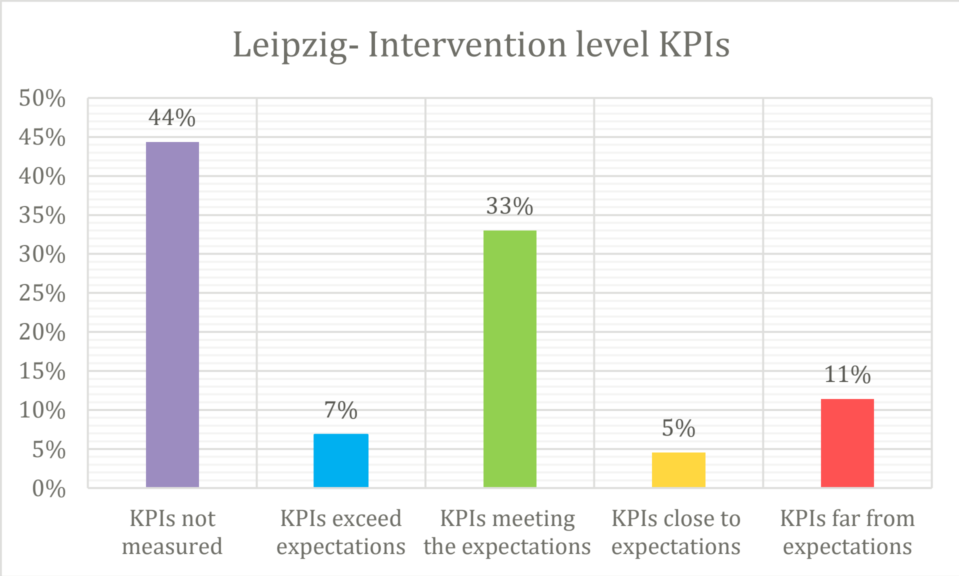

Figure 3. Overview of impact assessment- Leipzig

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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 electromobility as well as on the development of new business models.

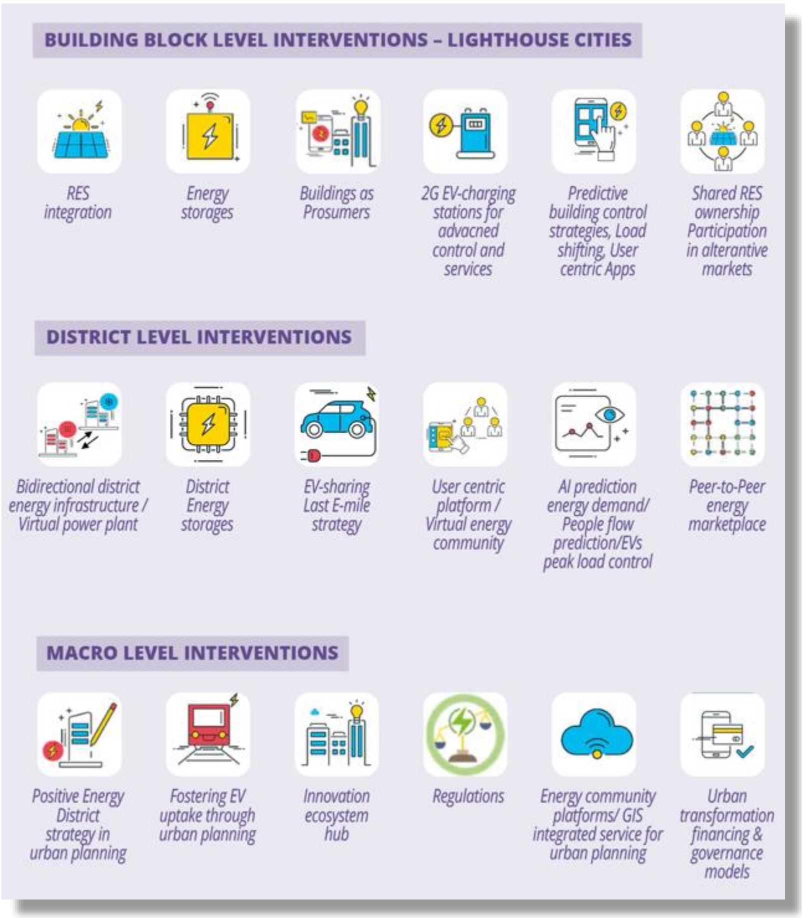

Figure 4. SPARCS interventions mapping

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:

- M30-M42 (1st period)
- M43-48 (2nd period)
- M49- M60 (3rd period)

The first monitoring period, which begun with the launch of the demo deployment in March 2022 is presented in this report, and the evaluation is based on the impact assessment framework as developed and presented in D2.1 and D2.2. It is noted here that this monitoring period had a different duration for the two LHCs due to delays in the implementation of interventions in Leipzig. For the city of Espoo, the monitoring phase covers a period of 12 months, from March 2022 to February 2023, while for Leipzig it covers a period of six months, from September 2022 to February 2023.

Both the evaluation methodology and the necessary KPIs with the relevant data for their calculation were thoroughly presented in these reports. In addition, the LHCs baseline establishment -presented on 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 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 in the following monitoring periods the goals are achieved. 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.

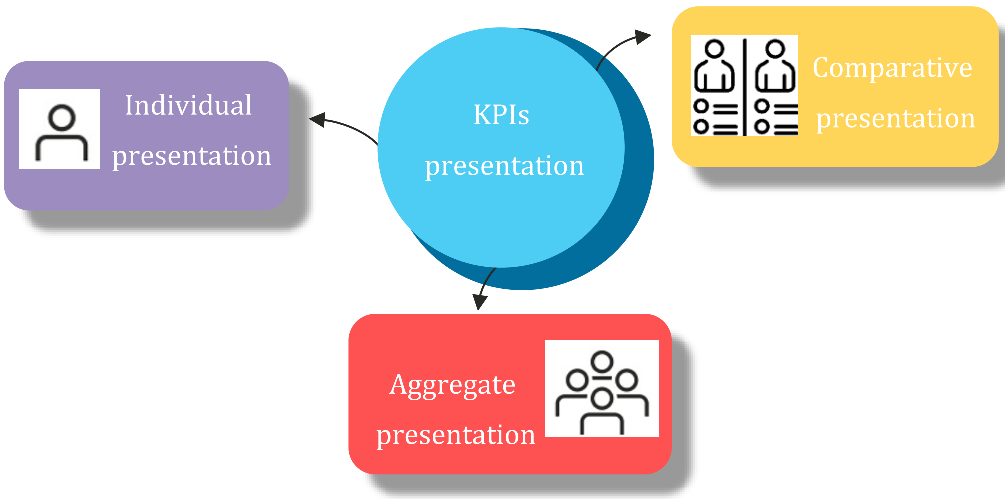

Figure 5. Demonstration categories of KPIs

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For the purposes of T2.4 the measured KPIs are planned to be presented in three ways (Figure 5):

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 the project's progress and the overall evaluation of the impact achieved by the interventions planned and are 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 as well as the conclusions and valuable lessons learnt so far from the first 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.

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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. It is an area that grows constantly, and it is expected to reach 400,000 residents by 2050. One special characteristic of Espoo is its urban structure that 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 2050 City Vision that focuses on digitalization, sustainable energy, air quality improvement, e-mobility solutions, and performance monitoring of developed solutions. Figure 6 below briefly presents the long-term sustainability targets of Espoo.

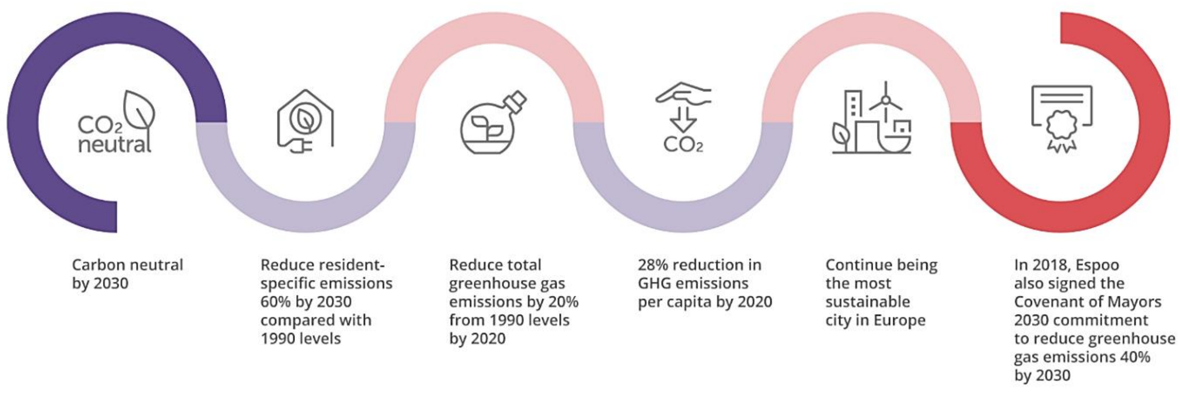

Figure 6. Espoo long-term sustainability goals

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 phase, Espoonlahti district is on a redevelopment phase and Leppävaara district is an already built-up area. In these demonstration areas 14 interventions were implemented within the SPARCS project; in addition, 9 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 photovoltaic PV, 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 discitis'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 2 below presents in brief the interventions related to Espoonlahti district.

Table 2. 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 redaction 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.

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 750kW PV plant in the summer and transitional months. During days with low solar irradiance, a virtual power plant supplies green electricity based on a

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Guarantees of Origins (GoOs) scheme, an instrument defined by European legislation[1] that tracks electricity from renewable energy sources and provides customers with information on the source of their energy. Table 3 summarises the interventions in Leppävaara district.

Table 3. 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 of heat 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 centralized 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 citizens during the next decades. The urban development of Kera focuses on implementing advanced sustainable district energy solutions. The main objective of SPARCS is to develop and pilot new models for co-creation, energy communities and stakeholder engagement to bring residents in the new 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 an innovative base for the further development of local energy 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 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 4 the interventions on Kera district are presented briefly.

[1] 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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Table 4. 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 lifestyle is 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 optimize 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 5 the interventions and actions at the macro level are summarised.

Table 5. 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.

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Intervention	Description	Actions
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	- 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 600,000 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 enhancing consumption of renewable energy produced in the city and virtually connecting all participating generation, storage, and consuming entities in order 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 7 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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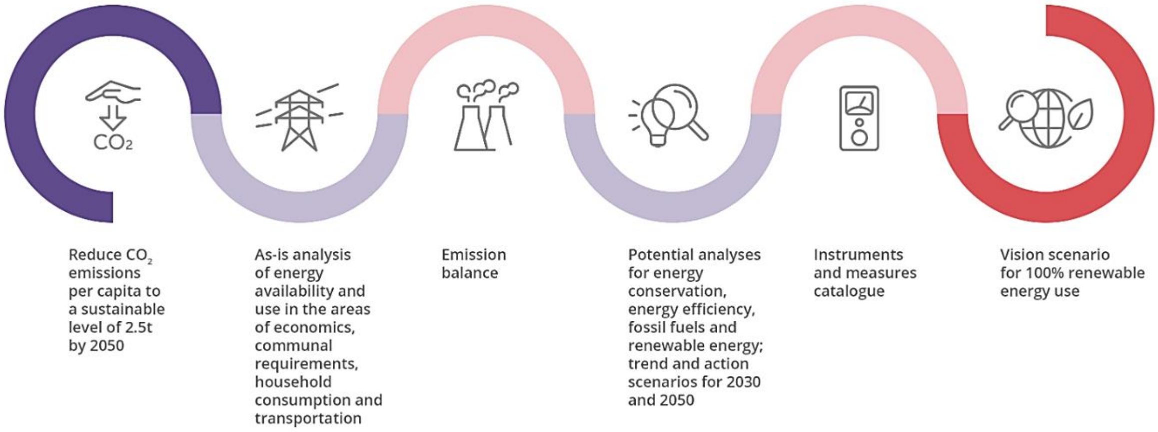

Figure 7. Leipzig long-term sustainability targets

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.

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 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. Table 6 presents the interventions and actions of the district.

Table 6. 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 optimization 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

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L3	Heating demand control	- Coupling heating needs with load profile of the micro grid - User interface with air quality info

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, via a dedicated platform that promotes active involvement of citizens, to optimize 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 7.

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 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 demand response programs.

Table 7. Leipzig West district interventions

Intervention	Description	Actions
L4	Personalized Informative Billing	- Personalized 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, in order 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

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 optimization of energy generation and consumption through integration, analysis and control of assets and devices and the implemented interventions are presented in Table 8.

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Table 8. 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 standardized 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	- Maximization 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 optimization 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	Conceptualization 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
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 9) 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.

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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 9. 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 the SPARCS goals and LHCs' long-term strategy are reviewed on a regular basis; it measures and keeps track of their progress, and it reveals potential shortcomings and deviations related to the 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 8 below.

