D1.13 Strategy for Developing Interoperability and Ecosystems for Positive Energy Districts

31/01/2023

VTT[1], ESP[2], LPZ[3], SUITE5[4], SPI[5], NEW[6], FHG[7], VERD[8], CIT[9], ADV[10], SIE[11], LSW[12]

[1] VTT Technical Research Centre of Finland Ltd, Tekniikantie 21, Espoo, Finland
[2] City of Espoo, Siltakatu 11, Espoo, Finland
[3] City of Leipzig, Neues Rathaus Martin Luther Ring 4-6, Germany
[4] SUITE5 Data Intelligence Solutions Limited, 95B Archiepiskopou Makariou III, Limassol, Cyprus
[5] Sociedade Portuguesa De Inovacao Consultadoria Empresarial E Fomento Da Inovacao Sa Second, Av Marechal Gomes Da Costa 1376, Porto Concelho Foz Do Douro, Porto, Portugal
[6] CNET Centre For New Energy Technologies Sa, Rua Cidade De Goa 4, Sacavem E Prior Velho Lisboa, Portugal
[7] Fraunhofer IAO, Nobelstraße 12, Stuttgart, Germany
[8] Elin Verd Anonymi Etairia Aeiforonproionton Kai Ypiresion, Pigon 33, Kifissia Athina, Greece
[9] Kiinteisto Oy Lippulaiva (CIT), Sibeliuksenkatu 5, Hämeenlinna 13100, Finland
[10] ADVEN Oy, Ayritie 18, Vantaa 01510, Finland
[11] SIEMENS Osakeyhtio, Tarvonsalmenkatu 19, Espoo 02600, Finland
[12] Stadtwerke Leipzig GMBH, established in Augustusplatz 7, Leipzig 04109, Germany

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

Deliverable administration

No & name	**D1.13 Strategy for Developing Interoperability and Ecosystems for Positive Energy Districts**				
Status	Released	**Due**	M40	**Date**	2023-01-31
Author(s)	VTT, ESP, LPZ, SUITE5, SPI, NEW, FHG, VERD				
Description of the related task and the deliverable. Extract from DoA	**T1.4 Strategy for Developing Interoperability and Ecosystems for Positive Energy Districts (VTT) M1 – M18** To be effective and produce the expected results, the process of Urban Transformation in cities should be accompanied by energy transition and digital transition in parallel. This task will develop a strategy for creating ecosystems and interoperable ICT platforms and interfaces essential for cities energy transition. The ecosystems bring together relevant stakeholders, including municipalities, energy operators and service providers, other companies, end users etc. Furthermore, the developed strategy guides how to integrate different energy systems (production, distribution, demand, storage) in energy positive districts. The aim is to digitally integrate all the involved energy data, services and infrastructures of the energy positive blocks/district, allowing holistic energy control throughout the whole energy system, and helping to optimise urban energy flows and demand. This enables among others demand side response and implementation of Virtual Power Plants (VPP) or other innovative energy aggregation business models. The platform integration aims for open, interoperable and scalable architecture, capable of integrating renewable energy in the existing grid infrastructure through smart grid solutions. Apart from digital infrastructure, the platforms should also be able to incorporate data storage and operate management, testing and evaluation procedures and GIS-based visualisation. A generic communication infrastructure, together with an accompanying formal modelling and an engineering method for distributed energy applications will also be introduced. In the long term, this enables cities and users' systems to automatically react to fluctuating conditions in near real-time, and to identify patterns and/or problems, which will help in making informed decisions and in stimulating a better use of city resources. This task produces a strategy for developing interoperability and ecosystems in energy positive districts (D1.8 and D1.13). The ecosystems operate mainly with existing platforms and legacy systems through interoperable interfaces.				
Participants	**VTT**, ESP, LPZ, CMM, RVK, KLD, KFS, LVIV, SIE, PIT, ADV, CIT, WSL, LSW, ULEI, SPI, NEW, SUITE5, VERD, LCE				
Comments	This deliverable is an update of D1.8				

V	Date	Authors	Description
0.5	02/11/2023	VTT	Guidance to deliverable contributors
0.6	20/12/2023	ESP, LPZ	Use cases checked and updated
0.7	15/01/2023	CIT, ADV, SIE, LSW	Use case mappings
0.9	17/01/2023	VTT et al	Version sent for internal review and quality review
1.0	31/01/2023	VTT	Coordinator submits the deliverable to the EC

Dissemination level

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

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

About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. SPARCS facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating VirtualPositiveEnergy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organizations, city planning and decision making entities, transforming cities to carbon-free inclusive communities. Lighthouse cities Espoo (FI) and Leipzig (DE) implement large demonstrations. Fellow cities Reykjavik (IS), Maia (PT), Lviv (UA), Kifissia (EL) and Kladno (CZ) prepare replication with hands-on feasibility studies. SPARCS identifies bankable actions to accelerate market uptake, pioneers innovative, exploitable governance and business models boosting the transformation processes, joint procurement procedures and citizen engaging mechanisms in an overarching city planning instrument toward the bold City Vision 2050. SPARCS engages 30 partners from 8 EU Member States (FI, DE, PT, CY, EL, BE, CZ, IT) and 2 non-EU countries (UA, IS), representing key stakeholders within the value chain of urban challenges and smart, sustainable cities bringing together three distinct but also overlapping knowledge areas: (i) City Energy Systems, (ii) ICT and Interoperability, (iii) Business Innovation and Market Knowledge.

Partners

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

Table of Contents

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

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

EXECUTIVE SUMMARY

The objective of the SPARCS project is to demonstrate and validate 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. This will be done through development of systemic solutions, and strategic interventions in SPARCS lighthouse cities, Espoo and Leipzig.

To achieve PEDs, there is a need for both energy and digital transitions. This entails the combination of not only different energy sources and data, but also data and information from distributed and at times, heterogenous data sources and applications from multiple stakeholders. Only when this data and information is combined can meaningful analysis be done, efficient demand-supply management of energy ensured, and actionable intelligence provided to stakeholders to make informed decisions.

This deliverable makes an attempt to understand the different data and information needs of PEDs, the main ICT requirements, and to explore the different planned interventions in Espoo and Leipzig to support their urban transitions. It, furthermore, presents the SPARCS ICT ecosystem, interoperability mechanisms, infrastructure requirements, and the main mechanism for optimising and visualising urban energy flows. A positioning framework (reference architecture) is also presented that supports mapping and visualisation of the ICT elements of the planned interventions in Espoo and Leipzig. This is expected to provide others with a better understanding of how to implement similar interventions in their respective cities because having an ICT solution alone is of course not enough. This deliverable also explores different PED implementation benefits for different stakeholders and presents the SPARCS approach to understanding and evaluating the replicability and scalability of solutions supporting the transition towards PEDs.

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

1. Introduction

1.1 Purpose and target group

One of the main objectives of the SPARCS project is to enable an urban transformation in cities towards Positive Energy Districts (PEDs). This can be achieved through parallel energy and digital transformation. There is a need for interoperable ICT platforms and interfaces that allow for data and information from multiple distributed and heterogenous sources to be mapped, combined, visualised and serve as a basis for informed decision making by relevant decision makers.

1.1.1 The challenge

One of the main challenges faced by cities in implementing holistic ICT-based solutions is the challenge of integrated data from multiple distributed and heterogenous sources. More often than not, data is available in multiple non-compatible formats and/or distributed across multiple applications and sources. This hinders interoperability and is a major bottleneck to development and use of systemic solutions. The SPARCS ICT ecosystem presents one mechanism to capture data from multiple sources, map them on to a common information model, perform meaningful analytics, and provide a framework for visualisation of different city KPI and also perform a comparative analysis.

1.1.2 Main objective(s)

The objective of this deliverable is to provide a strategy for developing interoperability and ecosystems for PEDs. This deliverable explores the different requirements from a PED ecosystem that would be able to combine data and information from multiple stakeholders and systems in a holistic manner and support urban transformation. It covers essential stakeholder requirements and specifications, technical requirements and functional specifications from an ICT perspective, in addition to determining key data requirements from urban data and energy data perspectives. It, furthermore, examines key identified use cases and interventions planned in the lighthouse cities of Espoo and Leipzig. Interoperability requirements and infrastructure needs are identified for the SPARCS ICT ecosystem covering capture of data and information from legacy systems to SPARCS data management platform, towards subsequent visualisation for informed decision making in the SPARCS visualisation framework. Based on these, a generic reference architecture (positioning framework) for interoperable ICT based interventions is developed. This serves as a basis for design and implementation of interventions identified by the lighthouse cities. The deliverable elaborates on implementation, replicability, scalability, and foreseen impacts of PEDs.

1.2 Contributions of partners

The content and structure of this deliverable was defined and developed by VTT with the help and support of various SPARCS partners. Key contributions from the lighthouse cities (Espoo, Leipzig) helped better understand their use cases and planned interventions in chosen districts. SUITE5 contributed towards definition of the main technical requirements of the ICT ecosystem, interoperability, infrastructure and optimisation and visualisation of urban energy flows and demands. CIT, ADV, SIE, and LSW contributed to mapping select Espoo and Leipzig use cases on to the reference architecture (positioning framework). SPI contributed towards understanding of key stakeholder expectations and implementation of the ecosystem. NEW contributed towards definition of key energy data requirements and specifications for better understanding of replicability and scalability. FhG provided a better understanding of urban data needs and importance. VERD helped define the potential expected impacts of PEDs.

