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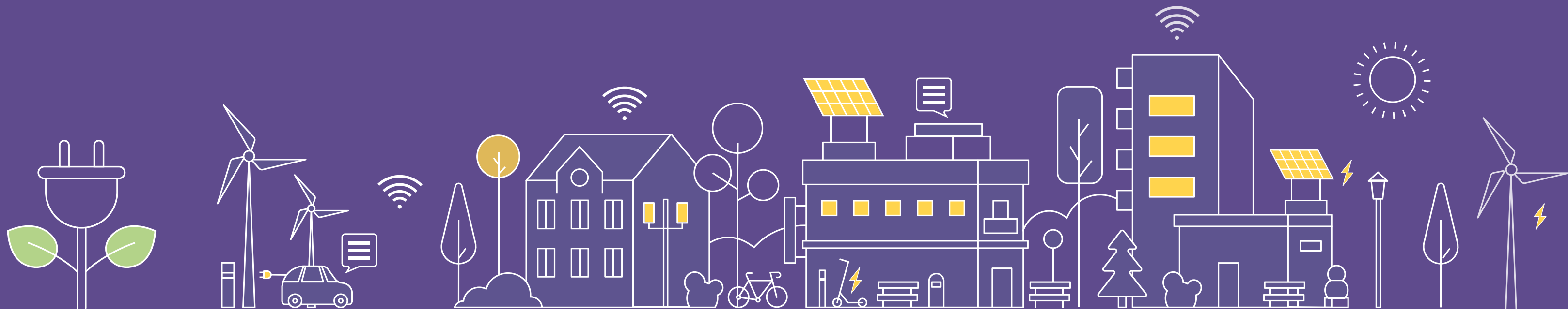
Energy Solutions Catalogue for **Positive Energy Blocks/Districts**



Horizon 2020
European Union funding
for Research & Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242. Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

No & Name	**D1.4 Energy Solutions Catalogue for Positive Energy Blocks/Districts**
Dissemination Level	PU Public
Published	September 2024
Description of the related task and the deliverable	The **D1.4. Energy Solutions Catalogue for Positive Energy Blocks/Districts is** an output from Task 1.2. Urban Transformation. The D1.4. focuses on developing 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 Use Cases captured in **Lighthouse Cities** (e.g. micro Grid, Virtual Power Plants, Building Energy Management Systems, Smart Home Systems, Decentralised Energy Generation, District Heating Systems, Public Charging System for Electric Vehicles, Electric Bike Sharing Systems, Electric Bus Systems, Urban Data Platform, among others). It provides a clear view on the energy-related outputs of the project, rendering a characterisation and the achieved results of the solutions
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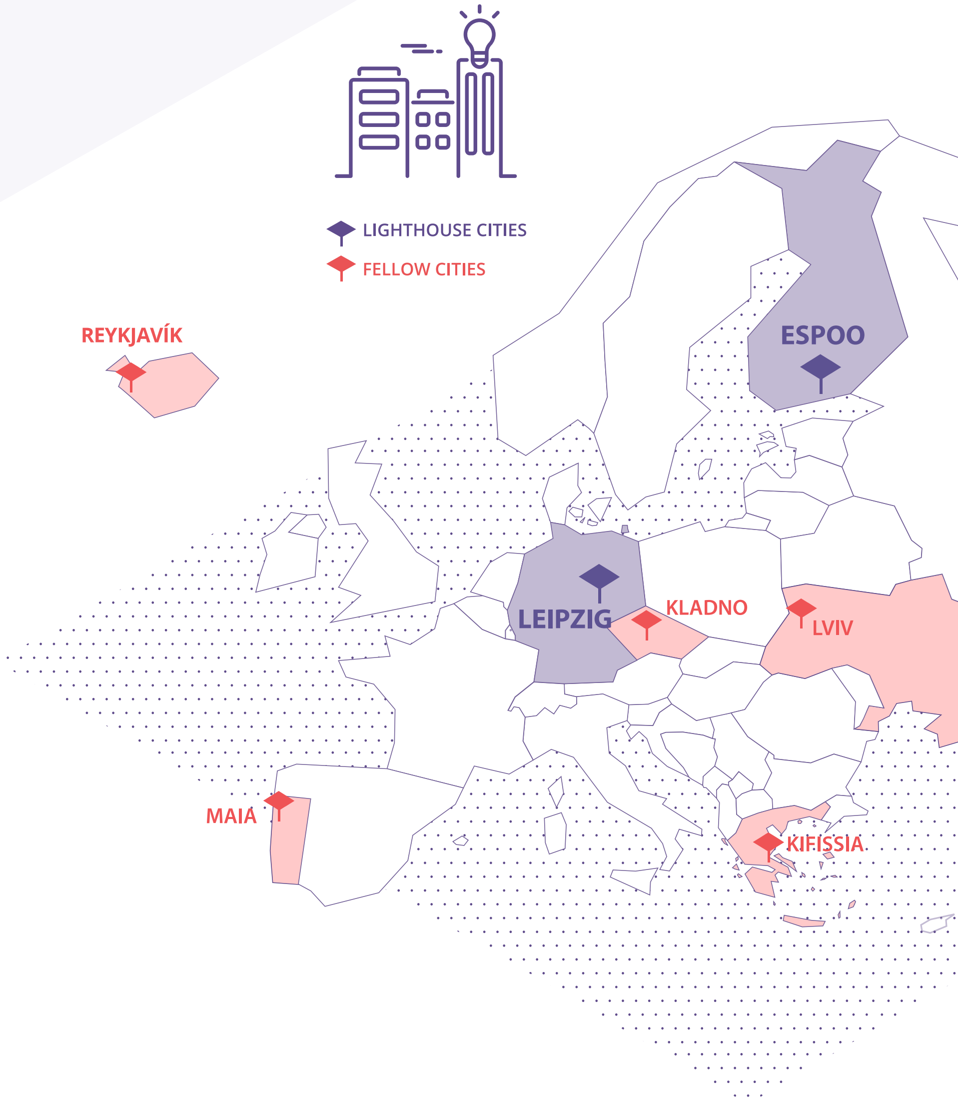

About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. **SPARCS** facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating VirtualPositiveEnergy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organisations, 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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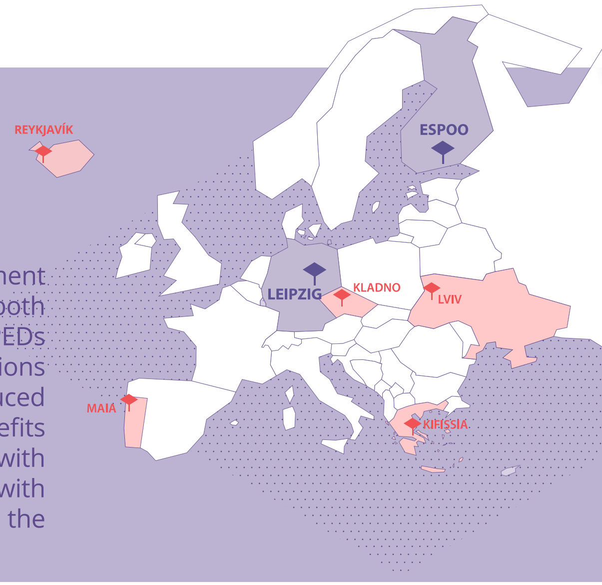
1 Introduction



CATALOGUE EXPLANATION

Brief Introduction: Under the SPARCS project (2019-2024) the cities of Espoo and Leipzig are pioneering the development of their own Positive Energy Districts (PEDs). This catalogue draws inspiration from the energy solutions tested in both Lighthouse Cities (LH cities), with the goal of creating a clear and accessible guide to facilitate the replication of PEDs in cities worldwide. Altogether, twelve energy solutions were selected to showcase effective implementation options for PEDs. These solutions are distributed across three levels: building, district, and city. Each solution is introduced by following a standardised structure, with a concise description that highlights key requirements, potential benefits and constraints, and encountered synergies with different energy typologies. To conclude, a simple framework with indicators is presented to allow comparison between solutions under the same level. The catalogue concludes with the demonstration of various strategies for stakeholder engagement, as developing energy solutions requires the involvement and participation of relevant stakeholders at every stage of the process.

Solutions content		
BUILDING LEVEL	**DISTRICT LEVEL**	**CITY LEVEL**
NZEB Solutions	Virtual Power Plant	Urban Data Platform
Storage Solutions	EV-Mobility Hub	P2P Energy Trading Platform
Smart Building Energy Management	Local Renewable Energy	Electricity Grids: Micro & Smart
Digital Twin	Sector Coupling	Multi-Modal Transport Solutions

Typologies

Each solution can contribute to multiple energy dimensions, with five key typologies considered relevant for PEDs: energy efficiency, energy production, energy distribution, energy storage, and energy management and flexibility. When a category is highlighted, it indicates that the solution is relevant and contributes to that specific energy dimension.

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY

PED/PEB typologies

Indicators

This section enables a quick comparison of solutions within the same level across different indicators. To rank each solution, a qualitative analysis was conducted in which several experts from the SPARCS project individually scored the solutions, resulting in a comprehensive ranking reflecting various internal inputs. Each indicator is rated on a scale from 1 to 3, with 1 corresponding to “low”, 2 to “medium” and 3 to “high”.

●○○ **1** corresponding to “**low**”,

●●○ **2** to “**medium**” and

●●● **3** to “**high**”.

The selected key indicators are as follows:

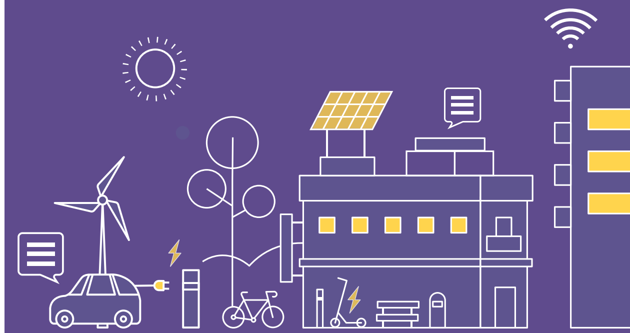
○○○ #	**TECHNOLOGY MATURITY**	assesses the readiness and availability of a solution in the market.
○○○ #	**IMPLEMENTATION EFFORT**	evaluates the level of human resources, planning, duration and coordination required to implement a solution successfully.
○○○ #	**INVESTMENT**	represents the financial resources required to implement a solution, including initial costs and operating expenses.
○○○ #	**GHG REDUCTION POTENTIAL**	is the capacity of a solution to mitigate greenhouse gas emissions, indicating its effectiveness in fighting climate change.
○○○ #	**COMMUNITY IMPACT**	evaluates the social, economic, and environmental effects of a solution on the local community.

It is important to note that for some indicators, the highest scale represents a positive association (such as technology maturity, greenhouse gas reduction potential, and community impact), while for the others, it represents a negative connotation (such as implementation effort and investment).

2 Introduction to PEDs/PEBs

"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



A Positive Energy Block (PEB) consists of at least three connected neighbouring buildings that, on an annual basis, generate more primary energy than they consume. The concept of Positive Energy Districts (PEDs) originated from PEBs and follows the same principle. The impact of PEBs/PEDs extends across social, economic, and environmental domains, aiming to transform urban structures by generating new employment prospects, addressing mobility challenges, fostering social cohesion, and enhancing overall quality of life. Based on previous studies, four ambition levels for PEDs (and PEBs consequently) have been initially defined and further consolidated over time, resulting in:

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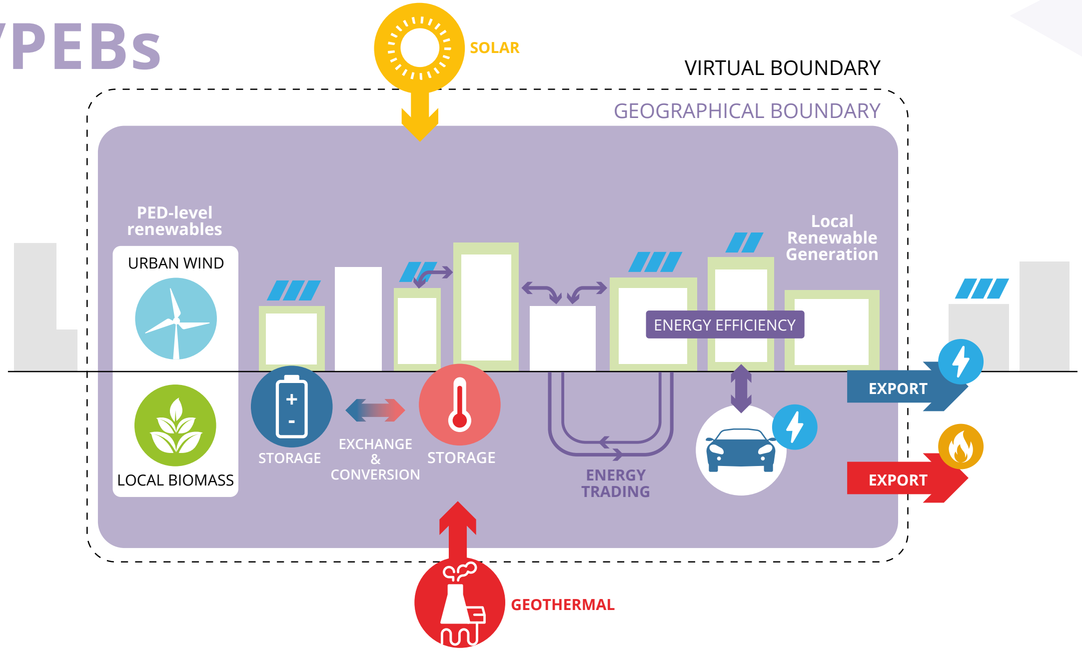
2 Introduction to PEDs/PEBs

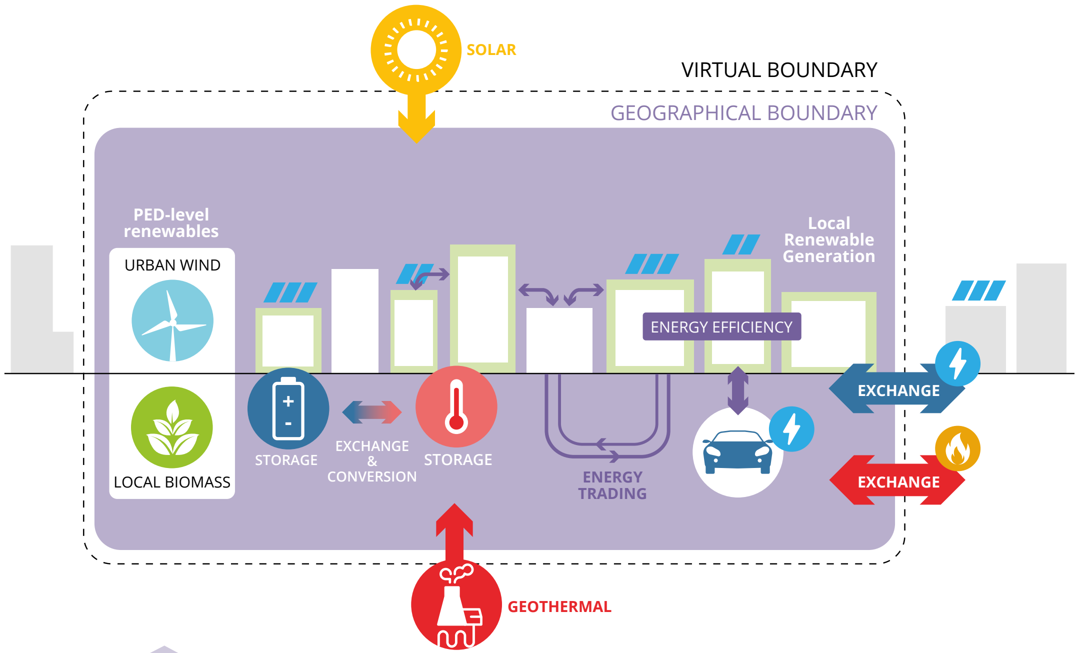
PED AUTONOMOUS

PED Autonomous maintain a permanent positive energy balance within their defined geographical boundaries, without importing energy from outside this perimeter.



