D1.3 Standardized Implementation Strategy of Energy Solutions on Positive Energy Districts/Blocks

30/09/2024

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Deliverable administration

No & name	**D1.3 Standardized Implementation Strategy of Energy Solutions on Positive Energy Districts/Blocks**				
Status	Released	**Due**	60	**Date**	2024-09-30
Author(s)	SPI				
Description of the related task and the deliverable. Extract from DoA	**T1.2 Urban Transformation (SPI) M12 – M60** The objective of this task is to initiate the design process of the urban transformation that will be taking place in SPARCS cities, building upon the detailed diagnosis developed in the first task of WP1 (Task 1.1) and systematized in the Characterization Report (D1.1), as well as following the guidelines set in the City Vision aiming at reaching the envisioned city scenario (Task 1.7). The personalized approach undertaken will allow developing a city-tailored strategy to promote a structural transformation directing the city's urban development towards sustainability. To be effective and manageable, it is important that this process starts at a smaller yet representative scale - Positive Energy Districts/Blocks - ensuring a proper scaling up and replication at a later stage. This will lead to the development of a Roadmap for Urban Transformation (D1.2), a strategic document that will demonstrate how the Replication & Scale-up Plans in LHCs (Task 5.5) and the Implementation Plans in FCs (Task 5.4) contribute to achieving the final City Vision 2050 (Task 1.7), underpinned data gathered from the City Diagnosis (Task 1.1) where intermediate milestones for 2030 and 2040 will also be set in order to monitor city's pathway to the desired future scenarios (2050). Furthermore, a relevant set of outputs both informing and supporting a wider urban transformation process in cities will be developed. Among these instruments are: i) a Standardized Implementation Strategy of Energy Solutions on Positive Energy Districts/Blocks (D1.3), building upon information and data gathered from Task 5.1.2; ii) an Energy Solutions Catalogue for Positive Energy Blocks/Districts (D1.4), focusing on specific and integrated sets of solutions leading to the creation of Positive Energy Blocks/Districts in urban ecosystems, relying on information and data gathered from Task 5.1.3; and iii) Recommendations for integrating Positive Energy Blocks in strategic and political city instruments (policies & regulations, masterplans, infrastructure plans, city budget) including recommendations for the national and supranational legislation (D1.5).				
Participants	SPI, VTT, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV (until 14.3.2024), MI-CI, ADV, FHG, BABLE, LSW, ULEI, NEW, CVUT, SUITE5, VERD, NECU, LCE, GOPA				
Comments					

V	Date	Authors	Description
0.1	28/03/2024	SPI	Draft outline
0.2	28/08/2024	SPI	Full draft version for peer review
0.3	30/08/2024	NEW	Reviewer comments, inputs and suggestions
0.4	13/09/2024	VTT	Reviewer comments, inputs and suggestions (final)
0.5	17/09/2024	SPI	Deliverable checked by WP leader and released to the Coordinator and the Quality Manager for quality check and subsequent submission to the EC.
1.0	30/09/2024	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)	

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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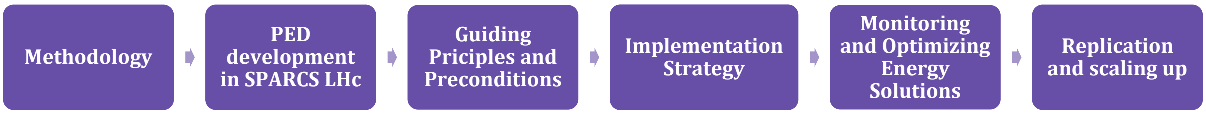
EXECUTIVE SUMMARY

This document presents a standardized implementation strategy for energy solutions on Positive Energy Districts (PED) and Positive Energy Blocks (PEB). Together with D1.4 “Energy Solutions Catalogue for Positive Energy Districts/Blocks” and D1.5 “Recommendations for integrating Positive Energy Blocks in strategic and political city instruments”, this report is part of a set of supporting instruments, produced under Work Package (WP) 1 “Urban transformation strategy”, aimed at facilitating wider urban transformation.

These instruments are based on data and insights gathered from activities carried out by the Lighthouse cities (LHc) and Fellow cities (FC), and consortium partners. These interventions have resulted in a set of technically and socioeconomically viable and replicable solutions that form the core of the PEDs implemented or under development in the project’s two Lighthouse cities and five Fellow cities.

The present strategy provides a standardized approach to the process of planning, developing, and implementing energy solutions that lead to carbon neutral territories. Following the SPARCS approach, the proposed strategy focuses on three levels of intervention—building, district, and macro/city level—and considers the solutions’ replicability and scalability, enabling their deployment in other territories and cities, beyond the project’s LHc and FC. It incorporates key strategic aspects such as governance models, business models, financing mechanisms, holistic monitoring and assessment frameworks, and replication and upscaling guidelines, which have been developed in detail by consortium partners across various WPs and Tasks. These elements provide a comprehensive overview of the project’s multifaceted approach.

The main components that form, provide context, and complement the strategy are presented in the diagram below.



The standardized implementation strategy begins with an overview of the **methodological approach** used to develop the strategy, including the main typologies of energy solutions referenced. This is followed by a **general contextualization of the LHc demo districts** and relevant interventions. Next, the **guiding principles and preconditions** for the implementation strategy are discussed, highlighting the conceptual framework behind PEDs, as well as relevant challenges, requirements, principles, and enablers. Additionally, preliminary steps towards PED implementation are presented, establishing the foundational guidelines upon which the implementation strategy for energy solutions should be built.

The proposed **implementation strategy** is divided into four methodological stages:

- **Stage 1. Setting the baseline**. This section outlines the preconditions necessary for defining the strategy, along with preliminary aspects related to assessment activities, stakeholder engagement, and the establishment of goals and objectives.
- **Stage 2. Defining the implementation plan and designing the solutions**. This section includes an overview of the supporting instruments (governance and stakeholder engagement model; business models and financing mechanisms; monitoring and evaluation model) and references the design stage of specific energy solution typologies, organized by level of intervention.

- **Stage 3. Implementing the solutions**. This section covers relevant aspects related to piloting the solutions and their full deployment. It also addresses the necessary monitoring and stakeholder engagement activities.
- **Stage 4. Using and operating the implemented solutions**. This section covers essential aspects of monitoring, maintenance, stakeholder engagement, and compliance with policy and regulatory requirements.

Furthermore, the methodology includes two complementary sections focusing on specific aspects of **monitoring and optimizing** the identified typologies of energy solutions, and the **replication and upscaling** processes leading to widespread adoption and effectiveness of these solutions in transforming cities into sustainable and carbon-neutral territories.

1. Introduction

This deliverable is aligned with WP1 and Task 1.2 goals of developing supporting instruments that serve the purpose of informing and contributing to a wider urban transformation process, starting at a smaller scale, with Positive Energy Districts (PED) and Blocks (PEB), and ensuring the conditions for further replication and upscaling.

1.1. Purpose and target group

This document aims at identifying relevant inputs concerning the implementation of energy solutions that contributed to the development of PED/PEB in the SPARCS LHc throughout the project. These inputs are fed into an overall implementation strategy for energy solutions that can be used as a future reference for the cities in their PED development initiatives, including further replication and upscaling, thus contributing to the goal of carbon neutrality.

1.2. Contributions of partners

The deliverable contains contributions from the partner cities and local consortiums, mainly based on the work developed for other tasks and deliverables in WP1, as well as for other WP, concerning the development of energy solutions for PED/PEB. For the development and fine-tunning of the strategic approach, VTT has provided invaluable contributions for the final version of the document.

1.3. Baseline and relations to other activities

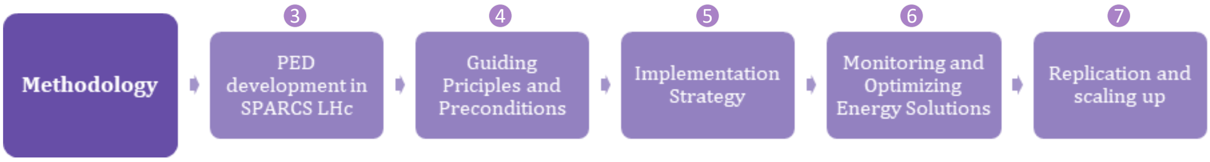
Table 1 shows the linkage between this deliverable and the timeline and activities of other WPs and related Tasks.

Table 1. Relation to other activities in the project

WP	Task	Relevant deliverables/references
WP1	**Subtask 1.1.2** Capturing Use Cases from LHCs and uploading on BABLE	The published use cases constitute a reference for the most relevant solutions developed during the project.
	T1.2 Urban Transformation	D1.2 Roadmap for urban transformation, includes relevant milestones in the cities' path towards climate neutrality, including the most relevant energy solutions for their PED development. D1.4 Energy Solutions Catalogue for Positive Energy Blocks/Districts identifies the main aspects concerning the different types of energy solutions used during the project. D1.5 Recommendations for integrating Positive Energy Blocks in strategic and political city instruments, including recommendations for the national and supranational legislation. This document points out a set of recommendations for optimizing the legal and regulatory aspects relevant for specific components of PED, including energy solutions.
	T1.3 Visualization framework for	The definition of Visualisation framework for assessing city performance (D1.6) provides a tool for the LHc to measure their PED/PEB performance, a relevant feature for the implementation

WP	Task	Relevant deliverables/references
	assessing city performance	strategy of energy solutions. The Scaling up and replication guidelines (D1.7) provide the framework and reference for this theme.
	T1.4 Strategy for Positive Energy District ecosystems and their interoperability	For the goal of developing PED/PEB in an effective way, the definition of a Strategy for developing interoperability and ecosystems for Positive Energy Districts (D1.13) is inherently linked to the development of a strategy for implementing energy solutions in PED/PEB.
	T1.5 New economic paradigms	D1.9 Urban Transformation: New Economic Paradigms and associated Business Models, creates a comprehensive understanding of the factors that make PED energy systems commercially successful, providing a practical tool for to asses and drive transformation in business models around PED ecosystems.
WP2	**All tasks**	The Monitoring and Impact assessment tools developed within WP2 are relevant for measuring and defining expected results from the implementation of energy solutions. T2.4 Socio-economic, environmental and technological Impact Assessment and D2.9 Long-term High-level Impact Assessment through Wide Replication of SPARCs provide relevant insights regarding the replication potential and impacts of the solutions developed during the project timespan.
WP3	**All tasks**	The activities developed in ESP concerning planning implementation and replication of energy solutions are transversally relevant for the development of an implementation strategy for energy solutions on PED/PEB.
WP4	**All tasks**	The activities developed in LPZ concerning planning implementation and replication of energy solutions are transversally relevant for the development of an implementation strategy for energy solutions on PED/PEB.
WP5	**T5.4** Project Development in Fellow City **T5.5** Project Upscaling and replication in LHCs	The outcomes of the referred tasks provide relevant insights regarding the results of the Project Development and Project Upscaling and Replication activities including energy solutions for PED development.
WP6	**T6.2** Building recommendations on cross-cutting issues	D6.6/D6.7 Recommendations on cross-cutting issues, includes relevant information concerning implementation of energy solutions.
WP7	**T7.3** Governance model for smart city business ecosystem	D7.3 Governance Models for Sustainable Smart City Business Ecosystems, includes relevant information concerning the development of governance models for PED.

2. METHODOLOGY



As part of Task 1.2 “Urban Transformation”, this report, together with the “Energy Solutions Catalogue for Positive Energy Blocks/Districts” (SPARCS D1.4, Gonçalves et al. 2024) and “Recommendations for integrating Positive Energy Blocks in strategic and political city instruments, including recommendations for the national and supranational legislation” (SPARCS D1.5, Gomes et al. 2024), comprise a set of supporting tools, based on the SPARCS experience, which aim at supporting cities and stakeholders in co-creating PED in an effective way. The proposed methodology is based on the approach tested and fine-tuned during the project timeline, and also on the activities developed by the consortium partners and research done on the subject of energy solutions and PED development.