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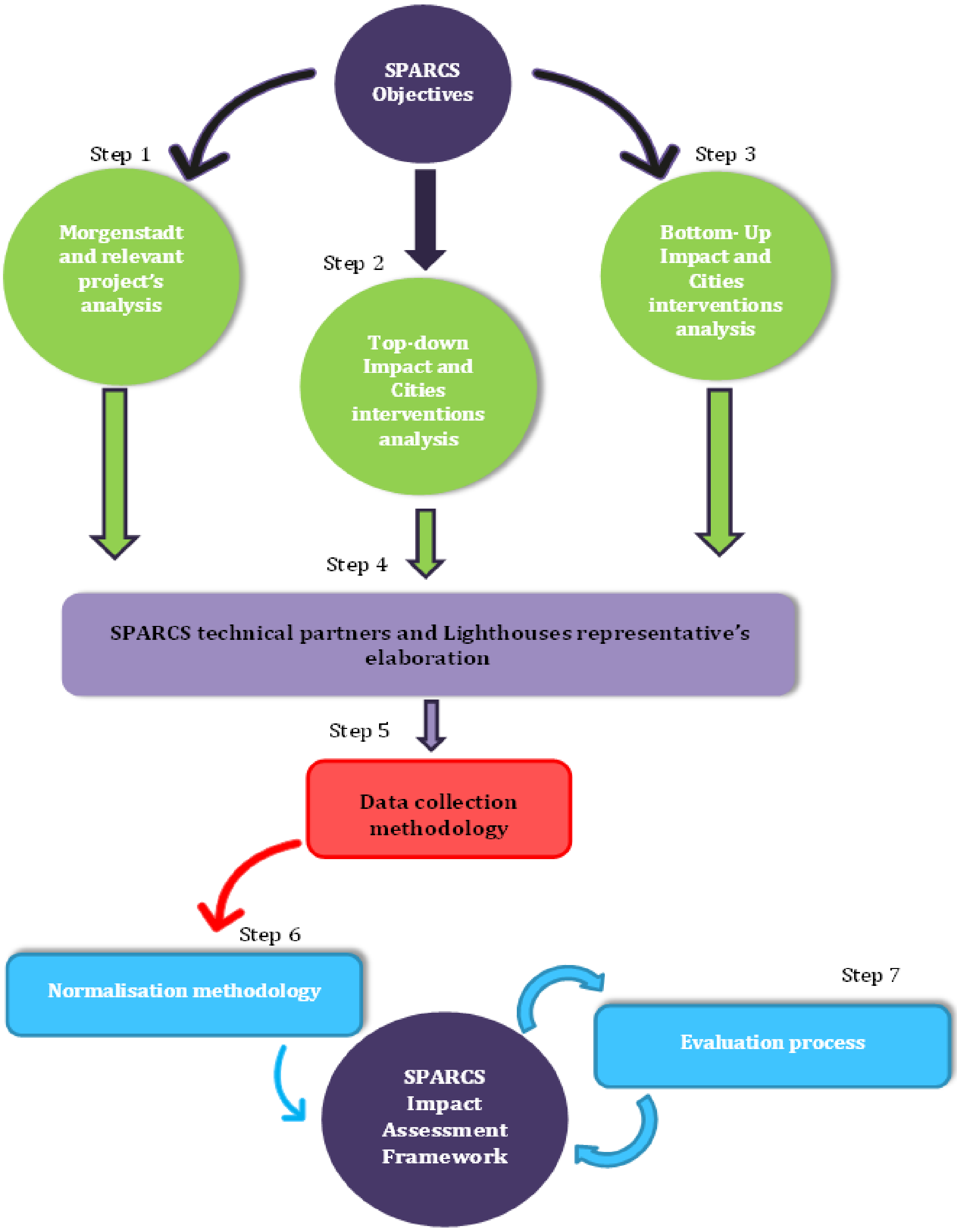

Figure 8. SPARCS Impact assesssment framework as defined in D2.2

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.

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.

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.

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Step 4 of the methodology, elaborated on 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, to enhance or modify it as required, clarify open points, and build a common understanding on the purpose of each indicator in the context of the planned city actions.

With a complete set of KPIs available, a detailed data requirements analysis to calculate the indicators was performed, followed by a verification of the availability of that data with the city partners, consisting of the Step 5 of the methodology.

The following step, namely the normalization methodology in Step 6, deals with the introduction of a tool for the comparative assessment of the KPIs, towards the objective evaluation of the SPARCS interventions and the easy cross-city adoption.

Finally, under Step 7, the SPARCS process evaluation approach and its corresponding activities were introduced, allowing for a complete impact assessment verification, regarding efficiency and effectiveness of the result achieved.

2.4 Challenges faced in first reporting period

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 organizations 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 were 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.

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

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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.

The calculation of financial KPIs for both LHCs was not carried out in the deliverable. 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 measures include entities not controlled by the city 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

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 well being

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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

To mitigate the problems identified above, the city of Espoo has already 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.

Meanwhile, the work on collecting data to calculate the financial KPIs for at least some interventions at the city level will continue in both cities. For the Espoo side, this work will focus on investments into public transport and energy efficiency measures for public buildings, as the most data has been found on these so far. In parallel, the approach to financial values is an exercise that will be carried out during the second 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 of the first period and includes both the individual monitoring of the KPIs at the intervention level and the aggregated monitoring at the city level. To easily categorize impact monitoring, the following colour mapping (presented in Table 10) was considered:

Table 10. Colour mapping legend

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

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.

3.1 Individual monitoring- intervention level

Intervention E1- Solutions for Positive energy blocks

Intervention E1 is about solutions for Positive Energy Blocks in Lippulaiva. The intervention includes actions about NZEV and PV optimization, 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.

Table 11. E1 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Share of RES (electricity)	Total energy consumption (electricity) (MWh) & Energy production using RES (electricity) (MWh)	100%	100%	100%	0%

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Share of RES (thermal, including heating and cooling)	Total energy consumption (thermal) (MWh) & Thermal energy production using RES (thermal) (MWh)	Total thermal energy consumption: 100%	100%	100%	0%
Excess Heat Recovery Ratio	Total excess heat (MWh) & Utilization of excess heat (MWh)	n/a	100%	100%	0%
Building energy efficiency measurement	Total energy demand (kWh/m2/a) Total Demand Electricity (kWh/m2/a) Total Demand Heating annual (kWh/m2/a)	Total: 275 Electricity: 109 Thermal: 166	Total: 108 Electricity: 49 Heating: 48	Total: 137 Electricity: 56 Heating: 61	Total: 27% Electricity: 14% Heating: 27%
	Total Demand Cooling annual (kWh/m2/a)	Cooling: n/a	Cooling: 11	Cooling: 21	Cooling: 90%
Energy Storage type	Type	n/a	An electric battery and geo -wells heat storage	An electric battery and geo-wells heat storage	0
Energy Storage	Number of equipment	n/a	2	2	0
Energy Storage capacity	Thermal storage (MWh) & Electric battery (MW/MWh)	n/a	Thermal storage: 5000 Electric battery: 1,5/1,5	Thermal storage: 5000 Electric battery: 1,5/1,5	0
Onsite energy ratio mrx	Energy production using RES (MWh) & Total energy demand (MWh)	Energy production using RES: n/a Total energy demand: n/a	100%	100%	0
Annual Mismatch Ratio (AMRx)	District Energy import (MWh) &	District Energy import (MWh): n/a	Heating 5% Cooling 0%	Heating 0% Cooling 0%	Heating 5%

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	Energy production using RES (MWh) & Total energy demand (MWh)	Energy production using RES (MWh): n/a Total energy demand: n/a	Electricity 0%	Electricity 0%	
CO_2 emissions	Total CO_2 emissions	n/a	-670 tCO_2/y	-1272 tCO_2/y	89%

In the first monitoring period, the share of RES was at the target level. The total energy demand was a little bit higher compared to the target. This applies to all energy modes including electricity, heating, and cooling demand. During the first monitoring period, there is a discharge period ongoing which causes higher energy demand. In addition, during the first year of operation, the initial aftercare phase is ongoing, and adjustments are widely done. Energy storage solutions were implemented as planned. Moreover, there was no need for the back-up district heating meaning that the RES solution of Lippulaiva works well.

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.

Table 12. E2 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Bicycle parking	Number of parking spaces	1 000	1 302	1 388	6%
Charging cabinets for e-bikes	Number of cabinets	1	1	2	100%
EV charging stations	Number of charging spaces	134	140	134	6
Demand from all EV mobility modes; impact on the grid	Demand from all EV mobility modes (considering EV Smart chargers)	n/a	2,0	1,7-3,7	0
Ratio of peak demand from EV mobility modes to local transformer capacity	Local transformer capacity (Block)	n/a	Local transformer capacity: 5 MW	Local transformer capacity: 5 MW	7%

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	Peak demand from all EV mobility modes		Peak demand: 1 MW Ratio: 20%	Peak demand: 0,663 MW Ratio: 13%	
Ratio of average demand from EV mobility modes to local transformer capacity	Local transformer capacity (Block) Average demand from all EV mobility modes	n/a	Local transformer capacity: 5 MW Average demand: 0,04 MW Ratio: 0,8%	Local transformer capacity: 5 MW: Average demand: 0,032 MW Ratio: 0,6%	0,2%
Level of utilization of EV charging stations	Time (minutes)	n/a	75	71	5%
District EV parking/charging places (car and bicycle)	EV Car parking/charging places (#) EV Bicycle parking/charging places (#)	n/a	EV Car: 140 EV Bicycle: 5 Total: 145	EV Car: 134 EV Bicycle: 10 Total: 144	0,5%
Utilization of the charging system	Percentage of chargers occupied	n/a	5%	3,98%	1%

In the first monitoring period, number of bicycle parking and EV charging stations were at the targeted level. Generally, demand ratios appeared to be at the target levels. The level of utilization of EV charging stations and the utilization of the charging system were a bit lower compared to the targets. It is assumed that the utilization of EV charging will increase in 2023 when number of customers will rise. The new Espoonlahti metro station opened in December 2022 and the bus terminal opened in February 2023.

Intervention E3– Engaging users

The implementation activities of this intervention focus on community engagement activities in the Espoonlahti demonstration area. The KPI data 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.

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Table 13. E3 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of engaged stakeholders	Number of people reached in total	n/a	14350	81820	500%
	Number of young people reached in total		100	100	0%
	Number of citizens contributed in co-created solutions		200	239	19.5%
Engagement of stakeholder	Engagement of young people: did the young people feel that they were able to contribute in the activity and feel engaged?	n/a	Average above 4 (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)	Result is merged between all citizens and young people, young people's results included in the below 4.44	11%
	Engagement of all citizens: did the citizens feel that they were able to contribute in the activity and feel engaged?		Average above 4 (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)	4.44	11%
Number of co-created solutions	Number of co-created solutions	n/a	3	6	50%
	Number of validated solutions		3	6	50%
Improving awareness of energy positive district solutions	The activity increased the participants' knowledge about the subject matter	n/a	Average above 4 (scales 1-5, 1=total disagree, 5=fully agree)	4.413	11%

The impact assessment of citizen engagement activities until M36 are 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

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Espoonlahti area (over 60 000 people more than targeted) and exceed the targeted number of citizens who contributed to co-created solutions (39 more than targeted). 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 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 = 4.413 with a target of 4). Data from activities will be added to the E3 tables once the data collection is finished in spring 2023.

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.

Table 14. E4 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Stakeholders reached to contribute in Business model / solution co-creation	Number of stakeholders reached in total	n/a	200000	545308	270%
	Number of stakeholders contributed to co-created solutions / business model co-creation		60	64	6%
Engagement of stakeholder	Did the stakeholders feel that they were able to affect and participate in the	n/a	Average above 4	4.25	6%

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	ideation of future directions?				
Number of co-creation sessions for (energy positive) business models	Number of co-creation sessions	n/a	6	9	50%

The impact assessment of business model co-creation activities until M36 are 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 organization) and eight start-ups besides organizers 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. 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).

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 an 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 display the improvements in energy use during the monitoring period.

Table 15. E5 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Share of RES (electricity) (MWh/%)	Total Energy consumption (electricity)	27853	25000	24625	1.6%
	Share of Energy consumption	100%	100%	100%	0%

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	using RES (electricity)				
	Total Energy consumption (thermal)	12040	11500	11102	3.5%
	Share of Thermal energy consumption using RES (thermal)	100%	100%	100%	0%
Onsite thermal energy ratio OER %	Energy production using RES (thermal) & Total energy demand	-	100%	140%	40%
Flexibility increase (thermal)	Change in thermal peak power demand from district heating	9.5	-1.5	-1.8	20%
	Potential thermal flexibility down regulation from integrated equipment	n/a	1.5	2	33%
	Thermal flexibility offered compared to modelled potential	n/a	80%	n/a	n/a
Number of energy subsystems monitored	Number of thermal energy subsystems monitored compared with not monitored subsystems	0	50%	90%	40%

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 because of limiting 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.

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The thermal flexibility was increased by implementing an interface between district heating provider Fortum and Sello building management (BMS) Desigo system 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 temperature is monitored constantly to make sure sufficient, pre-determined indoor conditions are always preserved. 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.

In order 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. 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.

Table 16. E6 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total change in energy demand	Total Demand Electricity (MWh)	27853	25000	24625	1.5%
	Peak Demand (MW) electricity	6.72	n/a	n/a	n/a
	Share of Electrical energy from renewable energy sources	27853	100%	100%	0%
Annual Mismatch Ratio (AMRx)	Electrical Energy production using RES (MWh)	583.2	6%	6%	0%
	Onsite production using RES	583.2			
	District PV Generation MWh	583.2			
Onsite electric energy ratio OER	Energy production using RES (MWh) % Total energy demand	-	2%	2%	0%

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Increase of integrated systems share (smart control/ VPP/ storage)	Total available (RES, storage, HVAC, EV Charging. etc) Number.	162	184	184	0%
	Number of equipment integrated	125	147	147	
	ratio		80%	80%	
CO_2 equivalent change due to the flexibility	CO_2 equivalent change	0	30	31.2	4%
Number of virtually monitored devices	Number of elevators/escalators units with virtual power demand meters monitored by VPP	0	2	0	100%
	Number of elevators/escalators units with physical power meters monitored by VPP	13	15	15	0%
Prediction Model Accuracy	Accuracy of the reserve market price, actual price vs. predicted price per market	n/a	70%	n/a	n/a
	Asset flexibility prediction accuracy, predicted vs. actual	n/a	90%	85%	5%
	Increased working efficiency due to prediction model (saved hours per day)	n/a	0.5	1	50%

An increase in the integrated systems share KPI was seen due to the addition of 22x22kW EV chargers. The addition of this charging station to Sello has brought a reduction of 31.2 CO_2 equiv.t with the increased flexibility in energy demand.

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.

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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 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.

The 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.

The EV chargers, 22 pieces, are added as a part of the smart flexibility platform. The interface between the systems still needs work and it is except to be ready in March 2023. After that the system will be optimised in order to provide best possible flexibility to the markets without compromising user experience.

The CO_2 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 89 $kgCO_2$ /MWh in Finland is used. The plant is assumed to operate with 100 kW power for 40 % of the time.

One important cornerstone for successful participation in the net stabilization 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. KPI data of 'Demand from all EV mobility modes', 'Greenhouse gas emissions reduction', 'Electric vehicle charging' and 'Ratio of demand to local transformer capacity' are based on Leppävaara bus charging system, that contains 5 pantograph chargers and 6 cable chargers. Siemens has done e-mobility work with Sello shopping centre, and these results are shown in 'Peak load reduction', 'Total flexibility available' and 'Flexibility % of normal load'. However, these are expected to be finished in end of March 2023 due to swapping the communication interface provider, which has affected the technical setup. VTT and

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PIT built a simulation model for charging strategies, and results from this task are included in E17.

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. There is no data about specific areas/districts (Leppävaara in this case) on modal share utilization 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).