PED DYNAMIC

PED Dynamic have yearly positive energy balance within their geographical boundaries, while exchanging energy with the outside environment, beyond the perimeter.

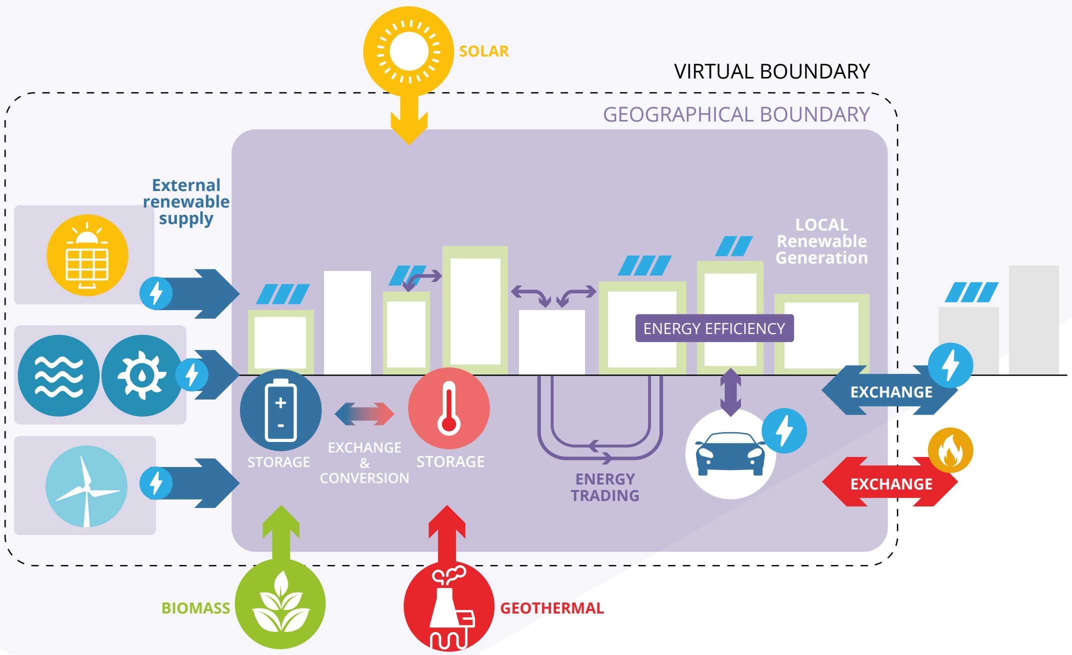


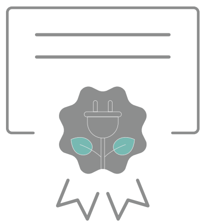
PEB AND PED VIRTUAL

PEB and PED Virtual achieve yearly positive energy balance within virtual boundaries, considering energy production infrastructure, which is located outside geographical limits, meaning there's dynamic interaction with systems outside the perimeter.

PRE-PED

Pre-PED are developing districts that do not yet achieve a higher energy production when compared to the consumption, thus green energy certificates are used to temporarily achieve positivity.





PED Ambition levels (From Vandevyvere, Ahlers, & Wyckmans, 2022)

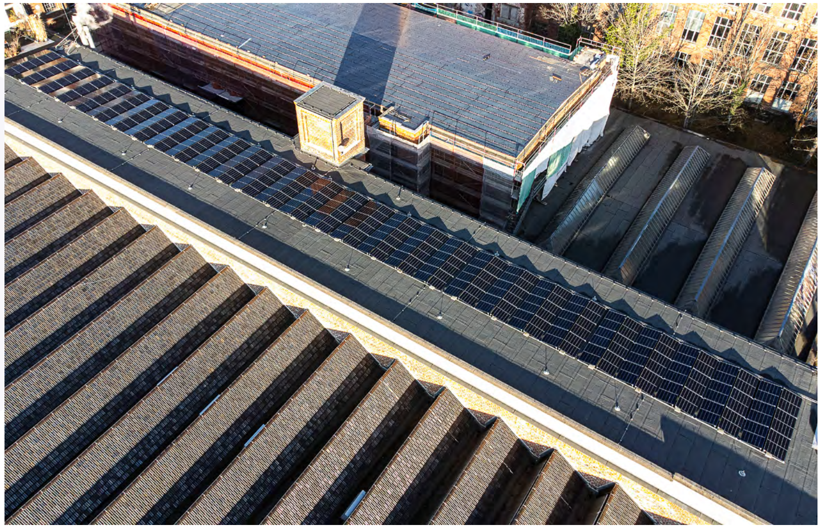
2 Introduction to PEDs/PEBs

The outcomes of the interventions in the SPARCS LH cities have demonstrated that it is feasible to promote different types of PED related solutions in an integrated way with a carefully planned and organised strategy. Espoo's demo districts include the implementation of tree dynamic PED projects, two in consolidated urban areas located near city centres (Sello; 1 and Lippulaiva; 2), and a third one in the context of the urban redevelopment of an old industrial brownfield (Kera; 3).

(1) Sello blocks in Leppävaara

(2) Lippulaiva blocks in Espoonlahti

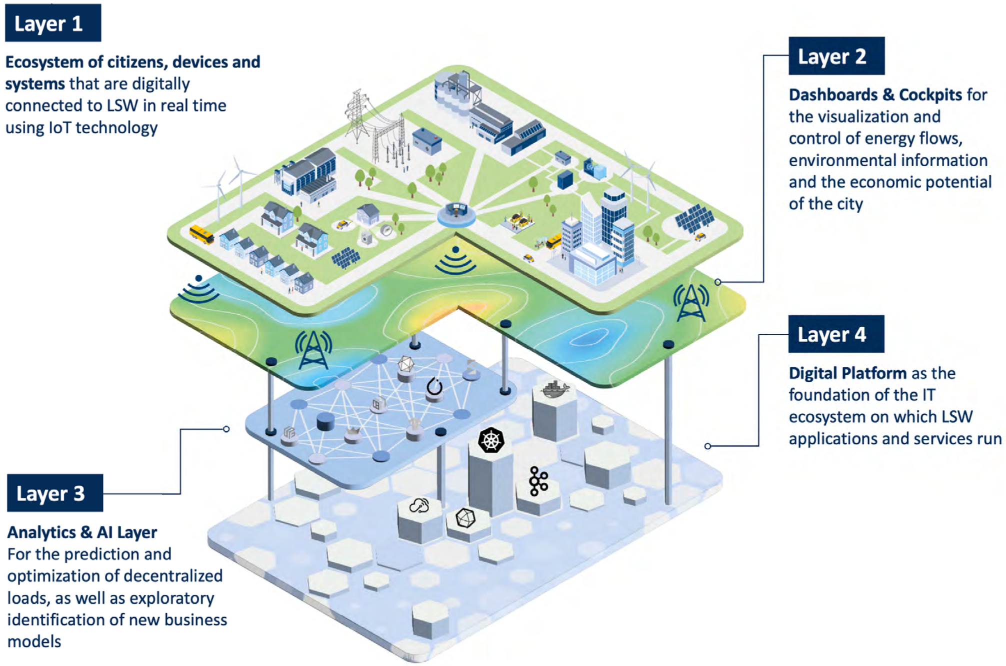
(3) Kera Area



(4) Baumwollspinnerei (former industrial site and a historic cotton mill)

(5) Leipzig-West district
(Duncker-Neighbourhood and the solar thermal plant in Leipzig-Lausen)

Leipzig focused on the development of two dynamic PED solutions for consolidated urban areas (Baumwollspinnerei; 4 and Leipzig-West district; 5) and a third virtual PED (Virtual Positive Energy community; 6), which extends across the city, including multiple generating, storing and consuming entities.



(6) Virtual Positive Energy community

ENERGY SOLUTIONS

Building Level

NZEB SOLUTIONS 11
STORAGE SOLUTIONS 13
SMART BUILDING ENERGY MANAGEMENT 15
DIGITAL TWIN 17

District Level

VIRTUAL POWER PLANT 19
EV-MOBILITY HUB 21
LOCAL RENEWABLE ENERGY 23
SECTOR COUPLING 25

City Level

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Solution Description

Net Zero Energy Building (NZEB) Solutions include all the strategies and equipment that can be applied to a building to minimise its energy consumption while maximising the on-site renewable energy generation, resulting in an annual energy balance equal to zero. An energy-efficient building incorporates design and sustainable construction techniques to reduce the energy consumption and environmental impact, while enhancing occupant comfort and well-being. This approach includes a range of strategies and technologies aimed at optimising energy performance throughout the lifecycle of a building, including passive design strategies, high-performance building envelope, efficient HVAC and lighting systems, and the use of sustainable and low-impact materials. To be successful in the application of this concept, NZEBs should follow the "energy efficiency first principle", which implies, whenever possible, the following order:

1. Energy-efficient building design and construction;
2. Renewable energy integration;
3. Energy storage and management systems;
4. Advanced building automation and control systems.

Passive design strategies aim to minimise energy demand for heating, cooling, ventilation, and lighting by taking advantage of the surrounding natural elements. This includes optimising building orientation to maximise solar gains in winter and minimise them in summer, using shading devices to control solar heat gains, and employing natural ventilation systems with controllable openings to reduce Heating, Ventilation and Air Conditioning (HVAC) loads while promoting natural daylighting. Additionally, improving the building envelope by minimising thermal bridging, air leakage, and heat transfer by considering advanced insulation materials, airtight construction techniques, and energy-efficient glazing systems is crucial. Sustainable and low-impact materials should be encouraged for construction to reduce life cycle impacts. Energy-efficient HVAC and lighting systems should be considered, by focusing on high-efficiency equipment with advanced controls. Integrating renewable energy sources like solar photovoltaic and geothermal heat pumps will enable buildings to offset a significant portion of their energy demand, thus reducing reliance on grid-supplied electricity and fossil fuel-based energy. Energy storage systems (ESS), such as batteries, are essential for optimising renewable energy integration and overall energy efficiency (See Storage Solutions). Automation and control systems, utilising Internet of Things (IoT) applications, smart sensors, and energy monitoring analytics allow real-time data-driven energy management and continuous improvement in building operations (See Smart Building Energy Management). The integration of such requirements is essential when envisioning NZEBs.

Benefits and Limitations

NZEBs offer numerous benefits, including reducing GHG emissions, decreasing energy consumption in buildings while simultaneously promoting a more efficient use of such resource, and enhancing indoor comfort for occupants. These advantages can represent significant impacts in energy bills for homeowners and building operators. The economic, environmental, and social benefits of NZEBs are reflected in the increase of legislations that support and incentivise the implementation of such buildings, and requirements towards implementation of such buildings. The financial dimension represents a barrier, with the initial high cost of implementing NZEB practices raising concerns among stakeholders. However, a study in Italy demonstrated that the economic payback period for NZEB construction, with incentives like feed-in tariffs on photovoltaic systems, is less than 14 years. Nevertheless, despite being a recognised concept in developed nations, efforts to promote NZEBs still face challenges. A primary concern is the lack of clarity and consistency in NZEB policies, resulting in varied approaches to technology adoption and design standards, which hinder the acceptance of energy-efficient building practices. Homeowners, designers, and contractors also often lack a comprehensive understanding of the carbon footprint of buildings and strategies to reduce them. Additionally, there's a resistance in adopting new technologies, stimulated by uncertainties about performance and economic benefits, creating difficulties to disseminate the advantages of NZEBs. The lack of trained personnel and professionals regarding NZEB practices further slows the progress. Addressing these challenges requires targeted incentives to encourage NZEB adoption, while simultaneously establishing standardised evaluation to promote transparency.

Indicators

●●○ 2,3	**TECHNOLOGY MATURITY**	Technologies for NZEBs are well-established, but their integration with existing structures often encounters challenges such as structural constraints or architectural limitations in protected buildings. Solutions are needed to overcome these barriers, and existing innovative technologies still require further development to reach higher maturity levels.
●●○ 2,0	**IMPLEMENTATION EFFORT**	Implementing NZEB solutions requires moderate effort due to the needed prior planning and integration of various energy-efficient solutions. Retrofitting existing buildings often encounters greater challenges compared to new constructions.
●●○ 2,0	**INVESTMENT**	Moderate investment is needed, including costs for energy-efficient materials and technologies, renewable energy systems and workforce. Nevertheless, the initial investment is recouped over the building's lifecycle through savings in operational costs and in the energy bill.
●●● 2,7	**GHG REDUCTION POTENTIAL**	Buildings contribute significantly to the overall GHG emission, so the adoption of NZEB solutions in both new constructions and retrofitted buildings has the potential to substantially reduce their carbon footprint.
●●○ 2,1	**COMMUNITY IMPACT**	NZEBs can have a moderate impact on communities by representing sustainable buildings with potential to lower energy bills and provide higher indoor comfort levels.