2.1. Methodological approach

SPARCS project includes specific tasks led by the project LHc – Espoo and Leipzig – , focused on planning and implementing PED[1], which serve as key references for this deliverable. Although the primary focus of the project is set on PED development, the overall approach is integrated and holistic, addressing the urban components of these districts – buildings, infrastructure, and public spaces – while considering the broader synergies that contribute to the sustainable development and integration of these districts within the cities’ ecosystems. The project involves various scopes of intervention, including technical solutions, service provision, data collection, and behavioural changes, across three different scales or levels of intervention, namely:

- **Building-Level Interventions**, which include the integration of solutions such as renewable energy sources (RES), energy storage systems, and electric mobility into the building’s energy infrastructure. The focus is also on empowering users to become active participants in the energy management of the buildings by upgrading operational functionalities as part of the deployment of virtual energy communities.
- **District-Level Interventions**, are the next hierarchical scale of the planned solutions, which address the district’s energy infrastructure, including district-level RES production, district storage solutions, and local electrical mobility infrastructures. The district level approach enables predictive control of energy generation, consumption and storage, allowing for bidirectional use of the energy infrastructure and flexible management of surplus energy produced. This contributes, among others, to exploring and demonstrating the challenges and benefits of peer-to-peer energy exchange solutions.

[1] “Positive Energy Districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems while securing the energy supply and a good life for all in line with social, economic and environmental sustainability” (JPI Urban Europe, 2020).

- **Macro/City-Level Interventions**, encompass overarching, such as city-level thematic energy community platforms and multi-modal transport solutions. In general terms, this level of intervention bridges local actions with the broader city planning instruments and initiatives, including regulatory and financing frameworks essential for PED deployment, and sets the conditions for the sustainable scaling up and replication of local solutions.

As presented in SPARCS D1.4 (Gonçalves et al. 2024) and in alignment with the project use-cases (UC) published on the BABLE platform[2], the main typologies of energy solutions applied throughout the project and used as references for this document can be summarised as follows:

- **NZEB Solutions (Building-Level)**. Net Zero Energy Building (NZEB) solutions include both active and passive measures aimed at minimizing energy consumption and producing renewable clean energy at the building level. Consequently, these buildings consume as much energy as they produce.
- **Storage Solutions (Building-Level)**. These involve systems that store surplus energy at the building level, which can then be consumed during more convenient periods.
- **Smart Building Energy Management (Building-Level)**. This includes the integration of various building-level systems, such as lighting and Heating, Ventilation, and Air Conditioning (HVAC), to optimize energy usage through remote monitoring, control, and automation. This enables building owners and users to manage energy consumption and production efficiently, ultimately reducing costs.
- **Digital Twin (Building-Level)**. Digital twins at the building level consist of virtual representations of a building's energy-related processes and systems. These models can be used to run simulations and optimize efficiency.
- **Virtual Power Plant (District-Level)**. A virtual power plant (VPP) aggregates dispersed individual energy resources to operate as a single entity, similar to a conventional power plant. This aggregation provides the necessary flexibility and scale, enabling specific roles in electricity systems, such as trading in energy markets and providing ancillary services.
- **EV-Mobility Hub (District-Level)**. Places of connectivity in large areas of influence with different modes of electric transportation available (including EVs, e-bikes, and scooters) ensuring optimal connectivity.
- **Local Renewable Energy (District-Level)**. This solution takes into consideration the production of clean energy within the district boundaries (e.g. solar or geothermal systems) to meet the district's energy needs.
- **Sector Coupling (District-Level)**. Sector coupling involves the integration and coordination of different energy sectors—such as electricity, heating, cooling, and transportation—to optimize energy use and efficiency within a district or urban area.
- **Urban Data Platform (City-level)**. This solution aims to map, store, and integrate data from various sources and stakeholders within the Smart City ecosystem. The data provided can serve as the basis for diverse energy solutions and applications in a smart city context.

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[2] https://www.bable-smartcities.eu/connect/projects/project/sparcs-sustainable-energy-positive-zero-carbon-communities.html#usecases

- **P2P Energy Trading (City-level)**. Peer-to-peer (P2P) energy trading aims to make renewable energy exchanging more accessible. This solution creates s sub-market where energy trading between prosumers and consumers can occur with lower barriers.
- **Electricity Grids: Micro & Smart (City-level)**. These grids consist of localized energy networks that integrate renewable energy production with digital technology to efficiently manage energy flow, enhance reliability, and promote sustainability at a local level.
- **Multi-modal transport solutions (City-level)**. These solutions provide integrated transportation options that seamlessly connect various modes of travel—such as public transit, cycling, walking, and shared mobility services. By offering diverse and interconnected transportation choices, they promote efficiency, accessibility, and sustainability in urban mobility.

For the development of this report, a thorough analysis of the activities conducted in SPARCS LH cities —Espoo and Leipzig— was undertaken to identify the most relevant features regarding the implementation process of energy solutions in the designated demonstration districts. This analysis considers the scale/level of interventions, as proposed by SPARCS project, and also to the main energy solutions applied, as described above and presented in Table 2.

Table 2. Energy solutions according to the defined scales of intervention (D1.4)

A. Building level	B. District level	C. City level
NZEB Solutions	Virtual Power Plant	Urban Data Platform
Storage solutions	EV-mobility hub	P2P Energy Trading
Smart Building Energy Management	Local Renewable Energy	Electricity Grids: Micro & Smart
Digital twin	Sector Coupling	Multi-modal transport solutions

Based on the results presented by the LHC, the tasks and deliverables developed throughout the project—addressing strategic aspects such as governance models, business models and financing mechanisms, holistic monitoring and assessment frameworks, and replication and upscaling guidelines—as well as extensive research on the subject, the proposed approach to a standardized implementation strategy for energy solutions in PED/PEB is presented in the following sections.

2.2. LHc Espoo's Co-creation model for sustainable and smart urban areas

The *Co-creation model for sustainable and smart urban areas*, developed by LHc Espoo, and applied for PED development in the Kera Demo district, consists of a toolkit for co-creating PED solutions in both old and new city districts, including the definition of specific tasks for implementing energy systems in the selected areas (Figure 1). The co-creation model was developed through an integrated process taking into consideration participatory activities such as design sprint workshops, interactive webinars, and questionnaires, among others. These activities included the participation of relevant stakeholders such as city departments, companies, research institutions, landowners, and citizens. As a successful endeavour developed within SPARCS project, this model was also used as a reference for the development of the standardized implementation strategy for energy solutions in PED/PEB presented in this report.

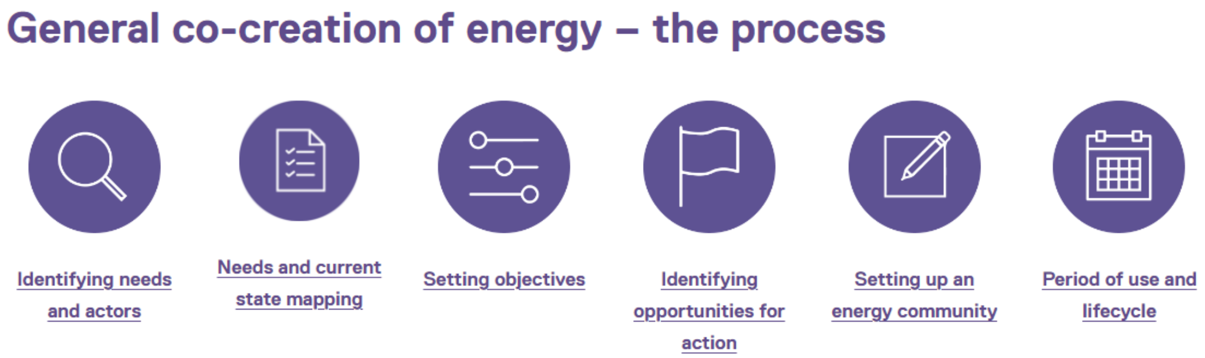


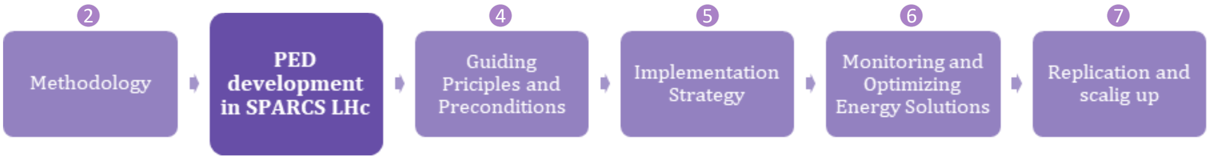
Figure 1. Process for co-creating positive energy systems

Source: Espoo. Co-creatingsparcs

The toolkit is available online[3] and, besides the focus on the co-creation methodology for implementing positive energy systems in urban areas, it includes detailed instructions and examples for implementing mobility solutions and green infrastructure.

[3] https://co-creatingsparcs.fi/en/model/

3. PED DEVELOPMENT IN SPARCS LH CITIES



3.1. Interventions in Espoo demo districts

SPARCS LHc Espoo, the second-largest city in Finland, comprises five city centres that form the structural core of five "cities within the city." The three Espoo demonstration districts include two areas located in consolidated, dynamic, and rapidly growing city centres—the Sello blocks in Leppävaara city centre and the Lippulaiva blocks in Espoonlahti city centre—as well as the Kera area, a former industrial brownfield being redeveloped for residential and workplace use (Figure 2).

Figure 2. Espoo Demonstration districts' locations

Source: Google Earth Pro

The Lippulaiva demonstration district entails a set of interventions focused on the new shopping centre (opened in 2022), with a 44,000 m² gross area, and the surrounding residential building blocks. The activities under SPARCS project for this area include the integration of RES; promoting the uptake of e-mobility; fostering community engagement, with an emphasis on encouraging energy-positive behaviour and sustainable mobility habits; and co-creating energy-positive business models.

In turn, the Leppävaara demonstration area includes the Sello shopping centre and multipurpose block (102,000 m²), encompassing shops, a library, a concert hall, a movie theatre and a parking lot with 2,900 parking spaces. These interventions focus on smart energy solutions, including solutions for storage systems, and integrating flexibility in the district heating grid. Information and Communications Technology (ICT) and interoperability solutions play a crucial role for the development of

Leppävaara/Sello PED, particularly through the creation of a Virtual Power Plant. This Virtual Power Plant covers local photovoltaic (PV) generation, electricity storage, and local power systems, enabling peak-load management. In terms of mobility, the interventions include the development of a new EV-Mobility hub, featuring charging systems for buses, shopping centre customers, and commuter parking. Relevant activities also include community engagement, primarily focused on promoting energy-positive behaviours and co-creating energy-positive business models.

Finally, the Kera district is currently being developed into a new urban local centre for the city, featuring residential blocks, office buildings, schools, and other essential urban functions. The urban planning process focuses on three areas: the centre of Kera, Karapelto, and Karamalminrinne. The SPARCS project interventions in this district concentrate on developing and exploring supporting tools for the planning and development of PEDs. This includes identifying energy infrastructure solutions that foster energy positivity, such as bi-directional electricity and district heating grids, and establishing guidelines to enhance the uptake of these solutions. In terms of ICT and interoperability solutions, studies were conducted on the use of 5G infrastructure, including opportunities for managing the smart power grid, developing new service models for autonomous transport and e-mobility, and exploring blockchain technology for enabling energy transfer and tracking bi-directional power grids. The e-mobility initiatives focused on supporting the development and implementation of multi-modal transport solutions. Regarding community engagement, activities included identifying citizens' preferred future multimodal mobility habits and integrating them into city planning solutions.

3.2. Interventions in Leipzig demo districts

Leipzig is home to three demonstration districts: Baumwollspinnerei, a former industrial site and historic cotton mill; the Leipzig-West district, which includes the Duncker neighbourhood and the solar thermal plant in Leipzig-Lausen; and a Virtual Positive Energy Community (Figure 3). While the first two districts have defined physical boundaries, the third one virtually connects energy-generating, storing, and consuming entities across the city. Generation and storage assets physically located in the first two districts can also contribute to the energy flows of the Virtual Positive Energy Community according to the contracted share of energy.