Table 17. E7 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Demand from all EV mobility modes; impact on the grid	A sum of the demand from all EV mobility modes kW/year	n/a	n/a	1389	n/a
Greenhouse gas emissions reduction	CO_2 kg reduction based on charged electricity (EV)	n/a	n/a	832tonnes	n/a
Electric vehicle charging	Charging time / day and charging time / month (average)	n/a	n/a	25,7 h/d 771,3 h/mth	n/a
	Charged energy month and charged energy / day.	n/a	n/a	2901,8 kWh/d 87053 kWh/mth	n/a
Ratio of demand to local transformer capacity	Peak demand from all EV mobility modes / Transformer capacity (hourly average)	n/a	n/a	46,3 %	n/a
		n/a	n/a	4 %	n/a
Peak load reduction	Peak demand (KWh)	n/a	n/a	100kW	n/a
Flexibility % of normal load	Flexibility % of normal load. Buildings/Prosumers	n/a	50%	n/a	n/a

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Charging simulations	Utilization of chargers in the system after charging strategy	n/a	n/a	35%	n/a
	Peak demand reduction using the charging strategy	n/a	n/a	300kW	n/a
	Number of charging strategies simulated.	n/a	n/a	9	n/a

Intervention E8– Engaging users

The implementation activities of this intervention are focusing on community engagement activities in Leppävaara demonstration area. 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.

Table 18. E8 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of engaged stakeholders	Number of people reached in total	n/a	18650	72483	289%
	Number of citizens contributed to co-created solutions		100	42	58%
Engagement of stakeholder	Engagement of all citizens: did the citizens feel that they were able to contribute to the activity and feel engaged?	n/a	Average above 4	4.48	11%
Number of co-created solutions	Number of co-created solutions	n/a	3	4	33%
	Number of validated solutions		3	4	33%
Improving awareness of energy positive district solutions	The activity increased the participants' knowledge about the subject matter?	n/a	Average above 4	4.36	9%

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Likelihood for using the developed solutions	How likely would you use the solution in your daily life?	n/a	This KPI is terminated. In Citizen engagement activities, the solutions were experimental concepts and thus not assessed and used in the daily life of citizens.

The impact assessment of citizen engagement activities until M36 are 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 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. 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 = 4.48 with a target of 4) and the activities improved their awareness (Average = 4.36 with a target of 4).

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 bring forward promising technical and infrastructure solutions for PEDs and to explore the benefits of using 3D city model in pursuing new opportunities and implementing PED solutions. During the KPI decision-making process, it was decided that the 3D-model will be monitored by collecting the number of yearly users. However, the city only collects data on the number of downloads and unique users of the API openly available on Espoo's webpages and does not collect information on internal users within the city. Still, a decision was made to use this data to assess the amount of use that the model has.

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During the first monitoring period, the number of users rose from 104 (in 2018) to 374 (in 2022). This is a 260 percent increase in four years but is also lower compared to the 664 unique users identified in 2020. Thus, the number of users has increased compared to the baseline period but decreased compared to its peak. According to the information gained from relevant city departments, this sharp decrease may indicate that the novelty of this solution has decreased in the eyes of potential users, and the relatively low number of users may indicate that the city model as a tool is still not a part of the everyday work of local companies. The city also collects the number of downloads of the model, and this data was given to the SPARCS project on a yearly granularity. The number of downloads between 2018 and 2022 can be seen below:

- 21187 in 2018
- 83557 in 2019
- 127981 in 2020
- 9475 in 2021
- 42589 in 2022

These numbers show a similar picture to the user amount, with a sharp increase between 2018 and 2020, and even a sharper decrease between 2020 and 2021. It was deemed that a dip in the number of automatic searches from the API service is the most likely reason for this decrease in downloads. As this data gave additional useful information for the intervention, it is suggested that "Increased number of downloads from the API service" is added as an additional KPI.

During the first monitoring period, it was also noted that assessing the number of users of the 3D model does not adequately monitor the types of interventions that SPARCS has on the development of the 3D model. This is because the aim of SPARCS is to test the ability of this model to simulate district-level energy production methods, and this pilot is not going to affect the usability of the current open 3D model. Thus, additional KPIs might be needed to get the full picture of how the SPARCS solutions have fared. These KPIs will most likely fall under intervention E17, as this intervention focuses on the concrete work done on the 3D model within SPARCS.
Apart from the 3D-model related interventions, other KPIs will be calculated after the completion of this deliverable. During the baseline phase, this intervention contained the following two KPIs:

- Successful completion of the SPARCS interventions.
- Relation of project to city strategy.

It was decided that these two KPIs should be moved to the general city level information, as they do not necessarily focus on the evaluation of this intervention. For the other KPIs not yet mentioned, values will be provided later. These are indicators that are only calculated once during the project. For the KPI "Utilization of energy system planning on the new urban development planning", a more SPARCS and Kera -focused KPI was brought up. "Utilization level of energy system planning solutions, roadmaps and reports produced in SPARCS". This provides a better focus, and a better opportunity to gain insights on how beneficial the SPARCS solutions are based on the opinion of local stakeholders.

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Table 19. E10 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increased number of persons using Espoo 3D city model	Number of people utilising Espoo 3D city model	104	200	374	87%
Number of promising technical and infrastructure solutions for PEDs	number of solutions	n/a	10	n/a	n/a
Utilization level of energy system planning solutions, roadmaps and reports produced in SPARCS	Likert scale to capture the utilization of energy system planning on the new urban development planning	n/a	>3	n/a	n/a
Expected on-site Energy Ratio [%] for Kera	Annual energy produced / consumed on-site	0	Over 1	n/a	n/a

Intervention E11– Engaging users

This intervention is about conveying insights to city planning authorities of citizens' preferable future multimodal mobility habits, schedules, and routes to optimize the people flow from energy and user experience perspectives. 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.

Table 20. E11 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of stakeholders reached	Number of stakeholders reached	n/a	>25	Final number counted once in the end of the project (12 in 12/2022)	n/a
Were the mobility insights useful for the city planning authorities?	Likert of the usefulness of the insights	n/a	>4	n/a (to be collected once in the end of the project)	n/a

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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 desktop studies, and thus the chosen KPIs will only assess the number of identified solutions within the final reports. 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. This difference in the number of 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[2] 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.

However, the single KPI for both themes, was deemed to be insufficient to fully assess how well the activities within this intervention achieved their goals. To give an example, the detailed plan of E12-1 is below:

- Current 5G projects in Kera and elsewhere have been investigated and documented.
- Literature review on 5G and smart infrastructure conducted.
- Opportunities for synergies in energy efficiency, DSM, prosumer transactions and innovative business models identified.
- Key stakeholders mapped and documented.
- Findings documented, reported and communicated.

The current KPI can be identified as assessing how well this action met the plans phase "Opportunities for synergies in energy efficiency, DSM, prosumer transactions and innovative business models identified". Thus, the KPIs do not necessarily assess how well the report identified any other parts of the detailed plan. Other additional KPIs could include the following:

- Number of stakeholders identified.
- Number of relevant projects identified.

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

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Table 21. E12 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of potential 5G solutions identified	Number of identified solutions	n/a	5	30	600%
Number of potential blockchain solutions identified	Number of identified solutions	n/a	5	7	40%

Intervention E1 – 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. The work on this intervention continues up to M60.

Table 22. E13 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Value of the developed solutions for the development of a future district	How valuable the developed solutions are considered to be for the development of future districts by the relevant stakeholders (Likert scale 1-5)	n/a	4<	n/a	n/a
Number of e-mobility solutions introduced for replication in Kera planning phase	Number of e-mobility solutions introduced	n/a	5	7	40%
Simulated demand for charging stations in Kera area		n/a	Simulation complete	yes	0%

One of the keyways this work has been carried out has been the organization of dedicated meetings on the topic of mobility between relevant SPARCS partners and Kera area

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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 form 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. The relevance of the presented and co-created solutions and concepts for utilization in Kera will be gathered through an online survey in a later date to align with the general Kera development process.

Charging demand for the Kera district has been studied on multiple levels. A 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.

Intervention E14– New economy/Smart governance models

This intervention is about co-creation for sustainable city development. The intervention aims to produce a co-creation model that supports the utilization and implementation of novel smart city solutions to urban areas and the general development of sustainable and smart urban areas. Kera is used here as a main context for developing the model, and later the model has been generalized to be applicable in any city and urban area development (see intervention E22).

The process to create the model has included the City of Espoo subcontract of a third party through a public procurement. The third party has supported the creation of the model. Design Sprints, questionnaires, interviews, and other workshops have been utilized to form the model with different stakeholders. As the model development process both for the Kera model and the generalized version is inseparably interlinked and form one large development entity, the KPIs are shared between this intervention (development of the Kera model) and intervention E22 (development of the generalized model).

Table 23. E14 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of stakeholders involved in co-creation of the co-creation model	Number of stakeholders	n/a	70	116	65%
Number of citizens involved in co-	Number of citizens	n/a	100	137	37%

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creation of the co-creation model					
Visitors on the co-creation model website (calculated monthly) (toolbox)	Number of unique visitors on the website (all months combined)	n/a	1500	1568	5%

As the co-creation model is developed in SPARCS, there is no baseline data available. A target of 70 stakeholders (representatives of companies, organizations, 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 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 organizations, and 137 citizens (of which 118 through an online questionnaire) participated in the co-creation model development process.

The KPI “Satisfaction of the participants in the co-creation process” 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 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 to measure the reach of the created model. The model is presented as an online toolbox (as a WordPress website) which provides the possibility to measure the number of visitors on the page. The webpage 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 on November 31st, 2022, to host the final version of the finished generalized model. So far, there has been 1,568 unique visitors to the website since February 2022 (re-calculated monthly). The aim at the moment is to keep the website up and running to the end of the project (M60). The model will be disseminated throughout the project, so the number of visitors is expected to grow in the future (the model is also available in text format for more traditional use and dissemination).

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 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

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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 charging stations was created via Siemen's 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...+100 %.

Identified possible business models include peak load management and ancillary services for electric power markets. The blockchain could be used to 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 aid in the reporting process. The number of identified solutions in relation to this report are provided in the KPIs of intervention E12.

Table 24. E15 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of smart business models created	Number of smart business models created	n/a	1	1	0%
Loads connected to demand response	Loads connected to demand response	0	4	5	25%
Number of blockchain solutions identified	Number of identified solutions	n/a	1	1	0%
Number of smart business models identified in relation to blockchain solutions	Number of smart business models identified	n/a	1	2	100%

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 the current demand-side management (DSM) solutions implemented within the local social housing company, Espoon Asunnot OY, further 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 with researchers from VTT, it was noted that the main aim of the DSM scheme utilized within the Espoon Asunnot buildings is not to reduce energy consumption in certain buildings, and instead to optimize 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

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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. According to the analysis so far during the 1st reporting period, this target has been achieved during the first few years of DSM operation. There has been a small reduction in energy consumption, as in 2021 flexibility has decreased energy consumption by a total of 1.74% compared to the calculated true consumption value in the analysed buildings. This reduction led to 4.47 tCO2 saved during 2021.

For the KPIs "Total current and potential heat load under DSM", and "Number of buildings or apartments participating in DSM scheme", some assumptions were required. Firstly, the total heat load available was assumed to be the peak special heating load of the analysed eight buildings, as we do not have the knowledge of how the district heating operator controls the DSM scheme. The real available heat load under the scheme can differ depending on what loads the operator controls. Secondly, the number of buildings or apartments participating in the DSM scheme is assumed to be all of the Espoon Asunnot apartments. Within their own reports, Espoon Asunnot notes that "nearly all" of their buildings are connected to the thermal demand side management but does not give a clearer number. Thus, the provided values might include apartments that are not connected to the system, particularly ones that are near the end of their lifespan.

Table 25. E16 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Heating flexibility increase as a percentage of normal load	Heat consumption per year	1 999	2500	2 679	75
	Heat consumption monthly average	167	200	223	11%
	Flexibility as a percentage of consumption	n/a	at least -1%	-1.74	1%
Total current and potential heat load under DSM	Total heat load under DSM	n/a	600	636	6%
Current and potential emission savings	Emission savings	n/a	Savings are observed	4.47	
Number of buildings or apartments participating in DSM scheme	Number of apartments	15 724	15800	15 879	5%

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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.

Table 26. E17 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increase of simulations executed via the Virtual Twins concept	Number of simulations executed via the Virtual Twins concept	n/a	1100	1800	63%
Number of innovative energy technologies incorporated in virtual twin for simulation purposes	Number of technologies introduced in virtual twin to improve simulations	n/a	2	5	150%
Accuracy of building heating and electricity load forecasting (error between virtual twin and real monitored data)	Forecasted and measured hourly data of building electricity demand, space heating demand and on-site PV electricity production	n/a	0,1	Electricity (NRMSE*): 0,1 District heating (NRMSE): 0,05 PV (NRMSE): 0,19	0 50% 9%

*NRMSE = normalized root mean squared error

During the 1st monitoring period, the number of simulations through the virtual twin has steadily increased 1800 and is already above the target. A further increase is expected in the coming monitoring periods. 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 normalized 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.

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

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commercial vehicles) and develop strategies to manage the peak power demand. In addition, the future needs are evaluated in order to provide recommendations for urban planning. As the number of EVs still is low but rising quickly, the optimization strategies and the future demand are based on simulations of the EVs and their anticipated charging behaviour.

Table 27. E18 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increase of integrated public EV charging units	# of public EV charging stations	24	n/a	178	n/a
Peak load (electricity) reduction	Peak demand electricity (MWh)	n/a	n/a	8,802	n/a
Demand from all EV mobility modes; impact on the grid	A sum of the demand from all EV mobility modes (MWh)	n/a	n/a	88,023	n/a
Developed recommendations for future urban planning/new districts (y/n).		n/a	yes	yes	n/a

During the 1st observation period the number of charging units has increased significantly in Espoo both in Sello and Lippulaiva locations. In Sello we observe increase from 24 to 48 chargers and in Lippulaiva starting from 0 we observe the increase to 130 chargers at the end of the first period. Regarding the peak load, it has not been calculated in the very beginning and at the end of the first period we calculated it as 8,8 MWh and the peak electricity demand for all EV modes for one day as 88 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 are focusing on community engagement activities in the Espoo macro level. The KPI data 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.

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Table 28. E19 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of engaged stakeholders	Number of people reached in total	n/a	30000	50461	68%
	Number of citizens contributed in co-created solutions		400	541	35%
	Number of other stakeholders contributed in co-created solutions		100	122	22%
Engagement of all citizens and stakeholder	Engagement of all citizens and stakeholders: did the citizens/stakeholders feel that they were able to contribute in the activity and feel engaged?	n/a	Average above 4	3.78	5%
Number of co-created solutions	Number of co-created solutions	n/a	10	16	60%
	Number of validated solutions		5	10	50%
Improving awareness of energy positive district solutions	The activity increased the participants' knowledge about the subject matter?	n/a	Average above 4	3.86	3.5%

The impact assessment of citizen engagement activities until M36 are 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,

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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).