Schneider battery Lippulaiva

Solution Description

Energy Storage Solutions (ESSs) are technologies capable to capture and store energy at one time for later use, balancing energy supply and demand more effectively. Energy demand fluctuates significantly throughout the day and year. Consequently, peak and off-peak periods are not constant and arise daily and seasonally, requiring ESSs. In buildings, several technologies can be considered for energy storage. Here, some of the most relevant and widely used solutions are introduced. Batteries, particularly Lithium-ion, are widely used due to their high energy density, efficiency, and declining cost over the years. Other types of batteries, such as Lead-acid, Nickel-Cadmium, and emerging technologies like solid-state and flow batteries, also have significant importance and can potentially gain higher relevance in the future. Thermal storage systems, which store energy in the form of heat or cold, are also common, such as Domestic Hot Water (DHW) tanks.. Fly wheels store kinetic energy by spinning a rotor at high speeds, providing rapid discharge capabilities and a long operational life. Compressed air energy storage (CAES) stores energy by compressing air in underground caverns or large tanks, which is later released to generate electricity. Although CAES is more suited to large-scale applications, under specific conditions it can also be used in individual buildings.

Benefits and Limitations

The deployment of ESSs in buildings can have positive impacts on energy management and sustainability. These systems facilitate peak shaving (decrease the demand power in periods with higher tariff) and load shifting (changing the consumption to instants with lower tariffs), allowing buildings to store energy during periods of low demand and lower electricity prices, and use it during periods of high demand and higher prices, thereby reducing overall energy costs. By providing a buffer against fluctuations in energy supply and demand, energy storage improves grid stability, which is particularly important as intermittent renewable energy sources become more widespread and introduce variability into the grid. Energy storage also promotes building energy independence by providing higher resilience to onsite energy generation, reducing grid reliance and improving energy security. This shift leads to environmental benefits by optimising energy use, lowering GHG emissions, and supporting the transition to renewable energy sources. Additionally, stored energy provides essential backup power during blackouts and ensures continuous operation of critical systems in buildings.

From a performance perspective, selecting technologies depends on the storage capacity, the response time, device lifespan, among others. For investors, the decision is likely influenced by storage costs and return on investment, so building owners should conduct a comprehensive cost-benefit analysis to understand the long-term economic advantages. Effective integration with existing building energy management systems (BEMS) is crucial for optimising the performance of ESSs, ensuring they work in seamless integration with renewable energy sources, HVAC systems, and other building controls. Additionally, scalability is important to consider as energy needs evolve and new technologies emerge, allowing the systems to adapt and remain efficient and cost-effective over time. Implementing ESSs in buildings involves meeting several key requirements to ensure their effectiveness and safety. Adequate physical space and infrastructure are necessary to install systems like batteries and thermal storage units. Safety considerations are also important, particularly for systems such as Lithium-ion batteries that can pose harming risks for building users, such as fire and explosions. Compliance with local regulations, building codes, and safety standards is essential, along with regular maintenance and monitoring to ensure safe operation.

Indicators

●●○ 2,0	**TECHNOLOGY MATURITY**	While some energy storage technologies have reached maturity (e.g., lithium-ion batteries), others remain in early stages of research and development, necessitating further knowledge before their full potential can be achieved (e.g., hydrogen fuel cells).
●●○ 1,7	**IMPLEMENTATION EFFORT**	Implementing storage solutions requires a moderate level of effort, involving understanding the appropriate technology and ensuring compatibility and integration with existing energy systems.
●●○ 1,8	**INVESTMENT**	The cost of energy storage systems is moderate, considering technology and installation expenses. In case of batteries, their shorter lifecycle and consequent need for replacements contribute to overall higher costs.
●●○ 1,8	**GHG REDUCTION POTENTIAL**	Energy storage has a medium potential for GHG reduction, mainly by optimising energy balance and supporting renewable energy integration, although some technologies are known by having a negative environmental impact due to material mining and lack of materials recycling options in the end of the lifecycle.
●○○ 1,4	**COMMUNITY IMPACT**	Storage solutions enable citizens to utilise their self-generated renewable energy at times different from when it was produced, allowing to reduce overall cost with energy, decreasing dependence on the grid, and providing backup power during grid interruptions.

SMART BUILDING ENERGY MANAGEMENT

Solution Description

Smart Building Energy Management (SBEM) systems combine technology and data analytics to optimise energy consumption patterns in buildings. By integrating systems such as lighting, HVAC, and other energy-consuming devices, SBEM systems can achieve higher efficiency in operations and resource utilisation. Such integration allows monitoring and centralised control of energy usage within the building, providing insights regarding energy consumption patterns and opportunities for optimisation. The major requirement for SBEM is the installation of sensors and IoT devices across the building to collect real-time data, such as energy usage, occupancy patterns, and environmental conditions. The data is then processed and analysed using advanced data analytics techniques. This analysis helps in identifying energy-saving opportunities and patterns, enabling informed decision-making for optimising energy consumption. Building automation systems can manage real-time energy consumption, but creating a reliable and flexible system is challenging. By including artificial intelligence techniques, smart building automation control can refine its standards through continuous observation, allowing safety and higher levels of comfort.

Benefits and Limitations

The implementation of SBEM systems can bring several benefits for building owners or users. Enhanced energy efficiency is a major advantage, as it leads to reduced energy waste and lower utility bills for the building owners, particularly through predictive maintenance that identifies potential issues before they escalate. Additionally, SBEM contributes to decreasing the building's carbon footprint, ensuring compliance with environmental regulations. Furthermore, these systems can significantly improve occupant comfort and productivity by maintaining optimal indoor environmental conditions, such as temperature, lighting, and air quality. Another significant advantage is the capability for remote monitoring and control. Through advanced control software and IoT devices, building operators can remotely monitor energy usage, environmental parameters, and system performance. This capability provides real-time insights and the ability to adjust or optimise as needed, contributing to a proactive building management. Integrating BEMS with automatic building control systems can leverage beneficial impacts of such systems. The integration of Building Information Modelling (BIM) (see Digital Twin) is essential for developing advanced BEMS, as it stores relevant building's data. The properties of building materials and equipment can be used to estimate energy performance based on physical characteristics. Consequently, BIM-based SBEMS are potentially more reliable and accurate than those based solely on metering.

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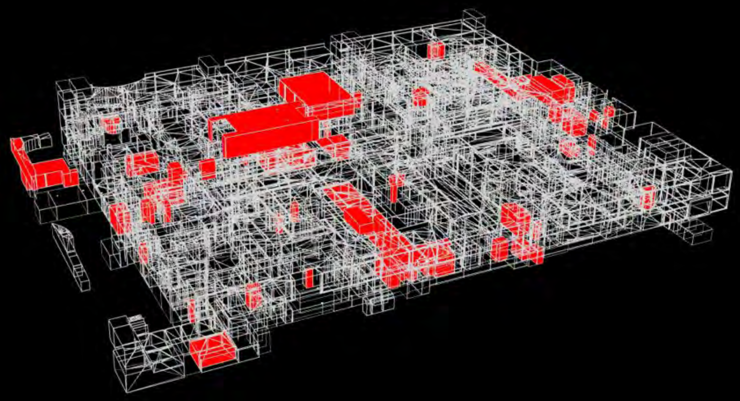
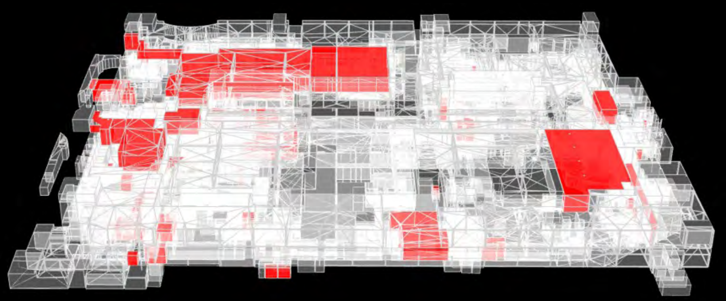
However, the implementation of SBEM comes with certain limitations. One of the primary challenges is the initial investment required for technology and infrastructure. The integration of various systems and technologies can be complex, requiring careful planning and expertise. Furthermore, ongoing maintenance and technical support are important to ensure the efficient operation of the systems. Robust security measures are essential to protect sensitive data collected by IoT devices and to safeguard the integrity of the system against potential threats. The interoperability of various components within the SBEM is crucial for continuous operation and data exchange. Developing a generalised energy management method for all building environments can be challenging, as complex and random factors impose limitations in creating accurate dynamic models. Additionally, uncertain parameters, such as renewable generation output, electricity prices, temperatures, among others, and coupled operational constraints in each energy subsystems (e.g., HVAC and storage systems) require coordinated decisions so that other systems are not negatively impacted.

Indicators

2,1	**TECHNOLOGY MATURITY**	SBEM systems are mature solutions, yet developing a universal energy management approach for all building environments remains challenging. Additionally, automation systems may still require further development.
1,9	**IMPLEMENTATION EFFORT**	Deploying SBEM involves installing sensors and IoT devices throughout the building, integrating them with existing infrastructure and applying advanced data analytics techniques to improve consumption patterns.
1,7	**INVESTMENT**	The initial investment in SBEM includes acquiring smart sensors, installing and integrating devices, and ensuring ongoing maintenance for long-term viability.
2,0	**GHG REDUCTION POTENTIAL**	Enabling smart energy management in buildings can lead to an overall reduction of the emissions by enhancing energy efficiency and optimising energy consumption, whether manually or automatically. If renewable energy technologies and storage systems are also implemented, SBEM facilitates the optimisation of all systems, thus offering even greater potential for reducing GHG emissions.
1,6	**COMMUNITY IMPACT**	The advantages of SBEM for citizens include improved energy efficiency, potential energy cost savings, increased occupant comfort, and remote monitoring capabilities.





Digital Twin Sello

Solution Description

A Digital Twin (DT) is a virtual replica of a physical object or process, used to simulate, analyse, and optimise performance. These identical models are important across various domains, and in the building construction sector, DTs provide detailed and high-fidelity building models to replicate their behaviour. Moreover, the scope of building DTs can evolve into comprehensive city-level platforms, integrating and visualising diverse datasets. These systems accurately replicate management elements and facilitate multi-dimensional visualisation analysis, contributing to the development of smart cities and sustainable urban environments. DTs rely extensively on data, from material properties to real-time information collected from sensors, enabling continuous monitoring. Implementing a DT involves five levels:

- **Level 1** involves Building Information Modelling (BIM) as a static 3D visualisation tool.
- **Level 2** combines BIM models with various analyses and simulations, such as thermal evaluations and energy performance assessments, to analyse construction processes and building performance.
- **Level 3** connects BIM with real-time data collected through sensors, allowing monitoring and management of building environments, and facilitating decision-making and strategy adjustments throughout the building's lifecycle.
- **Level 4** integrates algorithms (developed using data from smart sensors) for real-time predictions for more accurate and reliable decision-making.
- **Level 5** includes automatic feedback and control of the built environment, ensuring an adaptive and responsive system for managing building operations.

Benefits and Limitations

Therefore, key characteristics of digital twins include real-time data integration, simulation and analysis, optimisation and improvement and lifecycle management. Regarding lifecycle phases, DTs can be applied at different stages of the construction process, each serving different purposes and offering distinct benefits:

- During the design and **engineering phase** DTs integrate information with the physical model, allowing for iterative optimisation. DTs can support decision-making on project feasibility, energy analysis, sustainability, and material selection, reducing the overall design process time and minimising the risk of additional costs during construction.
- In the **construction phase** DTs are mainly used to assess the structural integrity of projects. In this phase, DTs can lower construction costs, managing resources and materials, enhance quality, and improve stakeholder management by supplying ample project information. Additionally, built models are created during execution to support in the following phase of operation and maintenance.

- While in the **operation and maintenance phase** the project is typically outside the constructor's control, making data management challenging, but DTs are usually used for facilities management, maintenance, monitoring, and energy simulation. They help facility managers make crucial decisions on building operations, performance management, and energy optimisation, enhancing operational efficiency through real-time data for predictive maintenance and informed decision-making.
- **Demolition and recovery phase**, which is often overlooked, involves the application of DTs to conserve and preserve heritage assets facing demolition. Knowledge of the object's behaviour is usually lost during this phase, but DTs can retain this information for future use, helping to solve similar problems.

In the current context of buildings sector, some gaps still limit DTs potential. One significant issue lies with data losses during transactional process due to software's incompatibility, differences in data format collected by different IoT sensors and external environmental interferences. Furthermore, current simulation methodologies often operate without correlation with real-time data, only relying on historical or synthetic data. Consequently, the accuracy of predictions decreases, as offline simulations cannot reflect real-time fluctuations. Control strategy optimisation represents yet another area were DT face barriers. Current implementations predominantly rely on human decision-making processes, which are often constrained by the consideration of a limited number of scenarios. However, by using digital twins for automatic decision-making and feedback loops, there is potential to enhance control systems' efficiency and reliability.

Indicators

●●○ 1,6	**TECHNOLOGY MATURITY**	The maturity of DTs varies depending on the implementation level and lifecycle phase. Creating efficient strategies for automatic feedback and control of the built environment, as well as for managing the demolition and recovery phases is important to achieve higher technology maturity levels.
●●○ 2,0	**IMPLEMENTATION EFFORT**	Implementing a DT can require some effort, depending on the building scale and systems complexity. Key effort factors include simulation, data collection and integration, development of IoT infrastructure.
●●○ 1,8	**INVESTMENT**	The investment cost is also linked to the scale and complexity of the project, potentially resulting in high expenses for sensors, data processing, and model creation. Nonetheless, careful planning, promoting cost-saving strategies, and improved decision-making can later compensate the initial investment.
●●○ 1,6	**GHG REDUCTION POTENTIAL**	Real-time monitoring and simulations to evaluate building performance and optimise construction, maintenance and rehabilitation processes foster the development of energy-efficient buildings with lower carbon footprint.
●○○ 1,3	**COMMUNITY IMPACT**	While DTs may not create a substantial impact on communities due to their technological nature, leveraging these solutions can create more efficient and resilient buildings, contributing to higher quality of life for all residents/users.