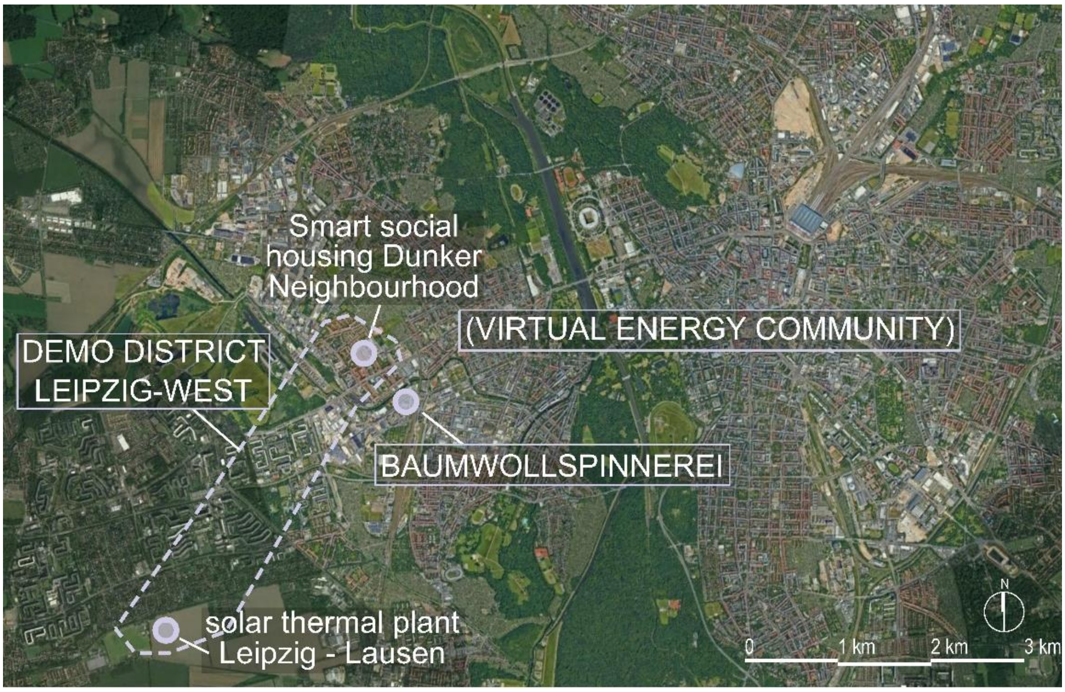


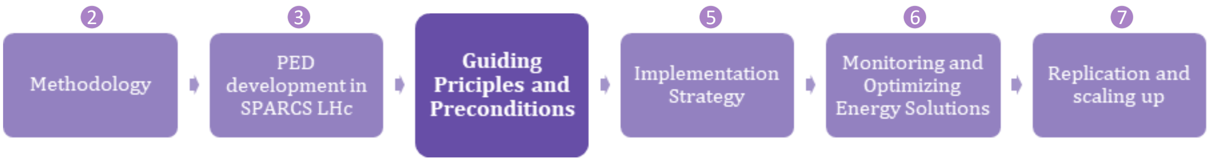
Figure 3. Leipzig Demonstration districts' locations
Source: Google Earth Pro

The Baumwollspinnerei demonstration district, a protected heritage site dating back to 1884, spans approximately 30,000 m² and serves as a successful model for transforming a former industrial area into a cultural hub, housing both startups and artists. The SPARCS project interventions in this district include intelligent heating demand control, the integration of RES into the local micro electricity grid, and bidirectional charging for electric vehicles.

The Leipzig-West demo district includes seven buildings (300 apartments) located in the Duncker neighbourhood, a district characterized by a diverse mix of urban elements, including social functions and industrial infrastructures. The district's residential area, built in 1950, is partly under monument protection. The demo activities also involve a solar thermal plant located in Lausen, near the Duncker district. The SPARCS interventions in Leipzig-West focus on increasing the share of RES in the central district heating system through the construction of the solar thermal plant and the integration of Power-to-Heat technology and heat storage into the existing district heating network. Additionally, the interventions aim to optimize thermal energy consumption in the residential buildings by implementing a human-centric thermal demand response program.

The third Leipzig demo district, the Virtual Positive Energy Community, seeks to enhance the interaction between energy-producing, storing, and consuming entities distributed across the city. This initiative creates a virtually connected community, allowing these entities to exchange energy based on advanced control functionalities and dedicated communication channels.

4. GUIDING PRINCIPLES AND PRECONDITIONS FOR THE IMPLEMENTATION STRATEGY



The proposed approach for a standardized implementation strategy for energy solutions on PED/PEB takes into consideration the preliminary need to define a strategy for the development of a PED or PEB. In this sense, the present section introduces an overall strategic framework for the development of these areas, paving the way for the subsequent methodological steps that define the strategy for the specific theme of energy solutions.

The implementation of PED or PEB aims to provide sustainable urban development across multiple dimensions, including social, economic, and environmental aspects, while addressing the challenge of promoting carbon neutrality in cities[4]. Achieving this goal involves overcoming a series of challenges in the “technological, social, economic, financial, environmental and legal/regulatory areas” (JPI Urban Europe, 2018).

These challenges and requirements, outlined in Figure 4, emphasize the critical need to develop integrated and innovative technologies for PEDs to ensure solutions that are locally tailored and responsive to diverse sectoral needs. This effort includes creating essential guidelines and tools for the planning and design of PEDs, which are crucial for addressing specific local conditions and driving innovation. Equally important is the emphasis on societal innovation, social entrepreneurship, and citizen participation as foundational elements in the broader urban transformation processes that accompany the deployment of these solutions.

Furthermore, priority should be given to the development of new energy markets and sustainable funding models that foster stable and credible investment environments aligned with cutting-edge energy solutions. This also requires adjustments to the regulatory framework to meet PED-specific requirements, including the definition of key performance indicators (KPIs) and the establishment of minimum standards for both solutions and buildings. Capacity-building, education, and training for key actors, including public administration and regulatory authorities, are essential for the successful implementation of these initiatives. Additionally, to ensure comprehensive stakeholder engagement in the pathway toward PEDs, co-creation and open innovation—particularly in the realms of public sector innovation and procurement—must be prioritized. Finally, in order to assure an effective contribution to the goals of carbon neutrality and long-term sustainability, large-scale deployment of the solutions is needed. For this, the replication, scaling, and mainstreaming of PED solutions across cities, along with the development of business models for their implementation and operation, is crucial.

[4] For more information regarding the PED conceptual and regulatory framework, SPARCS D1.5 should be consulted.

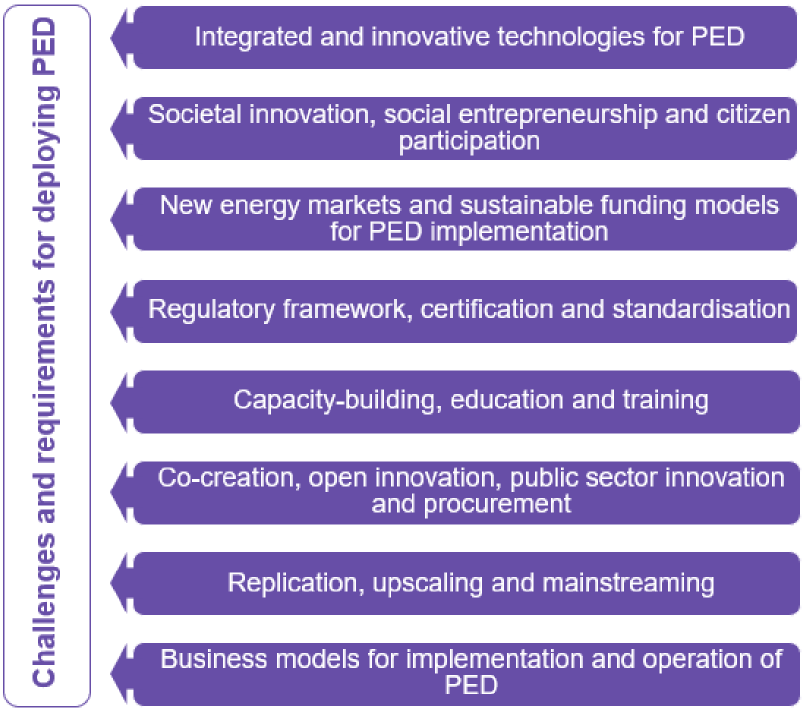


Figure 4. Challenges and requirements for PED deployment

Source: Adapted form JPI Urban Europe, 2018

To make PED attractive to cities and citizens, PED development should adhere to guiding principles such as quality of life, inclusiveness (with a special focus on affordability and prevention of energy poverty), sustainability, and resilience and security of energy supply. Furthermore, the development and implementation of these solutions should rely on enablers such as political vision and governance frameworks, active involvement of problem owners and citizens, integration of energy and urban planning, as well as ICT and data management (JPI Urban Europe, 2020).

The development of PEDs requires a multifaceted approach that considers the specific weather and geomorphological conditions specific of each territory. Additionally, the different layers that compose the urban fabric—such as buildings, public space, infrastructure, energy and mobility—should be planned and implemented in an integrated manner. Beyond the physical and technical aspects, governance and business models that align with people's and market aspirations must be considered. Moreover, a thorough participatory process involving residents, users, and relevant stakeholders for each of the aforementioned systems or layers is paramount throughout the entire process of planning, implementing, and optimizing the area as an integrated part of the city. Consequently, the development of solutions for each of these systems should align with the overall strategic approach and guidelines defined for the development of the PED in question. This approach should include, when justified, the coordination of strategies across different development domains with shared objectives and solutions that address common problems, sharing commitments and optimising resources.

Based on the aforementioned guiding principles, a summary of the preliminary steps towards implementing a PED/PEB is presented below, defining the structuring guidelines onto which the standardized implementations strategy for energy solutions should be grounded:

- **Drive / decision to create a PED.** The drive to establish a PED may stem from various motivations, such as contributing to the city's overall sustainability goals, reducing the carbon footprint, enhancing citizen well-being, or complementing the implementation of an energy community.
- **Assessment of the implementation area's general characteristics**. This includes factors such as scale (e.g., building block, neighbourhood, larger urban area), density (e.g., low or high density), level of consolidation (e.g., consolidated, partially consolidated, vacant/new area), type of occupation (e.g., mixed-use, industrial, office, residential), and property rights (involving public or private landowners as necessary).
- Preliminary **definition of the type of PED** suitable for the area. Depending on local conditions, needs, and potential, the following types of PEDs may be considered[5]:
  - "Autonomous PED". Solutions with the potential for complete self-sufficiency in energy through renewable sources generated within the area's defined boundaries;
  - "Dynamic PED". Solutions where annual onsite renewable energy generation exceeds annual energy demand, but interaction with energy networks outside its defined boundaries is still permitted;
  - "Virtual PED". Solutions where the positive energy balance is achieved through interaction with virtual renewable energy systems and energy storage solutions implemented outside the area's geographical boundaries, due to strategic choices or physical/functional constraints.
  - "Pre PED". Solutions where the positive yearly energy balance is not yet achieved within the geographical boundaries of the PED. The energy difference may be acquired on the market through green energy certificates.

  This stage also involves a preliminary assessment of available energy resources (e.g., RES or access to waste energy) within the defined boundaries or in the surrounding area, city, or region, and their potential for implementation.
- Preliminary **assessment of legal, regulatory and methodological frameworks.** This includes evaluating the frameworks relevant to the main domains of intervention and identifying available funding options for the necessary solutions. State-of-the-art research is also conducted to identify relevant use cases, supporting tools, and recommendations.
- Preliminary **identification of stakeholders to involve in the process**. This step may precede the previous ones if the entity(s) responsible for the initiative decide to invite relevant partners to form a core group or consortium and jointly determine the subsequent steps. Partners can include the municipality, service providers, academia, businesses, funding entities, and citizen groups, among others. During this stage, the roles and responsibilities of the partners should be defined.
- Preliminary **identification of priority interventions**. This task may result in the need to update the list of key stakeholders to involve if specific skills or contributions are required to address the defined priority tasks. The definition of structuring interventions depends on factors such as the type of area selected, scale and type of occupation, and type of PED. For example, in a consolidated building block area, the main interventions may focus on energy refurbishment

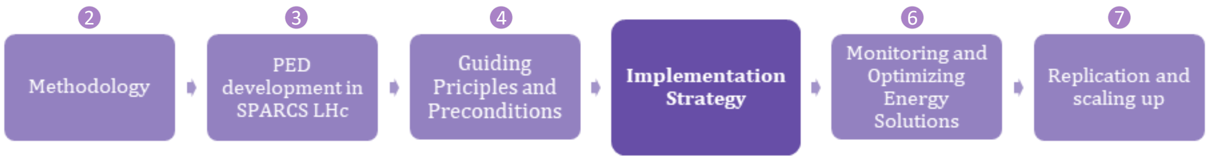
[5] Types of PED, based on definitions suggested by Vandevyvere, H. et al. (2022).

and RES implementation on buildings. In infill areas, the priority may be on implementing district-level RES production and/or energy storage solutions. In the case of a Virtual PED, the responsible entity or consortium may use this PED typology as a drive to create or capitalize on a city-wide RES production unit (e.g., solar plant, wind farm) or a region-level e-mobility hub.