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.

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 29**Error! Reference source not found.** 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[3]. The measured values are all under the limit values for good air quality for those that have been categorized by HSY. When studying the data gathered for the reporting period one, the values are even lower, which means that there is less pollution.

Table 29. E21 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Air quality	PM 2.5	6,14	≤10	6,03	4%
	PM 10	17,08	≤20	13,85	3%
	NO	10,47	≤10	6,98	3%

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

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	NO_2	19,62	≤40	15,15	62%
	PM 2.5	6,11	≤10	3,21	6%
	PM 10	14,93	≤20	7,26	6%
	NO	6,54	≤15	14,02	6.5%
	NO_2	13,70	≤40	6,54	82%

The difference is bigger in the case of Matinkylä and Lippulaiva, which is probably since Lippulaiva is a new building and the traffic around it is still partly hindered. Also, the measuring equipment has only been there from September and the average is not totally comparable with the other averages covering one whole year.

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 generalized 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 generalized version are closely interlinked, the KPIs are shared between this intervention (generalized model) and intervention E14 (Kera model).

Table 30. E22 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of stakeholders involved in co-creation of the co-creation model	Number of stakeholders	n/a	70	116	65%
Number of citizens involved in co-creation of the co-creation model	Number of citizens	n/a	100	137	375
Visitors on the co-creation model website (calculated monthly) (toolbox)	Number of unique visitors on the website (all months combined)	n/a	1500	1568	5%

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As stated above, the KPIs for this intervention are the same as for E14. The set targets on citizen and stakeholder engagement during the model development process have been met. The KPI on the satisfaction about the process has been removed and replaced by a KPI presenting the interest towards the model as a number of site visitors. Please see the intervention E14 for more detailed description about these KPIs and results.

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. 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.

Table 31. E23 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of new innovative projects leveraged beyond SPARCS	Number of projects	n/a	1	n/a	n/a
The total volume of additional funding	Volume of funding	n/a	n/a	n/a	n/a
Active collaboration with ecosystems developing sustainable solutions in smart city sector	Number of ecosystems	n/a	>5	6	20%
Participants in the Smart Otaniemi stakeholder events	Number of people	n/a	100	60	40%

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 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. The first one on active ecosystem collaboration 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 with 'RAKKE – a solution path to sustainable growth ecosystems and The Implementation Pathway for Environments that Accelerate Sustainable Growth (KETO) projects. The other added KPI indicates the number of stakeholders participants in the Smart Otaniemi ecosystem events, arranged by VTT and

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ESP, which are aimed for different organizations and stakeholders to develop smart city solutions.

3.2 Aggregated monitoring- city level

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 32 below presents the city-level KPIs focused on energy.

Table 32. Espoo city -level, energy KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Reduction of CO_2 equivalent emissions (%)	CO_2 -e calculations (1000Tons/year)	903	-Reduce CO_2 emissions by 150 t CO_2 /MW annually -Reduce emissions by 80% compared to 1990 levels by 2030	823	(Compared to annual emissions reduction target) 578 (compared to 2030 emission target)
Share of RES increase (%)	Total energy consumption & Annual RES generation (PV, Wind, Hydro, Biomass, other)	41% (heating) 52% (electricity)	55-65% in year 2023 (both electricity and heating)	51% (district heating), 54% (electricity)	4 % (heating) 1 % (electricity)
Air quality	THC Volatile hydrocarbons, NOx, Small particulates (PM10 and PM2.5) (ug/m3)	10.47 (NO) 19.62(NO2) 6.14 (PM 2.5) 17.08 (PM 10)	≤40 (NO2), ≤10 (PM 2.5), ≤20 (PM10)	6.98 (NO), 15.15 (NO2) 6.03 (PM2.5) 13.85 (PM10)	62% (NO2) 50% (PM2.5) 3% (PM10)
Total electricity demand reduction (%)	Annual total demand Electricity	Increase of 3.8% compared to 2015	Reduction of 7.5% between 2017 and 2025 (compared to 2015 levels)	Increase of 8.3% compared to 2015	16 %
Total heating demand reduction (%)	Annual total demand Heating	Decrease of 0.04% compared to 2015	Reduction of 7.5% between 2017 and 2025 (compared to 2015 levels)	Increase of 1.3% compared to 2015	9 %

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When compared to the baseline period, a decrease in CO_2 emissions and increase in the use of renewables in both heating and electricity can be observed. The amount of renewable production within the heating and electricity sectors are already nearly at the target levels provided within the SPARCS Grant Agreement and could reach the target when values for 2022 are provided. However, 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 Services Authority (HSY). In Finland, consumers can buy electricity from any retailer and the agreements are not public. As each retailer has a different energy mix, it is not possible to calculate the RES share at city level for electricity. The CO_2 emissions within Espoo have reduced by 9% compared to the baseline level, but the road towards the Espoo carbon neutrality target is still long. In addition, the air quality within Espoo is above the target values provided by HSY (good values of the HSY air quality index[4]), and thus is at an excellent level.

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 thus should not be used to set a target for the whole city. Thus, only a simple target of reducing overall consumption was chosen, but the aforementioned targets should still be kept in mind. Both heating and electricity consumption have remained at roughly the same space with a slight increase, thus not meeting the target. This is most probably due to an increase in the population of the city, and new construction causing new consumption sources. When looking at consumption divided by population, a decrease can be observed in both heating and electricity consumption.

Lastly, there are two KPIs within Table 32 that unfortunately do not have available city-wide data. These are excess heat recovery ratio and increase of integrated systems share. The city does not collect data on the recovery of excess heat within the city borders, the amount of total excess heat available for use, or the number available or integrated systems. However, these can still be provided for the demonstration sites of Lippulaiva and Sello. Table 33 below presents the general mobility related KPIs on a city-wide level.

Table 33. Espoo city -level, mobility KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
EV car sharing rate increase	Number of EVs; EVs available for sharing	346 full electric cars registered in Espoo area;	n/a	2.817 full electric cars registered. Approx. 150 full electric cars for	n/a

[4] Mikä on ilmanlaatuindeksi? - HSY

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		No EVs for shared use.		shared use registered	
Increase of EVs share in local transportation	Number of EVs & Number of vehicles & Number of bicycles	346 full electric cars 119.681 vehicles registered in Espoo area. No registration data available for bicycles.	n/a	2022: 2.817 full electric cars registered & 125.293 cars registered in Espoo area. No registration data available for bicycles	n/a
Transport infrastructure (km of roads for cars, bicycles)		Roads for cars: 1213Km Bicycle paths (partially joint pedestrian paths): 1195Km	n/a	Roads for cars: 1213 km Bicycle paths (partially joint pedestrian paths): 1195 km (no update data available compared to baseline)	n/a
Transport infrastructure (Public transportation lines, Number of stops [rail])		Rail-based public transportation: 6 metro stations, 7 commuter train stations in Espoo area (2020)	n/a	Rail-based public transportation: 11 metro stations, 7 commuter train stations (2023)	n/a
Stock of vehicles (Cars, Motorcycles, Bikes, Buses,)		Registered vehicles in Espoo (vehicle per capita): 567 (/1000) (in 2019)	n/a	568 (/1000) (in 2021)	n/a
Transport behaviour	Modal Split	By Public Transportation 33%	n/a	By Public Transportatio	n/a

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	Citizens going to work using a personal (non Ev) vehicle %; Citizens using public transportation to go to work %; Citizens going to work using a personal (EV) vehicle (%)	(2018); By Private car: 48% (2018) (No data available about private EV usage on commute trips)		n 33% (2018); By Private car: 48% (2018) (no update available)	
Increase of EV charging points	Number of smart EV charging points & Number of V2G EV charging points & Number of EV charging points	270	Addition of 20-140 EV charging points	270+134 (Lippulaiva premises)	n/a
Utilization of charging stations	kWh charged (only data available from Lippulaiva chargers	No baseline	n/a	214.846 kWh	n/a

Comparing the baseline with the 1st reporting results in terms of general e-mobility development in Espoo demonstration areas, the increase of the EV charging points in Lippulaiva premises forms a notable increase of local EV charging possibilities in the area. 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.

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 was opened a few years since the start of the project in 2017, and the extension of 5 new stations opened in December 2022 has brough the total number up to 11 metro stations (including Espoonlahti metro station, located under the new Lippulaiva centre, and Finnoo [replication site] metro station). These station areas act also as important

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public transportation and shared mobility hubs, including the existing shared (public) city bike system (with currently 4.600 bicycles in Espoo and Helsinki), organized 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 fast tramline connection (Jokeri Light Rail) will be opened in autumn 2023 (ahead of the early 2024 previously expected 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 34 below 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. The city doesn't apply for patents or contribute to standardization organizations. 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. Regarding the financial KPIs, discussions continue on what investments to include within the city level KPIs to provide a full picture that can still be compared via the KPIs provided in the table below. These KPIs proved to be more detailed than the data available for collections, thus leading to issues in completing calculations. 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.

Table 34. Espoo city-level, general KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Job creation	Number of new jobs created by SPARCS	n/a	New jobs created in lighthouse cities as a result of SPARCs actions: Espoonlahti:200 new jobs Leppävaara Center: 50 new jobs Leppävaara/ Kera: 300 new jobs	Espoonlahti: 52 new jobs (in total ~500 new jobs) Leppävaara center: 17 new jobs Kera: -	Espoonlahti: -74% Leppävaara *66% Kera: n/a

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Increase citizens quality of life, health and well-being	Life expectancy at birth (years)	80.6 (Men), 85.6 (Women)	n/a	80.3 (Men), 85.5 (Women)	n/a
Annual number of new patents	Patents filed in the context of SPARCS	n/a	n/a	0	n/a
Annual number of contributions to European Standardization Organizations	Contributions to European Standardization Organizations (#/a)	n/a	n/a	0	n/a
Successful completion of the SPARCS interventions	# of goals achieved # of total goals	n/a	All successfully completed	n/a	n/a
Relation of project to city strategy	Likert to evaluate the project goals towards the city goals	n/a	n/a	n/a	n/a
ROI	Return on Investment (%)	n/a	13-44%	n/a	n/a
Payback time	Payback time (years)	n/a	2-13 years	n/a	n/a
DSCR	Debt Service Coverage Ratio (%)	n/a	1.15-1.45%	n/a	n/a

City level values for the SPARCS citizen engagement actions are provided in the Table 35 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.

Table 35. Espoo city-level, citizen engagement KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of engaged stakeholders	Number of people reached in total	n/a	63000	204763	225%
Number of citizens contributed in co-created solutions	Number of citizens	n/a	700	821	172%
Number of other stakeholders	Number of stakeholders	n/a	100	122	22%

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contributed in co-created solutions					
Engagement of stakeholder	Engagement of all citizens and stakeholders: Did the citizens/stakeholders feel that they were able to contribute in the activity and feel engaged?	n/a	Average above 4	4,27	7%
Number of co-created solutions	Number of co-created solutions	n/a	16	26	62%
Number of validated solutions	Number of solutions	n/a	11	20	81%
Improving awareness of energy positive district solutions	The activity increased the participants' knowledge about the subject matter?	n/a	Average above 4	4,22	5%
Number of co-creation sessions for (energy positive) business models	Number of co-creation sessions	n/a	6	9	50%
Stakeholders reached to contribute in business model co-creation	Number of stakeholders reached in total	n/a	200000	545308	172%
Number of stakeholders contributed in business model co-creation	Number of stakeholders	n/a	60	64	6%
Were the mobility insights useful for the city planning authorities?	Likert of the usefulness of the insights	n/a	n/a (to be collected once in the end of the project)	n/a	n/a
Number of stakeholders reached	Number of stakeholders reached	n/a	Final number counted once in the end of the project (12 in 12/2022)	n/a	n/a

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3.3 Conclusions and lessons learnt in Espoo

The monitoring period in Espoo started in March 2022 and had a 12-month duration. As presented in Figure 9 and Figure 10 below, the 85% of the interventions were monitored (partially or fully) meaning that the necessary data for the calculation of the defined KPIs were obtained from different resources of the municipality.

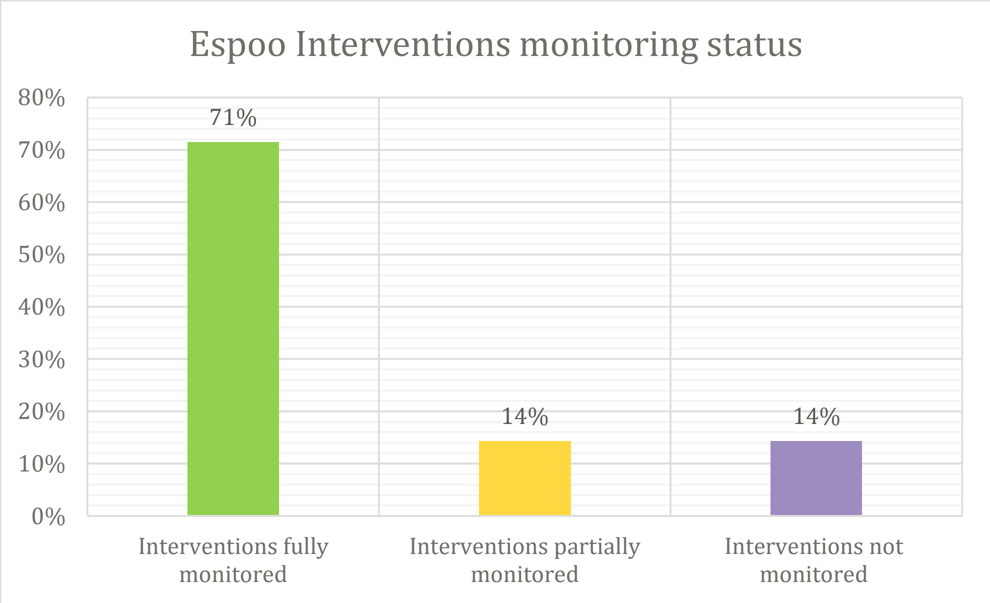

Figure 9. Espoo intervention s monitoring status

The evaluation of the interventions showed that 37% of the KPIs (84 in total) exceeded expectations while 42% of the KPIs met the set targets. Cumulatively, about 80% of the KPIs were achieved at the intervention level. KPIs that are close to the set targets (meaning the monitored values deviate between 10%-50% from the set target) are around 5% while only 1% of the KPIs are far from expectations (deviation greater than

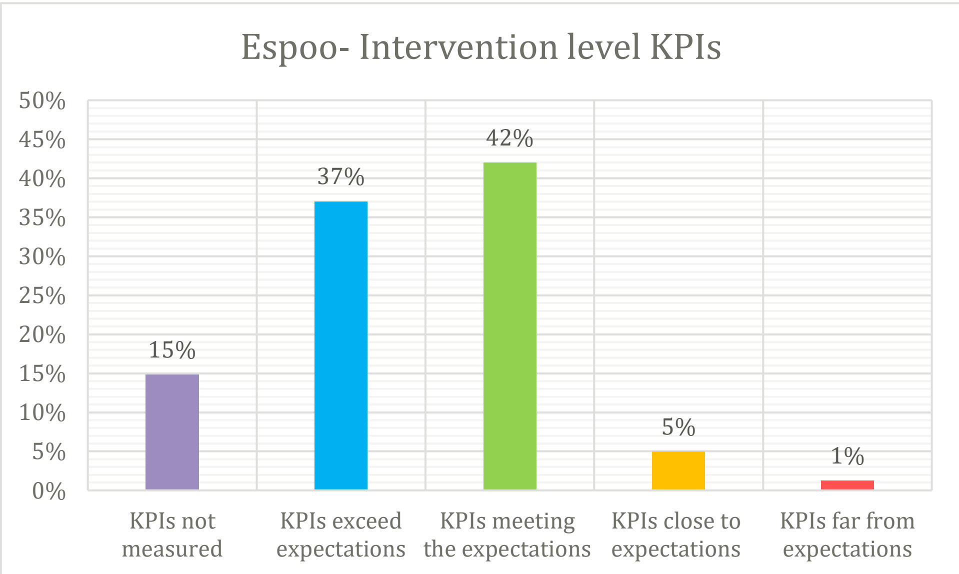

Figure 10. Overview of interventions impact assessment- Espoo

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50%) and corrective actions will be implemented for improvement in subsequent periods.