VIRTUAL POWER PLANT

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY

Solution Description

A Virtual Power Plant (VPP) can be described as a cluster of disperse individual energy assets aggregated to operate as a unique entity. These assets can be categorised into generation, such as distributed energy resources (DER) of various sources, energy storage, and flexible loads (participating through demand response schemes). The aggregation provides the VPP with a larger total capacity, allowing it to perform certain roles in the electricity systems such as trading in energy markets and providing ancillary services. Energy markets are mostly inaccessible to individual small-scale consumers and producers, due to large minimum size bid requirements. The aggregation of these players through VPPs has the main purpose of bypassing these restrictions and allowing VPP participants to access energy markets.

Various roles can be present within a VPP, such as: the aggregator, acting as the VPP operator by selling accumulated flexibility on wholesale energy markets or to the distributor system operator (DSO), energy service companies to optimise the energy profiles in response to e.g. dynamic prices, a facilitator to contribute to the implementation and/or expansion of the DER portfolio, grid operator, the prosumers (individuals who are both consumers and producers) and the DER asset owners. Regarding technological requirements, a VPP should include different elements, as smart meters, energy management systems (EMS), forecasting and optimisation tool, distributed controller to remotely control appliances, main software and user interfaces for participants and aggregator.

Depending on the context, each VPP can have a unique operation strategy, but there are three main logic interactions that can be applied. On the simplest operation of a VPP, implicit demand response, the aggregator receives information on the grid status and sets price signals for the participants, which have to decide whether to participate or not by shifting their consumption. By contrast, in explicit demand response, the aggregator can remotely control some devices, either fully or partially. Lastly, local flexibility markets are an arrangement where participants can place bids to the aggregator, which acts as the local market manager, aggregating all or some bids into a single bid to be placed on the main electricity market.

VPPs operation strategies often consider a central entity that acts as an energy management system (EMS) responsible for deciding the optimal operation of each component. The EMS can collect, store, and analyse data from the various remote monitoring and control devices within the VPP, as well as forecast renewable energy generation, load demand and market prices, and manage the assets within the VPP, accordingly. For this reason, VPPs offer advanced energy management and flexibility by optimising the operation of diverse assets.

Also, the VPP provides to the participants a better management of their consumption, usually to maximise profit and minimise costs (depending on the user preferences). VPPs also enhance energy efficiency by operating as decentralised systems, thus improving the overall efficiency of the grid. In terms of energy distribution, VPPs contribute to grid stability through the aggregation and management of DERs. By coordinating multiple energy sources, VPPs ensure a balanced and reliable distribution of power across the grid.

Benefits and Limitations

VPPs can bring benefits for multiple players as to the whole electricity system. DER owners, as producers or prosumers are enabled by a VPP to participate in energy markets and thus generate additional revenue. For grid operators, this can mitigate the complexity of monitoring and managing these assets, improving the overall grid stability and resilience, while improving the coordination between distributor and transmission system operators through simplified DER visibility, since multiple disperse assets become visible as a single point. From a local government perspective, such project can be incorporated in the local plans as a tool to promote smart cities and to contribute to decarbonisation by encouraging the installation of renewable energy. However, the current legal framework represents significant barriers to the implementation of VPPs. Both European and National legislations are still evolving to establish a more robust understanding of this concept. An important constraint is the minimum bid size, high values of which tend to be more detrimental to small aggregators as it increases imbalance of energy costs. Minimum bid sizes vary across different countries. Currently in Europe, only the Netherlands does not have a minimum value. In the UK, the range varies from 0 to 100 kW depending on the DSO, while in most other countries, minimum bid sizes range from 100 kW to 10 MW.

Indicators

1,2	TECHNOLOGY MATURITY	VPPs are still in early stages of development, primarily due to regulatory obstacles. Since small players currently face limitations in participating in flexibility markets, the evolution of maturity may be hindered.
2,3	IMPLEMENTATION EFFORT	Implementing a VPP requires a moderate effort, including establishing information and communication technology (ICT) infrastructure, collecting a portfolio of assets, ensuring regulatory coordination, and integration with the grid and energy markets. Additionally, the coordination of various stakeholders is also needed.
1,7	INVESTMENT	Initial investment for implementing a VPP include the IT infrastructure, IoT devices, and software development. Additionally, there are ongoing costs associated with maintenance and operation.
2,2	GHG REDUCTION POTENTIAL	VPPs promote the installation of renewable energy while allowing a better coordination and optimisation between energy production and consumption, contributing to an overall reduction in GHG emissions.
1,7	COMMUNITY IMPACT	A VPP can impact communities by generating a new revenue stream for participants with reduced financial risk through aggregation and allowing cooperation among neighbourhood VPPs. However, limited awareness regarding flexibility markets can limit such beneficial impact.

Lippulaiva EV mobility hub

Solution Description

An Electric Vehicle (EV) Mobility Hub aims to enhance electric mobility by offering a comprehensive range of services and infrastructure for EVs. This concept transcends traditional fueling or charging stations, transforming into multifaceted centers that gather various modes of electric transportation, including EVs, e-bikes, and scooters. Beyond just serving private EV owners, these hubs play a crucial role in promoting shared mobility by providing infrastructure for car-sharing and bike-sharing services. This is especially important in urban areas where reducing the number of private vehicles can significantly alleviate traffic congestion and pollution. These hubs are designed to be more than just functional spaces; they aim to become community centers that offer a variety of amenities. Mobility hubs may feature cafes, restaurants, and even coworking spaces, making them convenient spots for users to relax and engage in other activities while their vehicles charge. These hubs may also often include parks, green rooftops, and other recreational areas, contributing to the overall well-being of the community, and additional maintenance services and vehicle cleaning. The goal is to make these hubs a one-stop solution for all electric mobility needs, making the transition to electric vehicles as convenient and efficient as possible for users.

The core components of an EV-Mobility Hub include charging stations and an EMS. Additionally, it could have energy storage systems, distributed energy sources, user interface and management software.

- The primary feature of an EV-Mobility Hub is its charging infrastructure, equipped with different types of stations compliant with EV models and user requirements. They typically include Level 2 Chargers (7-22 kW), which are suitable for longer stops, providing a full charge in several hours. They could also have DC Fast Chargers (>50 kW), designed for quick stops, capable of charging an EV to 80% in 20-30 minutes. Different charging technologies are available, such as inductive charging, ultra-fast charging, bidirectional charging and battery swapping.
- The EMS controls the energy flow to optimise efficiency and cost during charging process. Often such systems incorporate smart charging algorithms that optimise the charging process based on grid demand and electricity prices, helping reduce energy costs for users and assisting in balancing the grid.
- Some hubs have the potential to offer bidirectional charging services, allowing EVs to discharge energy back into the grid during peak demand periods, thus enhancing grid stability and enabling EV owners to earn from their stored energy. Vehicle-to-Grid (V2G) technology enables bi-directional energy flow between EVs and the grid. Nevertheless, successful V2G integration depends on a compatible infrastructure, communication systems, and regulatory support, which may vary by region and market dynamics.

- Renewable energy sources such as solar panels can be integrated to generate clean energy.
- User interfaces include mobile apps for users and operator dashboards for hub operators.

Benefits & Limitations

EV-Mobility Hubs offer a multitude of benefits and face some limitations, impacting a wide range of stakeholders, including individual users, grid operators, urban planners, and the broader community. Both the benefits and limitations can be grouped into technical, economic, and social dimensions. Technically, these hubs provide a variety of charging options with built-in smart charging algorithms and V2G technology to balance the local grid. However, they also face challenges such as grid integration and ensuring compatibility between different charging technologies, EV models, and EMSs. For instance, the number of compliant EV models is currently limited and the Europe's bet on V2G, Combined Charging Systems (CCS), a standard that provides bidirectional charging resides on a V2G communication protocol IEC 15118-20 that is only expected to be fully implemented by 2025. From a social perspective, EV-Mobility Hubs enhance convenience for users through centralised services and foster community engagement through community-centric services and green spaces. Yet, they face limitations in terms of public awareness and the need for significant behavioral change to shift from traditional mobility to more innovative mobility services. Economically, EV-Mobility Hubs can generate revenue through various streams and create jobs in various sectors, contributing to local economic growth. However, high initial investments, maintenance costs, and the regulatory landscape for energy management, urban development, and transportation pose the most significant challenges.

Indicators

●●○ 1,9	**TECHNOLOGY MATURITY**	The technology for EV Mobility Hubs, including vehicles, charging infrastructure, and sharing services, is well-developed. However, the planning process (such as selecting optimal locations and identifying the most beneficial services to integrate) could benefit from a more comprehensive and standardised methodology.
●●● 2,6	**IMPLEMENTATION EFFORT**	Establishing EV Mobility Hubs requires substantial effort in planning the location, developing infrastructure, deploying technology, integrating citizen-centric services, and engaging stakeholders.
●●○ 2,1	**INVESTMENT**	Establishing EV Mobility Hubs requires a moderate investment, primarily in infrastructure, technology, and service provision.
●●○ 2,2	**GHG REDUCTION POTENTIAL**	EV Mobility Hubs facilitate and encourage the adoption of a variety of electric vehicles, thereby reducing fossil fuel dependency. Using renewable energy for charging will further increase the potential to reduce GHG emissions. However, without that in consideration, promoting EV mobility could have a counterproductive effect, as people who previously used walking or traditional cycling may switch to electric modes.
●●● 2,7	**COMMUNITY IMPACT**	EV Mobility Hubs impact communities at multiple levels: in urban areas they reduce traffic congestion, in suburbs they support longer commutes, and on highways they facilitate long-distance travel. Additionally, they foster engagement with community-focused services and green spaces.

LOCAL RENEWABLE ENERGY

(© Citycon)
Local Renewable Energy (Lippulaiva)

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY

Solution Description

Local Renewable Energy focuses on producing clean energy within district boundaries to reduce reliance on traditional energy sources and minimise carbon emissions. Renewable energy sources (RES) have significant potential to contribute to the sustainable development of specific areas by offering various socioeconomic benefits, such as diversification of energy supply, enhanced regional development, and new employment opportunities. The availability of renewable resources varies widely based on the natural conditions of each region, making it crucial to evaluate their potential to determine the most economically advantageous solutions. Common RES include solar (photovoltaic and thermal), geothermal, urban wind, biomass, among others.

Urban solar PV systems are typically small-scale, with the median size of a residential installation being around 6.4 kW. Such systems are either installed on or integrated (BIPV) in the roofs and facades of buildings. PV systems in urban areas present some challenges, such as limited space or visual restrictions due to protected areas.

Geothermal technology is primarily employed to decarbonise the sector of space heating and hot water. Application in cities has been growing, but implementing such systems is significantly more cost-effective in new urban areas compared to installing these systems into established infrastructure.

In the Clean Energy Package Directive, three models to allow sharing of energy locally produced between communities, fostering local energy production and engagement:

- **Collective self-consumption** involves the sharing of locally produced renewable energy between individuals (renewable self-consumers) at a building or block scale.
- **Renewable Energy Communities** are legal entities with a structured governance framework operating on an open and voluntary basis to facilitate collective actions driven by shared values. They have a proximity requirement with a focus solely on renewable energy sources and aim to expand the share of renewable energy in national level.
- **Citizen Energy Communities** follow the same legal requirements, but don't have geographical restrictions, and the focus is on electricity without specifications regarding the technology itself.

Benefits and Limitations

Local renewable energy projects offer significant environmental and economic benefits. For producers, the benefits extend beyond generating clean energy and reducing dependency on fossil fuels and the grid, with a significant advantage of decreasing the energy bill. Additionally, sharing renewable energy fosters a strong sense of community. Diversifying the energy supply by considering multiple sources can further enhance overall energy supply efficiency. It can also stimulate economic development by creating jobs in manufacturing, installation, and other related sectors. On-site power generation projects serve as a hedge against financial risks and enhance power quality and supply reliability. These benefits collectively contribute to a cleaner environment, a more secure energy supply, and stronger local economies.

Renewable technologies, although mature, rely heavily on local characteristics like resource availability, space, and demand profiles for successful implementation. Hence, deployment strategies must be customised to each city's technological options and policy frameworks. Local governments can support in overcoming these challenges by assessing local renewable resources, evaluating technology costs, considering permitting requirements and engaging stakeholders. While communities demonstrate an overall positive attitude towards sharing energy, there are considerable challenges regarding investment needs, therefore, cities should also create financing options. Additionally, to promote distributed energy generation, cities should invest in urban energy system planning focused specifically on integrating renewables (in power, buildings, transport, heating, and industry sectors) to enhance system efficiency and climate resilience. Recognising regional variations in renewable energy sources, cities need methods to assess the compatibility of their strategies with national and global energy systems for a transition to 100% renewable energy.

Indicators

●●● 2,7	**TECHNOLOGY MATURITY**	Local renewable energy solutions have reached a high level of maturity, with established technologies and extensive deployment. Nevertheless, innovative solutions have been developed to address certain barriers (e.g., organic photovoltaic cells) that may still benefit from further maturity stages.
●●○ 2,0	**IMPLEMENTATION EFFORT**	Implementing local renewable energy solutions requires moderate effort in planning, installation, maintenance, and grid integration analysis. If energy-sharing schemes and sectoral integration are also considered, additional efforts will be required.
●●○ 2,2	**INVESTMENT**	Investing in local renewable energy solutions involves initial expenses for equipment (highly dependent on the technology itself), installation, grid connection, and ongoing maintenance. If integration is included, additional costs for ICT infrastructure would also be incurred.
●●● 2,8	**GHG REDUCTION POTENTIAL**	While local renewable energy solutions alone may not fully decarbonise districts, they offer significant potential to reduce GHG emissions and opportunities to maximise the use of local RES should be thoroughly explored.
●●○ 1,8	**COMMUNITY IMPACT**	Local renewable energy solutions can impact communities by reducing energy costs and potentially creating new jobs. Additionally, sharing locally produced energy within communities can enhance engagement, contributing to higher impacts.

SECTOR COUPLING

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY

Solution Description

Sector coupling is the integration and synchronisation of different energy sectors and vectors aiming to achieve synergies between traditionally separate energy systems, such as electricity, heating, cooling, and transportation, to enhance efficiency and optimisation in district's energy use. Building a unified system, by integrating grids and the transportation system, can highly facilitate operation processes. In PEDs, sector coupling involves strategies like using excess renewable electricity to produce heat or cooling through technologies like heat pumps or district energy systems. It also includes promoting electric vehicles and using them as mobile energy storage units that can be charged during off-peak renewable energy production periods. The goal of sector coupling is to create a more balanced and efficient energy system by maximising the use of renewable energy, reducing overall energy consumption, and minimising environmental impacts at a district level.