These methodological steps are presented as a guiding reference that can be adjusted to local conditions and circumstances. The subjects may need to be approached in a different sequence, combined, or completed depending on the specific situation on the ground, or revisited after initial discussions and decisions by the responsible entity(s) or consortium.

These preconditions form the foundation for an overall strategy concerning the development of a PED. Based on these, the responsible entity(s) can define the main goals of the endeavour, identify the scope of the relevant strategic areas or systems (e.g., energy, sustainable mobility, land use, governance) to be addressed, determine the structuring projects and connected activities for each strategic area, establish the overall timeline for the interventions, develop the general governance model for the implementation and post-implementation stages, and define the monitoring and evaluation mechanisms.

5. IMPLEMENTATION STRATEGY - METHODOLOGICAL STAGES



As previously mentioned, although the PED framework encompasses various domains, the energy sector naturally plays the most significant role. After defining the general strategic approach for developing a PED, a specific strategy focused on energy solutions can be established. The proposed strategy for implementing energy solutions in PED/PEB follows the methodological stages outlined in Figure 5.

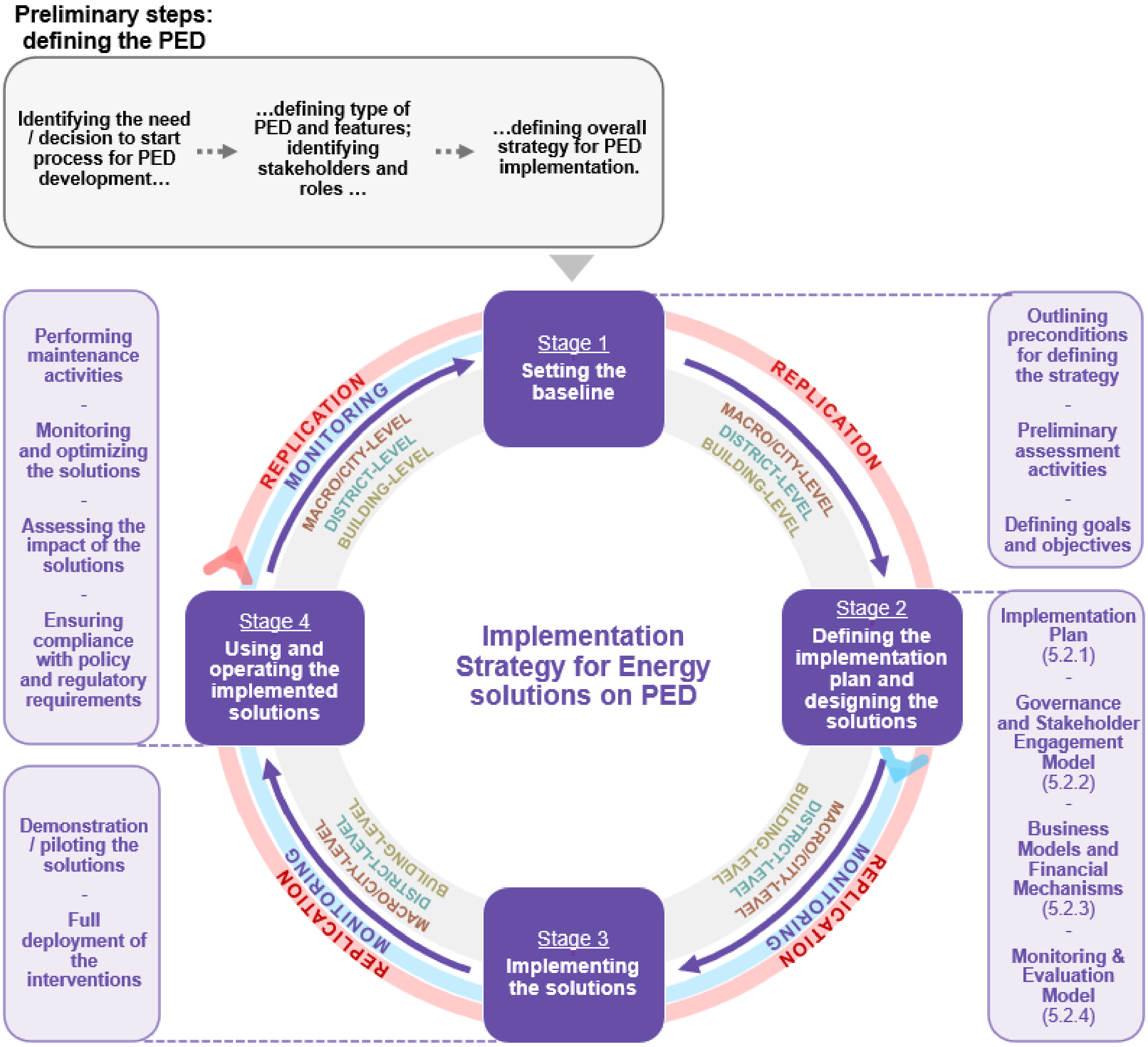


Figure 5. Implementation strategy for energy solutions on PED – general scheme

Source: SPI

5.1. Stage 1 - Setting the Baseline

The overarching goal of PED development (and the development of related energy solutions) is to produce an annual local or regional surplus of renewable energy. To achieve this, when establishing the baseline for the planning process, it is important to consider three primary functions within the context of local urban and regional energy systems (JPI Urban Europe, 2020):

- The **energy production** function, driven by the goal of relying primarily on renewable energy, thereby contributing to climate neutrality;
- The **energy efficiency** function, focused on optimizing energy use and balancing the needs of different sectors (e.g., retrofitting buildings, shared mobility solutions);
- The **energy flexibility** function, ensuring that the implemented solutions are adaptable to the variability of renewable energy loads. This function also considers different energy ecosystem scenarios that require various energy vectors, ultimately contributing to the resilience and balance of urban district energy systems with regional energy systems.

Furthermore, when developing an integrated approach to implementing energy solutions for PED/PEB, it is paramount to consider the local context and conditions. Energy demands and potential solutions can vary substantially depending on local characteristics, geographical conditions, urban structure, types of occupation and use, regulations, and socioeconomic factors. E.g., elements such as local climatic conditions or electricity prices can influence energy demands, while geographical and geological properties can impact the feasibility of implementing renewable energy sources like wind and hydro, or storage solutions such as compressed air and pumped hydro[6].

Considering the above-mentioned conditions and functional framework, the following activities establish the **general baseline** for the proposed implementation strategy:

- 
Assessment of Energy Needs and Potential. It is crucial at this stage to assess existing energy consumption patterns and the capacity of current energy systems. In the case of new urban areas, the assessment of needs should align with urban planning efforts, identifying the area's potential in terms of land use/occupation and associated energy needs. Additionally, a general assessment of the potential for implementing different types of solutions, such as energy efficiency, energy production, energy distribution, energy storage, and energy management/flexibility, should be conducted. These preliminary assessments provide a foundation for further detailed analyses of specific aspects relevant to solution development.
- 
Setting goals and objectives. The overall ambition of a PED is achieving climate neutrality and energy positivity. With reference to this overall strategic goal, specific, clear and measurable goals should be defined by the consortium. These goals should consider the priority interventions previously defined for the PED (see section 4.1), the needs and potential identified in the aforementioned assessment, and the ambitions put forward by the population and local stakeholders.
- 
Involving the local population and stakeholders. This is a critical aspect at this stage and throughout the entire process. It involves gathering input on needs, expectations, and concerns through participatory activities such as workshops, focus groups, surveys, or questionnaires. Representation from key stakeholder groups, including hard-

[6] Lindholm et al. 2021.

to-reach citizen segments, should be ensured, considering the cultural, social, and economic diversity within the community, when devising engagement strategies. Additionally, effectively communicating the project's objectives, benefits, and potential impacts to keep stakeholders informed and engaged is essential. This can be achieved through public information sessions and the establishment of adequate communication channels (e.g., websites, social media). Finally, educational campaigns should be promoted to inform and educate stakeholders about the benefits of PED in general and the specific energy solutions being developed.

5.2. Stage 2 - Defining the Implementation Plan and Designing the Solutions

Based on the previously identified needs, the potential for each type of solution, and the defined goals for the PED's energy system, the consortium should develop an integrated approach to defining the necessary energy solutions to be implemented at each level of intervention (building, district, macro/city level). This process should consider the necessary synergies between solutions and across different scales of intervention. Here it's important to note that some energy solutions may only be viable if certain conditions are met, which depend on the implementation of other scale solutions (e.g., implementing a Virtual Power Plant at a district level requires the existence of different assets, such as RES or storage systems implemented at a building or district level). The approach should also ensure that the designed solutions comply with local, national, and international regulations and standards.

Promoting stakeholder engagement, including residents and other actors not directly involved in the project, in activities such as participatory design sessions, where they can contribute with ideas and understand the challenges, is essential for building trust and commitment to the project goals. As demonstrated during the SPARCS project, in reference to the activities developed by Espoo (see section 2.2 and SPARCS D3.6, Santala et al. 2022), involving stakeholders in co-creating solutions provided valuable insights and contributions.

5.2.1. Implementation Plan

The defined solutions should be integrated and articulated through a general implementation plan, including the overall timeline for developing the solutions, and considering the aforementioned synergies between different scales of intervention. The plan should define specific milestones that lead to achieving the proposed goals and identify the needs and requirements for implementing pilot interventions to test the feasibility and impact of the solutions.

The following items correspond to the core components of this stage and should be devised in conjunction with the implementation plan. Their main aspects are summarised in the subsections below, including references to the design-phase of specific typologies of energy solutions approached by SPARCS LHc, organized by level of intervention.

- Developing a governance and stakeholder engagement model;
- Defining business models and financing mechanisms;
- Developing a monitoring and evaluation model;
- Designing energy solutions at a building, district, and macro/city level.

In this stage, highlight should also be set to the role of energy communities[7], in connection to PED development, as the later can both benefit from and contribute to the creation of the former. Energy communities, which can be deployed at different levels/scales (building, district, macro/city/region), enable local communities (including citizens, businesses, and local authorities as members or shareholders) to jointly manage energy production, storage, and consumption. They can also act as participants in local energy markets. To develop energy communities, it's important to start by identifying opportunities for collective energy management, including determining the ownership and governance structure for energy community formation. RES potential within the building or urban area should be assessed, including solar, wind, and waste-to-energy systems. Collective energy storage solutions should also be evaluated, allowing participants to store and share excess energy. This initiative contributes to the goal of decentralizing energy production and management and reducing dependency on the previous centralized model, often based on fossil fuels.

5.2.2. Governance and Stakeholder Engagement Model

The governance model should provide an integrated framework that insures institutional and functional coordination throughout the implementation process and post-implementation stage. This framework should enable the strengths and potential of each entity involved to be fully realized. In this sense, it is crucial that the organizational model fosters interaction and active communication among the various institutional players, while also ensuring the appropriate allocation of human, logistical, and financial resources across the different phases of the process, including monitoring, and evaluation activities.