1.3 Baseline

This deliverable makes use of the work done mainly in WPs 1, 3, 4. Specific tasks entailed include:

- T1.1 City diagnosis, data collection & preliminary analysis
- T1.1.1 Identification of Use Cases in the LHCs
- T3.3 ICT and interoperability (Espoo LHC)
- T4.3 ICT and interoperability (Leipzig LHC)

1.4 Relations to other activities

These deliverable feeds back into the activities undertaken in WP1, WP3 and 4 in terms of use case and intervention planning and implementation, in WP2 for development of the visualisation framework, and WP5 in supporting of ICT based mappings to support development and implementation of PEDS.

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

2. Requirements for Positive Energy District Ecosystems

ICT-based systems play a major role in the development and management of PEDs. This section introduces the key stakeholder requirements and expectations from ICT solutions to support PEDs, importance of city data (key requirements and specifications), technical and functional specifications of an ICT ecosystem (SPARCS ICT ecosystem), and key requirements and specifications of energy data to be used for optimisation of energy solutions and visualisation of relevant KPIs.

2.1 Stakeholder Requirements and Expectations

There is a need for the integration of different existing energy systems (e.g., production, distribution, demand, storage) at the district and city level, towards integrating the involved energy data, services, and infrastructures of the energy positive blocks/district. Therefore, the objective is to have a common mechanism through which the different users and stakeholders will interact with the various components of their energy systems, having at their disposal a centralized control/information dashboard of both the inputs and outputs.

From the energy point of view, among other relevant fields, the so-called Smart Cities are comprised of a "system of systems" that may include smart lighting systems, emergency management systems, building automation systems, access and security control systems, smart intelligent grids, renewable power, traffic control systems, water treatment and supply, among others. Even if the concept of Smart City is not new and recognising that many of these systems also already existed long before the term was coined, the main endeavour is the attempt to integrate information from these disparate systems into a unified platform that provides each group of stakeholders/users with relevant information/data to supporting their choices and decisions.

To ensure the development of a digital ecosystem that brings about added value, it is key to identify most relevant groups of actors interacting with the platform, as well as their possible requirements and expectations (Table 1).

Table 1. Relevant groups of stakeholders – requirements and expectations from ICT solutions

Group of stakeholders	Requirements and expectations
City / municipal administrations	• A tool that supports high level decision-making; • A tool that supports the optimization of energy consumption; • A tool that allows structural operational cost savings; • A tool that allows the provision of better-quality services to the citizens; • A tool that allows short-, medium- and long-term strategic planning and policy design based on data analysis and trends.
Relevant city / municipal departments	• A tool that allows efficiency gains in the services provided; • A tool that allows real time data and performance management; • A tool that allows real time visualisation of the energy performance;

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

Group of stakeholders	Requirements and expectations
	• A tool that allows remote asset monitoring and real time application enablement; • A tool that is flexible enough to the integrate/be fed by the already existing infrastructure and platforms;
City services companies	• A tool that allows the provision of added value services (new functionalities, etc.); • A tool that allows efficiency gains in the services provided; • A tool that is flexible enough to be complemented by new software, applications, etc. that they can develop.
Utility providers	• A tool that can easily integrate the existing sourcing infrastructure; • A tool that integrates, to the extent possible, the aspects related to production, distribution and commercialization aspects; • A tool that provides them with accurate and detailed information about the demand curve (peak and valley hours and associated energy consumption).
Building owners	• A tool that allows the real time visualisation and management of the building performance; • A tool that allows remote monitoring and real time application enablement at the building level; • A tool that allows the instant identification of the energy system flaws, leaks and/or malfunctions; • A tool that allows the integration of technological innovation in energy control systems; • A tool that allows improving the human experience in the built environment; • A tool that allows maximizing space utilization and efficiency.
Citizens / end users	• An easy-to-use tool, providing them with real-time and reliable information; • A tool that allows them to visualize and optimize consumption patterns; • A flexible platform, capable of being integrated by local/personal/home gadgets and applications (therefore making citizens sources of data); • A tool that significantly contributes to improving the end user experience in its relationship with the energy consumption.

The combination and pooling of the requirements and expectations of all the stakeholders and actors involved will play a critical role in paving the ground towards the development solutions tailored to their real needs and respective user profiles. In doing so, the users will be able to interact, turning the data gathered into actionable, contextualized information that can be used

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

to optimize energy consumption and lighten operational costs while improving the safety and quality of life of the citizens and end-users.

2.2 City Data – Requirements and Specifications

Urbanization is currently undergoing a fundamental digital change that extends to all areas of sustainable urban development. Whether urban mobility, energy efficiency, or urban environmental protection, all sectors generate data differently. They are produced not only by different methods but also by various organizations. It is not only municipalities that possess many data, but also companies, citizens, and research institutions. The data diversity can be divided into research data, company data, personal data, behavioural data, and official data. That includes static, dynamic, or real-time data.

Importance of City data

The views behind data generation are as diverse as the players involved: local authorities want to make processes and procedures more efficient, improve the quality of work and life, detect and avoid various dangers at an early stage, stabilize local and regional companies and improve their decision-making ability. Companies are looking for ways to support local authorities profitably, citizens* receive direct value in the form of information and networking, and research institutions deepen their knowledge and gain new insights.

Different data are often offered for sale to local authorities and districts, or local authorities and districts are interested in them in the context of individual projects and questions. The tricky part of the purchase of data is the financial evaluation and justification. Often, those involved (stakeholders) do not know the data's value and lack the necessary know-how to determine the potential value.

Furthermore, it is also a long way from raw data to valuable information based on data. Only if interfaces are programmed, data models standardized, legal requirements ensured, and data quality guaranteed can cities be designed intelligently, responsively, competitively, and socially justly through digital applications. Therefore, to recognize the value of data and use and intelligently apply it, investment decisions and new approaches are needed at the political and administrative level, based on the potential added value to be achieved through data in the local context.

How is the city data captured and shared?

The handling of data acquired in public space is currently not very productive. Most municipalities do not know about the usefulness and value of data, which data they need, even which data could be collected, and which information already exists. How much must and should be invested in the preparation of a data set. That is compounded by the lack of an overview of their data stocks and technical infrastructure, and organizational processes to link them effectively.

Companies, on the other hand, already operate with data in the public domain. That can be done by providing a free WLAN, bike or car-sharing systems, or measuring various other behaviour-generated data. They offer their services for the public space for little money, generate data, and use it for their future turnover. They already know that data can also be used to pay for urban value-added, as they serve as a basis for policy decisions. Municipalities thus become a profitable customer for companies. Also, access to data for small and regional SMEs (small and

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

medium-sized enterprises) is organized differently from the giants already established in the market, such as Google and Co.

Furthermore, there is the problem of how to deal with behaviour-generated and personal data. On the one hand, most citizens willingly make personal data available to commercial third-party providers via apps. On the other hand, they rightly fear a state intervention in their data and are sceptical or even reject data collection in public places or the processing of private data (e.g., their energy consumption or their facial profile). The consequence of this is that commercial providers come into possession of a considerable amount of data (e.g., high-resolution information on occupancy and movement in public transport systems, but also publicly accessible facial profiles). Most of them are made available as raw data or aggregated information to cities and municipalities for a fee. The users thereby indirectly become customers of their data.

To recognize the value of urban data, we need to experience the holistic benefits of digital possibilities. Those aspects can lead to the creation of digital urban value in very different areas of urban management.

Data sharing:

The municipalities must ensure the technical infrastructure for a successful data exchange. Examples could be a barrier-free access to data must be guaranteed to give science, economy, civil society, and politics the chance to use data equally. A common database in the urban data space, trustworthy and secure, can increase quality, develop new offers, and ensure that it is up to date. Data is no longer stored separately but within a single digital room.

Exchange of knowledge

In addition to data sharing, the knowledge must also be shared (through municipalities or companies). Data alone is not helpful if cities do not know what to do with it and achieve goals. A model is needed that has been developed and tested based on different municipalities and can thus be made applicable to others. The use of innovative technology and data-based methods must be ensured and must include the financial aspects. Also, however, replicable, trustworthy, and scalable package solutions must be developed. Supra-regional agreements on the structures and architecture of the data landscape are also necessary to ensure that local authorities' independence and platform customers are always guaranteed.

Transparency

The handling of data - particularly behavior-generated and personal data - must be clearly defined and transparently communicated. Data protection must play a significant role here and must never be overlooked. The behavior of citizens and their data must not become a commercial product without their consent. A trustworthy and transparent framework must be created to generate safe, protected, and valuable output for cities and municipalities.

Added value

The added value of data must be clear to cities and municipalities, and the population. Data generation and targeted use, always from data protection, can considerably increase work and life quality in urban living spaces. Generated data can be used for new services and products that improve the city's experience and strengthen local and regional businesses, such as mobility services that use an excellent database to consider current construction sites, events, weather, and traffic conditions. Creating a unified data room can also promote start-ups that deal with business models of urban data. New business areas can also be brought to life by municipal

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

companies that manage significant urban data assets such as energy supply, public lighting, waste disposal, or mobility.