Respectively according to Figure 11 at the current monitoring period approx. 41% of KPIs (32 in total) were not measured due to lack of data. KPIs that exceed or met the expectations were cumulative 50% while the KPIs that were far from the set targets were approx. 9%.

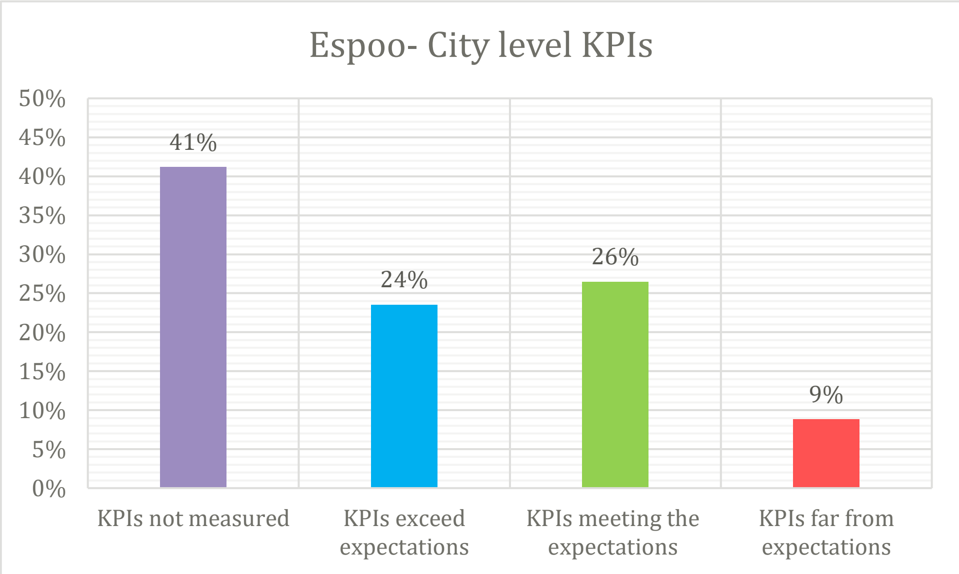

Figure 11. Overview of city-wide KPIs impact assessment- Espoo

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 optimization 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.

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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 optimization time when the similar solutions are used.

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.

The Kera interventions 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, utilization 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.

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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 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 utilization 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 of the demonstration sites have proceeded as planned, from the Sello demonstration site that was already in operation before the start of the project to Kera, which will begin a long construction process this year. Data from Sello and Lippulaiva is

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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 presents the values of the KPIS for Leipzig interventions and city wide aggregated KPIs in the first monitoring period from September 2022 to February 2022. As in chapter the presentation of Leipzig interventions covers both the individual monitoring of the KPIs on the intervention level and the aggregated modelling on the City Level. The colour mapping for the visual representation of the impact in the different KPIs was presented in Table 10.

4.1 Individual monitoring- intervention level

Intervention L1- Intelligence EV parking and storage

The L1 intervention demonstrates the integration of e-mobility and the bidirectional charging of e-vehicles into a microgrid at the Baumwollspinnerei site. The aim is to improve the stability of the microgrid. The car battery can be used as intermediate storage and feed electricity back into the grid when demand is high. When supply is high, electricity can be taken from the grid and stored in the car battery therefore load peaks by feeding EV-battery stored energy back into the grid when appropriate (V2G concept). CEN uses load management software to link the e-mobility platform and is monitoring and analysing the results.

Table 36. L1 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Energy Storage Type	Type	Electrical Storage	2	2	0%
Energy Storage Number of Equipment Increase	Amount (Number #)	0	2	2	0%
Energy Storage capacity Increase	kWh	0	48	48	0%
Peak Load Reduction	Peak demand (kW)	381	350	350	0%
Reduced System Average Interruption Duration Index (SAIDI)	(min)	0	0	0	0
Reduced System Average Interruption Frequency Index (SAIFI)	System Average Interruption Duration (min)	0	0	0	0

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Demand from all EV mobility modes; impact on the grid	A sum of the demand from all EV mobility modes Considering EV Smart chargers (Sum of peak demand of all charging stations) (MW)	0	66	19	71%
User satisfaction of minimum charging level in EVs	User Satisfaction of minimum charging levels in EVs Likert survey results	survey	n/a	n/a	n/a
monetary gains for user (charging costs vs flexibility revenues)	EV User charging costs (ct/kWh)	0	45	45	0%
Accuracy of Generation forecasting and storage utilization	Predicted generation compared to the actual generation	survey	n/a	n/a	n/a
Accuracy of storage utilisation	The storage utilisation predicted compared to the actual utilisation of the storage (Number of full charging cycles per year)	0	833	0	n/a
Increase in shared EVs availability	Number of EVs available for sharing	0	2	2	0%
increase of integrated smart EV charging units	Number of smart EV charging stations	0	3	3	0%
Increased level of utilisation of EV charging units	Sum of energy charged (kWh)	0	5,000	1,744	65%

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Within the microgrid, the number of on-site storage devices was increased from zero to two; one, in the conventional form of a bulk battery in Hall 18, the other in the more innovative form of a car battery in a bidirectional EV. Studies show that, on average, private vehicles are stationary for approximately 95% of the day. However, this does not mean that the vehicle will be stationary on site at the Baumwollspinnerei. Since this form of storage is very unpredictable and undependable, we have not included it in the increase in energy storage capacity but see its availability as a bonus. In the future, when this technology is more readily available, the bidirectional EV could offer greater storage benefits and frequency balancing potential in a microgrid, especially when more vehicles are entered into a fleet management system, and the established hierarchy can offer a calculated prediction regarding availability.

We have set a target to reduce the peak load by 8-9%. This reduction has been achieved and as these values are derived from annual assessment values, an even greater reduction can be expected given that the highest value for the reporting period was recorded in January 2022. Reducing the peak load can reduce both the physical strain on the grid and associated high costs when electricity is sourced from the public grid.

For the interruption index KPIs, the baseline values are zero, which cannot be improved. However, we can confirm that there has been no surge in interruptions. As there were no charging stations for electric vehicles before this project, the baseline value is zero. Our goal is to increase the overall use of EVs for two reasons. Firstly, because they are a more environmentally friendly form of transport compared to conventional combustion engines, especially if the electricity comes from renewable energy sources. Secondly, due to the balancing effect on grid stability. A grid frequency that is too high can be just as detrimental as a grid frequency that is too low. It is therefore important to draw energy from the grid when supply exceeds demand. It is precisely at these times that charging electric vehicles benefits the grid. CENERO as grid operator aims to eliminate the risk of any interruptions within the network. That is why no interruptions at all are entered as target, which was reached in 2020 and in 2022.

The user satisfaction with the minimum charge level of the e-vehicle is assessed qualitatively by means of a survey. This gives an indication of the users' ability to reach their destinations and return to the site for recharging. As a result of the first survey for 2022, users reported that the availability of the charging station from KOSTAL was not reliable. This was due to the technical problems that continue to occur at irregular intervals at wall-box level. Through detailed technical analyses, the BMW i3 and the local grid could be ruled out as the source of the error. Coordination with KOSTAL is currently taking place and fewer failures are expected for the subsequent monitoring period. However, the availability of the Walther Werke charging boxes has not led to any mobility restrictions for the tenant. The accuracy of the storage utilisation forecast could not be evaluated for 2022 within the framework of a qualitative analysis, since the storage integration into the load management has taken place, but the PVA as generation capacity has not yet been commissioned. Regarding the increase in shared e-vehicles, the target of an increase by a factor of 2 has been achieved. Currently, 2 charging stations are rented by Seecon. They offer an internal EV sharing system for their employees. Furthermore, the goal of increasing the number of rented charging stations up to 3 was achieved and we see potential to further increase this number in the future.

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Each charging column has a charging potential of approximately 2,500 kWh/a. As only 2 of the 3 charging stations are currently leased, our target is 5,000 kWh/a, bearing in mind that the vehicles are not always charged at these stations. They could also remain fully charged for longer periods of time. 1,744 kWh of charging output was recorded. This value is quite low in relation to the target, but again, it is important to bear in mind that the values are based on annual values.

In summary, the first phase of feedback can be considered a success, even if there is still room for improvement. There were some technical problems with the wall-box/EV interface, which were usually fixed quickly, but unfortunately the wall box was unused during this monitoring period.

Intervention L2- Micro grid inside the public grid

The L2 intervention aims at integrating on-site electricity generation and storage facilities into the immediate microgrid in order to increase the degree of self-sufficiency and optimise the use of the generated energy. At the Baumwollspinnerei, CEN has installed a 71-kWP PV plant along with a large-scale storage unit in addition to the already existing CHP plant. The batteries of bidirectionally capable e-vehicles, which are sometimes connected at the site, serve as additional intermediate storage capacities.

A digitised load management solution along with smart meters and intelligent sensors ensure the necessary granularity and depth in information, as well as the proper user-demand oriented control of electricity flows. Furthermore, the interface to the public grid is equipped with a data exchange device to balance the public grid with the on-site-demand by a peer2peer-energy-trading-platform.

Table 37. L2 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
District self-consumption rate	Total district energy demand (MWh)	1,972	1,873	2,108	33%
	Total district Energy Production (MWh)	301	860	255	
	ratio	-	45%	12%	
Reduction of the customer energy cost	Energy cost for the customer (ct/kWh)	22	27	29	7%

The baseline values of energy consumption were established during the initial phase of the Corona pandemic. Due to the nature of the pandemic, most businesses had to stay closed, and people were told to stay at home. The Baumwollspinnerei properties are predominantly leased to businesses that are not considered essential. For this reason, baseline consumption data is very low. Our target was to achieve a 5% decrease in

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consumption. Unfortunately, we could not achieve this, but instead had an increase of over 6%. Our main reason is the low baseline, but we the consumption will be reduced by further raising tenants' sensibilisation of consumption patterns and behaviour, as well as through smart heat demand management. We expect to see better results in the next reporting period.

The power generation plants at the Baumwollspinnerei have not all been put into operation yet, which means that the measured power generation at the site will still increase. This is due to the delayed commissioning of the PV plant on the Baumwollspinnerei site. A comparison of the energy costs with the baseline values from 2019 is also difficult to present due to the dynamic market environment in 2022.

The costs of energy production and the related customer prices increased more strongly than the reported target values. The background to this is the increased electricity prices in procurement and the in-house production which is in 2022 less then formerly planned. The aim is to be able to achieve a positive effect here with the commissioning of the PV system in Q1/2023. It should be noted, however, that the prices are determined for all customers at the entire Baumwollspinnerei site and the prices for H14 and H18 cannot be considered individually in this regard. This may result in less concise results in subsequent reporting periods.

Intervention L3- Demand oriented heating system and user information

This task involves adapting the heat generation in Hall 14 to the specific heating requirements of selected tenants and providing a tenant information concept. This is realised by installing intelligent radiator thermostats, which use the LoRaWAN communication protocol to forward tenant-specific heat demands or the absence thereof to compatible components in the heat distribution system. If there is no demand for heat, the electrically operated devices that can be assigned to the rental area, such as the pump and valve, are switched off. Energy savings in heat generation and electrical operating energy are intended to increase the efficiency of the technical system. The concept is supplemented by the provision of digital information for the relevant tenants, which shows past consumption and makes it possible to identify savings opportunities on the demand side.

Table 38. L3 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total energy demand reduction	Total energy demand (MWh/a)	1,972	1,873	2,108	13%
	Total Demand Electricity (MWh/a)	689	655	617	6%
	Total Demand Heating (MWh)	1,282	1,218	1,491	22%
Onsite energy ratio OER	Energy production using RES & Total	-	100%	n/a	n/a

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	energy demand (MWh)				
Peak Load Reduction	Peak demand Heating (MW)	1.442	1.370	1.665	22%

The total demand for heat increased in the first reporting period compared to the 2020 baseline. As mentioned above, one reason for this is the Corona pandemic, which resulted in many commercial spaces with their significant consumption being vacant in 2020. At the same time, demand for electricity has decreased, which can be attributed to the fact that electricity is consumed in a more targeted manner than heat, and a partial utilisation of office space in 2022 is reflected here, resulting from the still strong presence of home office. Due to the connection of the charging stations at the end of the year, an increase in the value can be assumed for the period 2023. Total energy demand as a synthesis of electricity and heat consumption has increased as more heat has been consumed than electricity has been saved.

The onsite energy ratio has remained far below the target value for 2022 due to the missing generation capacities of the PV plant and the missing district heating connection. However, this should improve significantly for the following reporting periods.

The previously included key figures for heat storage potential were removed from the monitoring in agreement with S5, as no valid method could be established to measure and realistically depict this existing but diffuse potential.