Based on the activities developed during the preliminary stage of the process (see section 4), namely in terms of assessing the roles, expectations, and the level of participation required of each group of actors, the governance structure should define the coordinating guidelines for the engagement process. This involves setting up clear coordination and governance mechanisms, specifying roles and responsibilities, and determining the decision-making process. In terms of stakeholder engagement, the model should include

a stakeholder engagement strategy in order to allow for an effective participation and a balanced and objective distribution of responsibilities between all the actors involved or affected by the implementation of the energy solutions in the selected area. This strategy should be holistic in its approach and consider the specific needs and defining aspects of all the systems that compose the PED (e.g. mobility, energy, urban planning, infrastructure, governance).

The responsible entity(s) or consortium should ensure mechanisms to supervise and coordinate the governance process and define the governance structure. This includes defining clear objectives and ensure their effective monitorisation, coordinating interactions (defining the type of forums for discussions and decision-making, the scope and objectives and also the frequency of the meetings), and ensuring the effective management and implementation of the model (defining clear structures and processes for accountability and reporting).

An essential aspect of the governance model is ensuring the commitment of the participants to the process. This can be done through formal agreements, such as

[7] Introduced by the Clean Energy for all Europeans Package (2019), considers two different legal concepts, Citizen Energy Communities (CEC) and Renewable Energy Communities (REC).

resolutions or participation charters, and continuous communication to ensure all stakeholders are informed and engaged. This step is essential for long-term success of the collaborative process, as it helps maintaining transparency and building trust among stakeholders. In this context, it is worth mentioning the *Kera Area Development Commitment*[8] developed by Espoo, together with a wide range of partners in the *Clean and Smart Kera* project. This pioneering approach consists of a set of development objectives in accordance with the city's carbon neutrality and sustainable development goals. The document is part of the land use agreement for the Kera area, signed by the city of Espoo and local landowners, binding the participants with common goal in the following areas:

- Cooperation;
- Clean energy;
- Circular economy services;
- Housing and smooth everyday life;
- Planning and construction;
- Demolition and soil;
- Mobility and logistics;
- Smart urban solutions;
- Communications and brand.

Finally, it's important to establish a process for evaluating the governance and stakeholder engagement model. This evaluation should be ongoing, using defined indicators to assess the effectiveness of the model and identify areas of improvement. Regular evaluation helps ensure that the model remains effective and that any necessary adjustments are made to improve the collaborative process. This step ensures that the model evolves in response to feedback and changing circumstances, maintaining its relevance and effectiveness over time.

5.2.3. Business Models and Financing Mechanisms

Demonstrating the economic feasibility of the solutions and developing business models and financial mechanisms is essential to secure the required funding. The approach should include preliminary estimates of the investment required to implement the solutions and define resource allocation, including personnel, equipment, and budget, for each phase of the project.

The development of business models should be tailored to the specific ecosystem where the solutions are going to be implemented. This involves exploring various ownership and operational structures, such as public-private partnerships, community-based models, or utility driven approaches. As a result, financially viable solutions should be created, aligning with stakeholder interests, ensuring scalability, and maximising environmental and social benefits. During SPARCS project, an approach to co-creating business models was developed, aiming to study how co-creation can function as a method to gather relevant contributions and involvement of stakeholders for developing innovative and creative business models, leading to sustainable transition.

[8] https://www.espoo.fi/en/news/2021/09/development-commitment-kera-will-make-it-pioneering-area-sustainable-development-unique-land-use

Furthermore, robust financial mechanisms should be designed to support the implementation of the identified energy solutions. This includes analysing different financing options such as green bonds, carbon pricing, tax incentives, and subsidies. It is important to leverage public and private investments, as well as identifying risk-sharing strategies to attract capital. These financial mechanisms should incentivize early adoption, support long-term sustainability, and ensure equitable access to benefits.

5.2.4. Monitoring and Evaluation Model

The monitoring and evaluation model should provide a structured approach to assessing the project's progress and impact against its objectives. It should establish clear objectives (aligned with the overall goals of the project) and include milestones and specific, measurable key performance indicators (KPIs) to track progress toward each objective. Furthermore, appropriate data collection and management mechanisms should be defined, including identifying sources of data relevant to the project’s indicators and establishing systems for data collection, storage, and analysis. The plan should account for regular monitoring activities, including progress tracking (to help identify deviations and make necessary adjustments) and adaptive management (to adapt and improve the project based on insights gained from monitoring).

The evaluation component of the model should include impact assessment (evaluating the project's overall impact on its primary objectives at various stages and at the end of the project) and identifying lessons learned and best practices for future replication or upscaling. Furthermore, the model should consider reporting and communication components, including regular reporting to stakeholders about the project's progress and outcomes, ensuring transparency to maintain accountability and build trust, and incorporating stakeholder feedback into ongoing project management and future planning.

Feedback from the community affected by the solutions should be collected during the implementation and post implementation stages to understand their experience and satisfaction. Educational and awareness-raising programs should inform the community about the benefits of the solutions and ways to improve savings and optimize energy usage. Incentive programs should encourage participation and usage of the solutions, incentivizing and rewarding positive behavioural changes (e.g., discounts on energy-efficient appliances, rewards for households achieving significant energy savings, public acknowledgment of good examples). Additionally, public reports and/or interactive dashboards should be used to provide easily accessible reports on the project’s performance, including energy savings, emissions reductions, and other key metrics.

5.2.5. Designing Building-Level Energy Solutions

At the building level, the focus is on retrofitting and upgrading the building to improve its energy performance, implementing energy management systems, and enhancing the building’s operating functionalities. The following interventions can be performed independently or in combination, depending on the needs and capacity.

a. NZEB solutions

In general terms, for the implementation of a PED, energy efficiency in buildings is essential; thus, implementing building-level solutions such as Net Zero Energy Buildings (NZEB) is a starting point for most other energy solutions.

Interventions leading to NZEB require a preliminary audit of the building's performance, including energy audits, assessment of the building's envelope, RES potential, structural conditions, and the capacity of electrical systems. Based on the results, interventions such as energy efficiency improvements to the building's envelope, HVAC system implementation or upgrade, energy-efficient lighting and appliances, integration of RES on rooftops or facades, integration of energy storage solutions, integration of smart building technologies, and development of a digital twin for the building can be developed. For new buildings, the design can consider sun exposure and incorporate passive solar features in addition to the aforementioned solutions.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1). Subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC2).

Relevant assessment & design aspects:

- *Determining base-case for future energy costs comparisons;*
- *Calculating energy costs in the area;*
- *Determining the energy consumption profiles of the buildings;*
- *Determining the waste heat possibilities from buildings and assessing their possibilities for heating;*
- *Assessing the use of geothermal heat to residential heat;*
- *Assessing the possibilities of connecting geothermal heat to district heating network;*
- *Assessing the dimensioning of the PV plant, considering the capacity of roof structure;*
- *Assessing the potential to minimize electricity costs by optimizing electricity usage, production of own energy, and participating in electricity reserve markets;*
- *Providing solutions for installation of equipment allowing for intelligent balancing of PV, CHP, and user demand control.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

b. Storage solutions

To develop storage solutions at the building level, an evaluation of energy storage needs based on the building's energy demand patterns should be conducted. The proposed storage solutions should be designed to meet the identified needs and complement existing or proposed RES solutions. Specific battery storage systems should be specified to store excess renewable energy, including determining battery capacity and type. The design of storage systems should also consider integrating these systems with the building's electrical and energy management systems.

SPARCS references: LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks; LHc Leipzig (UC1). Subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC2).

Relevant assessment & design aspects:

- *Assessing the optimal size of battery energy storage;*
- *Assessing different control strategies for smart electricity consumption, production, and battery usage;*
- *Designing an interface for digital battery monitoring.*

For complementary information see SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1). SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Smart Building Energy Management

Developing smart building energy management (SBEM) solutions begins with identifying current or proposed energy systems, such as lighting, HVAC, and elevators. An integrated energy management system should then be designed, including Internet of Things (IoT) sensors and smart devices to be integrated throughout the building, enabling monitoring and centralized control of energy usage. Finally, a user-friendly interface should be designed for occupants to interact with the building's energy systems.

SPARCS references. LHc Espoo. Subtask 3.3.2 Smart energy services (UC1); Subtask 3.3.3 Smart Building Energy Management (UC2). LHc Leipzig. subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC3).

Relevant assessment & design aspects:

- *Defining the level of actuation of the SBEM (monitoring, manual control or automation control);*
- *Estimating heat and power demand profiles;*
- *Assessing flexibility potential regarding EV chargers, stationary battery and on-site PV production;*
- *Creating technical solution and assessing business model;*
- *Defining the concept, designing and planning for the installation of sensors;*
- *Collaborating with partners to agree the timeline, design, and concept;*
- *Defining the concept, designing and planning the user interface equipment (tablets) to allow the tenants to directly access the information received by the installed sensors.*

For complementary information see; SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case 1; link to SPARCS use-case 2); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case3).

d. Digital twin

The development of a digital twin (DT) of the building requires a preliminary collection of detailed data on the building's features, including the building's structure, installed or proposed systems, and usage patterns. Based on this baseline information, a digital replica of the building should be developed, including structural and functional models of the building, allowing real-time monitoring and control of the building's energy systems. The digital twin should be designed to integrate data from various sensors and systems, offering real-time performance analytics. The DT can be used for different stages of the building's lifecycle (engineering, construction, operation & maintenance, and demolition and recovery).

SPARCS references. LHc Espoo. Subtask 3.5.1 Energy Positive District Planning (UC1); Subtask 3.2.2 Smart energy solutions for self-sufficiency in the Leppävaara center (UC2).

Relevant assessment & design aspects:

- *Establishing the necessary data collection mechanisms;*
- *Creating a BIM model (ifcSpace) of a building block;*
- *Developing an AI based digital twin solution that can be easily be scaled up and replicated for other buildings.*

For complementary information see SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case).

5.2.6. Designing District-Level Energy Solutions

At a district level, the solutions can go beyond the boundaries of individual buildings or blocks, optimizing and creating synergies between building-level solutions or complementing them functionally. The following district-level solutions present a reference for relevant interventions implemented during SPARCS project:

a. Virtual Power Plant

Implementing a VPP involves identifying the existing or proposed energy assets within the district, such as Distributed Energy Resources (DER), renewable energy sources (RES) production, storage systems, and demand response schemes. The design phase should focus on aggregating and optimizing these resources to create a unified entity with greater capacity to access energy markets and provide complementary services. Communication protocols must be established to facilitate real-time data exchange and ensure the VPP operates efficiently and in harmony with the grid.

SPARCS references. LHc Espoo. Subtask 3.2.2 Smart energy solutions for self-sufficiency in the Leppävaara center (UC1); Subtask 3.3.1 Virtual Power Plant for optimized RES energy use (UC2). LHc Leipzig. subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC3); subtask 4.5.1 Energy Positive District Planning (UC3).

Relevant assessment & design aspects:

- *Defining participants and specifying roles;*
- *Assembling the assets portfolio;*
- *Gathering data on all the city properties;*
- *Analysing reserve flexibility potential of different properties;*
- *Choosing pilot site;*
- *Identifying architecture of blockchain solutions;*
- *Assessing pros and cons of blockchain solutions;*
- *Assessing legal framework regarding blockchain solutions;*
- *Integrating decentralized systems and devices for the automated provision of data.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1; link to SPARCS use-case2); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case3).

b. EV-Mobility Interfaces

Solutions for deploying local EV-Mobility interfaces, including electric vehicles, e-bicycles, and micro-mobility solutions, should begin with a thorough assessment to identify suitable locations. This assessment should consider available space, public accessibility, proximity to relevant urban functions, and connections to local road and cycling networks. Additional factors include the dimension and number of parking spaces required, e-charging infrastructure needs, and the technical and regulatory conditions necessary for bi-directional charging stations. The possibility of integrating supporting facilities, such as warm storage for e-bikes and complementary services like repair shops or coffee shops, should also be explored. Moreover, the design phase should emphasize the integration of the charging infrastructure with renewable energy sources whenever possible, and the implementation of smart charging systems to manage load and optimize energy use.

SPARCS references. LHc Espoo. subtask 3.4.1 Boosting E-mobility uptake in the Espoonlahti district, Lippulaiva blocks (UC1). LHc Leipzig. subtask 4.4.2 Load-balanced fleet management (UC2).