Data makes it possible to link separate systems with each other and use synergies more efficiently, such as sharing work surfaces, vehicles, and homes. The consumption of resources and the production of greenhouse gas emissions can also be reduced, utilizing various measurements and the knowledge gained from them, which will help develop more accurate systems.

2.3 Technical Requirements and Functional Specifications – ICT Ecosystem

Information Communication & Technology (ICT) and data management has been identified as one of the main enablers for the development and implementation of Positive Energy Districts (JPI, 2020). ICT has the ability to enable the necessary communications and integration of the various city/district wide systems and their corresponding data, to achieve positive impacts and finally enable a successful transformation to a PED. Under the same context, Lai et all. (2020) summarize that for a city to become smart, various sources of data coming from a range of urban activities and domains must be connected to reveal opportunities to bring innovation to today’s connected citizens.

As such, it can be said that in the case of smart cities’ transformation and more specifically towards the achievement of PED status, ICT has a crucial role in creating the necessary links and delivering an interoperable infrastructure enabling cities/districts to communicate and operate effectively in the most optimal way. Such an ‘infrastructure’ shall be able to gather and aggregate city-wide data and information towards proving insights and an understanding of how a city/district is performing in terms of resources utilization, services, etc. In the context of SPARCS, ICT will be extensively utilised to bring the project’s Lighthouse and Fellow cities together, delivering the appropriate communication and networking infrastructure (ICT Ecosystem), thus enabling interoperability among the various systems and technologies. As an outcome, such an ecosystem will allow the utilisation and visualisation of data deriving from different data sources, from various data consumers.

It is thus clear, that there are various technical requirements that need to be addressed and considered, when developing a holistic PED ICT ecosystem capable of enabling cities/districts to communicate constantly and exchange information without problems, while ensuring security and data privacy. Within the context of the project, the developed ICT ecosystem shall be able to manage the data coming from various devices and energy components/systems, in order to perform its operations and lead to the achievement of PED in the project’s Lighthouse and Fellow cities.

As a starting point for identifying the required technical requirements for such a system, the project’s Use Cases (UCs) (Section 3 of this document) developed under SPARCS T1.1.1 relating to the ICT infrastructure shall be fulfilled. Since the majority of the UCs cover a broad field of domains (i.e., Energy, ICT, Mobility, Governance, etc.) there is a need for the developed ICT ecosystem to be open, secure and capable of addressing all the project’s technological and data management needs. Consequently, the developed SPARCS ICT Ecosystem shall deliver a city-wide IT ecosystem, acting as the backbone for gathering the various city/district data from the various domains and planned interventions. Its main outcome shall provide a holistic view and utilisation of these data by the relevant stakeholder (citizens, decision makers, app developers/companies, etc.), while offering data collection, security/privacy and the required infrastructure for the storage and dissemination of such data. To provide a learning content, the

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

developed ICT ecosystem shall also be capable of proving appropriate tools for the visualisation of the various city-wide data and Key Performance Indicators (KPIs) derived from the city-wide collected data; thus, allowing monitoring and evaluation activities to take place. A conceptual view of the envisioned SPARCS ICT ecosystem is presented in the following figure.

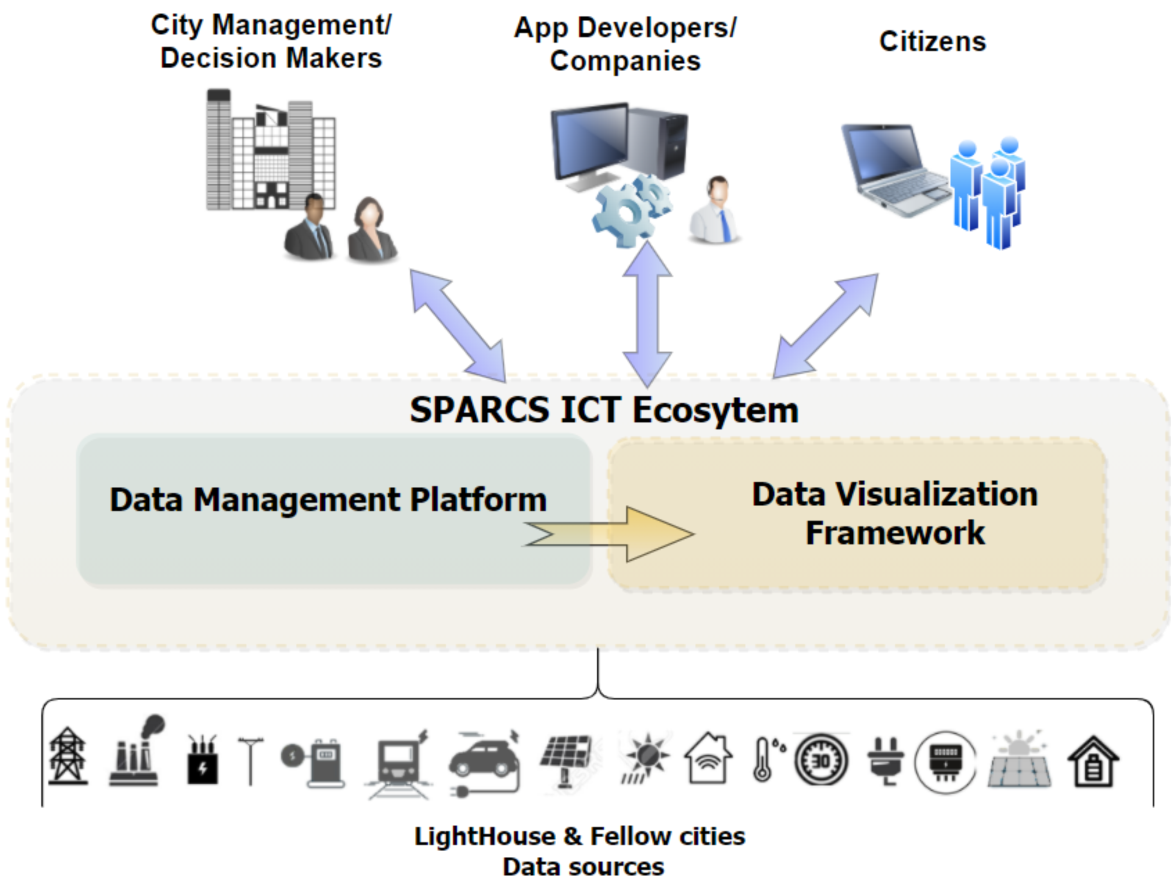

Figure 1 Conceptual view of the SPARCS ICT ecosystem

The overall scope of the SPARCS ICT Ecosystem is to deliver an interoperable platform capable to integrate and manage data coming from various devices and energy components (through appropriate interfaces), in order to perform its operations, contributing to the achievement of positive energy districts in the Lighthouse and Fellow cities. The required data for the operations of this PED enabling ICT Ecosystem will derive from the various Distributed Energy Systems (DERs) of the cities, such as Renewable Energy Sources (RES), smart IoT devices, smart meters and any submeters installed under the context of the project's planned interventions. Such data will provide insights of the cities/districts' performance in terms of energy demand, energy consumption generation, energy storage, CO_2 emissions, operation of energy components, etc. The outcome of the overall SPARCS ICT Ecosystem is intended to bring together all potential data consumers (such as cities' decision makers, energy companies, service providers, end users/app developers etc.) by disseminating such data through the provision of appropriate interfaces (open APIs) along with the delivery of visualisation dashboards.

To address the project's needs and requirements, the SPARCS ICT Ecosystem will be responsible for preparing and executing the collection, manipulation, storage and visualisation of various city/district data, so as to be finally accessible to all relevant stakeholders. The SPARCS ICT Ecosystem will consist of two main components; the Data Management Platform and the Data Visualisation Framework each of them with a unique set of tools and functionalities, which are briefly described here and presented in more depth in section 4.3 of this document.

SPARCS Data Management Platform

Taking into consideration the project's data requirements, as well as the additional data needs and required services of the planned interventions in the Lighthouse & Fellow cities, the envisioned SPARCS Data Management Platform at the early design activities is considered to provide the necessary interfaces and components/services to assist in the overall energy transition of the cities through:

a) collection/ingestion of all available datasets through various data sources and via appropriate communication interfaces, (e.g., upload of files, APIs, database extracts, etc.)

b) handling and mapping of the various data formats under a uniform and common language, thus enabling syntactic and semantic interoperability

c) secure storage of the ingested and transformed datasets, enabling access policies where required

e) data dissemination to any authorised data consumer via appropriate interfaces enabling data queries and

d) visualisation of metrics and Key Performance Indicators enabling the evaluation and monitoring of the cities/districts' performance.

In general, the SPARCS Data Management Platform (DMP) will act as the central data platform of the project; its role will be the ingestion, integration, and storage of all data required for the utilization of the SPARCS UCs. The DMP components perform the required data management processes, so that the collected data can be used both for the operations of the SPARCS visualisation applications, as well as in order to be retrieved by other data consumers for analytical purposes and/or control strategies optimization.