To differentiate between two types of sector coupling, the terms end-use sector coupling and cross-vector integration are further elaborated bellow:

End-use sector coupling involves connecting end-use sectors with the energy supply sector, while electrifying demand. An example it would be to power electric vehicles through renewable energy sources (e.g., photovoltaic).

Cross-vector coupling refers to the combined use of energy infrastructures, mainly electricity, heat, and gas. This can occur on the supply side, such as converting electricity surplus into hydrogen, or on the demand side, by using residual heat from power generation or industrial processes for district heating.

Benefits and Limitations

Electrification is a key strategy for decarbonising the energy sector, though it can be challenging for certain sectors and end-uses, where renewable or carbon-neutral gas provides a viable alternative. End-use sector coupling can enhance the deployment of intermittent renewable energy sources, while cross-vector coupling offers additional flexibility and energy security. This integrates strategy helps the energy system manage fluctuations in demand and supply more effectively. The European Commission recognises sector coupling as a strategy to improve energy system flexibility, making decarbonisation more cost-effective and enhancing the sustainability and resilience of energy infrastructure.

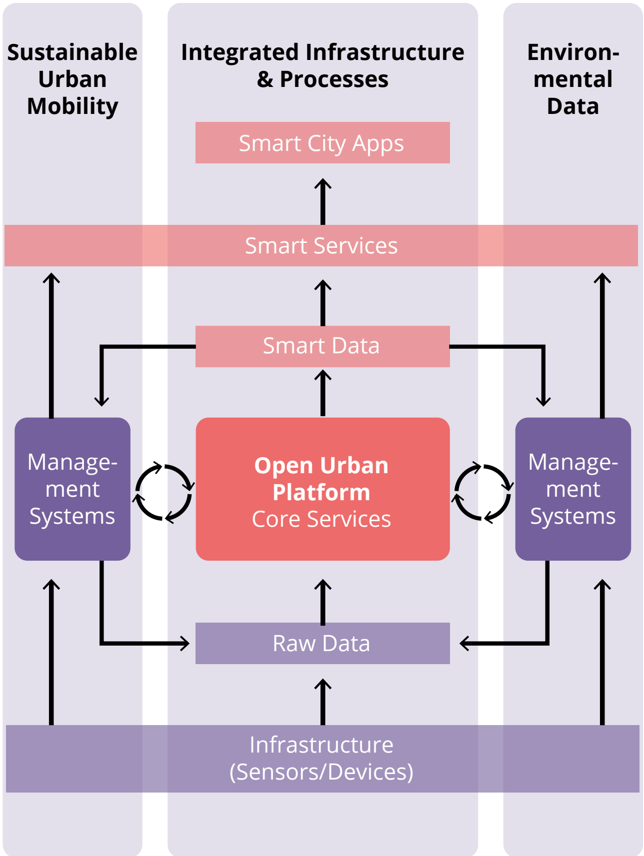
To achieve sector coupling, electrification can significantly reduce heat demand in buildings and emissions from passenger and light-duty road transport. Decarbonising industry, however, requires a combination of electrification, increased use of hydrogen and biomass/gas, and potentially carbon capture and storage. Power-to-gas technologies can absorb surplus renewable electricity and provide low-carbon energy for industrial and transport applications. End-use sector coupling can help balance fluctuations in electricity supply and demand, while cross-vector integration between the power and gas sectors can produce gases for seasonal storage or provide back-up power, enhancing the overall flexibility and resilience of the energy system.

Limitations to sector coupling include technological and infrastructure barriers as well as legal framework constraints. Many sector coupling technologies are currently neither cost-effective nor competitive, and the suitability of such solutions is highly dependent on resource availability. To facilitate sector coupling, operational standards for energy infrastructure need to be revised and interconnecting energy-using sectors will require the digitalisation of numerous processes. Lastly, the planning and operation of the European energy system still lack a proactive and integrated approach. This uncertainty in EU climate and energy policies hinders the large-scale development of sector coupling projects.

Indicators

●○○ 1,4	**TECHNOLOGY MATURITY**	Sector coupling technologies are still in the early stages of development, with many of these not being cost-effective or competitive, and their viability largely dependent on resource availability.
●●● 2,8	**IMPLEMENTATION EFFORT**	Cross-vector and end-use coupling require substantial efforts in integrating the entire energy system, including both technology development and infrastructure integration. New implementations should consider the energy system as a whole to allow integrated planning and facilitating the transition.
●●○ 2,3	**INVESTMENT**	Sector coupling investments vary with the chosen technologies, making overall cost estimation challenging, but to achieve integration requires considerable investments and fundamental changes to energy systems. Nevertheless, research indicate that system integration and coupling sectors ultimately lowers the costs associated with transitioning to a decarbonised energy system.
●●○ 2,2	**GHG REDUCTION POTENTIAL**	Electrification is one of the key drivers to achieve sector coupling, and assuming a long-term scenario where electricity is generated mainly by renewable sources, the potential to decrease GHG emissions increases.
●●○ 1,7	**COMMUNITY IMPACT**	Sector coupling technologies also create beneficial impacts for communities, improving energy efficiency, fostering economic development, and promoting more sustainable cities.

URBAN DATA PLATFORM



Architecture of an open urban platform
(From Architecture Model Open Urban Platform DIN SPEC 91357)

Solution Description

Urban data platforms are core systems designed to gather, store, organise, and integrate data from various domains and sectors, creating a foundation for numerous data-driven applications within smart cities. By centralising relevant data, a comprehensive framework can be established to connect and align different city services. The data within these platforms serve multiple purposes, as it can be analysed to enhance services, published to inform the public, or shared with others for extended improvements.

Therefore, an urban platform should adopt an open design approach, incorporating open interfaces and supporting open standards for data exchange, allowing the scope to continuously expand and adapt. The scheme exemplifies a potential architecture of an open urban platform (OUP), with three core thematic areas – sustainable urban mobility, integrated infrastructures, and sustainable districts and built environments — illustrating the benefits of an integrated infrastructure approach.

The main concept of an OUP typically consists in a cloud-based system, in which the integrated infrastructure aggregates the data received from the remaining structures of the platform, also making connection with other building and city systems such as building management system, traffic control, electric vehicle charging etc.

Benefits and Limitations

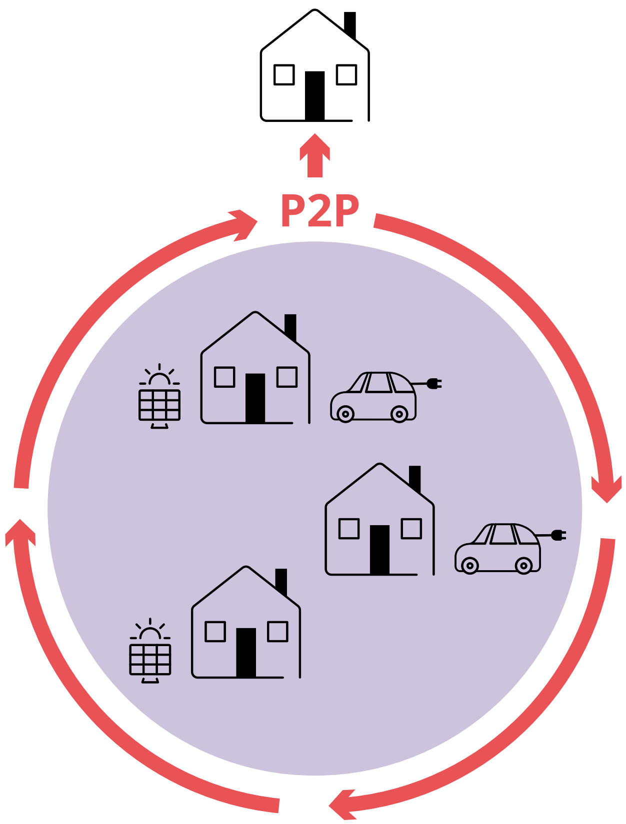
An OUP offers numerous benefits that can significantly enhance the functionality and efficiency of a smart city, supporting energy policies and decision-making processes. These platforms can collect and integrate various energy-related data to monitor current conditions, identify inefficiencies, and uncover opportunities for improvement, facilitating efficient energy management in smart cities. By analysing real-time data, it also enables dynamic adjustments in energy usage. One of the key advantages is the ability to generate smart data, which can be utilised to deliver valuable insights such as predictions, recommendations, and effective incident management. Other benefits include improved data accessibility, which ensures that various stakeholders, including businesses and public entities, can easily access necessary data. This multisided market approach greatly benefits small and medium enterprises by providing easy access to data without requiring substantial initial investments. It also increases data transparency, promoting openness and accountability by making data available to the public. Additionally, the platform facilitates citizen engagement by enhancing the interaction between citizens and city services, encouraging community involvement and feedback. However, key concerns regarding urban data platforms include security and privacy, emphasising the need for robust architectures and reliable platform operators.

Indicators

●●○	1,8	**TECHNOLOGY MATURITY**	Urban data platforms are moderately mature, with several demonstrations available across different cities. However, integration and standardisation methods are still evolving.
●●●	2,6	**IMPLEMENTATION EFFORT**	Implementing local renewable energy solutions requires moderate effort in planning, installation, maintenance, and grid integration analysis. If energy-sharing schemes and sectoral integration are also considered, additional efforts will be required.
●●○	2,0	**INVESTMENT**	Investing in local renewable energy solutions involves initial expenses for equipment (highly dependent on the technology itself), installation, grid connection, and ongoing maintenance. If integration is included, additional costs for IDC infrastructure would also be incurred.
●●○	1,8	**GHG REDUCTION POTENTIAL**	While local renewable energy solutions alone may not fully decarbonise districts, they offer significant potential to reduce GHG emissions and opportunities to maximise the use of local RES should be thoroughly explored.
●●○	2,2	**COMMUNITY IMPACT**	Local renewable energy solutions can impact communities by reducing energy costs and potentially creating new jobs. Additionally, sharing locally produced energy within communities can enhance engagement, contributing to higher impacts.

P2P ENERGY TRADING

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY



Structure of P2P Energy Trade
(Adapted from Liu et al., 2019)

Solution Description

Peer-to-peer (P2P) Energy Trading is an emerging sub-market for exchanging energy within local communities or as virtual transactions across large geographical regions. P2P sub-markets can operate alongside conventional energy markets, while adopting a horizontal structure between small-scale prosumers (individuals who are both consumers and producers). In these markets, prosumers trade electricity at mutually agreed prices through an online marketplace. P2P energy trading emphasises the freedom of participants to enter and exit the market without disrupting the network. Transactions can occur without intermediaries, and assets can be individually owned or shared. While P2P markets encourage competitive behaviour among participants, the primary focus is on environmental and social impact. The goal is to make renewable energy more accessible while empowering consumers to optimise their resource use. By facilitating local power trading, P2P eliminate most transmission costs for consumers and enable prosumers to have higher profits when compared to selling back to the grid, while also giving rights to choose renewable electricity sources.

To facilitate energy trading in P2P markets, it is essential for facilitators to develop secure and collaborative platforms. These platforms rely on the digitalisation of the energy system and require several key components: smart meters to monitor energy production, an independent network such as a microgrid, and information and communication technology (ICT) infrastructure to enable connection and communication between participants. These platforms must incorporate data analytics tools, algorithms for the automated execution of P2P transactions, power demand and supply forecasting analysis, and a common communication protocol for coordinating communication among stakeholders. Additional non-technical specification includes policies and regulatory requirements. Supportive policies should encourage the decentralisation of power systems and the development of pilot projects to experiment such solutions. Regulatory requirements include the establishment of local rules to facilitate the power trade among participants, data management to allow privacy for both platform owners and participants, to define clear roles and responsibilities for stakeholders. In the distribution network, it is important to allow distribution operators to procure flexibility from P2P platforms and to determine costs for when P2P trading is using the main grid.

Benefits and Limitations

Several key factors drive P2P energy trading, offering benefits to various players. A significant motivator is accelerating the decarbonisation of the energy system, as it incentivises the production of renewable energy while connecting prosumers, simultaneously reducing investment risks. Managing the intermittency of renewable energy sources serves as another primary driver, addressing challenges of network congestion and need for grid reinforcements. Another significant driver is creating additional revenue streams for DERs flexibility services, bringing economic benefits for participants. Moreover, P2P energy trading leverages digital systems to transition the market from a centralised to a decentralised structure, promoting the democratisation of the power supply chain and tackling social issues like energy poverty and accessibility.

P2P energy trading faces several limitations related to the legislative framework, which have been partially addressed by the Clean Energy Package. The European legislation recognises the role of aggregators, allows contracts between aggregators and consumers without the need for the supplier's authorisation, and protects participants from disadvantageous procedures and heavy charges typically imposed on stronger market players. Although the legislation does not limit P2P trading to digital platforms, many experts acknowledge that such platforms are likely to play a crucial role due to their ability to facilitate the whole process. Another limitation is the need for incentives to encourage P2P participation. Participants should be exposed to relevant price signals and receive financial incentives to adjust their consumption patterns. Flexible electricity offerings, such as dynamic pricing or subscription models are expected to enhance engagement within P2P sub-markets. Effective governance structures are essential for a successful operation, and their absence can create significant limitations. Additionally, consumer participation can be limited by community's lack of knowledge and digital literacy.

Indicators

●○○ 1,2	**TECHNOLOGY MATURITY**	P2P energy trading is still in its early stages, relying on complex technological requirements and facing delays due to gaps in the regulatory framework.
●●○ 1,8	**IMPLEMENTATION EFFORT**	Implementing P2P energy trading systems involves a moderate effort, requiring the development of the platform, navigating new market mechanisms, and ensuring regulatory compliance.
●●○ 1,7	**INVESTMENT**	Investment costs will depend on the development status of smart metering, independent networks, and ICT infrastructure at the city level. However, the development, maintenance and operation of the software needed for trading and user interfaces will always incur costs.
●●○ 1,6	**GHG REDUCTION POTENTIAL**	The aim of P2P is making renewable energy more accessible by facilitating exchange and reducing investment risk, thus there's the potential to reduce greenhouse gas emissions by promoting the widespread adoption of renewable energy assets.
●●○ 1,8	**COMMUNITY IMPACT**	P2P platforms can enhance the sense of community by enabling sharing mechanisms and creating new revenue streams for prosumers. This allows prosumers to earn higher profits from selling their renewable energy while consumers benefit from lower costs by avoiding transmission fees.