Relevant assessment & design aspects:

- *Dimensioning and designing EV parking for shopping center customers and residential buildings;*
- *Designing smart charging infrastructure to EV together with service provider;*
- *Assessing possibilities of Vehicle to Grid solutions;*
- *Examine existing city-level plans and local and regional bicycling strategies, and existing shared city bike system, and facilitating discussion with different city departments;*
- *Assessing e-bicycling possibilities in the city (integration to city transportation system, integration to existing and future mobility hubs);*
- *Assessing the possibility to offer warm storage room for e-bikes;*
- *Assessing e-charging requirements and facilities;*
- *Organizing a public event for locals where e-bikes and sustainable mobility are presented and promoted, possibility to try e-bikes, together with local e-bike companies and other stakeholders.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Local Renewable Energy Production

The development of local renewable energy production requires a preliminary assessment of the area's potential for clean energy sources, such as solar plants or geothermal heat pumps. These solutions are heavily influenced by local conditions, including climate, geology, and the urban fabric's structure, as well as installation costs. Some solutions may not be cost-effective for specific sites, so these factors must be carefully evaluated. The solutions should also be designed for seamless integration with the district's energy management systems to ensure efficient operation and synergy with other energy solutions.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1); LHc Leipzig. Subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC2).

Relevant assessment & design aspects:

- *Providing the description of the thermal energy system, on-site heat recovery and control strategies;*
- *Designing a regenerative ground source heat pump system;*
- *Developing a feasibility study for a solar thermal plant, finding suitable locations, and concluding the conceptual design phase;*
- *Securing of national funding for the project.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case 2).

d. Sector coupling solutions

To design effective sector coupling solutions at the district level, it is essential to assess the potential for integrating different existing or proposed energy systems, such as electricity, heating, cooling, and transport. Based on the assessment results, the designed solutions might include technologies such as Combined Heat and Power (CHP) systems or the use of surplus renewable electricity to charge electric vehicles. These solutions should be closely integrated with the district energy management systems for coordinated operation, ensuring they contribute to the overall efficiency and sustainability of the district's energy ecosystem.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1); LHc Leipzig. Subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC2); subtask 4.4.2 Load-balanced fleet management (UC3).

Relevant assessment & design aspects:

- *Developing a flexible and efficient energy management system combining geothermal heating and cooling systems, solar panels and electric battery;*
- *Identifying and analysing potential heat sources in urban areas and assessing their suitability for heat use;*
- *Examining possible waste heat sources suitable for integrating in district heating;*
- *Developing a realisation plan for upgrading existing EV charging stations to allow for intelligent charging, including demand response.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2); (link to SPARCS use-case3)

5.2.7. Designing Macro/City-Level Energy Solutions

At a macro level, besides contributing to PED/PEB development and optimization, the energy solutions presented below play a significant role regarding broader city functions and sustainability goals, such as clean mobility, large-scale RES deployment, and the optimization of energy systems.

a. Urban Data Platforms

Designing requires an integrated approach, beginning with the identification of key stakeholders responsible for the systems and processes to be included in the platform. These stakeholders may include municipal departments, utility companies, technology providers, and end-users. An assessment should also be conducted to identify existing data sources related to energy usage, grid infrastructure, building energy performance, transportation, and renewable energy potential (e.g., GIS tools, 3D models). Additionally, the platform's data needs should be defined by analysing available data and identifying gaps where complementary sources are required. Based on this assessment, the platform should incorporate a framework for integrating data from various sources and provide tailored user interfaces for different stakeholder groups (e.g., city planners, utility managers, residents).

SPARCS references. LHc Leipzig. subtask 4.5.1 Energy Positive District Planning.

Relevant assessment & design aspects:

- *Monitoring and collecting energy and building data during the implementation phase of the energy positive community;*
- *Determining requirements for the integration of data into the urban data platform (data formats, APIs, etc.).*
- *Determining possible use cases and integrate data into the urban data platform.*

For complementary information see: SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case).

b. P2P Energy Trading

Deploying a Peer-to-Peer (P2P) Energy Trading Platform requires a thorough market analysis of current and projected energy demand and supply within the designated area, as well as an assessment of participants' willingness and readiness to engage in P2P energy trading. It is also essential to evaluate the types and quality of data available, identify potential sources, and pinpoint any gaps. The design phase involves developing the platform's architecture, user interface, and trading mechanism, along with security and privacy measures. Additionally, the platform must be integrated with the grid and local energy management systems to ensure seamless operation.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1); LHc Leipzig. Subtask 4.3.2 Blockchain supported energy services (UC2).

Relevant assessment & design aspects:

- *Assessing the potential to minimize electricity costs by optimizing electricity usage, producing own energy, and participating in electricity reserve markets;*
- *Developing a feasibility study on the coordinating role of the blockchain in the energy sector;*
- *Testing blockchain-based solutions to enable prosumers to sell their surplus electricity on a Peer-to-Peer marketplace;*
- *Developing economic evaluation of potential business models for a blockchain solution; Preparing the practical implementation of the solution;*
- *Demonstration of the integration and interactions of IoT devices e.g. distributed power production and storage backed by blockchain.*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Electricity grids: micro & smart

Designing electricity microgrids requires a comprehensive assessment of the area's energy needs and existing grid infrastructure, including the identification of existing or proposed energy assets related to production, storage, and controllable loads. The microgrid must be seamlessly integrated with local energy systems as well as the main grid. The system should be designed to withstand and recover from natural disasters and other disruptions, incorporating redundancy and robust physical infrastructure. Moreover, a robust communication network is essential for enabling real-time data exchange and control. This network should support technologies such as automated demand response, advanced metering infrastructure, and grid automation systems.

SPARCS references: LHc Leipzig. subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC1); subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC2).

Relevant assessment & design aspects:

- *Defining which part of the energy network is included in balancing of the microgrid and the virtual power plant;*
- *Designing the solution for energy monitoring equipment to measure the energy flow between the microgrid and the citywide energy network.*

For complementary information see: SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case1; link to SPARCS use-case2).

d. Multi-modal transport solutions

Developing multi-modal transport solutions requires a comprehensive approach to the city's mobility system, incorporating several complementary features such as EV-mobility hubs, ICT solutions for existing and proposed transport options, and Mobility-as-a-Service (MaaS) solutions. For the implementation of EV-Mobility Hubs, it is necessary to evaluate the area's transportation patterns and identify strategic locations for hub facilities, considering their relationship and connectivity to public transport networks and road infrastructure. Additionally, current and future transportation needs should be assessed. The hubs should be designed to accommodate EV charging, shared mobility services, and connectivity to public transport, while also integrating smart systems for efficient management and enhanced user experience.

SPARCS references. LHc Espoo. Subtask 3.4.2 New E-mobility hub in Leppävaara center.

Relevant assessment & design aspects:

- *Examining the possibilities for further development of the implemented bus charging system into an EV-mobility hub;*
- *Analysing the EV-mobility hub charging needs for some of the following: passenger cars, taxis, shared cars, service vehicles, mobile machinery and electric bikes;*
- *Gathering data from the local charging system;*
- *Analysing the requirements and impacts on the electrical grid;*
- *Developing a sustainability strategy with a focus on 'last mile' solutions and e-bicycles, assessing similar strategies globally for Metro (or similar rapid public transportation connection) access;*
- *Examining potentials for different electric vehicle type charging services (with relevant stakeholders) and EV sharing (services) - and analysis of the impacts on the grid.*

For complementary information see SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case).

5.3. Stage 3 - Implementing the Solutions

The implementation phase can include a preliminary phase focused on testing solutions through relevant pilot projects. These pilot projects can help identify challenges, make necessary adjustments to the solutions, and refine the original plans and schedule. Subsequently, the full deployment of the solutions should be executed gradually, following the implementation plan's guidelines and incorporating lessons learned from the pilot interventions.

During this phase, the results of pilot interventions should be **monitored and evaluated** and lessons learned as well as needs for adjustments should inform the subsequent deployment of the energy solutions. During the execution of interventions, monitoring should focus on progress toward objectives and achievement of proposed milestones. Identified deviations from the plan should be addressed, and necessary adjustments to the schedule should be made. Regular reporting to stakeholders regarding the progress and outcomes of the project should be assured throughout this stage.

Social engagement should involve residents, businesses, and utilities, providing regular updates on project progress and establishing mechanisms for stakeholders to offer feedback on the implementation process. This includes communicating issues and concerns through the previously established communication channels. During this stage, participatory activities should be considered, allowing stakeholders to learn about the technologies being implemented and understand how they can benefit from them.

During the implementation of the project in Leipzig's demo district *Duncker neighbourhood*, an energy advisor was made available to support residents in the energy transformation of their buildings. Additionally, desk support services were offered to interested citizens, providing information on the cost-efficient installation and use of renewable energy sources, as well as assistance to local businesses and individuals interested in implementing the project's solutions (see SPARCS D4.6, Bolognesi et al. 2023).

5.4. Stage 4 - Using and operating the implemented solutions

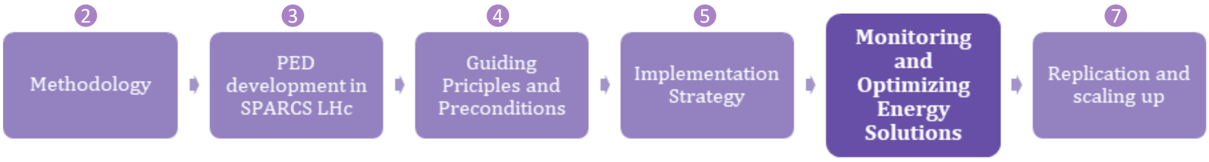
Relevant aspects regarding the post-implementation stage should be previously considered while developing the implementation plan and complementary models. These include, among others, monitoring, maintenance, stakeholder engagement, and policy and regulatory compliance. As described in section 5.2.3, continuous monitoring and performance evaluation of the implemented solutions, as well as feedback loops will contribute to adjusting strategies and operations.

In terms of **monitoring and evaluation** activities, in this stage it is important to conduct performance monitoring of the adopted solutions (e.g., energy consumption and emissions) and to track results against the set KPIs.

Based on the collected performance data, feedback loops should be established to identify areas for improvement, efficiency enhancement, and effectiveness. The impact (environmental, economic, and social) of the implemented solutions should also be evaluated and reported. In terms of maintenance and operational efficiency, the implementation of effective measures such as infrastructure upkeep, software updates, training for operators, and use of advanced energy management systems is essential to ensure that all systems are kept at optimal efficiency levels, minimizing energy waste and extending the lifespan of the technology.

Finally, it is crucial to ensure that all implemented solutions comply with current and evolving local, national, and international **regulations and policies.** This includes emissions standards, energy efficiency mandates, and safety requirements. As the regulatory landscape changes, the energy system may need to be adapted to remain compliant and take advantage of new incentives.

6. MONITORING AND OPTIMIZING ENERGY SOLUTIONS



As mentioned in section 5.2.3, the monitoring and evaluation process focuses on both the implementation stage and the post-implementation or utilization stage. This section describes relevant activities related to monitoring and optimisation of energy solutions, by scale of intervention. It includes reference to the use-cases developed in SPARCS LHc, and lists relevant KPI proposed for the solutions.

6.1.1. Building-Level Solutions

a. NZEB Solutions

The monitoring activities can consider the use of building automation systems (BAS) to monitor and control energy usage. Regular reviews of performance data are important to identify areas for improvement.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1). Subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC2).

Relevant KPI:

- *Share of RES (electricity);*
- *Share of RES (thermal, including heating and cooling);*
- *Excess Heat Recovery Ratio (%);*
- *Total building energy efficiency measurement (kWh/m²/annum);*
- *Energy Storage (number of equipment);*
- *Energy Storage capacity (electric, MWh);*
- *Energy Storage capacity (thermal, MWh);*
- *Onsite energy ratio (OER);*
- *Annual Mismatch Ratio (AMRx) heating;*
- *CO_2 emissions reduction (tCO2/annum);*
- *Reduction of customer energy cost (cent/kWh).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

b. Storage Solutions

Solution performance should be monitored using defined KPIs, allowing for adjustments to ensure maximum efficiency. Energy management systems should be used to optimize the charging and discharging cycles.

SPARCS references: LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks; Subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC2).