Additional details of the envisioned platform distinct set of services mentioned above, are described in the following sections:

- **Data collection/ingestion**

The data collection process shall cover the gathering/ingestion of data from the various cities' databases, from any backend-to-backend interfaces and any IoT sensor interfaces. Towards this direction standard APIs shall be provided by the platform to allow seamless and secure communication with the various data sources/providers. The developed platform shall also enable the various data providers to configure their datasets, regarding the data retrieval methods, scheduling, etc.

- **Data handling/integration**

The various datasets from the different distributed information systems collected by the Data Management Platform should be finally stored in an interoperable and uniform way in order to be available for subsequent analysis and visualisation purposes. As such, the SPARCS DMP shall be based on the design and development of a ***Common Information Model*** (CIM), whose purpose is to act as a common language for the various datasets that are handled within the Data Management Platform. As a starting point, the development and design of the SPARCS CIM shall be based on existing standards and data models and shall be associated with widely

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

accepted open standards for smart cities communication and interoperable information exchange. In addition, to support the project's activities, the establishment of such a data model, shall also be based on detailed study and a thorough investigation of all the data available from the distribution information systems of the cities, the IoT sensors, the submeters and actuators, as well as on datasets acquired from the deployed devices and energy components of the project's planned interventions. The data handling/integration service will be responsible for undertaking the required set of mapping and transformation of the ingested data from their native data model and format to the SPARCS Common Data model; in order to ensure information consistency and compatibility.

- **Data storage**

Upon all data handling operations are completed, the various data along with their metadata and further sensitive data shall be securely stored in a secure storage infrastructure. As such the developed Data Management Platform shall be capable of providing appropriate database(s) offering data and metadata storage; in addition, data indexing capabilities may be considered to enable enhanced searching capabilities of the stored datasets. The selection of the final database type(s) shall be based on the specific data storage and processing requirements of the project.

- **Data Security**

In addition, to the storage of data, their privacy shall also be safeguarded. A major concern when storing data is confidentiality; since some data may not be eligible to be openly distributed or may lead to identifying individuals. As such, the envisioned platform shall enable the provision of access control policies from the original data providers to the ingested datasets, so as to be accessible only by the intended and authorized users. Such access policies shall be capable of ensuring security, privacy and integrity for both the data and data models stored in the SPARCS Data Management Platform, while allowing access to authorised data consumers only.

- **Data preparation**

In order to provide meaningful outcomes, the ingested data should be combined, transformed and linked to other data. The Data preparation service provided in the context of the SPARCS management Platform shall be responsible to formulate these necessary linkages among the various datasets, so as to enable appropriate visualisations to be performed under the functions of the Data Visualisation framework. Data privacy and security is here also a major concern that needs to be addressed, since some datasets shall not be provided to non-authorised users. It is thus important, that the Data Preparation service shall be capable of not only perform the required operations to enable the visualisation of data, but also to verify which data are actually permitted to be combined based on the access policies enforced from the data providers.

- **Data dissemination**

Further to the above responsibilities, the SPARCS ICT shall act as a centralized data dissemination point for the Lighthouse & Fellow cities, as well as for any other authorized third-party application which may require such data for their operations. It is thus crucial, for an access policy framework to be established, so as to enable access to the datasets over the SPARCS ICT ecosystem's APIs, to datasets that are eligible to be publicly distributed. Nevertheless, others'datasets might be restricted to specific authorised users only, according to the access policies enforced to these datasets by the original data providers. It is thus critical, that the provided API interfaces, shall be able to identify the different users, manage the different access authorization rights and provide further user validity checks (e.g., use of tokens).

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

SPARCS Data Visualisation Framework

As previously mentioned, the main objective of the SPARCS ICT Ecosystem is to utilize the ingested data in order to create added value for the project's Lighthouse & Fellow cities and thus support in the overall transformation to PEDs. Towards this direction, the visualisation of the ingested datasets is considered (upon manipulation), as a meaningful way to communicate the complex information contained in these datasets, through visual forms. The subsequent visuals will enable users to compare/correlate datasets, thus contributing to the overall evaluation and monitoring of the urban performance, as well as decision making.

As such, the SPARCS Data Visualisation Framework, developed within the context of the SPARCS ICT ecosystem, shall be responsible for utilisation and manipulation of the collected datasets, in order to enable their visualisation through appropriate user interfaces (UIs), such as dashboards. In general, dashboards consist of powerful "advisory" tools which are able to utilize/analyse the collected data in order to provide meaningful visualisations of the cities/districts performance, thus supporting the overall transformation to PEDs. To enable such visualisations, the various datasets deriving from different data sources and across different domains need to be combined and manipulated; such functionality will be provided from the Data Preparation service described previously. Considering also that the visualisation of datasets should be only available to authorised users, the developed Data Visualisation Framework shall be capable to verify which data are actually permitted to be visualised, based on the access policies enforced from the data providers.

As a summary, it is clear that there are various technical requirements that need to be considered for the development of the SPARCS ICT Ecosystem. Table 2 provides a non-exhaustive list of core technical requirements for the development of the SPARCS ICT Ecosystem as identified at the early development activities. It should be noted that such requirements, after being enriched and refined by incorporating the SPARCS UCs needs and supplementary technical requirements of the planned cities' interventions, will comprise the basis for the description of the SPARCS High-Level Architecture and the related ICT components described in the following chapters.

The following structure has been used for the presentation of the technical requirements presented in the Table below, where:

- *ID*: is the unique identifier (ID) of the technical requirement (e.g., T-01, T-02).
- *Description*: a description of the technical requirement is provided.
- *Priority*: The priority (i.e., High, Medium, Low) for the fulfilment of the requirement by the SPARCS ICT ecosystem's components.

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

Table 2 SPARCS ICT Ecosystem- Core Technical Requirements

ID	Description
T-01	The SPARCS ICT ecosystem should deliver a citywide platform provided as a service.
T-02	SPARCS ICT ecosystem shall provide the capability for provisioning of gateways and devices.
T-03	SPARCS ICT ecosystem shall enable management and configuration of gateways and devices.
T-04	SPARCS ICT ecosystem shall allow only secure communication; only registered applications/users/devices can have access.
T-05	SPARCS ICT ecosystem shall ensure privacy; only authorized applications/users/devices can have access to the data.
T-06	SPARCS ICT ecosystem shall provide an authentication and authorization mechanism.
T-07	SPARCS ICT ecosystem shall be able to handle authentication and authorization mechanisms provided by remote platforms (such as accessing the remote REST API in the cities' distributed information systems).
T-08	SPARCS ICT ecosystem shall enforce access rights mechanisms associated to data and metadata access.
T-09	SPARCS ICT ecosystem shall support intraplatform interaction.
T-10	SPARCS ICT ecosystem shall support storage of data.
T-11	SPARCS ICT ecosystem shall support data updated at various levels of granularity (i.e., per minute, per hour, daily, etc)
T-12	SPARCS ICT ecosystem shall enable data providers to manage their resources/datasets, (i.e. set access policies, aggregation levels, schedules, etc).
T-13	SPARCS ICT ecosystem shall enable the communication with Ethernet TCP/IP protocols.
T-14	SPARCS ICT ecosystem shall endorse usage of ontologies and semantic modelling of data.
T-15	SPARCS ICT ecosystem shall provide the transformation of Lighthouse & Fellow city specific data models to the concepts/attributes of the SPARCS Common Information Model.
T-16	SPARCS ICT ecosystem shall ensure a generic structure for data representation.
T-17	SPARCS ICT ecosystem shall provide the output data through visualisations of all datasets used.

2.4 Energy Data Requirements and Functional Specifications

The generation of appropriate input data for energy modelling for planning purposes is essential for reliable results and intervention planning. The lack of open licenses to original sources of data is a challenge with the open modelling approach. However, in recent years there has been a push to make input data publicly accessible and there are various sources on a National, European and International level that can be used to provide accurate results.

Typical energy data (generation; distribution; demand; consumption and generation; and that used in integrated solutions) of relevance is presented in the following tables.