ELECTRICITY GRIDS: MICRO & SMART

ENERGY EFFICIENCY	ENERGY PRODUCTION	ENERGY DISTRIBUTION	ENERGY STORAGE	ENERGY MANAGEMENT AND FLEXIBILITY

Solution Description

A microgrid can be described as a limited area of the distribution network that combines local energy assets (production, storage and controllable loads) to create a self-sufficient energy system. These systems act as smaller versions of centralised electricity systems, able to function independently or in synchronisation with the utility grid. Historically, microgrids have been present for several decades powering large unit sites, such as industrial complexes or hospitals, or isolated areas. Recently, interest in microgrids has been growing with the development of smart cities, given their potential to effectively integrate renewable energy sources, manage diverse energy loads, and respond to emergency needs. Cities are increasingly looking towards microgrids as systems that can serve multiple users and leverage existing distributed generation capacity instead of expanding infrastructure.

Likewise, smart grids are systems that integrate the power network with information and communication technology (ICT), a crucial component for a successful implementation. To implement a smart grid, the following key requirements must be taken into consideration:

- Self-Healing and Secure: These networks need to be highly reliable and secure, featuring decentralised control trough measuring equipment and sensors.
- Economical: This involves a network with a high degree of automation, a non-hierarchical distribution structure of power systems, and the implementation of demand response mechanisms and demand side management to optimise the use of assets.
- Low Emissions: Control and management of CO2 emissions, low losses percentage across distribution chain, and integration of multiple DERs.
- Two-way Communication: Smart devices must follow a bidirectional approach, enabling communication between consumers and operators.

Benefits and Limitations

Smart microgrids offer numerous benefits, including decreasing network operational costs, improving energy supply efficiency, and guaranteeing energy service during emergencies, while strengthening the central grid by increasing reliability, managing energy demand, and reducing grid congestion. Additionally, there’s a reduction of GHG emissions by facilitating the integration of renewable energy sources and avoiding transmission losses due to the proximity of energy production and consumption. Such systems also bring benefits to communities by lowering electricity tariffs and ensure power reliability for isolated populations.

For microgrids, some technical obstacles include the transition between off-grid and grid-connected modes and the integration of renewable generation causing instability and distribution congestion. Dealing with a limited regulatory framework pose additional challenges. Complementarily, major barriers for smart grids include transforming the current conventional network into an active system with bidirectional communication capabilities. To overcome such barrier, the following specifications must be considered: heavy deployment of smart sensors, a centralised software (back-end) and a user interface to support daily operations (front-end), automated fault detection, enabling demand response to electricity price signals, integration of low-voltage control with real time monitoring of high-voltage systems.

Indicators

●●○ 2,2	**TECHNOLOGY MATURITY**	Microgrids are well-established, having been successfully implemented in isolated areas. However, smart microgrids with bidirectional capabilities are less mature. Fully integrating smart microgrids into the existing network remains a challenge.
●●○ 2,4	**IMPLEMENTATION EFFORT**	Setting up micro and smart grids requires moderate effort due to the need for infrastructure upgrades, technology integration, and management of grid stability and synchronisation.
●●● 2,6	**INVESTMENT**	Micro and smart grids require substantial investment for integration with existing systems and technological infrastructure. However, they lead to decreased network operational costs.
●●○ 2,0	**GHG REDUCTION POTENTIAL**	Smart microgrids reduce GHG emissions by facilitating the integration of renewable energy sources and minimising transmission losses.
●○○ 1,2	**COMMUNITY IMPACT**	While smart microgrids have the potential to reduce electricity tariffs and enhance overall distribution reliability, their direct impact on the community is often not perceived, as the benefits are mainly technological and not immediately visible to citizens.

MULTI MODAL TRANSPORT SOLUTIONS

Solution Description

Multimodal Transport Solutions aim to transform urban mobility by connecting various modes of transportation to create an efficient and accessible mobility network. To promote multi-modal transportation, central areas should provide a wider variety of travel options, bringing public transport and essential services within closer proximity, leading to an overall reduction in the distance travelled to create greener cities. Public transport will serve as the cornerstone of future urban transport systems, complemented by shared mobility services and soft mobility modes, such as cycling and walking. Investing and strengthening the connections between these modes should be the focus for effectively implementing multimodal transport solutions. By offering citizens multiple transportation options, a multimodal solution promotes sustainable urban mobility and discourages the use of private motorised vehicles, thereby decreasing traffic congestion, reducing fossil fuels' energy demand, and lowering greenhouse gas emissions. Achieving this will require the integration of land-use and transport planning and a collaborative approach involving politicians, urban planners, public transport operators, industry, and citizens.

To develop an efficient and accessible multi-modal transportation plan that creates corridors and regions with diverse transport options, several key components must be considered. An important initial step is integrating transport and land use data to identify constraints, such as areas with unsafe conditions for walking and cycling. The following multi-modal strategies can enhance transportation systems: improvements on public transportation, encouraging soft mobility modes through safe pathways, implementing shared mobility services like car-sharing and bike-sharing, designating high-occupancy vehicle lanes to reduce congestion, optimising parking resources, and create commute trip reduction programs to decrease the need for single-occupancy vehicle trips. In addition to these strategies, the following components should also be considered:

- Mobility Hubs are connectivity centres where different transport modes converge, allowing users to switch between at least two modes of transport (see EV-Mobility Hub for reference).

- ICT solutions allow the integration of various transport options being essential to simplify and provide comfort in multimodal strategies. Applications that provide real-time information can provide details regarding shared mobility services availability, transportation schedules, between others, allowing data-driven decision making.

SPARCS

- Mobility-as-a-Service (MaaS) is a form of collaborative transport, where data from different sources is integrated, allowing to meet user's needs by providing multimodal routes and personalised real-time information. MaaS platforms offer a unified interface for planning and paying for different modes of transportation, simplifying multimodal transport solutions.

Benefits and Limitations

Implementing multimodal transport solutions allow cities to achieve flexible and efficient urban mobility by actively managing flows within the transportation sector. An efficient transportation system will contribute to the reduction of the energy needs by diminishing the number of running vehicles on the streets, most of them private, enhancing sustainability and improving quality of life in cities. Additionally, the promotion of public transport and sustainable modes of transportation, multi-modal solutions can significantly reduce emission and facilitate environmental targets achievement. For citizens, seamless transportation connectivity and shorter travel times can improve life quality and contribute to higher accessibility. If customised routes are provided, the associated cost of travel can also significantly reduce. However, developing the infrastructure needed for multi-modal transport system can require significant investment and effort in coordinating different transportation modes and integrating various systems. Furthermore, encouraging residents to change their daily habits and shift from private car to multi-modal transport options will require continuous structured approach to raise awareness for sustainable traveling.

Indicators

●●● 2,6	**TECHNOLOGY MATURITY**	Multimodal transport solutions are well-established, but the ICT infrastructure needed to coordinate them still require further developments.
●●● 2,6	**IMPLEMENTATION EFFORT**	Planning and implementing multimodal systems involve different challenges depending on whether the process occurs in a new city development or an existing urban environment, particularly concerning infrastructure. However, such solutions will always require considerable effort in coordinating transport modes and optimising the system.
●●● 2,6	**INVESTMENT**	Developing multimodal transport solutions can require significant investment in infrastructure, technology, and system coordination. Additionally, ongoing investment will be necessary to maintain and operate the ICT infrastructure.
●●● 2,7	**GHG REDUCTION POTENTIAL**	A multimodal solution promotes sustainable urban mobility by fostering the use of public transport, shared mobility, and soft mobility modes, while simultaneously discouraging the use of private motorised vehicles. Thus, such approach can significantly lower greenhouse gas emissions, boosting clean and green cities.
●●● 2,9	**COMMUNITY IMPACT**	Multimodal transport solutions can impact communities on a great level by offering citizens multiple and sustainable transportation options, reducing traffic congestion, and improving air quality, leading to better overall quality of life.

6 Stakeholder Engagement

Developing energy solutions for PED/PEB requires the involvement of relevant stakeholders in all stages of the process. In SPARCS project, a great focus is set in the development of social engagement activities including the involvement of stakeholders, citizens and technical partners in co-creation processes aiming at promoting their empowerment, sense of ownership, and commitment in the shared goals of sustainability and carbon-neutrality. As part of the project's methodology, specific tasks were designed in both LH cities aiming at community engagement related to the interventions developed in the respective demonstration districts, namely Task 3.6 "Community Engagement", in LH City Espoo[1]; and Task 4.6 "Community support for energy transformation in the district" in LH City Leipzig[2].

As part of the overall social engagement strategy promoted by the project, the participatory activities included different levels of engagement and different scales and scopes regarding the solutions and interventions in question. The focus was set on changing behaviours towards sustainable ones, by raising awareness regarding the impacts of everyday choices, incentivising the use of sustainable energy sources and promoting energy saving habits. These activities took the form of surveys, webinars, and workshops, as well as longer-term engagement activities involving students during the school year (e.g., Buddy Class, ESP) or the establishment of energy advisory and desk support or technological solutions for energy saving and data collection (e.g., LWP-App and SPARCS-App, LPZ).

The engagement activities with relevance for energy solutions also included understanding the users' point of view, in terms of needs and habits related to, e.g., day-to-day urban mobility. Such activities were mainly performed through interviews or studies focused on participants everyday experiences related to mobility (e.g., Mobile ethnographic user study, ESP). Additionally, for the development of a methodological approach for creating user-centric solutions for positive energy blocks (PEB), a series of workshops were held to facilitate communication, dialogues, and discussions with citizens (LPZ).

Although some of the highlighted activities were cross-cutting in their nature and designed with a focus that goes beyond energy solutions, overall, they are considered highly relevant and beneficial for the successful implementation of the solutions in the SPARCS project context. Some solutions demonstrated in SPARCS to promote the citizen engagement are presented below with higher detail.

a Desk support for citizens
Personalised assistance and guidance to individuals regarding energy-related topics, as for example helpdesk services (e.g., one-stop shops), where citizens gather information and receive assistance for energy related matters such as energy solutions available, retrofitting options, energy efficiency programs, renewable energy incentives, among others (LPZ).

b Establishing community management & energy advisor
Empowering local communities to manage their energy resources effectively and support the residents with the energy transformation of privately owned buildings. This approach promotes energy efficiency, renewable energy adoption, and sustainable practices tailored to specific community needs. It can include the access to the energy solutions, as virtual power plants or smart grids (LPZ).

c Co-creation methodologies
Co-creation methodologies can be used to design energy positive areas, focusing on creating a collaborative effort of various community stakeholders, as local authorities, citizens, research institutions, companies, and cross sector organisations. This approach allows the definition of common targets, expectations alignment and enables the integration of innovative solutions across various stages of urban development processes.

The Co-creation model Toolkit for Sustainable and Smart Urban Areas reflects the experiences and insights gained by the city of Espoo during SPARCS project, from the development of Kera region. It offers a comprehensive set of tools designed to support the development of sustainable and smart urban areas, facilitating PED/PEB development. This model emphasises collaboration among a broad network of actors, ensuring a robust framework either for new projects or exiting urban areas (ESP).

1 For further details concerning the social engagement activities developed in Espoo see SPARCS D3.6 "Optimizing people flow and user experience for energy positive districts".
2 For further details concerning the social engagement activities developed in Leipzig see SPARCS D4.6 "Citizens and stakeholders in Leipzig´s energy transition".

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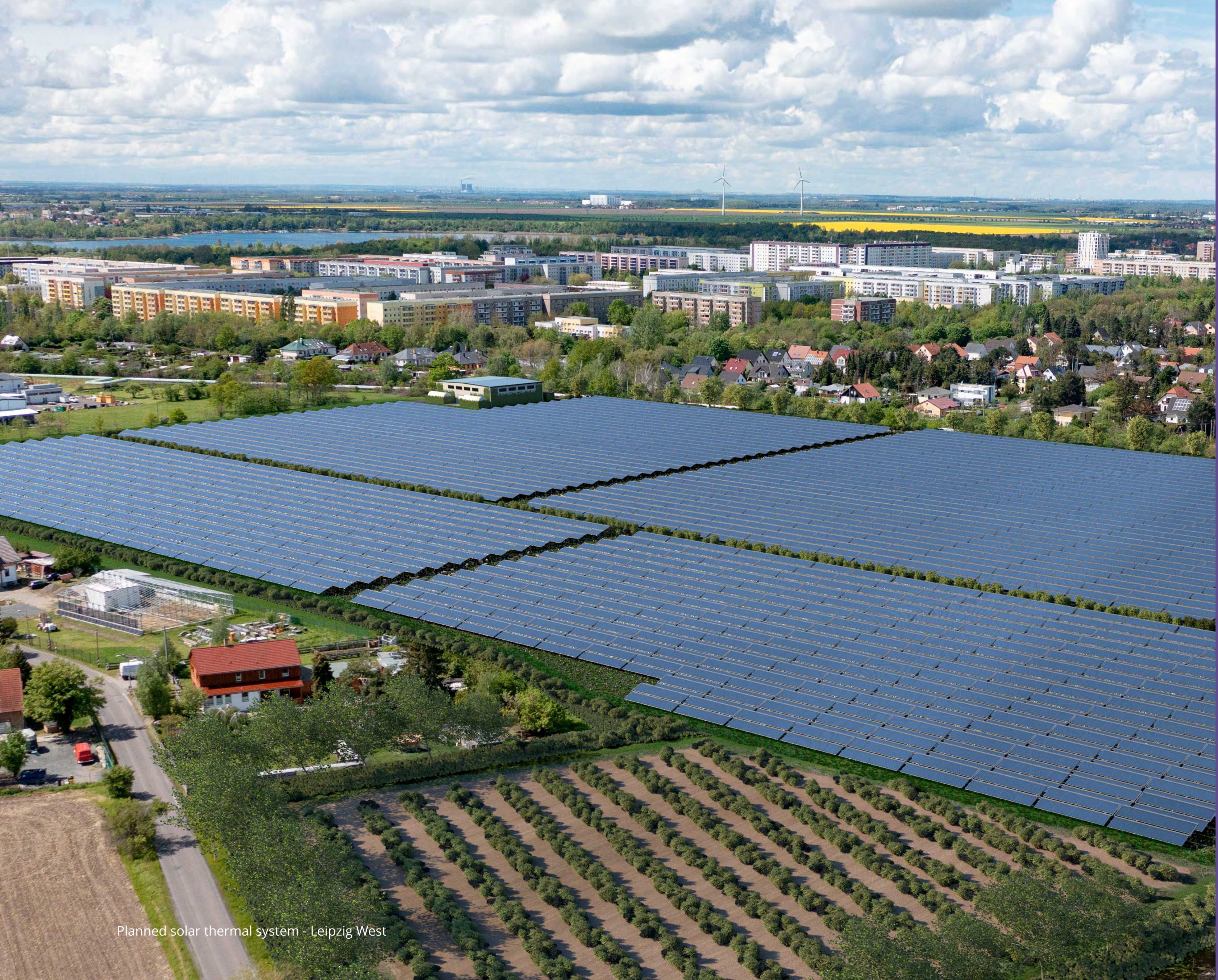
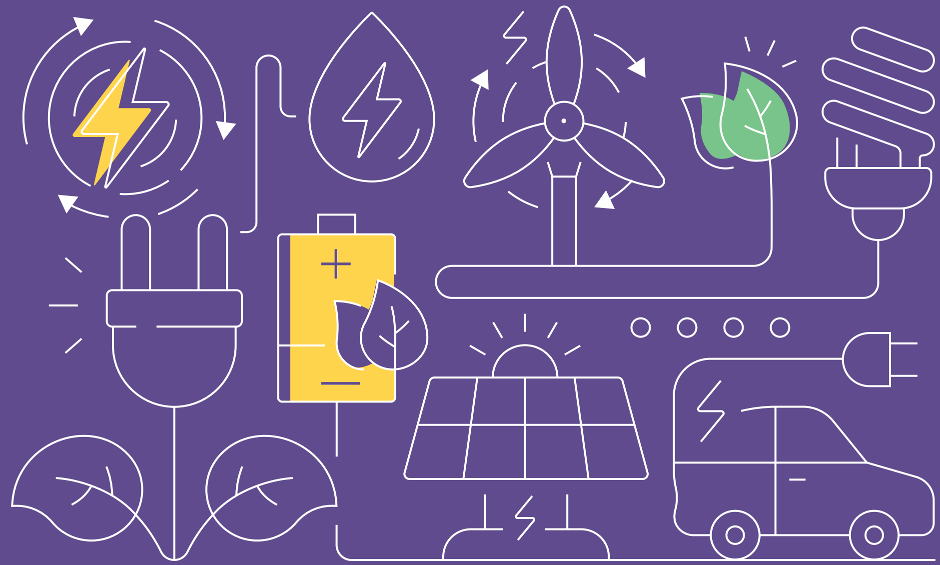