Relevant KPI:

- *Energy Storage (number of equipment);*
- *Energy Storage capacity (electric, MWh);*

- *Energy Storage capacity (thermal, MWh).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Smart Building Energy Management

AI and machine learning algorithms can predict energy usage patterns and optimize energy distribution across the energy system components. Feedback from end-users should be collected, and demand response awareness should be raised to reduce energy consumption during peak periods.

SPARCS references. LHc Espoo. Subtask 3.3.2 Smart energy services (UC1); Subtask 3.3.3 Smart Building Energy Management (UC2). LHc Leipzig. subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC3).

Relevant KPI:

- *Annual Mismatch Ratio (AMRx);*
- *Total available (RES, storage, HVAC, EV Charging. etc);*
- *Number of equipment integrated (No.);*
- *Number of elevators/escalators units with physical power meters monitored by VPP;*
- *Increased working efficiency due to prediction model (saved hours per day);*
- *CO_2 equivalent reduction (tonnes);*
- *Total energy demand reduction (MWh/annum);*
- *Peak Load Reduction (MW).*

For complementary information see; SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case 1; link to SPARCS use-case 2); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case3).

d. Digital Twin

These solutions can be used for real-time monitoring, simulation, and predictive maintenance of the building's energy system, anticipating and preventing equipment malfunctions, and optimizing maintenance schedules.

SPARCS references. LHc Espoo. Subtask 3.5.1 Energy Positive District Planning.

Relevant KPI:

- *Increase of simulations executed via the Virtual Twins concept (No.);*
- *Number of innovative energy technologies incorporated in virtual twin for simulation purposes (No.);*
- *Accuracy of building heating and electricity load forecasting electricity;*
- *Accuracy of building heating and electricity load forecasting District heating;*
- *Accuracy of building heating and electricity load forecasting PV;*
- *Number of scenarios for positive energy block evaluated (No.);*
- *Number of technologies utilised in the scenarios for positive energy block (No.).*

For complementary information see SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case).

6.1.2. District-Level Solutions

a. Virtual Power Plant

The VPP's performance should be monitored using defined KPIs, allowing for operational adjustments and efficiency maximization. AI algorithms can help predict and respond to energy demand and supply fluctuations.

SPARCS references. LHc Espoo. Subtask 3.2.2 Smart energy solutions for self-sufficiency in the Leppävaara center (UC1); Subtask 3.3.1 Virtual Power Plant for optimized RES energy use (UC2). LHc Leipzig. subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC3); subtask 4.5.1 Energy Positive District Planning (UC3).

Relevant KPI:

- *Share of on-site electricity production (%);*
- *Total thermal energy consumption reduction (MWh/annum);*
- *Onsite Thermal energy ratio (OER), (%);*
- *Potential thermal flexibility (MW);*
- *Thermal peak power demand (MWh/h);*
- *Share of monitored thermal energy sub-systems (%);*
- *Share of integrated systems (smart control/ VPP/ storage);*
- *Stored heat (MWh per anno);*
- *Supplied heat to heating grid (per anno).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1; link to SPARCS use-case2); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case3).

b. EV-Mobility Hub

Usage patterns should be monitored, and infrastructure deployment adjusted accordingly. Data analytics can optimize the operation of deployed mobility services.

SPARCS references. LHc Espoo. subtask 3.4.1 Boosting E-mobility uptake in the Espoonlahti district, Lippulaiva blocks (UC1). LHc Leipzig. subtask 4.4.2 Load-balanced fleet management (UC2).

Relevant KPI:

- *Bicycle parking places (No.);*
- *Charging cabinets for e-bikes (No.);*
- *Number of EV charging stations (No.);*
- *Number of smart EV charging points (No.);*
- *Demand from all EV mobility modes; impact on the grid (kWh);*
- *Ratio of peak demand from EV mobility modes to local transformer capacity (%);*
- *Ratio of average demand from EV mobility modes to local transformer capacity (%);*
- *Level of utilisation of EV charging stations (%);*
- *District EV parking/charging places (car and bicycle) (No.);*
- *Utilisation of the charging system (%);*
- *Number of EVs in fleet management (No.).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Local Renewable Energy.

Relevant KPI such as renewable energy production and consumption should be monitored in real-time. Predictive analytics should be used to optimize the operation and maintenance of implemented energy systems.

SPARCS references. LHc Leipzig. subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC1; UC2).

Relevant KPI:

- *Supply of renewable heat to the grid (MWh/annum) (overall);*
- *Supply of renewable heat to the project specific districts (MWh/annum);*
- *Amount of saved CO_2 emissions (t/annum).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

d. Sector Coupling

Performance of implemented sector coupling systems should be monitored for system optimisation. Integrated control systems should be used to optimise energy flows between sectors.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1); LHc Leipzig. Subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC2).

Relevant KPI:

- *Share of RES (electricity) (%);*
- *Share of RES (thermal, including heating and cooling) (%);*
- *Excess Heat Recovery Ratio (%);*
- *Total building energy efficiency measurement (kWh/m^2/annum);*
- *Energy Storage (No. of equipment);*
- *Energy Storage capacity (battery - MWh);*
- *Energy Storage capacity (thermal - MWh);*
- *Onsite energy ratio (OER) (%);*
- *Annual Mismatch Ratio (AMRx) (heating) (%);*
- *CO_2 emissions reduction (tCO_2/annum).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

6.1.3. Macro/City-Level Solutions

a. Urban Data Platform

Defined KPIs should be continuously monitored to measure the platform's effectiveness. Data should be continuously collected and analysed to support optimized performance. Insights collected can support decision-making and improve urban energy planning and operations. Feedback loops should be established for continuous improvement of the platform.

SPARCS references. LHc Leipzig. subtask 4.5.1 Energy Positive District Planning.

Relevant KPI:

- *Number of energy and building datasets for creating district refurbishment concepts integrated in the Urban Data Platform (No.);*
- *How much has the project benefitted from, contributed to, and followed into the strategic documents of the city;*
- *Number of city units involved in planning (No.).*

For complementary information see: SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case).

b. P2P Energy Trading

Defined KPI should be continuously monitored to measure the success and impact of the platform. Data should be continuously collected and analysed to support optimized performance. Insights collected can support decision-making and improve urban energy planning and operations. Feedback loops should be established for continuous improvement of the platform.

SPARCS references. LHc Espoo. Subtask 3.2.1 RES integration in Energy Positive Lippulaiva blocks (UC1); LHc Leipzig. Subtask 4.3.2 Blockchain supported energy services (UC2).

Relevant KPI:

- *Share of RES (electricity) (%);*
- *Share of RES (thermal, including heating and cooling) (%);*
- *Total building energy efficiency measurement (kWh/m²/annum);*
- *Energy Storage (No. of equipment);*
- *Energy Storage capacity (battery – MWh));*
- *Energy Storage capacity (thermal - MWh);*
- *Onsite energy ratio (OER) (%);*
- *Annual Mismatch Ratio (AMRx) (heating) (%);*
- *Number of (active) participants (No.);*
- *Number of transactions (No.);*
- *Sum of total traded energy (MWh);*
- *Turnover (€);*
- *Availability of the system (uptime, stability) (%).*

For complementary information see: SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case1); SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case2).

c. Electricity Grids: Micro & Smart

Monitoring KPIs will help measure the success of the micro and smart grids. Monitoring and optimization activities should include microgrid performance monitoring and management of energy flows to optimize system reliability and efficiency. Advanced control systems should ensure seamless integration with the main grid. Evaluating the environmental impact of the microgrid, including emissions reduction and land use considerations, is also important.

SPARCS references: LHc Leipzig. subtask 4.2.2 Optimal energy distribution in industrial Spinnerei block (UC1); subtask 4.2.1 Carbon-free district heating in Leipzig-West (UC2).

Relevant KPI:

- *Flexible Loads (No. of smart meters);*
- *Share of integrated systems (smart control/ VPP/ storage) (%);*
- *Total energy generation (MWh);*
- *Supply of renewable heat to the grid (MWh/annum -overall);*
- *Supply of renewable heat to the project specific districts (MWh/annum);*
- *Amount of saved CO_2 emissions (t/annum);*
- *Demand from all EV mobility modes; impact on the grid (kWh);*
- *Ratio of peak demand from EV mobility modes to local transformer capacity (%);*
- *Ratio of average demand from EV mobility modes to local transformer capacity (%);*
- *Level of utilisation of EV charging stations (%);*
- *District EV parking/charging places (car and bicycle) (No.);*
- *Utilisation of the charging system (%).*

For complementary information see: SPARCS D4.3 (Riedel et al. 2022) and BABLE website (link to SPARCS use-case1; link to SPARCS use-case2).

d. Multi-Modal Transport Solutions

Monitoring should focus on the usage of the covered solutions and service performance. Data analytics can contribute to optimising operations and enhancing user experience.

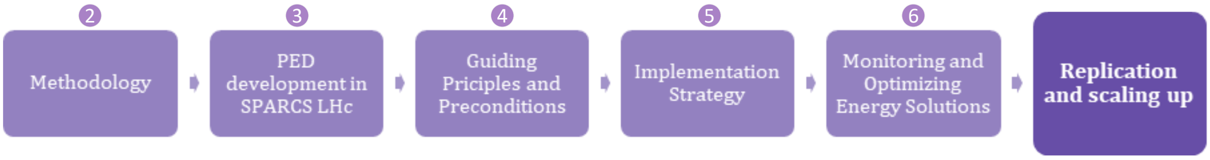
SPARCS references. LHc Espoo. Subtask 3.4.2 New E-mobility hub in Leppävaara center.

Relevant KPI:

- *Peak demand from all EV mobility modes (kWh);*
- *CO_2 reduction based on charged electricity (tonnes);*
- *Average charging time/day (h/d);*
- *Average charging time/month (h/mth);*
- *Charged energy/day (kWh/d);*
- *Charged energy/month (kWh/mth);*
- *Peak demand from all EV mobility modes/Transformer capacity (hourly average) (kW);*
- *Average demand from all EV mobility modes/Transformer capacity (kW);*
- *Peak demand reduction (KW);*
- *Flexibility % of normal load. Buildings/Prosumers (%);*
- *Utilisation of chargers in the system after charging strategy (kWh);*
- *Peak demand reduction using the charging strategy (kW);*
- *Number of charging strategies simulated (No.).*

For complementary information see SPARCS D3.3 (Wanne et al. 2022) and BABLE website (link to SPARCS use-case).

7. Replication and Scaling up of Energy Solutions on PED/PEB



Replicability and scalability are foundational concepts within the framework of PEDs and PEBs, essential for the widespread adoption and effectiveness of these solutions in transforming cities into sustainable and carbon-neutral territories. This subject has been addressed throughout the project's lifespan across various work packages, leading to the effective replication and upscaling of the developed energy solutions. Additionally, supporting materials and activities were developed to optimize further replication and upscaling processes.

Overall, the solutions developed throughout the project represent integrated urban solutions that exhibit cross-effects and synergistic relationships. These solutions are holistic in nature, meaning they are more than just the sum of their components and must be approached as a whole rather than individually. Therefore, the approach to their replicability needs to consider contextual factors such as size, culture, geography, weather conditions, challenges, and complexity, as well as the possible synergies of different domains relevant for the energy system in the city where they are to be deployed (SPARCS D1.7, Serra et al. 2021).

The aforementioned document (Serra et al. 2021) provides a comprehensive approach to the replication process of energy solutions for PED/PEB. The document presents relevant challenges, technical requirements, and social considerations related to the solutions, as well as the requirements for their impact assessment. Additionally, a replication methodology is provided to help identify the appropriate context for replicating each type of solution. The methodology includes the following steps:

- **Step 1.** Separation of the integrated solutions in their components;
- **Step 2.** Evaluation of the components of the integrated solutions (Technical characterisation; Impact evaluation; Main stakeholders; Requirements for their implementation);
- **Step 3.** Characterization of the city (target city) – evaluation of the city needs, and potential regarding the components of the integrated solutions;
- **Step 4.** Assessment of the applicability of the solutions - individually and holistic - in the city, as of today.