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

Table 3: Energy Data - Generation

Generation	Input data	Unit	Data sources
PV	Solar radiation on a horizontal plane	W/m^2	https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP Sunbird form Joint research centre Solcast
PV	Optimal angle of panel inclination	Degrees	Calculated from the sun angle and the azimuth
PV	Solar radiation on a plane with the optimal angle of panel	W/m^2	https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP Sunbird form Joint research centre Solcast
PV	Global horizontal irradiation	kWh/m^2	Includes direct and diffuse irradiance to the horizontal surface
PV	Global irradiation optimum angle	kWh/m^2	Includes direct and diffuse irradiance at optimum angle
PV	Global irradiation at certain angle	kWh/m^2	Includes direct and diffuse irradiance at certain angle
PV	Daily and monthly average temperatures	Degrees Celsius	Meteorological public services
Hydro	Flow	m^3/s	On site data collection (Flowmeter)
Hydro	Height	m	On site data collection
Geothermal	Temperature	ºC	On site data collection
Geothermal	Fluid temperature	ºC	On site data collection
Geothermal	Conductivity of soils	mS/m	On site data collection
Geothermal	Flow	m^3/s	On site data collection
Wind	Wind average speed	m^3/s	European wind Atlas
Wind	Power density	W/m^2	European wind Atlas
Wind	Wind speed long term profile	m^3/s	New European Wind Atlas

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

Table 4: Energy Data Distribution

Distribution	Input data	Unit	Data sources
Annual consumption	Energy	kWh	On site data collection
Hourly consumption	Energy profile	kWh	On site data collection
Supply voltage level	Voltage level	V	On site data collection
Substations (primary/secondary)	Type of distribution feeders	1. Radial 2. Parallel feeders 3. Ring main 4. Meshed systems	On site data collection Utility data
Substations (primary/secondary)	Technical layout of primary and secondary power distribution systems	Technical layout	Utility data
Circuit breakers/switches	Circuit breaker characteristics	1. Rated voltage [V] 2. Rated current (A) 3. Overload relay trip-current setting (Irth) 4. Short-circuit relay trip-current setting (Im) 5. Rated short-circuit breaking capacity (Icu)	
Grid nodes	Technical layout of generation and load nodes	Technical layout	Utility data
Point of common coupling (PCC – for microgrids)	Voltage regulation	Rated voltage at PCC [V]	On site data collection Utility data
Overhead lines, underground lines	Technical layout of lines	Technical layout	Utility data
Overhead lines, underground lines	Distance	m	On site data collection Utility data
Overhead lines, underground lines	Conductivity	S/m	Utility data
DSO characteristics	Voltage level	V	European standardisation bodies CEN/CENELEC

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

Table 5: Energy Data - Demand

Demand	Input data 1	Input data 2	Data sources
Buildings	Appliance consumption	kWh	On site data collection HEMS/BMS/Smart meters
Buildings	Appliance load profile	kWh [hourly, 15mn, …]	On site data collection HEMS/BMS/Smart meters
Buildings	Appliance load priority regime	Always on; can be disconnected when strongly needed; flexible; very flexible	On site data collection
Buildings	Peak demand	kW / kVA	On site data collection HEMS/BMS/Smart meters
Buildings	Demand forecast	kW / kVA	On site data collection
Districts	Consumption per unit (building, household, street…)	kWh	On site data collection HEMS/BMS/Smart meters
Districts	Consumption Profile per unit	kWh [hourly, 15mn, …]	On site data collection HEMS/BMS/Smart meters
Districts	Consumption priority regime per unit	Always on; can be disconnected When strongly needed; flexible; very flexible	On site data collection
Industry	Appliance consumption	kWh	On site data collection
Industry	Appliance load profile	kWh [hourly, 15mn, …]	On site data collection
Industry	Appliance load priority regime	Always on; can be disconnected when strongly needed; flexible; very flexible	On site data collection
Transport	Supply hubs	Number of stations, plugs and power	On site data collection
Transport	EV fleet consumption per unit	kWh	On site data collection
Transport	EV fleet consumption global	kWh	On site data collection
Transport	EV fleet number of units	Number	On site data collection

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

Table 6: Energy Data – Consumption and Generation

Storage	Input data 1	Input data 2	Data sources
Consumption	Total loads	kWh	On site data collection
Consumption	Load profile	kWh time based [hourly, 15mn, …]	On site data collection
Consumption	Controllable loads	kWh per controllable unit	On site data collection
Generation	Generation total	kWh	On site data collection
Generation	Generation profile	kWh time based [hourly, 15mn, …]	On site data collection
Grid independence	Grid independence	% of grid independence	On site data collection

The data that should be available in the SPARCS project should be for a defined district, physical or virtual.

Table 7: Energy Data Sources – Integrated Solutions

Integrated solution	Solution (component)	Data
Positive Energy Blocks	RES (PV Geothermal)	Energy generated time profile Saved CO_2 emissions On-site energy ratio (OER) = On-site produced renewable energy / Total energy used % of heat from Geothermal source
Positive Energy Blocks	Storage (electrical and thermal)	Energy (electrical and thermal) storage capacity Energy stored/delivered time profile Increase of OER by using storage
Positive Energy Blocks	Energy (heat + electricity) demand response	Energy (electrical and thermal) demand response potential and time availability Amount of energy shifted from peak to off-peak period
Positive Energy Blocks	VPP	Power measurements Energy generated Energy flow (consumption, generation and locations) Transaction ledger
Positive Energy Blocks	Energy infrastructure	Network restrictions Battery use (charge, health, losses) Consumers Loads priority
Positive Energy Blocks	EMS	Energy consumption time profile Energy generation time profile Storage Energy stored/delivered time profile
Electrical mobility	E-mobility hub	Car charging capacity CO_2 emissions avoided
Electrical mobility	EV car sharing and power management	Number Expected utilisation rate of car sharing at a certain moment
Electrical mobility	Park & charge	Number or charging hubs Energy and power User should be informed of EV charging stations main features: indication of available spots in charging stations, plug compatibility, power capacity, estimated time of charging
Electrical mobility	V2Grid	Energy/power delivered to the grid vs energy/power delivered to the vehicle (including when vehicle can be used

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

		for V2Grid, and when its battery needs to be ready for use, requests (+ responses) from grid)
Electrical mobility	EV integration in VPP	Energy storage available for VPP
Electrical mobility	Last mile electrification	Kms covered by last mile electrification Type of mobility: car, bike, other
New Economy	Engaging users in new businesses	Growth rate of users of new businesses Assessment of the level of involvement with the platform activities/updates
New Economy	Co-creating new business models	Number of contributions Number of new business models from co-creation activities Number new business models created per area
New Economy	Smart local sustainable businesses	Number of new smart local sustainable businesses Growth rate of new smart businesses Number new smart local sustainable businesses per area
New Economy	Dynamic pricing of EV charging	% of users that prefer dynamic pricing Users' reaction to pricing assessment
Urban innovation ecosystems	Induce citizens behaviour to energy positiveness	Assessment of the engagement of citizens in the new solutions that contribute for energy positiveness
Urban innovation ecosystems	Optimize peoples flow	Information on road traffic, public transportation data and e-mobility solutions (cars, bikes, scooters) usage.
Urban innovation ecosystems	Co-creation of urban solutions	Number of contributions % of contributions that lead to a solution
Urban innovation ecosystems	City planning district development	Build on municipality planning with ideas from co-creation sessions
Urban innovation ecosystems	Sustainable lifestyle	CO2 budget per citizen Environmental impacts (measured by the Planetary Boundaries methodology applied to the city)
Urban innovation ecosystems	Promotion of soft mobility solution	kms in soft mobility CO2eq avoided
ICT	Predictive model for buildings	Temperature and humidity data for building thermal model of the building Energy/power generation in the building Energy consumption in the building Power and capacity of storage systems Energy delivered/stored in storage systems Loads priority
ICT	Integrate electricity and heat Demand response in a VPP	Energy savings from integration of electricity and DR in a VPP
ICT	Smart building energy management	HEMS and BMS systems Temperature and humidity data Energy/power generation in the building Energy consumption in the building Power and capacity of storage systems Energy delivered/stored in storage systems Loads priority
ICT	Block chain enabled services	P2P transactions between prosumers
ICT	Virtual twin	Integration of building and energy data from demos that with help of big data and machine learning can help in decision making

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 SPARCS project will rely on both open data, that is *"data that anyone can access, use and share"*[1]and furthermore proprietary / protected data (in compliance with GDPR). It should be available in a common, machine-readable format, to allow for ease of access, use, analytics, visualisation, and informed decision making. Data that is not "open data" will be secured, protected, and where needed anonymised.

SPARCS should ensure that used data has the following characteristics:

- **Quality and Accessibility** - ensure that is under a standard format, has an adequate data structure, and is accessible. It should also apply the FAIR (Findable, Accessible, Interoperable, Re-usable) principles. An example can be data in JSON and providing the ODI (Open data certificate);
- **Interoperability** – information and knowledge can be shared between different organizations throughout data sharing in their ICT systems, either in present and in the future[2];
- **Governance** – the data is collected, stored and used protecting sensitive personal information, namely implementing the General Data Protection Regulation (GPRD[3]), whereas preserving data owners' rights.

In SPARCS project the data is used to contribute to improve the key project areas: Positive energy Districts, Mobility, New Economy, urban innovation ecosystem and ICT.

The energy data should be structured in:

- **Consumer layer** – Where the users access to the platform services;
- **Integration layer** - Where the different modules are integrated;
- **Service layer** – Where the energy services enabled by the energy data are implemented;
- **Governance layer** – Where data anonymization and GPRD are addressed.

The stakeholders that will engage with the energy data in SPARCS are:

- **Citizens** – will assess info about the EV charging grid, the RES potential for a location, the electrical grid traffic (for the VPP), among other;
- **Municipalities** and **Regulators** – Will be able to virtually test new urban solutions and new regulation using the service layer;
- **Building** and **household** (owners or tenants) – will be able to optimise their energy position, either as consumers or prosumers;
- **Companies** – via the energy data will be able to develop new products and business models. Example offer of shared ownership appliances;
- **Energy retailers -** via the energy data will be able to sell new products and services develop new products and business models. Example optimisation of the electrical mobility operation;
- **ESCOs** (includes storage, ancillary services) – implement project regarding energy savings, energy infrastructure, energy conservation power generation, among others.