Planned solar thermal system - Leipzig West

APPENDICES



As the foundation for this work, the implementation actions from the LH cities were thoroughly analysed (see D3.1 Detailed plan of the Espoo smart city lighthouse demonstrations and D4.01 Detailed plan of the Leipzig smart city lighthouse demonstrations for more detail), highlighting and categorising all present energy solutions, as demonstrated in the tables below. Subsequently, a workshop with project partners was conducted to refine these broad selections of solutions and categories, resulting in the final framework presented in the catalogue.

LHs ENERGY SOLUTIONS PER CATEGORIES

Legend

- Energy Efficiency
- Energy Generation
- Energy Distribution
- Energy Storage
- Energy Infrastructure
- Energy Management
- E-mobility
- ICT
- Others

Complete solutions tables

Espoo Solutions	Specific Demonstration Action
E1 – Solutions for Positive Energy Blocks	E1-1 Optimisation of the NZEB energy system with integrated RES and Virtual power plant (ADV CHP-bio, electricity contracted via Nord Pool27) based on big data and predictive building control strategies. The system uses a regenerative geo-energy field also storing thermal energy to the ground. The source provides enough heating and cooling for the Lippulaiva blocks. Momentary excess can be exchanged with renewable DH network.
	E1-2 Final dimensioning of the PV plant (capacity depends on the detailed design of the roof structures, and relations between PV and the green roofs)
	E1-3 Assessing the potential to use a battery energy storage system as emergency power while it provides frequency-controlled reserves and local cost minimisation. Control strategies are developed together with business models.
	E1-4 Improving the self-sufficiency of surrounding blocks, emulating the heat export from the ground source heat pump to the surrounding residential building blocks through the local district heating network.
	E1-5 Proof for the predictability for the energy costs and the profitability of the nZEB solution, paving way for scaling up.
	E1-6 Automation steering system development. Development work on optimising the efficiency of the building automation steering of HVAC systems in connection to geothermal energy production, including system control, air conditioning, demand flexibility and the utilisation of weather forecasts. Case Lippulaiva act as pilot.
E2 – Boosting Emobility uptake	E2-1 Integrating and grid impact assessment of community and residential EV parking in the Lippulaiva blocks: up to 140 charging units, currently grid access dimensioned for maximum 400 EV
	E2-2 Opportunities to support and enable e-bicycling with appropriate parking and charging infrastructure (inverters, parking facilities, size demands, secure charging infrastructure) boosting the Emobility in the whole Espoonlahti district
	E2-3 Boosting the uptake of e-mobility: Sustainability strategy for how to access Metro and Lippulaiva with other sustainable mobility modes, developing Lippulaiva as hub for shared eVs. Development of commercial electric vehicle charging services. Analysis of energy demand for electric buses, taxis, garbage and delivery trucks and other service vehicles and impact on electric grid. Development of smart charging services.

Espoo Solutions	Specific Demonstration Action
E3 - Engaging users	E3-1 Piloting ways to engage and encourage citizens' energy positive ways of behaviour, developing new energy positive district solutions and improving the awareness of existing ones during the construction time and the daily use of the Lippulaiva services.
	E3-2 Define and validate solutions for encouraging people to change their daily mobility habits optimising people flow from energy and user experience perspectives. Developing and validating the chosen lead user innovations in the Espoonlahti district. Encouraging people to use positive district solutions for their daily lives, optimising urban flow from energy and user experience perspectives.
	E3-3 Co-creation of shopping centre in collaboration with young consumers. Cocreation of the design of Lippulaiva with the aim to improve convenience and usability for young people. Focus on catering to the needs of young people for customer experience and their needs to enable and improve their use of environmentally friendly modes of transportation.
E4 – Smart Business Models	E4-1 Engaging (lead) users and co-creating (energy positive) business models in Lippulaiva
E5 – Solutions for Positive Energy Blocks	E5-1 Predictive model for the storing energy to the building structures and battery storage to be created and evaluated.
	E5-2 Integration with the local district heating grid operated by Fortum (Bio oil Plant 40 MW) for selling cooling/heat and heat demand side management.
	E5-3 Evaluate increase of self-sufficiency through the Sello extension. Evaluate deep heat station in new build
E6 – ICT for Positive energy blocks	E6-1 Improving the prediction of the energy performance, both heat and electricity, and the predictions for energy market participation for Sello block based on data collected nearly in real time and stored historic data pursuing the Virtual Power plant (VPP) operations. VPP considers Kone's elevators energy control, optimal use of local PV generation, electricity storage, air conditioning, lighting and emergency power systems. Introducing peak-load management, artificial intelligence technologies
	E6-2 Developing new potential smart energy services based on the digital platform (open cloud based IoT operating system, MindSphere by SIE) from the energy performance view point in the Leppävaara area by finding new value for residential buildings of being flexible part of the greater energy system, including district heating and cooling usage control based on the grid conditions.
	E6-3 Solutions in Smart Building Energy Management. The activity demonstrates how elevators, escalators, and people flow intelligence solutions, could be utilised in smart building energy management and demand response via interoperability with energy management system through APIs. Aim to reduce peak demand.
E7 – New Emobility hub	E7-1 Developing Leppävaara EV-mobility hub as a whole. Helsinki Region Transport (HSL) and the City of Espoo have high targets for the electrification of transport. The Sello block and area will be developed into a new E-mobility hub connecting local and long-distance trains, city E-buses, and a new fast E-tramline. First mile/last mile services will be enhanced by including charging services for car sharing. Interoperability of charging infrastructure will be ensured to provide access for other user groups, e.g. electric service vehicles and mobile machinery. The requirements and impacts on the electrical grid will be analysed in collaboration with all relevant stakeholders.

Legend

- Energy Efficiency
- Energy Generation
- Energy Distribution
- Energy Storage
- Energy Infrastructure
- Energy Management
- E-mobility
- ICT
- Others

Legend

- Energy Efficiency
- Energy Generation
- Energy Distribution
- Energy Storage
- Energy Infrastructure
- Energy Management
- E-mobility
- ICT
- Others

Espoo Solutions	Specific Demonstration Action
E7 – New Emobility hub	E7-2 Development of EV charging for customers of the shopping centre and commuter parking as a part of the total building power management and microgrid solutions. Optimisation of EV car charging and power management. Utilisation of activity based models for load prediction and development of energy demand response services (V2G), control strategies based on business models (Park&Charge concept). Dynamic pricing models for electric vehicle charging and price of electricity depending on the flexibility resource the EV can bring. Test would focus also to gain user experience data out of the EV charging usage for the future energy optimisation purposes and to connect EV charging stations to VPP. Integrating data and services. 5G is enabling the data transfer.
	E7-3 Optimal charging strategies for commercial vehicle fleet. Utilisation of activity-based models for demand response prediction. PlugIt Finland will be responsible for developing the services related to electric commercial vehicle charging.
E8 – Engaging users	E8-1 Study lead user citizens' energy positive mobility behaviours, develop new and improve the awareness of existing positive district solutions during the daily use of Sello services. Input for actions in Lippulaiva and Kera. Identifying lead users and studying their behaviour related innovations, which have the most extensive impact on everyday energy consumption. Developing new energy positive district solutions and improving the awareness of existing ones. Input for experimentation and piloting in Leppävaara and Espoonlahti districts.
	E8-2 Experiment concepts for encouraging people to use E-mobility solutions for their daily mobility habits optimising people flow from energy and user experience perspectives. Experimenting lead user innovations in the Leppävaara district. Encouraging people to use existing positive district solutions for their daily lives, optimising urban flow from energy and user experience perspectives.
	E8-3 Evaluate feasibility for shopping behaviour in the EV charging concept
E9 – Smart Business models	E9-1 Engaging lead users and co-creating energy positive business models in Sello
E10 – Solutions for Positive Energy Blocks	E10-1 City Planning for Positive Energy Blocks. Exploring the possibilities to utilise the continuously updated Espoo 3D City model as a support and tool in the development and planning of the new Kera area.
	E10-2 Energy infrastructure. Planning and on-site follow up of energy infrastructure solutions for positive energy blocks. Solutions enabling energy transfer (consumers as prosumers), including a bi-directional electricity grid and open district-heating network.
	E10-3 Energy system planning. The energy system planning explores options for energy demand side management of all buildings by using energy demand response and energy efficiency, as well as acting as heat storage, and enabling the use of emission-free eco heating energy products and services, and demand flexibility
E11 – Engaging users	E11-1 Citizen mobility. Conveying insights to city planning authorities of citizens' preferable future multimodal mobility habits, schedules and routes to optimise the people flow from energy and user experience perspectives. Utilise input from actions in Leppävaara and Espoonlahti.

Espoo Solutions	Specific Demonstration Action
E12 – ICT for Positive energy blocks	E12-1 Smart infrastructure 5G. Investigating opportunities offered by the Kera digital platform and local district 5G network for management of the smart power grid, optimisation, bi-directional energy flows, energy demand side management and demand flexibility.
	Action E12-2 5G as service enabler. Developing new service models for autonomous transport and e-mobility linked to the local 5G network, solutions enabling the use of car batteries as energy reserve and the operation of autonomous transport.
	Action E12-3 Blockchain technology as enabler. Enabling energy transfer and tracking in bi-directional power grids (electricity and heat) with the use of blockchain technology
E13 – E-mobility in Kera	E13-1 Multi-modal transport solutions with focus on last-mile including charging of the e-fleet. The aim is for an emission-free, clean multi-use area (living, shopping and services) by minimising the need for private cars.
	E13-2 Replication of e-mobility solutions. Further development and implementation of Leppävaara e-mobility solutions. (Action E7-1) Charging stations for company-owned electric vehicles.
E14 – New economy/ Smart governance models	E14-1 Co-creation for sustainable city development. Coordinated and collaborative and replication of SPARCS Espoo Lighthouse actions in Kera area solutions for smart and energy efficient future living are codeveloped as co-creation between the City of Espoo and the local consortia of stakeholders, including close collaboration with e.g. energy utility companies Fortum and Caruna.
E15 – Virtual Power Plant	Action E15-1 Feasibility study paving the background for the virtual power plant formed from the loads of the local buildings to balance RES boosted local power network, identifying new business opportunities for aggregators in order to combine small demand response loads and offering them to reserve market (Fingrid). The target is to find and connect enough flexible loads from a local building stock (swimming pools, ice skating halls, sport halls, and office buildings) for 1 MW demand response, to participate to the electricity reserve markets.
	E15-2 Blockchain technology options for supporting demand response and virtual power plant in positive energy districts. Blockchain enabled business cases and control strategies will be studied, while possible policy and regulation related challenges will be identified.
E16 – Smart heating	E16-1 Buildings demand side management and demand flexibility. The aim is to implement demand side management to achieve demand flexibility on large scale in both public and private buildings. Solutions based on emission free district heating. Espoo Asunnot Oy (Espoo social housing company) has already connected all its 15,000 apartments to demand response and eco heating. During SPARCS, the solution is further developed and replicated. The development of energy efficiency and energy consumption peak loads are monitored to optimise the city level energy system.
E17 – Virtual twin	E17-1 Virtual twin of a real demo for a positive energy building block, to build a showcase and support replication. Provides both the visual of the building and the operational behaviour (same energy load as in the real buildings and the block) for the building energy system.