Furthermore, a thorough assessment of the replication potential and impacts of the solutions developed during the project using was developed (SPARCS D2.9, Aapo et al. 2024). This long-term high-level impact assessment was performed using CITYkeys replication indicators (social compatibility, technical compatibility, ease of use for end-users, ease of use for professional stakeholders, trialability, advantages for end-users, advantages for stakeholders, visibility of results, solutions to development issues, and market demand). The results show that although most of the solutions are relevant to European cities, they are context-specific and their replication requires adaptation to the local context to ensure social and technical compatibility.

The aforementioned documents should be consulted for further information concerning replication and upscaling of energy solutions for PED/PEB.

8. CONCLUSIONS

8.1. Summary of achievements

The standardized implementation strategy for energy solutions presented in this report is primarily derived from SPARCS experience in realizing various components that contribute to urban transformation and carbon neutrality in the seven partner cities. The project focused on strategic aspects related to governance models, business models and financing mechanisms, monitoring and assessment frameworks, and replication and upscaling activities, among others, paving the way for the effective design, implementation, and operation of PED-related energy solutions. Based on the project's approach and the results obtained, the strategic guidelines presented in this document offer a comprehensive overview of practical aspects related to the planning, development, and implementation of energy solutions.

However, it is important to recognize that energy demands and potential solutions can vary substantially depending on local characteristics, geographical conditions, urban structure, types of occupation and use, regulatory frameworks, and socioeconomic factors. In this sense, the proposed strategic approach provides clear structuring guidelines for the overall energy system development process, facilitating the necessary adjustments to local conditions and broader goals defined for the PEDs where these solutions will be implemented.

By offering a flexible yet comprehensive framework, the strategy provides an effective tool for cities in their pursuit of sustainable urban transformation, ensuring that energy solutions are not only technically feasible but also contextually appropriate and aligned with the overarching objective of achieving carbon neutrality.

8.2. Summary of recommendations for a standardized approach to an implementation strategy

Throughout the project, it became evident that the development of PEDs requires a multifaceted approach that accounts for the specific conditions of each territory, as well as the various layers that make up the urban fabric—such as buildings, public spaces, infrastructure, energy systems, and mobility networks. Beyond the physical and technical dimensions, it is essential to consider governance and business models that align with the aspirations of both the citizens and the market. Moreover, as extensively referenced throughout the document, a thorough participatory process involving residents, users, and relevant stakeholders across each of these layers is crucial for the entire process of planning, implementing, and optimizing the area as an integrated part of the city.

Below, a summary of the main recommendations presented throughout the report is provided, regarding each methodological stage of the strategic process:

Guiding Principles and Preconditions

Relevant recommendations:

- For the definition of an integrated strategy for energy solutions within PEDs, it is necessary to meet a set of guiding principles and preconditions related to the development of the PED across its multiple systems.

- Guiding principles for PED development that make them attractive for cities and citizens include quality of life, inclusiveness (with a special focus on affordability and prevention of energy poverty), sustainability, resilience, and security of energy supply.
- Preconditions that form the foundation for an overall strategy concerning PED development include preliminary assessments of need and potential, identification of stakeholders to involve, and the definition of priority interventions in each relevant system (e.g., energy, mobility, urban development).

Implementation strategy

Stage 1 – Setting the baseline

Relevant recommendations:

- This stage requires assessing existing energy consumption patterns and the capacity of current energy systems. It is also essential to understand the potential for implementing various types of solutions, such as energy efficiency, energy production, energy distribution, energy storage, and energy management/ flexibility.
- The definition of goals should consider the priority interventions previously identified for the PED, the local energy needs and potential, and the ambitions of the population and stakeholders. Establishing adequate communication channels is crucial to effectively convey the project's objectives, benefits, and potential impacts to stakeholders.
- It is also important to gather input regarding their needs, expectations, and concerns through participatory activities. When preparing these activities, all relevant stakeholder groups, including hard-to-reach citizen segments, should be considered.

Stage 2 – Defining the implementation plan and designing the solutions

Relevant recommendations:

- 
The **implementation plan** should take into account the synergies between solutions and across different scales of intervention. It should specify the overall timeline for the process and define relevant milestones toward achieving the proposed goals. Furthermore, it should be developed in conjunction with the core components of the process presented below.
- 
Governance and stakeholder engagement model. This model should provide an integrated framework that ensures institutional and functional coordination throughout the implementation process and post-implementation stage. It should enable the full realization of the strengths and potential of each entity involved. The stakeholder engagement strategy should facilitate effective participation and ensure a balanced distribution of responsibilities among all actors. Commitment to the process can be secured through formal agreements, such as resolutions or participation charters, and continuous communication to keep stakeholders informed and engaged.

- **Business models and financing mechanisms.** Demonstrating the economic feasibility of the solutions and developing business models and financial mechanisms is essential to secure the required funding. The approach should include, among others, preliminary estimates of the investment required, resource allocation for each project phase, and an assessment of financing options suitable for the solutions.
- **Monitoring and evaluation model.** This model should provide a structured approach to assessing the project's progress and impact against its objectives. It should establish clear objectives, define milestones, and identify specific, measurable KPIs to track progress, along with appropriate data collection and management mechanisms.
- **Energy solutions design.** The presented energy solutions span different levels of intervention (building, district, and macro/city levels). Their design should consider a holistic approach, including the combination of solutions, their interdependence, and synergies with other systems relevant for PED development.

Building-level

These solutions focus on retrofitting and upgrading buildings to improve energy performance, implementing energy management systems, and enhancing operational functionalities.

District-level

These solutions can go beyond the boundaries of individual buildings or blocks, optimizing and creating synergies between building-level solutions or complementing them functionally.

Macro/City-level

These solutions contribute to PED/PEB development and optimization, playing a significant role in broader city functions and sustainability goals, such as clean mobility, large-scale RES deployment, and energy systems optimization.

Stage 3 – Implementing the solutions

Relevant recommendations:

- Testing the solutions through relevant pilot projects can help identify challenges, make adjustments, and facilitate full implementation.
- During execution, monitoring mechanisms should focus on progress toward objectives and the achievement of proposed milestones, allowing for the identification of deviations and adjustments to the schedule.
- Stakeholders should be regularly updated on the project’s progress, and their feedback (e.g., on the impact of the interventions on their routines) should be collected and addressed as necessary.

Stage 4 – Using and operating the implemented solutions

Relevant recommendations:

- Continuous monitoring and performance evaluation of the implemented solutions, along with feedback loops, will contribute to adjusting strategies and operations during this stage.

- Implementing effective maintenance and operational efficiency measures is essential to ensure that all systems operate at optimal efficiency levels, minimizing energy waste and extending the lifespan of the technology.
- It is also crucial to ensure that all implemented solutions comply with current and evolving local, national, and international regulations and policies.

Monitoring and Optimizing the Energy Solutions

- ***NZEB Solutions.*** *Regular reviews of performance data are important to identify areas for improvement. The monitoring activities can consider the use of building automation systems (BAS) to monitor and control energy usage.*
- ***Storage Solutions.*** *Solution performance should be monitored using defined KPIs, allowing for adjustments to ensure maximum efficiency. Energy management systems should be used to optimize the charging and discharging cycles.*
- ***Smart Building Energy Management****. AI and machine learning algorithms can predict energy usage patterns and optimize energy distribution across the energy system components. Feedback from end-users should be collected, and demand response awareness should be raised to reduce energy consumption during peak periods;*
- ***Digital twins.*** *These solutions can be used for real-time monitoring, simulation, and predictive maintenance of the building's energy system, anticipating and preventing equipment malfunctions, and optimizing maintenance schedules*

- ***Virtual Power Plant.*** *The VPP's performance should be monitored using defined KPIs, allowing for operational adjustments and efficiency maximization. AI algorithms can help predict and respond to energy demand and supply fluctuations.*
- ***EV-Mobility Hub.*** *Usage patterns should be monitored, and infrastructure deployment adjusted accordingly. Data analytics can optimize the operation of deployed mobility services.*
- ***Local Renewable Energy.*** *Relevant KPI such as renewable energy production and consumption should be monitored in real-time. Predictive analytics should be used to optimize the operation and maintenance of implemented energy systems.*
- ***Sector Coupling.*** *Performance of implemented sector coupling systems should be monitored for system optimisation. Integrated control systems should be used to optimise energy flows between sectors.*

- ***Urban Data Platform.*** *Defined KPIs should be continuously monitored to measure the platform's effectiveness. Data should be continuously collected and analysed to support optimized performance. Insights collected can support decision-making and improve urban energy planning and operations. Feedback loops should be established for continuous improvement of the platform.*
- ***P2P Energy Trading.*** *Defined KPI should be continuously monitored to measure the success and impact of the platform. Data should be continuously collected and analysed to support optimized performance. Insights collected can support decision-making and improve urban energy planning and operations. Feedback loops should be established for continuous improvement of the platform.*
- ***Electricity Grids: Micro & Smart.*** *Monitoring KPIs will help measure the success of the micro and smart grids. Monitoring and optimization activities should include microgrid performance monitoring and management of energy flows to optimize system reliability and efficiency. Advanced control systems should ensure seamless integration with the main grid. Evaluating the environmental impact of the microgrid, including emissions reduction and land use considerations, is also important.*
- ***Multi-Modal Transport Solutions.*** *Monitoring should focus on usage and service performance. Data analytics can contribute to optimizing operations and enhancing user experience.*

Replicating and upscaling the Energy Solutions

Relevant recommendations:

- The energy solutions leading to PED development are holistic—more than just the sum of their components—and require a comprehensive approach that considers local contextual factors and potential synergies across different domains relevant to the energy system.
- The replication methodology should evaluate the components of potential solutions, assess the needs and potential of the city or area, and determine the applicability of the solutions both individually and holistically.

9. ACRONYMS AND TERMS

List of acronyms used in SPARCS

Partners	
Teknologian Tutkimuskeskus VTT OY	VTT
Espoon Kaupunki	ESP
Stadt Leipzig	LPZ
Camara Municipal da Maia	CMM
Reykjavikurborg	RVK
Statutarni Mesto Kladno	KLD
Municipality of Kifissia	KFS
Municipal Institution City Institute	MI-CI
Kone OYJ	KONE
Siemens Osakeyhtiö	SIE
Plug-IT Finland OY	PIT
Citycon OYJ	CIT
Suomen Rakennusinsinöörien Litto RIL RY	RIL
Adven	ADV
Fraunhofer Gesellschaft Zur Forderung der Angewandten Forschung E.V.	FHG
BABLE UG	BABLE
WSL Wohenen & Service Leipzig GMBH	WSL
Stadtewerke Leipzig GMBH	LSW
Cenero Energy GMBH	CEN
Seecon Ingenieure GMBH	SEE
University of Leipzig	ULEI
Sociedade Portuguesa de Inovacao consultadoria empresarial e fomento da inovacao S.A	SPI
NEW - Centre for New Energy Technologies S.A	NEW
Orkuveita Reykjavikur SF	OR
Ceske Vysoke Uceni Technicke V Praze	CVUT
Suite5 Data Intelligence Solutions Limited	SUITE5
ELIN VERD S.A	VERD
National Ecological Centre of Ukraine	NECU
LCE Lvivavtodor	LCE
CiviESCo	CiviESCo
Gopa Com	GOPA

Abbreviations	
Annual Mismatch Ratio	AMRx
Building Automation Systems	BAS

Combined Heat And Power	CHP
Digital Twin	DT
Distributed Energy Resources	DER
Electric Vehicles	EVs
Fellow Cities	FC
Heating, Ventilation, And Air Conditioning	HVAC
Information And Communications Technology	ICT
Internet Of Things	IoT
Key Performance Indicators	KPIs
Lighthouse Cities	LHc
Mobility-as-a-Service	MaaS
Mega Watt	MW
Net Zero Energy Building	NZEB
Geographical Information System	GIS
Onsite Thermal Energy Ratio	OER
Peer-To-Peer	P2P
Photovoltaic	PV
Positive Energy Districts	PED
Positive Energy Blocks	PEB
Renewable Energy Sources	RES
Smart Building Energy Management	SBEM
Use-Cases	UC
Virtual Positive Energy Community	VPEC
Virtual Power Plant	VPP
Work Package	WP

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