[1] https://www.europeandataportal.eu/elearning/en/module1/#/id/co-01

[2] https://eur-lex.europa.eu/resource.html?uri=cellar:2c2f2554-0faf-11e7-8a35-01aa75ed71a1.0017.02/DOC_1&format=PDF

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.119.01.0001.01.ENG&toc=OJ%3AL%3A2016%3A119%3ATOC

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

3. LHC Use Cases for Positive Energy District Ecosystems

The Lighthouse cities of SPARCS, Espoo and Leipzig have identified a comprehensive set of use cases (interventions) to support transformation towards PEDs. These include district heating, NZEB optimisation systems, battery storage, electric vehicle charging, stakeholder information provision, planning processes, geothermal heating, and much more. The interventions are defined under T1.1 and elaborated in detail (including implementation plans) in WPs 3 (Espoo) and 4 (Leipzig).

3.1 Espoo

Espoo is the second largest city in Finland with some 300.000 residents. The city has had goals in the field of sustainability since the 1990's and the current city strategy 2021-2025 emphasises sustainable development goals, including the carbon neutral Espoo 2030 target.

One special character of Espoo is its structure: instead of one city centre, Espoo has five smaller city centres that act like cities within the city, providing different services close to the residents. In this project, we have demonstration areas located in two of these city centres: the Sello demonstration area in the Leppävaara district and Lippulaiva demonstration area in Espoonlahti district. Leppävaara, already the largest city centre in Espoo, would be the 13th – 15th largest city in Finland by population if it became an independent city. Both city centres are currently developing rapidly - for example, major rail-based public transportation investments are changing the urban landscape in both areas in the upcoming years.

The Espoo demonstration sites assume a comprehensive approach to energy systems. Electricity, heat, cooling, mobility, flexibility and storage capacity are controlled by smart solutions that minimise emissions and costs while ensuring reliability and local ownership. Sector coupling yields more degrees of optimisation, but requires comprehensive automation, new business models and transaction platforms such as blockchains.

Two of the demo sites, Sello and Lippulaiva, comprise of a shopping center, adjacent residential buildings, libraries and other public services, and rail and bus terminals with improved e-mobility, cycling and pedestrian options. Citizens have various roles as residents, passengers customers, or simply socializing without being confined in any specific category. The third demo site, the Kera district, is a new residential district that will be built on a current brownfield area for logistics during the next decades. In all three sites, promotion of sustainable lifestyles is as important as adopting new technologies.

The three sites are in different stages of development. The Leppävaara center, with the Sello shopping center, is an already built dense urban area. The new Lippulaiva shopping center (replacing the old Lippulaiva building), with new residential buildings and a recently opened metro station (opened in December 2022), are key ingredients in the redeveloped Espoonlahti area. The development of the Kera district - and its transformation from a brownfield area into a new urban district with housing and workplaces - is currently in the city planning and development phase and its first construction phases are set to begin sometime in 2023.

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

3.1.1 Interventions in Lippulaiva

The Lippulaiva demonstration district focuses on the energy systems in the new shopping center and the surrounding residential building blocks. Leasable gross area of the shopping center alone is 44,000 m2, with additional 550 residential apartments and senior house with approximately 120 apartments. Figures below show an architecture sketch of Lippulaiva shopping center with residential blocks and a picture of the construction site on 12th of August 2020. The opening of Lippulaiva shopping center took place on 1st of April 2022.

On-site RES production includes 4 MW regenerative ground source heat pump plant, 50,000 m of bore holes and approx. 200 MWh/a PV system. The new Lippulaiva shopping Centre together with surrounding buildings create a district with a multi-mix consumption and the potential to achieve zero-energy level and beyond. Heating and cooling demand of Lippulaiva shopping center as well as residential buildings and senior house is mostly covered with heat pump plant.

Optimisation of the NZEB energy system

This activity will determine the energy consumption profiles in Lippulaiva shopping centre and residential blocks through simulations as well as to describe the consumption of heating, cooling and electricity and possible waste heat sources that can be utilized. It will also provide the description of the thermal energy system (heating and cooling) including the virtual power plant, on-site heat recovery and control strategies and examine the possibilities of heat recovery from metro tunnel. Big data and predictive building control strategies concerning heating and cooling are developed, supported by relevant terminologies and KPI's definitions. The task also includes feasibility studies on heat recovery from the metro tunnel and connecting the on-site geothermal system to local DH network.

Lippulaiva will be developed to an energy positive district by increasing electrification of vehicles which will also result in an increase in electricity demand. Multiple renewable energy sources ensure that one may compensate for the shortcomings of another, whether climate or infrastructure related. Furthermore, integration allows for selling and buying from main grid while, depending on levels of demand, still producing electricity locally.

Physical solutions include a 4MW geothermal heat pump plant providing heating and cooling demand and recycling waste heat sources, with the possibility to sell heat to the city-wide district heating network. PV panels and certified renewable electricity are used as primary energy. By optimizing electricity usage, EV charging, and other demand side management tools electricity costs can be minimised, curtailment is avoided and participating in Nordpool electricity reserve markets yields additional income.

Assessing the battery storage

This activity will assess the optimal size of battery energy storage and the potential to minimize electricity costs in Lippulaiva by optimizing electricity usage, producing own energy and participating in electricity reserve markets. Different control strategies for smart electricity consumption, production and battery usage will be assessed, as will the potential to use a battery energy storage system and the suitable control strategies as emergency power to minimize costs.

The benefits and possible risks for the Lippulaiva if participating in reserve markets will be elaborated and different control strategies for smart electricity consumption reviewed, production and battery usage as well as assessing the potential to use a battery energy storage system as emergency power for cost minimizations.

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

Successful implementation of an energy positive district requires that energy storages together with smart control strategies are used to optimize energy production and consumption as well as minimize energy costs. Thermal energy is stored in the ground (geothermal wells), in which excess thermal energy will be returned to and stored in the ground. In addition, energy can be stored in local buildings. Electric battery is used to optimize electricity consumption and production and minimizing the costs.

Geothermal heat export to adjacent residential building

In this activity energy consumption profiles in residential buildings of Lippulaiva will be determined, as well as waste heat possibilities from residential buildings and their possibilities for heating. The use of Lippulaiva geothermal heat as residential heat will be assessed and the possibilities of connecting geothermal to district heating network (operated by Fortum) examined.

Delivering Geothermal heat and cooling to residential towers and service homes to be built in connection to Lippulaiva shopping Centre.

CIT provides input data of energy consumption in Lippulaiva shopping center and surrounding residential blocks and writes the description of consumption. ADV provides system description of thermal energy and VTT assists in action when needed, for example calculating needed KPI's and providing feasibility studies on connecting geothermal to district heating network (operated by Fortum) together with Citycon and Adven.

Automation steering system

By connecting building automation to Adven energy production automation we are able to optimize more efficiently energy production and minimize expenses and CO2 emissions. ADV specifies interface and steering procedure together with building automation service provider and CIT connects Adven to Citycon's chosen building automation service provider

3.1.2 Interventions in Leppävaara/Sello

Smart energy solutions for self-sufficiency in the Leppävaara centre focuses on increasing efficiency and self-sufficiency through digital tools and through local thermal energy production.

Leppävaara is one of the fastest growing areas in Espoo and Sello Centre is the local Energy hub of Leppävaara. Sello multipurpose centre has an area if of 102 000 m2 including shops, a library, concert hall, movie theatre. Sello center has 2900 parking lots that includes tens of EV charging station. Sello gets 23 million yearly visitors. A new plan of Sello Centre extension is under development.

Sello's thermal energy processes are modelled to understand the potential increased energy efficiency, self-sufficiency and thermal flexibility. In the following action, Sello's flexibility potential is realized by providing the thermal flexibility to local district heating company (Fortum). In the last action, increasing the self-sufficiency through deep heat geothermal well is evaluated

Thermal and battery storage prediction

This activity will define solution architecture, KPIs, install needed submeters for energy and calculate time constant and create prediction algorithms for storing energy (heat and cool) in Sello based on physical structure (if available), historical and real time energy data: energy,

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

indoor environment, weather and (visitors and people flow, if available). It will also integrate the time constant and prediction algorithm to Sello energy management system via APIs and Sello energy management system through APIs to local DH company for DH demand side management.

Additionally, if resources are available, a BIM model of Sello (ifcSpace, of a tbd Sello block) will be developed and the prediction model integrated to Digital Twin model via APIs

The solution predicts 48hrs ahead Sello's heating and cooling flexibility with high accuracy based on the different heating and cooling strategies and uses the prediction model to provide increased flexibility for DH DSM and optimize energy demand.

SIE will define solution architecture, provide data needed and create APIs towards VTT and Fortum and carry out BIM model creation. VTT will define solutions architecture, calculate time constant and prediction algorithm, (integration to digital twin, temperature data linked to 3D BIM-model to e.g., visualize temperature, CO2 and RH, changes during demand response period)

Integration with district heating network

This activity will define system architecture for district heating integration, provide flexibility data via API to Fortum. Flexibility will be executed based on Fortum's signal via API

Important results include lower CO2 emissions level of local District Heat and consumers empowered to become active part of the energy sector by providing flexibility. SIE will coordinate the work with Fortum and Sello and is responsible for implementation.