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Espoo Solutions	Specific Demonstration Action
E17 – Virtual twin	E17-2 CityGML as a tool for energy positive block development. Starting 2019, The City of Espoo offers an open, and public, Espoo 3D City model. The model covers all of Espoo and all objects included are described in the CityGML standard, except for bridges and tunnels. The action implements the MODER tool using Apros simulator and City GML integration, for assessing the potential for energy positive blocks in Espoo. The methodology has been developed in the H2020 project MODER, Mobilisation of innovative design tools for refurbishing of buildings at district level (Innovation Action, EeB-05-2015).
E18 – EV charging effects to grid	Action E18-1 Optimal integration of EV charging, taking into account all modes and types of electric vehicles, commercial as well as private, in the E-mobility nodes of Leppävaara (Sello block), Espoonlahti (Lippulaiva blocks) and Kera, managing of peak power demand and related effects from the urban planning. Analysis of future demand and development of smart charging strategies for different scenarios. This takes into account predictions of expected numbers of electric vehicles in each use case segment up to 2030 and beyond, the foreseen demand for power and energy and their impact to the grid.
E19 – Sustainable lifestyle	E19-1 I Define and validate solutions for optimising urban people flow from energy and user experience perspectives. Identifying the benefits and the added value for citizen and other stakeholders in different district lifecycle phases.
	E19-2 Sustainable lifestyle. Espoo wants to be a responsible pioneer. The city is building a sustainable future through mobility, construction and energy solutions, by offering teaching and education supporting a sustainable lifestyle, by providing culture, sports and social and health care services enhancing wellbeing and by maintaining comfortable nature and green areas nearby. SPARCS actors integrate this support in their daily work including support for low-emission solutions, guidance and energy advisor services.
E20 – District development	E20-1 FINNOO REPLICATION. Identifying the requirements for buildings to be integrated in the energy infrastructure; smart building requirements. The smart building and open interface requirements can be put into practice through terms for the plot assignment.
E21 – Air Quality	E21-1 Effects on air quality. Follow up of air quality development in the Espoo Lighthouse demonstration districts during the project duration
E22 – Cocreation for Positive Energy District	E22-1 Co-creation for smart city development. Co-creation models to support land use planning are developed as a collaboration between industry, SMEs, citizens and other stakeholders to support functional solutions of new development areas regarding e.g. energy, mobility, and service solutions based on digital platforms and fast networks.
	E22-2 UN SDG 2030. The Lighthouse City of Espoo strategy aims at creating an inclusive, safe, resilient and sustainable community, as per the UN Sustainable Development Goal 11. The City of Espoo is also committed, as a selected pioneering city, to begin the work as SDG City with Sustainable Development Goals 4 (Quality Education) and 9 (Industry, Innovation and Infrastructure), and to reach all 17 goals by 2025. The Espoo Lighthouse consortia and actions form an integral part of the roadmap towards reaching these targets, especially goal 7 Affordable and clean energy, 11 Sustainable Cities and Communities, 13 Climate action and 17 Partnerships for the goals. This action coordinates, assembles and channels SPARCS work towards replication and dissemination on European level, towards the European Smart City community, and towards the global international UN community.

Espoo Solutions	Specific Demonstration Action
E23 – New economy/ Smart business models	E23-1 Smart Otaniemi pilot platform. Smart Otaniemi innovation ecosystem as facilitator of developing bankable smart city solutions for worldwide replication. Focus areas: efficient use of energy, intelligent use of data, and creating solutions for real customers. https://smartotaniemi.fi/
	E23-2 Smart business. The development of new business out of Espoo Lighthouse actions is supported by connecting and linking to local (e.g.YritysEspoo) and national actors

Leipzig Solutions	Specific Demonstration Action
L1: Intelligent EV charging and storage	L1-1: Development of bidirectional e-charging system for allowing parked vehicles to be used as additional storage capacity.
	L1-2: Eco-friendly and CO_2-reducing corporate e-car sharing in combination with load-oriented fleet management solution. Analysis of the effects of integration in the micro grid.
	L1-3: Demonstrate bi-directional charging with micro grid stabilisation
	L1-4: Extend the charging optimisation algorithms for EVs bidirectional charging
L2: Micro grid inside the public grid	L2-1: Installation of equipment to allow for intelligent balancing of PV, CHP and user demand control
	L2-2: Balancing the micro grid against the city-wide virtual power plant selling energy when demand is exceeded in the micro grid and vice-versa. This action will be closely linked to the business models based on blockchain technology (L17-2)
	L2-3: Analysing and integrating Energy storage solution with bulk batteries to balance production and consumption within the micro-grid
L3: Heating demand control	L3-1: Coupling the heating needs with the load profile of the micro grid and taking into account the specifics of the historic building which function as a heat buffer
	L3-2: Provide user-interface with air quality info and implicit demand control: demand is expected to be lowered through direct feedback and consumption overview as well as recommendations for the tenants behaviour
L4: Personalised Informative Billing	L4-1: Personalised Informative billing based on real-time energy prices for engaging users in energy saving actions
	L4-2: Demonstration of Dynamic Thermal Energy Tariff schemes which will be made available to consumers and will engage them in action towards altering their energy consumption patterns and shifting them away from peak periods
	L4-3: Appropriate normative comparison mechanisms will be applied so as to help consumers position themselves against best-performing peers and, thus, better quantify their energy bill savings potential, through the utilisation of their energy consumption flexibility

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Leipzig Solutions	Specific Demonstration Action
L4: Personalised Informative Billing	L4-4: Improving the connectivity of buildings to allow for integration in the Virtual Positive Energy Community (PV and CHP) and the thermal demand response programmes by means of advanced smart meters
	L4-5: Assessment of different tariff schemes, including peer-to-peer tariffs and a collective self-consumption scheme (Mieterstrom model33)
	L4-6: Feasibility study for replication of Mieterstrom model and informative billing in all buildings operated by WSL (30.000 flats)
	L4-7: Demonstration of decentralised energy storage within building blocks for optimised self-consumption of locally produced energy (PV)
L5: Human-Centric Energy Management and Control Decision Support	L5-1: Defining the detailed and accurate comfort profiles for identifying context-aware thermal demand flexibility profiles, considering energy behaviour patterns, comfort preferences, indoor quality constraints
	L5-2: based on the action L13-1, targeted guidance on control actions (will be performed manually) for shedding or shifting the operation of thermal loads within buildings and air quality info through user-interface will be provided
L6: Decarbonisation of district heating	L6-1: The integration of Solar Thermal Energy to District Heating – specifically at Lindenauer Hafen – using the total area with a size of prox.. 130,000 m², a gross collector area of approximately 40,000 m² will be installed.
	L6-2: Estimating potential of the decentralised district heating solution for replication in the replication district Leipzig 416
	L6-3: Research to increase the share of renewable energies in the district heating network for a post-fossil future
	L6-4: Assessing waste heat potential within the city boundaries for integration in the central district heating system
L7: Heat storage (P2H)	L7-1: Integration of a P2H in the seasonal heat storage to increase the solar coverage rate and equalise the solar heat output integrated into the heating network for the minimisation of operating costs through integrated solar power generation
L8: ICT integration	L8-1: Linking of the existing and newly constructed heat storage solutions with the demand side and allow for more efficient controlling of the district heating network

Leipzig Solutions	Specific Demonstration Action
L9: Implementation and installation of an open standard based ICT platform that we call the "LBox".	L9-1: The integration of RES (1,53 MW PV) with flexible consumers (L11-1) that are interested in an active management of their devices from the outside depending on environmental or economical determinants, flexible Prosumers that are interested in an active interaction with CHP, GeoThermie, Lindenauer Hafen solar plant, their HVAC and grid participants with controllable and actively manageable energy storage systems
	L9-2: Study the replication potential of the Positive Energy Community in the Replication districts Leipzig 416 and Stadtraum Bayerischer Bahnhof
L10: Economically reasonable integration of open and standardised Sensors and Systems	L10-1: different kind of technologies will be leveraged to establish Wide Area networks (WAN) such as DSL, LTE, Radio, and LoRaWAN. Especially the demonstration and usage of LoRaWAN Network for connecting sensors and devices through a low energy, low frequency bandwidth with minimum of antennas across district. This will give the chance to integrate a wide area of additional use cases (car parking spot sensors, intelligent waste disposal) throughout the whole district.
L11: Establishment of a distributed cloudcentric ICT System which enables an intelligent energy management system.	L11-1: In collaboration with WSL, a monitored and externally controlled "green" power outlet will be installed in about 1000 dwellings across multiple buildings to prove economies of scale for larger installations.
	L11-2: Real-time simulation of the integration of an existing 10 MW battery storage typology
L12: Implementation of a human-centric interface/ application	L12-1: Demonstrating an application which allows for monitoring, controlling and providing normative feedback about the individual energy consumption. Through the application building occupants will be able to trace the impact of their everyday activities and behaviour on the building energy performance

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Leipzig Solutions	Specific Demonstration Action
L13: Visual metaphors and constructs/ dashboards for energy footprint analysis	L13-1: Demonstration of Energy Behavioural Profiles, revealing the energy related aspects of behavioural profiles and allowing for selfevaluation and normative comparisons of energy behavioural patterns. Energy saving based on the footprint analysis will be achieved by accurate benchmarking and comparison of normalised energy performance information against peer topperforming consumers with similar characteristics
L14: Commissioning on specific energy savings targets	L14-1: For maximising of energy savings at the community level, individual consumers will be able to pledge to achieve specific energy savings over specific timeframes. This will cause the Social Engagement Loop to engage and sustain the involvement of consumers in energy saving actions
L15: Integration of 2G ebus charging	L15-1: Integrating, balancing and optimising load depending electric busses charging stations into the Positive Energy Community
	L15-2: Integrating of Bus disposition schedule into optimisation, including real-time grid constraint forecasts emerging from planned demand and supply
	L15-3:Implementing a standardised charging station monitoring and control protocol for electric bus charging stations
L16: Load-balanced fleet management	L16-1: Upgrade existing charging stations to allow intelligent charging, including bi-directional charging, installing additional 2G charging stations across the city according to needs
	L16-2: Explore business models and services tailored for residents; allow for reservation of charging spaces, allow for selection of charging tariffs and priority setting
	L16-3: Implement and test a mobile user app for reservation and configuration of charging/mobility needs of his privately-owned or currently used (shared company fleet) vehicle, integrate the necessary interfaces of participants
	L16-4: Demonstrate load-balancing with an electric vehicle fleet in accordance to local grid needs and measure the effects of up to 500 evehicles on the grid balance

Leipzig Solutions	Specific Demonstration Action
L17: Conceptualisation and application of a public Blockchain for transactions between energy consumers, producers, service providers and grid system operators in a microgrid	L17-1: Feasibility study on the coordinating role of blockchain in local market dynamics between generating plants and consumers and methods on how meter point operation and meter data management might be done more efficient and cost effective via blockchain
	L17-2: Developing new potential blockchain-based solutions to enable prosumers to sell their surplus electricity on a Peer-to-Peer marketplace to prosumers
	L17-3: Demonstration of the integration and interactions of IoT devices e.g. distributed power production and storage backed by blockchain
L18: Integration of the planned "community energy storage" (CES) and "community demand response" (CDR)	L18-1: Further developing and refining the Resource Planning and Optimisation (IRPopt) modelling approach and of the web-based software environment to allow longterm and short-term scenario calculations. This includes the integration of cascading time slices, policy-goals such as renewable energy quota or CO2-emissions and standard reporting tools.
	L18-2: Defining and developing the interface to the municipal data platform
	L18-3: Demonstrating the optimal prediction of user behaviour for the Virtual Positive Energy Community and integrating the data model in the energy platform of the municipal utility. Derivation of implications regarding the formulated policy goals
	L18-4: Extending the virtual community to Leipzig. Exploration of development paths with respect to varying scenario assumptions
L19: Energy Positive District Planning	L19-1: Integrating energy and building data into the Urban Data Platform of the City of Leipzig for advanced and integrated district and building planning
	L19-2: Identifing the requirements how buildings can be integrated into the Virtual Positive Energy Community; determine the smart building requirements to support the creation of holistic system intelligence
L20: Standard model for smart cities	L20-1: Assessment of a standard model for the Leipzig replication districts in close collaboration with partners, stakeholders and the responsible city departments undertaking survey on resulting benefits for citizens and creating synergies for new smart and clean city solutions

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Leipzig Solutions	Specific Demonstration Action
L21: community empowerment support activities through dialogues, transferring ownership, knowledge transfer etc.	L21-1: Establishing community management/energy advisor which supports the residents with the energy transformation of privately owned buildings. This includes the access to the newly established Virtual Power plant and the smart grid in general.
	L21-2: Desk support for citizens with the cost-efficient installation of renewable energy sources such as PV and participation in the Positive Energy Community and for local businesses and private persons interested in rolling out project solutions
	L21-3: Creating methodological approach for developing positive energy building blocks user centric solutions in the urban context and facilitating dialogues and discussion with citizens in the format of regularly scheduled workshops (4 per year), building upon Leipzig's long tradition of citizen engagement
	L21-4: Conducting a comprehensive empirical research program on how personal-level (e.g. personal attitudes) and collective-level variables (social identity variables) provide pathways to positive energy districts and communities, identifying the ingredients of successfully communicating collective sustainability transitions that in fact change people's course of action

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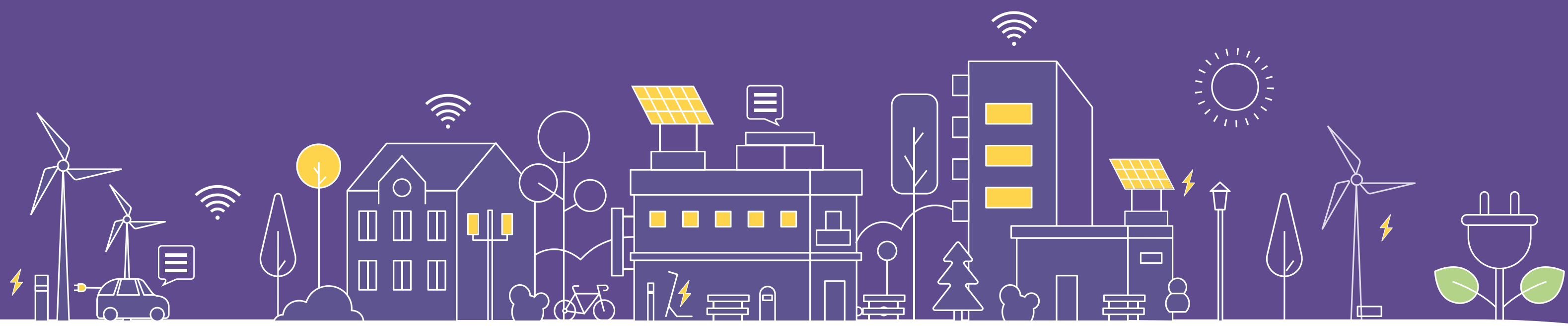

Horizon 2020
European Union funding
for Research & Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 864242. Topic: LC-SC3-SCC-1-2018-2019-2020: Smart Cities and Communities. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.