Intervention L4- Personalized Informative Billing

With a clear focus on 27 apartments located in Leipzig West Beckerstr. 52-56, which are considered the testbed for the verifying the efficiency of all actions under this intervention, targeted activities were initiated allowing the data collection, to serve the monitoring needs and the calculation of the defined Key Performance Indicators.

With the installation of 100 smart heat cost allocators, placed on all radiators of the apartments participating in this intervention, real time streaming of data was enabled, allowing for capturing the temperature of the apartment rooms, the temperature of each radiator and the thermal energy consumption per radiator.

With those real time measurements as a basis, the SPARCS Application that was developed to fulfil actions of this intervention, can offer to the building tenants a mobile application environment, in which their users, are able to monitor their personalized informative billing details regarding heat energy consumption, engaging them in energy saving actions, as described in L4-1. In addition, and utilizing the available tenant consumption patterns, the SPARCS Application offers the functionality to present to the tenant's alternative energy tariff schemes, to capture their willingness to alter their behaviour while testing the dynamic thermal heating controller, as presented in action L4-2. Furthermore, having a complete picture of all tenant heat consumption values, a normative comparison mechanism is implemented as part of the SPARCS Application based on the description in action L4-3, that allows consumers to position themselves against best performing peers and expose their energy bill savings potential. Finally, as part of the action L4-7, the goal is to increase the self-consumption, by combining an energy storage with a PV plant to use the energy within the building grid. This will be

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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.

With the primary goal of the intervention L4 and its related actions being to properly configure and deploy a novel solution for optimizing thermal energy consumption, allowing via the implemented applications to monitor, control and provide normative feedback regarding the individual consumption of the tenants, is considered the key factor that will increase awareness and trigger energy saving actions. Utilizing the Key Performance Indicators as defined and documented in deliverable D2.2, the results of the actions taken are considered, affecting the overall thermal energy consumption, the need for thermal energy import, the district self-consumption rate and the peak load reduction. As already captured in D2.3 the overall district heating demand is around 1300MWh, while for the 27 apartments under consideration, this value is 75.5 MWh. It is also worth mentioning that the entire thermal energy is imported to the district.

In the table below, all KPIs defined for this intervention 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 39. L4 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Decrease of thermal energy import share in the district	District thermal Energy import (MWh)	1300 1300 kWh per year (average)	10% reduction of thermal energy import share	n/a	n/a
	Total District thermal Energy Demand (MWh)	1300 1300 kWh per year (average)		n/a	
Reduction of Heating Energy Consumption of the district	Energy Consumption	1300 kWh per year (average)	10% reduction of heating energy	n/a	n/a
Reduction of Heating Energy Consumption of the buildings	Total Building thermal Energy Demand (MWh)	75,5 MWh per year (average)	Reduction of Heating Energy Consumption of the buildings	n/a	n/a
District self-consumption rate	Total District thermal Energy Demand (MWh)	1300	20% Increase of self-consumption rate	n/a	n/a
	Total district Energy Production (MWh)	0		n/a	

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	Total Demand Electricity (MWh)	473,6		n/a	
Peak Load Reduction	Peak demand (MWh)	n/a	Reduction of peak loads	n/a	n/a

Even though the data is being collected from the apartments, GDPR protection principles do not allow a direct mapping between IDs of the devices with the related apartments and users. This linkage is only established, as soon as the user installs the SPARCS application and accepts the terms and conditions, allowing the utilization of the collected data from the application. 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. Although several engagement actions took place to motivate the tenants to download and install the application, participation on the roll out phase was very low up to this point. With the plan to further 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.

Finally, since the data capturing process was initiated during September 2022, a full year of monitoring data that would allow the comparison of the values is not yet captured.

Intervention L5- Human-Centric Energy Management and Control Decision

In this intervention, the same testbed is utilized, consisting of the 27 apartments designated in intervention L4. The data that 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 utilization. In the table below, the defined KPIS in D2.2 [Reference] 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 first reporting period will serve as the basis for evaluating the progress in the updated versions of this report.

Table 40. L5 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total thermal energy demand reduction	Total Demand Heating (MWh)	75,5	Reduction of Heating Energy Consumption of the buildings	n/a	n/a

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Peak Load Reduction	Peak demand (MWh)	n/a	10% reduction of the peak demand	n/a	n/a
Flexibility increase (%) of normal load.	Flexibility % of normal load Buildings/Prosumers	n/a	5% increase of flexibility	n/a	n/a
Total flexibility available Increase (KW)	Total flexibility available (KW) Buildings/Prosumers"	n/a	5% increase of total flexibility	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 L6- Decarbonization of district heating

Construction and integration of a solar thermal plant into the district heating grid of the city of Leipzig. In the area of Leipzig West, a new solar thermal plant is planned with a collector area of approx. 65.000 m^2 and an expected heat yield of 25.000 MWh/year (the first construction stage will be approx. 33.000 m^2 with 12.500 MWh/year). Construction start is currently set for end of 2023 and commissioning is planned for the 1st to 2nd quarter of 2025.

Table 41. L6 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Share of RES increase (heat solar thermal)	Average Total Energy Production (Heat)	Approx. 1.500.000 MWh/year	~ 0,8 to ~ 1,6 % (Stage 1 & 2)	Solar thermal system is not yet in operation	
Share of RES increase (heat solar thermal)	Energy Production using RES (heat)	0 MWH/year	12.500 - 25.000 MWh/year (Stage 1 & 2)		
CO_2 -emission reduction through RES heat increase	Amount of saved CO_2 -Equivalents	n/a kg or t	0 t/year		

Intervention L- Heat storage

Heat storage technology is vital for optimised and reliable operation of a district heating grid. Especially with ongoing transformation processes towards clean and renewable energy sources. Therefore, LSW has constructed a new, large heat storage with approx. 1.800 MWh of max. storage capacity. To reach elevated storage temperatures the technology used is a 2-zone device with a top layer (approx. 16.000 m3) for hydrostatic

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pressure and a connected bottom zone usable for heat storage (approx. 43.000 m3). Thus, it's possible to reach temperatures of up to 120 °C. After completing construction and filling in 2022 commissioning started early 2023 and is still ongoing.

Table 42. L7 intervention KPIs

KPIs	Data	Baseline	Target (B)	1st reporting period	Difference
Heat Storage Utilization	Average Charge Level	MWh	n/a	Temperature & Volume Flow of water in heat storage is logged and can be provided as power (hourly) or work (daily/monthly/yearly	
Heat Storage Utilization	Heat Input	MWh/year	n/a		
Heat Storage Utilization	Heat Output	MWh/year	n/a		

Intervention L8- Linking of the existing and newly constructed heat storage solutions with the demand side and allow for more efficient controlling of the district heating network.

Depending on the season, LSW operates the district heating grid at elevated temperatures which exceed the boiling point of water. Therefore, a pressurised hot water storage system was constructed in 2016 to increase the degree of utilisation and efficiency of the CHP Combined Heat & Power plants in the grid.

To increase the heat storage capacity, a new 2-zone, hot water storage tank is constructed together with a new CHP plant (see L7). To facilitate elevated water temperatures and prevent boiling, an insulated layer divides the tank in two zones. The cooler upper zone increases the pressure in the lower zone, enabling temperatures above boiling point.

The KPIs in L8 are the same as in L7.

Intervention L9- Integration of RES

The integration of RES such as controlled or uncontrolled PV with flexible consumers that are interested in an active management of their devices from the outside depending on environmental or economical determinants, flexible prosumers that are interested in an active interaction with CHP, solar plant, geothermal system, their HVAC and grid participants with controllable and actively manageable energy storage systems in a virtual power plant.

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Table 43. L9 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Share of RES increase	Total Energy Production (MWh)	Electricity: 1.412,76 Heat: 105,210 MWh	2500	Electricity: 1.863,111 MWh	Electricity 32% Heat n/a
Share of RES increase	Energy production using RES (MWh)	1.412,76 MWh (WSL PV)	2500	1.863,111 MWh	32%
District self-consumption rate	Total district energy demand (MWh)	Heat demand: 262,462 MWh	n/a	n/a	n/a
District self-consumption rate	Total district Energy Production (MWh)	790,13 MWh PV systems 68,79 MWh (self-consumption)	464	PV: 737,61 MWh Self-consumption 78,41 MWh	2%
	Total Demand Electricity (MWh)	273.8 MWh	n/a	167,13 MWh	50%
Total flexibility available Increase (KW)	Total flexibility available (KW)	0	20	1	95%
Flexibility increase (%) of normal load.	Flexibility % of normal load	0 KW	1%	0.1%	90%
Flexibility increase (%) of normal load.	Buildings/ Prosumers, EV	0 %	1%	0.1%	90%
Flexibility provided (KWh)	Flexibility provided (KWh)	0	170kWh /day	25kWh/day	86%
Number of demand requests	Number of demand requests	0	1/day	0.5/day	50%
Renumeration due to flexibility delivered (Euro)	Renumeration due to flexibility delivered (Euro)	0 Euro	n/a	n/a	n/a
Onsite energy ratio OER	Energy production using RES (MWh)	-	n/a	n/a	n/a

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Fossil fuels Energy Generation decrease	Fossil fuels Energy Generation MW	0 MW	n/a	n/a	No fossil generation
Increase of integrated systems share (smart control/ VPP/ storage)	Total available (RES, storage, etc) (Number)	57 PV (WSL)	n/a	n/a	n/a
Number of smart equipment	Smart meters for electricity and heating available (Number)	0	4,000 (Heat meters)	4,000	0%
Number of smart equipment	Smart sensors for temperature, humidity, illuminance (Number	0	400 smart heat pump controllers	400	0%
Number of smart equipment	Smart actuators (Number)	0	400 smart heat pump controllers	400	0%
Number of digital platforms used	Number of digital platforms used	0	5	5	0%

Intervention L10- LoRaWAN network

The introduction and usage of LoRaWAN network for connecting sensors and devices through a low energy, low frequency bandwidth allows the connection of sensors in cellars and across district with minimum of antennas. This provides the possibility to integrate a wide area of additional use cases (car parking spot sensors, intelligent waste disposal) throughout the whole demonstration district.

Table 44. L10 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of smart equipment	Number of smart equipment	0	4,000 (heat meters)	4,000	0%
Number of smart equipment	Number of smart equipment	0	10	10	0%

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Number of digital platforms used	Number of digital platforms used	0	5	5	0%
Number of piloted solutions	number of piloted solutions	0	3	3	0%

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

In collaboration with WSL, monitored and externally controlled power outlets were installed in various living units across multiple buildings to prove economies of scale for larger installations on a citywide level.

Renewable energy systems mostly comprise a highly volatile energy generation. Big electrical storages seem to be an answer, but it is not totally clear, how to integrate them in an energy system. The real-time simulation of the integration of an existing 10 MW battery storage takes place.

Table 45. L11 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of smart devices (green plug)	Number of smart devices (green plug)	0 Number of devices	20	30	50%
Number of inquiries about green plug	Number of inquiries about green plug	0 Number of inquiries	20	25	25%

Thereby the power outlets demonstrate efficient demand side management by monitoring and controlling energy consuming devices.

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, 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 46. L12 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total energy demand reduction	Total Demand Heating (MWh)	75,5	10% reduction of thermal energy	n/a	n/a
	Total Demand Electricity (MWh)	40,5	10% reduction of electricity energy	n/a	n/a
Reduction of the energy demand per apartment	Reduction of the total energy demand of each apartment	n/a	10% reduction of total energy	n/a	n/a
	Reduction of CO_2 emissions per apartment	n/a	10% reduction of CO_2 emissions	n/a	n/a
	Reduction of the customer's energy costs per apartment	n/a	10% reduction of the energy cost	n/a	n/a
Peak Load Reduction	Peak demand (MWh)	n/a	10% reduction of the peak demand	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 utilizes the same environment to demonstrate the creation of Energy Behavioural Profiles, allowing through the utilization of the application for self-evaluation and normative comparisons of energy behavioural patterns. Via comparison of normalized 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 46.

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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 utilization 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 46.

Intervention L15- E-bus charging

This intervention transforms the bus lines 89/74/76 from diesel fuel buses to e-buses. Furthermore, LVB will modernize the central bus garage at the location "Lindenauer Bushof", also located in Leipzig West. The location will receive a central charging system with about 10 charging points. As the charging process during the operation of the lines (e.g. at the station Connewitzer Kreuz) often occurs during the peak consumption time slots, it challenges the congestion management of the distribution grid. The nightly charging processes at the central home station however occur during times when the consumption pattern exhibits less variances. Accordingly, a load shifting away from the charging during operation in favour of home station charging will ease the grid operation and thus the overall integration of renewable energy assets (that are difficult to forecast and plan) into the virtual power plant.

Table 47. L15intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increase of EVs share in local transportation (%)	Total number of vehicles in local transportation (#)	164	181	181	1%
	Electric vehicles in local transportation (#)	1	38	37	
	ratio	-	21%	20%	
Increase of integrated smart EV charging units	Number of smart EV charging stations	2 stations	46	46	0%
Increased level of utilization of EV charging stations	∑kWh charged	n/a	n/a	n/a	n/a

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

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positioning of additional charging points (38 before project start, amounting to 85000 kWh) on the city surface. Additionally, LSW integrates 50 fleet-based electric vehicles in an instantly available load-shifting program.

Table 48. L16 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increase of integrated smart EV charging units	Number of smart EV charging stations	38	200	455	127%
Increased level of utilization of EV charging stations (kWh)	∑kWh charged	90,000	1,000,000	2,000,000	100%

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.

Table 49. L17 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total flexibility available Increase KW	Total flexibility available	0	n/a	1 kW	n/a
Flexibility increase (%) of normal load.	Flexibility % of normal load	0 %	n/a	1 kW	n/a
Flexibility provided KWh	Flexibility provided	0	n/a	1 kW	n/a
Number of demand requests	Number of demand requests	0	n/a	25	n/a
renumeration due to flexibility delivered (Euro)	Buildings/ Prosumers, EV smart chargers, escalators/elevators	0	n/a	20 EUR	n/a

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

This subtask takes on the task of understanding and predicting the behaviour of energy system participants. The reliable integration of the planned "community energy storage" (CES) and "community demand response" (CDR) represent possible business cases for a successful system transformation at the municipal level.

As the roll-out of the smart plugs (formerly: green sockets) is not fully done, the monitoring data regarding the households that will be a part of the CDR is not yet available. Therefore, a modelling approach based on IRPopt was applied to generate data based on realistic assumptions regarding the total residential load and load shifting parameters for 2025.