3.1.3 Interventions in Kera

The interventions in Kera makes it a testbed for locally adapted PED solutions. Already in previous and concurrent projects, the local district heating operator has made a decision to invest in a district-level low-temperature network, operating via an industrial-grade air-to-water heat pump solution. This solution is planned to provide more heat than is consumed within the area, thus providing an opportunity to transfer heat to the larger grid and serve as a basis for Kera to become a PED.

In the energy sector, solutions such as demand side management and prosumer support require additional enhancements from the ICT sector, providing opportunities to assess technologies such as blockchain and 5G within the field. Energy communities could be established to collaborate with peers and improve self-consumption. New business models provide new opportunities to gain value from the market and provide value to locals within the district. The Espoo 3D city model can be used to assess city blocks and districts from the viewpoint of PED planning. The SPARCS actions under this intervention demonstrate city planning tools and study the feasibility of solutions within Kera to facilitate an innovative and citizen-centred approach to developing the Kera energy system.

The city planning function is a combined effort by different city departments. For key development areas such as Kera, the city assigns a project manager to oversee the area's development, including city planning, stakeholder engagement and the various city projects active in the district. These projects include SPARCS, the 'Clean and Smart Kera' (including local energy utility companies) (2019-2021) and its continuation project 'Smart and Clean - Collaborative Kera' (2022-2023), 'The Implementation Pathway for Environments that Accelerate Sustainable Growth (KETO)' (2021-2023), and 'A solution path to sustainable growth ecosystems (RAKKE)' projects (2021-2023). Other already completed projects include

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 'Neutral Host Pilot' (2019-2021) and SixCities (the European Regional Development Fund and the European Social Fund) funded projects 'Low-carbon mobility in mobility hubs' (2019-2022) and 'Partnership model for sustainable neighbourhoods (KIEPPI)' (2019-2021).

City planning process and the Espoo 3D city model

PED development requires more comprehensive design and communication by city authorities, facilitated by comprehensive digital tools. One such tool used within the city is the Espoo 3D model, which can aid city planning, and provide new and innovative avenues for assessing PED solutions.

Within SPARCS, the City of Espoo will facilitate communication with city architects and zoning personnel to understand and document the role of the 3D city model in Kera planning. In addition, VTT will support in identifying technologies relevant to PED development leveraging experiences from similar Lighthouse projects. Using a city block in Espoonlahti as a simulation pilot, VTT will disseminate their learnings to the city at large, and thus give an insight on how the 3D model can aid in PED planning within Kera as well.

The above activities will enable a draft process to mainstream 3D city model support in PED development in Espoo and mainstreamed integration of PED considerations in the early stages of city planning. This will reduce costs and improve the effectiveness of energy efficiency and distributed energy generation measures in district development activities.

Co-creation model for sustainable and smart urban areas - Case Kera

Kera is developed in a close collaboration between the local landowners, companies, organizations, research institutions and residents. In SPARCS, this collaborative approach to urban development is taken further in the PED theme, and a 'co-creation model for sustainable and smart urban areas' is developed through a co-creation process involving different local stakeholders.

The model aims to provide insight to how sustainable and smart urban solutions could be incorporated to the development processes of urban areas and districts. The model, stemming from the PED thinking, treats urban areas as systems where different components of the area affect the whole in a reciprocal manner. The learnings from the Kera area development have been used as a key ingredient to formulate the model, and the model can support the further development of the Kera area, especially in the area's upcoming construction and detailed planning phases. The model is also generalized to be applicable in urban development processes in any city and for any area (from a small area to a full urban district).

The model focuses, in specific, on questions related to energy and mobility, and how new sustainable and smart urban solutions can be incorporated to the planning and development of an area. The model provides practical methods, tools and steps for bringing different stakeholders together, for creating a shared vision for the area (related to sustainable development), for defining roles and responsibilities between the stakeholders, for deciding on the operational and practical working modes (e.g., utilization of the 'alliance model' for construction), and for realizing the projects.

On-site technical solutions and business models

This activity will identify emerging and established clean energy solutions relevant to Kera, comprising technology, business models and citizen engagement, as well as assess technology readiness, cost-efficiency, required stakeholder engagement, policy implications and replicability. EU directives have introduced Energy communities, and this activity will result in prosumer models based on new national legislation. Financial and climate impact of

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

bidirectional electricity and DH grids will be assessed, and guidelines to enhance the uptake of solutions in collaboration with relevant city departments, communities and technology suppliers will be developed.

Also, ESP will map technical, economic and regulatory barriers in piloting innovative PED solutions and identify opportunities offered by energy community legislation and new cost-efficient renewable energy generation and distribution technologies. New business models for generation, aggregation, storage and distribution will be assessed. Reports for all of these activities have been written and released, and the most beneficial learnings from these processes will be disseminated between city departments and to further stakeholders.

These activities will result in pilot guidelines for the development of the Kera energy system, with a focus on solutions within the power sector. These guidelines will be known as the Kera energy playbook.

E-mobility in Kera

Kera is planned to be a new pedestrian, bicycle, shared mobility and public transportation oriented urban district, with dedicated parking facilities. An existing and actively operated commuter train station is located in the heart of the Kera district. The station will form a major mobility hub for the area, combining walking and bicycle trips to shared mobility services and rail-based public transportation.

The redevelopment of Kera area provides a unique opportunity to redevelop an existing station area by utilizing the learnings from the Lippulaiva and Sello activities from the project focusing on local e-mobility hub development. The main goal is to examine how these new technological and practice-related solutions developed in Leppävaara and Espoonlahti could be incorporated already to the planning and design phase of a completely ‘new’ urban district and help to create an active e-mobility hub in Kera both during and after the main redevelopment and construction phase of the area.

Activities on the e-mobility hub development include the close follow-up of the Leppävaara and Espoonlahti demonstrations and contextualizing them into the Kera and general planning development phase. This work has been carried out through working groups with local stakeholders, thematic reports, and workshops.

3.2 Leipzig

Leipzig has a long history as an energy metropolis; since 1990, the use of renewable energies such as wind turbines and solar parks has steadily increased. The businesses and research centres in the Energy & Environment Cluster are becoming a major growth driver for Leipzig’s economy. The City of Leipzig has also been participating in the European Energy Award (EEA) Benchmarking System since 2009. In 2011 Leipzig received its first certification and received the Gold Certification in 2017. For short- and mid-term planning, the City of Leipzig revised its Integrated Urban Development Concept (INSEK) 2030 which came into force in 2018 and puts sustainable growth front and centre. The City of Leipzig is not only member of the German Climate Alliance and committed to fulfil its objectives, but recently also joined EU Mission “100 climate neutral and smart cities until 2030”. As defined in the current city strategies, it is Leipzig’s goal to become carbon-neutral latest by the year 2040. To fulfil this goal, the SECAP from 2014 (Energie- und Klimaschutzprogramm 2014) and the “CO2 Immediate Action Program” from 2019 have been updated by a new SECAP. The new SECAP covers the years 2022-30, complemented by biannual realisation programmes (the recent being 2023-24). The SECAP contains a set of necessary measures with priorities to be implemented

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

by the municipality, public transport association or municipality utilities. A new climate city contract for the EU Mission “100 cities” aims at committing external actors to climate action. The Climate Protection Unit together with the Digital City Unit currently work on the respective involvement process. The challenge of SPARCs is to support the development of a long-term vision for 2040/2030 with the aim of enhancing self-consumption of RES produced within the city boundaries and virtually connecting all participating generating, storing and consuming entities in order to balance energy consumption & production and enable new services for reducing CO2 emissions.

There are three demonstration districts: the former industrial site (Baumwollspinnerei, a historic cotton mill), the area of the Duncker-Neighbourhood (Duncker-Viertel, that includes (social) housing from the 1960ies till 1980 and newly constructed social housing and a kindergarten) together with a solar thermal plant, and a Virtual Positive Energy community. The first two districts have defined physical boundaries, while the third has not, but virtually connect generating, storing and consuming entities. Generation and storage assets physically located in the first two districts can also contribute to the energy flows of the Virtual Positive Energy community accordingly with the contracted share of energy.

The activities in the three demo-sites can be clustered in different interventions.

3.2.1 Interventions at Baumwollspinnerei

Premises of the Baumwollspinnerei (former cotton mill), originally constructed in 1884, are protected by the heritage protection act. The buildings are mainly built with bricks and partly renovated. The buildings demo area is about 17000 m2. The area is a best-practice example for the revitalisation of a former industrial site used for cultural activities and including a StartUpLab („from cotton to culture “). Start-ups and artists have been based here ever since the Baumwollspinnerei was reopened in its current form. The next step is to develop a positive smart energy district with flexible & intelligent heat and electricity management combined with an e-mobility hub.

The actions on the Baumwollspinnerei premises include intelligent heating demand control, integration of RES in the local micro grid electricity grid and bidirectional charging for electric vehicles, using their storage capacity as a buffer.

The aim of this demo is to address: 1) the technical integration of additional RES and power energy storages into the district network (e.g. the type and mix of second-life battery accumulators); 2) bidirectional energy management (intelligent multi-use) involving cooperation between local Microgrid and public network; and commercialisation of the district power system including the network, power generation assets and storages (e.g. the design of equitable energy tariffs and supporting policies).