The subtask analyses the optimal customer behaviour as reaction to flexible electricity tariffs. In addition, the demand-side management measures are 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. The assumed flexible tariff is designed to optimally support the generation-demand-ratio of the VPP at all timesteps and therewith provide a service for the VPP.

The technical parameters for the 1000 households (hh) in 2025 under moderate assumptions are presents 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

Table 51. L18 intervention KPIs

KPIs	Data	Baseline	Target*	1st reporting period	Difference
Increase of integrated systems share	Green sockets available (#)	0	1000	n/a	n/a
Total flexibility available increase	Total flexibility available (kW)	0	117	n/a	n/a

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Flexibility increase (%) of normal load in kW	Potential Flexibility % of normal load	0	15.6	n/a	n/a

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

L19 shall integrate energy and building data from SPARCS demo districts into the Urban Data Platform of the City of Leipzig, in order to allow for advanced and integrated district and building planning. For this, relevant energy and building data sets have been researched from various data owners (e.g., on municipal, regional and federal level) and first assessment of the quality of the data sets and relevance to municipal planning procedures is under investigation. Furthermore, City of Leipzig will determine the requirements for integrating data into the urban data platform (data formats, API's, etc.), and define possible use cases.

Table 52. L19 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Data availability	Number of energy and building datasets necessary for creating district refurbishment concepts integrated in the Urban Data Platform (GIS)	0	8	10	25%
How SPARCS is integrated into city plans	How much has the project benefitted from, contributed to and follows the strategic documents of the city?	4	4	4	0%
Professional stakeholder involvement	How many city units have been involved in planning ?	0	8	8	0%

Intervention L20– Standard model for smart cities

In L20, the city of Leipzig will assess a standard model for potential Leipzig replication districts in close collaboration with partners, stakeholders and the responsible city departments. The elaboration departs from assessing improvement needs in the process of developing energetic district development actions. Hereby, the possibilities to include new smart and clean city solutions are also assessed. Currently a focus is on making data

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easily available with an Urban Data Platform (UDP). Actions carried out under T4.2, T4.3 and T4.4, and findings and recommendations derived from their implementation will be carefully reviewed to determine a standard approach for integrating relevant energy-related district and building data.

Table 53. L20 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Number of check lists or maps with relevance to the topic	Check lists/ maps available	0	3	1	60%
Leadership - How much effort is the project putting into creating support?	Number of Workshops with city units		5	3	40%

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

L21 shall establish an Energy Advisor in order to offer support and information to residents regarding both energy efficiency and transformation of privately owned buildings, cost-efficient installation of renewable energy sources, the participation in the Positive Energy Community and to develop daily habits to reduce energy consumptions.

To facilitate dialogue with citizens in the urban context, at least four workshops per year are planned in the model district.

To achieve these aims, we concentrated our workshops in the Duncker neighbourhood area, trying to reach the inhabitants of social housing through different approaches of co-involvement:

- inform
- raise awareness
- involve

The events in 2021/2022 included among others the presentation of the LWB-App and the SPARCS-App which are two technological solutions developed by SPARCS to engage communities and individuals in energy saving behaviours and data collection.

For every marketing action, on every flyer distributed and, on every poster, a personal contact was always appointed who could answer further questions or comments on the topics communicated.

Although it is difficult to define and collect quantitative data and KPIs for monitoring and evaluation of results, we have tried to quantify the achievements in the table below.

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Table 54. L21 intervention KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
How many events and co-creation activities were conducted in the reporting period?	Nr. of events	n/a	4	4	0%
% of people are aware of the existing solutions before and after interventions	Workshop participants and flyer recipients with Link on the use of the app	n/a	100	80	20%
Did you feel that you were able to affect and participate in the ideation of future directions?	Number of people who attended our events, asked questions, contacted us with questions or comments.	n/a	150	130	13%
How well does the business model(s) cover the four lenses of innovation (desirability, feasibility, viability and sustainability)?	we believe that our citizen engagement model reflects the four lenses of innovation. Our events were citizen-friendly, sustainable, accessible to all, and met the needs of the population by answering their questions on energy efficiency and the environment. Nevertheless, we have any empirical data, conclusion are based on discussion with the Dunkerviertel community during the local activities				n/a
Number of co-creation sessions for positive energy districts	Likert list	n/a	n/a	n/a	n/a
Citizens' co-ownership of energy utilities	Likert list	n/a	n/a	0	n/a
Inclusion of hard-to-reach groups in energy transition	Likert list	n/a	50	25	50%

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.

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Table 55. ULEI study KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Longitudinal socio-psychological evaluation study	Number of survey waves	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 (1st survey in M23-25): 273; 2nd survey in M32-33: 161).

The focus of our monitoring and impact assessment refers in particular 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 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 organized, 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 in order 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 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

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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). However, the survey at the University of Leipzig was independent of the participation formats and it is not possible to make statements about knowledge growth after participation in a specific event, but potentially only something about knowledge growth in general over time.

4.2 Aggregated monitoring- city level

The indicators help to see to what extent SPARCS demo district measures have an impact at city scale.

Data regarding the energy consumption are only available earliest with a 2-3 year delay, as the respective data of the energy providers must go through an internal audit before becoming publicly available; only thereafter, the city of Leipzig can calculate its balances – which then later are being published. The next balances are expected in summer 2023.

In cases that city-wide targets are available, they are provided on the tables. However, the city targets are under update: whereas the recently accepted climate action programme (SECAP 2030) agrees on a target of climate neutrality by 2040 (and equalling it with a reduction of 95% of emissions), the participation in the EU programme 100 climate neutral and smart cities by 2030 points to climate neutrality by 2040. However, the SECAP 2030 is backed by a biannual implementation programme. Therefore, here targets from the current official state in the SECAP 2030 are given (indicating if ambitions are likely to rise).

Where sector specific targets are missing, targets are based on own assumptions and calculations. To come up with targets, a conservative calculation method has been applied: climate neutrality by 2040 is equalled with a reduction of 95%, hence 5% of the current emissions in 2040 (although normally the baseline is 1990 and emissions have probably risen since). The reduction is divided linearly over the years (with two security years), resulting in yearly necessary percentage points of reduction. In many cases, the direction of the target was given, in order not to interfere with upcoming municipal targets.

Table 56. Leipzig city-level, general energy KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Total electricity demand reduction	Total Demand Electricity (MWh/a)	2.304.100	Reduction is not goal as city is growing and EVs and heat pumps will increase electricity demand. Emission factor reduction of 43% to 288g CO_2 -eq/kWh	Energy balance data earliest available with 2-3 years delay	
Total thermal energy demand reduction	Total Demand Heating (MWh/a)	5.491.900	Reduction of 19% by 2030	Energy balance data earliest available with 2-3 years delay	

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Reduction of CO_2-eq emissions	Emitted e CO_2 measurements/calculations (Tons/year)	3.408.033	Reduction of 161 881,6 t/y to be at 5% by 2040	Energy balance data earliest available with 2-3 years delay
Share of RES increase	Electricity production using RES (MWh)	157.300	Increase to 450-500 MW PV by 2030, >700 MW by 2040 Share of renewable electricity of 65% in 2030,	Energy balance data earliest available with 2-3 years delay
	Heat production using RES (MWh)	112.300	30% RES by 2030	
	RE Electricity share (%) (=No.4/No.1)	6,8	-	
	RE Heat share (%) (=No.5/No.2)	2	-	

As the demo districts are small compared to the overall size of Leipzig, changes we see in the KPIs are mostly not directly due to SPARCS; SPARCS effects are difficult to tell apart from normal city variation. For electricity demand, it has been assumed that despite efficiency gains, the overall demand will moderately rise because the city is growing and new demands due to the increasing number of heat pumps and electric vehicles.

The RES share so far is given twice, in MW, and in unquantified 65 % of demand. As future demand is not extrapolated, this might be specified in the coming years. Moreover, due to risen federal ambition, which is waiting to be put in local law, this is likely to rise to 80%.

Table 57. Leipzig city-level, air quality indicators

KPIs	Data	Baseline	Target	1st reporting period	Difference
Air quality improvement and emission reduction	O3 ($\mu g/m^3$ yearly average)	51	40	53	33%
	Nox ($\mu g/m^3$ yearly average)	53	40	11	72%
	Small particulates ($\mu g/m^3$ yearly average)	41	23	16,3	30%

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Air quality is improved through electric busses. Renewable heat will mostly affect houses already connected to district heating, so the air quality improvement is happening at the generation source, not at Leipzig West air quality measurement station. Improvements are also due to other trends (such as general improvements in combustion standards).

Table 58. Leipzig city-level, specific energy indicators

KPIs	Data	Baseline	Target	1st reporting period	Difference
Increase of integrated assets	Number of systems integrated to VPP	0	n/a	n/a	n/a
Decrease of energy import share	Electricity import (MWh)	2.152.000	n/a	n/a	n/a
	Electricity import share (MWh) = No.12/No.1	n/a	n/a	n/a	n/a
Peak load reduction	Electricity peak load (MW) on a day of the year	212	decrease	226	n/a
	Heat peak load (MW)	878	decrease	1219	n/a

The change in energy import shares highly depends on the boundaries chosen. As energy is not provided on territorial basis, but since the liberalisation of the energy markets in 1998 everyone can choose their energy provider from all over Germany, the definition at city level is unclear. Additionally, the value is not yet available (see comment about municipal energy balances), and it is unclear whether data will be publicly available at all. As the KPI mainly refers to the district level, we suggest suppressing it in the future. Peak loads were defined as maximum daily loads occurring.

Table 59. Leipzig city-level, transportation KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
EV car sharing rate increase	Total number of motor vehicles registered in Leipzig	268.059	Decrease	271218	n/a
	Total number of EV cars registered in Leipzig	1450	65% alternative drives in 2030 (at 30% modal split), 90% alternative	2950	n/a

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			drives in 2040 (at 10% modal split)		
	Number of shared EVs	20	increase	29	n/a
Increase of EV share in local public transport	Total number of vehicles in local public transportation	434	n/a	n/a	n/a
	Thereof trams with driving engines	233	n/a	n/a	n/a
	Thereof electric busses	n/a	Full electrification of 3 lines with 21 busses.	21	0
Transport behaviour	Bicycles in local transportation mode (mode share of trips, %)	18,7	23 %	n/a	n/a
	Cycling (mode share of pkm, %)	10,5	Not available - increase	n/a	n/a
	Bicycles counted past 12 months at counting stations	6.991.905	increase	7.863.016	n/a
	Share of citizens using a personal vehicle (non EV) for going to work (%)	43	decrease	40	n/a
	Share of citizens using public transport for going to work (%)	26	increase	24	n/a
Increase of (smart) charging points	Public or semi-public charging points	369	Increase to cater for 65% alternative drives in 2030 (at 30% modal split), 90% alternative drives in 2040 (at 10% modal split).	700	n/a
	Smart charging points		increase	454	n/a

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	Bidirectional charging points (V2G)	0	increase	1	n/a

Not all the traffic indicators 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 not necessarily 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 60.Leipzig city-level, economic KPIs

KPIs	Data	Baseline	Target	1st reporting period	Difference
Job creation	Jobs created by SPARCS (#)	0	270	84	186
Improvement of citizens' quality of life, health, and well being	Life expectancy (years)	81	increase	80,8	n/a
Annual number of new patents	Patents filed in the context of SPARCS (#/a)	n/a	n/a	n/a	n/a
Annual number of contributions to European Standardization Organizations	Contributions to European Standardization Organisations (#/a)	n/a	n/a	n/a	n/a

The improvement of citizens' quality of life, health and wellbeing is difficult to measure. The indicator "life expectancy" is a good indicator for quality of life, health, and wellbeing, but doesn't vary at SPARCS time - and regional scale. Unfortunately, there is no better one available: neither noise reduction nor peace of mind regarding energy provision are available at relevant scales. Therefore, we suggest suppressing the indicator in future reports.

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Table 61.Leipzig city-level, financial indicators

KPIs	Data	Baseline	Target	1st reporting period	Difference
Financial KPIs	municipal funds (€)	0	n/a	n/a	n/a
	Private funds (€)	n/a	n/a	n/a	n/a
	Return on investment (%)	n/a	13-44%	n/a	n/a
	Payback time (years)	n/a	2-13 years	n/a	n/a
	Debt Service Coverage Ratio (%)	n/a	1,15-1,45%	n/a	n/a

On the city level, for the financial KPIs we refer to all measures regarding smart and climate neutral city improvements that have a relationship to SPARCS measures, as tracked within in the European Energy Award tool. This listed only investments up to 2020. Investments from 2021-22 could not be tracked as there is no municipal data base available so far.

Regarding private funds, some partners could not disclose their investments. Others could only provide forecasts and not investments made. So, the number given includes all available investments, but is incomplete. However, all involved consortium members are working to find the most appropriate process to make these KPIs measurable in the updated version of this deliverable.

4.3 Conclusions and lessons learnt in Leipzig

As mentioned earlier, the monitoring period for Leipzig took place during a 6-month period (from September 2022 to February 2023) instead of a 12-month period as in in Espoo. This was due to some delays on the implementation of the interventions; in the case of Solar thermal plant (related interventions L6-L8) the implementation is still not finalized and consequently the impact monitoring is not possible. The shortening of the monitoring period resulted in difficulties to obtain the necessary data to calculate the defined KPIs and as Figure 12 presents, only 61% of the interventions were fully or partially monitored.

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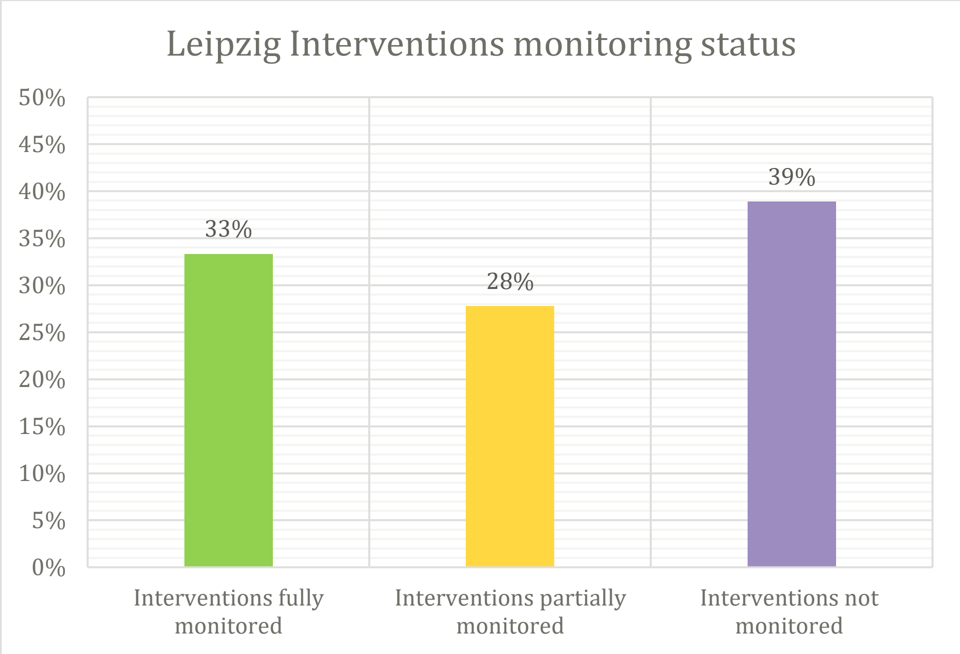

Figure 12. Leipzig interventions monitoring status

The interventions' evaluation presented in Figure 13 indicated that 7% of the KPIs (80 in total) are exceeding the targets set and 33% are completely fulfilling the expectations. the 5% of the KPIs that are close to the set targets and approx. 11% are far from the target. The number of non-measured KPIs reach the 44% of the total KPIs due to delays on the implementation of the interventions and the incomplete collection of the necessary data due to the short monitoring period. In the second monitoring period it is expected that these values will improve for the city of Leipzig as more recovery solutions in terms of data are under development.

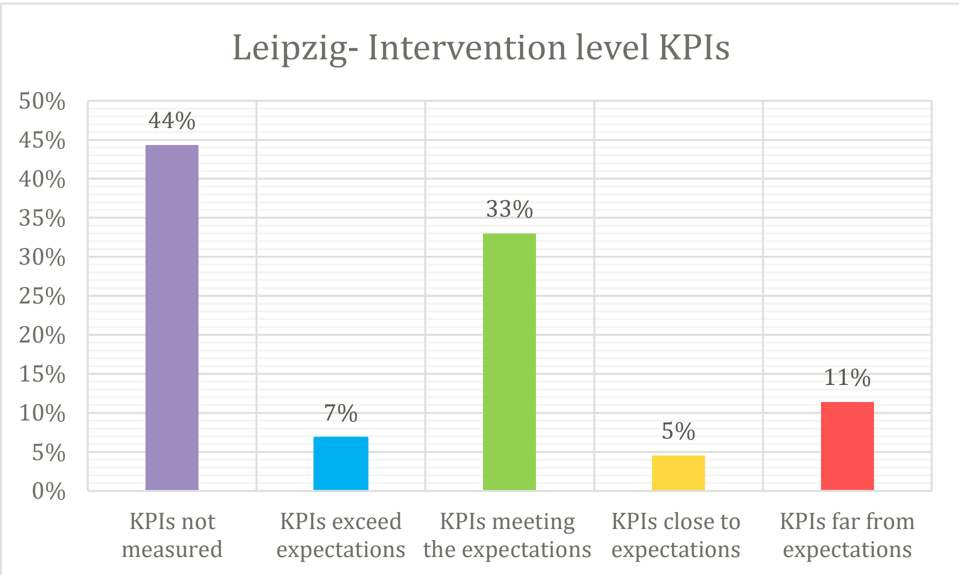

Figure 13. Overview of interventions impact assessment- Leipzig

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The issues identified regarding data collection affect as expected the performance indicators related to the city, the majority of which – approx. 65% from 24 KPIs in total - are not monitored (Figure 14). KPIs that meet expectations are approx. 15%, while both KPIs in categories near and far from expectations are at the same level, approximately 10% of the total city wide KPIs.

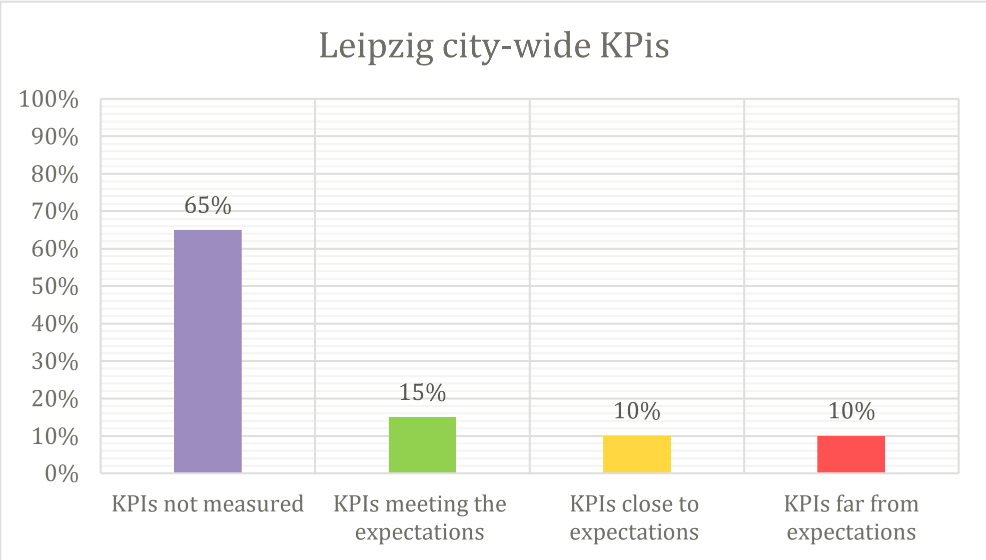

Figure 14. Overview of city-wide KPIs impact assessment- Leipzig

Spinnerei District

Regarding the demo district 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, 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 have to 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.

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.

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

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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 visualization 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 have to be developed further on higher levels; or it has to 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. Electromobility, energy efficiency, decentralized generation, connection of decentralized systems with large centralized 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 has to 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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Excursus: legal barriers to blockchain trading in Germany

For instance, from the perspective of owners of small assets: §5 of the German Energy Industry Act (EnWG) sets out the requirement for energy trading to be conducted by authorized companies. This requirement can be seen as a barrier to P2P energy trade and blockchain use cases, as it limits the ability of individuals to engage in direct energy transactions without intermediaries. The requirement for authorization may limit the potential for P2P energy trading, as it creates a barrier for individuals to participate in these types of transactions. Additionally, blockchain technology offers new possibilities for secure and transparent energy trading, but these opportunities may be limited by the need for authorized companies to participate in such transactions.

Regarding the double-selling issue: §80 of the German Renewable Energy Sources Act (EEG) sets out the rules for the feed-in and priority dispatch of electricity generated from renewable sources. One aspect of this section is the prohibition of double selling, which prevents small distributed energy resources (DERs) from participating in local markets. The prohibition of double selling means that electricity generated by small DERs, such as rooftop photovoltaic (PV) systems, cannot be sold twice to different parties. This restriction makes it difficult for small DERs to participate in local energy markets, as it limits their ability to sell surplus energy to others. The prohibition of double selling can be seen as a barrier for small DERs to participate in local energy markets, as it restricts the potential revenue streams for these systems. This in turn may discourage investment in small DERs and limit the growth of decentralized energy production.

For the context of energy taxation: §9 of the German Electricity Tax Act (StromStG) imposes a tax on the generation, transmission, and distribution of electricity. This tax applies to all electricity transactions, including local P2P energy trades. The taxation of local P2P energy trade may reduce incentives for individuals to engage in these transactions, as it increases the cost of energy for both the buyer and the seller. This increase in cost can make P2P energy trading less attractive, as it reduces the potential financial benefits of such transactions. Additionally, the tax on local P2P energy trade can limit the growth of decentralized energy systems, as it discourages investment in small-scale renewable energy production and energy efficiency measures. This is because the tax reduces the potential financial returns from such investments, making them less attractive for individuals and companies.

Regarding different balancing groups: §26 of the German Electricity Market Regulation (StromNZV) sets out the rules for the balancing of electricity supply and demand in the German electricity market. One issue with regards to P2P energy trade is the lack of clarity in how P2P transactions should be treated in different balancing groups. Balancing groups are responsible for ensuring that the electricity supply and demand in their respective areas are balanced in real-time. However, the legal status of P2P energy trades with regards to different balancing groups is unclear, as the current regulations were not designed with P2P transactions in mind. This lack of clarity can create uncertainties for participants in P2P energy trades, as it is not clear which balancing group is responsible for ensuring the balancing of electricity supply and demand in P2P transactions. This can make it difficult for P2P energy trading to be implemented in practice and limit the growth of decentralized energy systems.

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The issue of immutability of many blockchain systems: §20 of the General Data Protection Regulation (GDPR) sets out the rights of individuals with regards to their personal data. One issue with regards to the use of blockchain technology for P2P energy trading is the lack of user data portability due to the immutability of the blockchain. The immutability of the blockchain means that once data has been written to the blockchain, it cannot be altered or deleted. This is a key feature of blockchain technology that provides security and reliability, but it also creates challenges for data portability. Under the GDPR, individuals have the right to data portability, which means that they have the right to receive their personal data in a structured, commonly used, and machine-readable format, and to transmit this data to another controller without hindrance. However, the immutability of the blockchain makes it difficult to meet this requirement, as it is not possible to alter or delete personal data once it has been written to the blockchain.

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 has to 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 have to carefully reflect when and where citizen engagement is likely to be possible. Regarding general support for developing renewable energies in a city, projects have to 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

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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 of some of the actions can be difficult with available data and resource 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 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 crime rates, 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 assessment. 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.

As mentioned at the beginning of the deliverable, due to delays in the implementation of the interventions in the city of Leipzig, the time frame for monitoring the two cities was

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different; for Espoo it was a 12-month period while for Leipzig it was a six-month period. This fact combined with 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 aspires to become a landmark for cities that want to increase efficiency, facilitate citizen participation, reduce the environmental impact of people and their activities.

This SPARCS deliverable-report presents the impact assessment of the interventions developed at the LHC regarding the first monitoring phase. This monitoring period had a different duration for the two LHCs due to delays on the implementation of interventions in Leipzig; 6-month period for Leipzig versus 12-month period for Espoo. Figure 15 presents briefly the impact monitoring of the intervention- related KPIs for both LHCs.

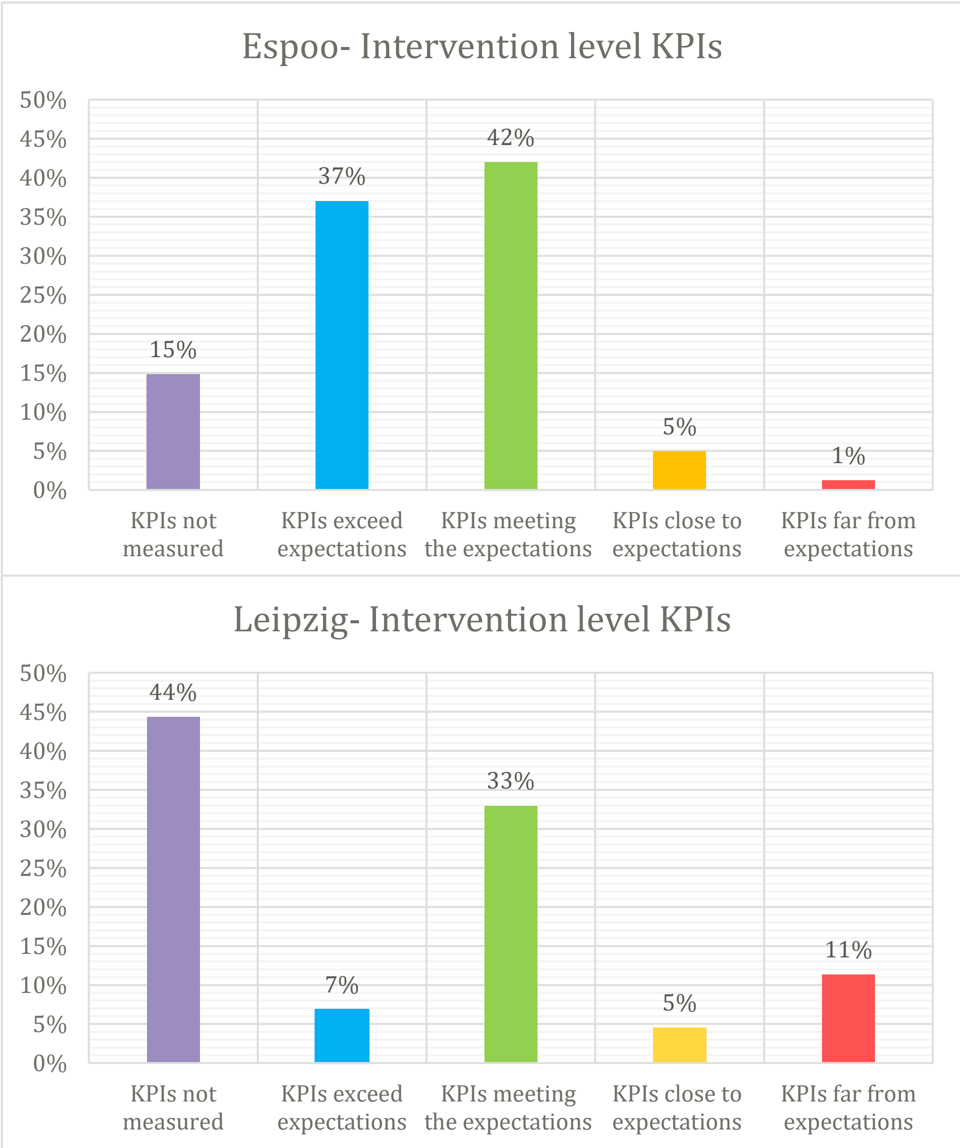

Figure 15. Overall interventions' impact assessment- LHCs

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By evaluating the implemented interventions, the progress of the LHCs is measured through the presentation of the KPIs both in intervention and city level, while the basis of the evaluation is the defined objectives per intervention. However, these targets were set to be achieved by the end of the project and not during this first monitoring period. In some cases, progress towards sustainable targets has not been as expected due to a variety of reasons, such as the complexity of urban systems and definitional conflict in different KPIs (e.g., reducing electricity consumption versus increasing the use of electric vehicles). Nevertheless, within this report, corrective actions were presented to improve the impact of the interventions in subsequent SPARCS monitoring phases.

In addition, in this report, valuable lessons from the two LHCs from the implementation and evaluation process were offered that can be used by cities planning to replicate the solutions developed.

The work described by the SPARCS team in this deliverable is ongoing and an updated version will be available in September 2023. The updated version will present the results of the second six-month reporting period, which aims to significantly improve the issues presented in the assessment of the first period.

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