Intelligent EV charging and storage

This intervention will demonstrate the bi-directional charging for micro grid stabilisation. Within this context CENERO implemented a test setup which includes a charging station and an electric vehicle prototype with the function of bidirectional charging, as well as a local battery storage system. For renewable energy generation a 71kWp photovoltaic plant was installed on the roof of a hall nearby building No. 14 at the Spinnerei. The electrical car will be used as an additional battery during times of excess electricity production as it will be fully loaded and during times of low production, the energy can then be fed back into the electricity grid to aid in peak shaving and load management.

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

Micro grid inside the public grid

This demonstrates solutions for energy positive blocks and districts that operate as an active part of the city's whole energy system, including RES integration, solutions for integration of RES (for example solar photovoltaic (PV) panels) in an existing district heating network and in a virtual power plant. As previously mentioned, a 71kWp PV plant has been installed at the Baumwollspinnerei and will in combination with an electrical battery in building No. 18 be used to increase the percentage of renewable energy in the network. There will also be sensors and controlling equipment installed, to ensure user demand control. There is a combined heat and power (CHP) unit already in the network and it will also be used in the intelligent balancing of the energy network.

LSW is going to develop a citywide virtual power plant. A Virtual Power Plant consists of a group or network of decentralised energy generation technologies such as solar PV panels connected to flexible power consumers and energy storage. One part of this system is an interconnection to the energy microgrid at Baumwollspinnerei to buy and sell energy.

CEN will install energy monitoring at the transformation station near Baumwollspinnerei to measure how the energy flow between Baumwollspinnerei and the Leipzig citywide energy grid is.

LSW will establish a continuous exchange of information regarding extra energy supply or demand and prices for this energy and will process and bill these transactions. In order to achieve the effective balancing of the microgrid against the VPP in Leipzig, energy storage solutions are needed. This means installing an electrical battery which can be used as a buffer to store energy, for example from Photovoltaics, when overproduced and from CHP, when the price of electricity is low. The batteries will be used to cover the energy demand during high peak demand periods, allowing the CHP to feed electricity to the city network. During days with high solar irradiance PV energy will be fed into the grid when not needed in the microgrid.

Heating and demand control

The aim of this intervention is to significantly improve the overall energy performance and energy efficiency of building No. 14, as well as optimise energy consumption by installing innovative new technologies in energy management and RES integration. The main task is the installation of smart equipment which will be capable of reacting to the changing heating needs of building No. 14 and forecast the future needs of the tenants to ensure that energy waste is minimised and that the microgrid can adapt to the changing needs over the seasons proactively with the help of the building itself as a heat buffer. This means that the supply of energy is always matched to the heating needs of the tenant spaces. This helps to save energy in comparison to standard heating systems with standard settings, where for example the supply is orientated to the external temperatures of the heated area. In the demonstration building No. 14, there will be an online application available to the included tenants to allow them direct access to the information received by the sensors installed (Action L3-1). The information will include the current temperature of the building, the amount of energy consumed over various timescales, and air quality. The tablets will be used for the tenants to react to the information by giving feedback through the tablet.

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

3.2.2 Interventions in Leipzig-West district

The district of Leipzig-West combines the Duncker-Neighbourhood and the solar thermal plant in Leipzig-Lausen.

The Duncker neighbourhood is located in Leipzig West, in proximity to the Baumwollspinnerei. With its active and involved tenants, the neighbourhoods are the ideal testing ground for the proposed user centric control, by means of a dedicated platform for an active involvement of citizens, in order to optimize energy flows.

Within the neighbourhood, there are seven buildings with 290 apartments owned by LWB, which are supplied by district heating. These buildings will be our demonstration area. All apartments will be equipped with net (smart) metering technology for thermal energy. Within the district, a novel solution for optimizing thermal energy consumption through the implementation of human-centric thermal demand response programs (implicit demand response) operated by WSL will be demonstrated. Important for social housing is the optimization of the utilities and therefore WSL will implement a dynamic thermal heating controller, which optimizes the heat production with the information of the real thermal need of the building (demand-centric).

In addition, the heat generation of the solar plant will be examined and compared (LSW) to the heat consumption of the demonstration buildings in a time-resolved manner with regard to the possibility of different tariffs from a district heating supplier.

The aim of this task is to properly configure and deploy a novel solution for optimizing thermal energy consumption through the implementation of novel human-centric thermal demand response programmes (implicit demand response) in selected residential building blocks operated by WSL. These housing blocks include social housing flats, which are available to low- or no-income tenants.

Personalized informative billing

This intervention will focus combing data/information from multiple sources and present it to residents in a personalised manner. It will provide an overview of thermal consumption, annual billing information, and environmental impact per apartment, visualisation of historical energy consumption data, billing and environmental impact, display a distribution of thermal consumption between rooms, apartment and room specific information, such as temperature, humidity, etc. These measurements will be made through different instruments and sensors.

Human-Centric energy management and control decision support

Human-Centric Energy Management and Control Decision Support: SPARCs will focus on the definition of detailed and accurate comfort profiles, which will comprise the basis for the subsequent definition of context-aware thermal demand flexibility profiles. Such holistic flexibility profiles will comprise the basis for human-centric optimization recommendations to be offered to consumers, thus providing targeted guidance on control actions (to be performed manually) for shedding or shifting the operation of thermal loads within buildings, towards significantly reducing energy costs, while safeguarding indoor environment quality (IEQ) and without compromising building occupants' comfort.

Decarbonisation of district heating

As a part of the transformation of the heat market it is planned to increase the share of heat from solar thermal plants up to 32 GWh/a. As a first stage of expansion, it is planned to construct a solar thermal plant, which generates about 13 GWh heat per anno. In the second stage this will

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

extend to 25 GWh/a. The location of the plant will be in the district Lausen. The remaining 7 GWh/a need to build at a different location (or several locations), in separate extension stages, due to limited space in Lausen. Demonstration activities about the integration of solar thermal plant and of heat storage solutions) into district heating network are considered under this district, while the ICT development for energy community and the active energy management of the produced energy under the Virtual Positive Energy community demo district.

Heat storage (P2H)

LSW plans to build a Power2Heat plant as well as a heat storage system in parallel to the planning and construction of the solar thermal plant. The Power2Heat plant will be realized by the same project team tasked with the construction of the solar thermal plant. The aim of the heat storage is to improve the flexibility and efficiency of heat generation throughout the district heating network. It will help to stabilize the solar heat output into the heating network as well as make solar heat available in times of little or no solar radiation. A Power2Heat solution will also be implemented into the district heating network to utilize excess solar energy from the electricity grid.

ICT integration

LSW operates the district heating grid at elevated temperatures, depending on the season, above the boiling point of water. Therefore, to increase the degree of utilization and efficiency of the CHP Combined Heat & Power plants in the grid a pressurized hot water storage system was constructed in the recent past.

To increase the heat storage capacity, a new hot water storage tank will be constructed together with a new CHP plant. To facilitate elevated water temperatures without boiling, an insulated layer in two zones divides the tank. The cooler top zone increases the pressure in the bottom zone, enabling temperatures above boiling point.

The heat storage system will be located in the south of the city, at a different location than the existing heat storage. The system will be integrated in the district heating grid and can therefore be used by all heat generation plants of LSW. The demonstration activities (solar thermal plant, P2H and heat storage) are linked with the Virtual Positive Energy community interventions, as the optimal control of the various energy systems is part of a bigger scale vision that the city has connected primarily to consumer behaviours. That will allow for more efficient controlling of the district heating network.

3.2.3 Interventions in Virtual positive energy community

The main aim of the intervention is to upgrade the interaction between energy producing, storing and consuming entities. From the current level based on energy network status (district heating and city medium/voltage electrical grid) to a virtual connected community where these entities can exchange energy based on advanced control functionalities and dedicated communication channels (ICT model, blockchain infrastructure and prediction of the demand).

It is important to note hereby that “Virtual Positive Energy community’’ does not refer to the conventional understanding of the physical block of densely located group of buildings in a sub-urban area but rather to the variety of energy related actions virtually connecting the multiple buildings across the district on various locations. The implemented solutions bundle up a multitude of actions that will be partly integrated and implemented in “Leipzig West” as well as across other buildings within and across the city.

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

Implementation and installation of an open standard based ICT platform ("L-Box")

This action is the digital foundation of Leipzig's part of SPARCS project. Here LSW delivers all prerequisites for peer-to-peer energy trading, energy communities, a citywide decentralized virtual power plant and the link of heat and power sector. In L9-1 LSW deals with all three demo districts. LSW sets up a link to a microgrid at Baumwollspinnerei (realized by CEN). LSW interacts with the solar thermal power plant for the heat demand and the district in "Leipzig West" and LSW integrates solar power from WSL to the citywide virtual power plant. Together with consumption data, LSW can then balance the energy consumption and generation with respect to ecological and economical restrictions and goals. LSW will work on basis of (almost) real time data and continuously. Therefore, LSW has to implement some real time forecasting and optimization methods.

The integration of an energy storage in this local energy structure will be simulated and LSW aims to demonstrate that the ecological and economic efficiency of the energy supply can be further increased.

The citywide virtual power plant is an important part of Stadtwerke Leipzig's Digital Platform ("Digital Platform"). Here LSW stores all data related to asset telemetry and offers micro services for ETL as well as performs analysis of jobs running (and numerous other things).

To give a deeper insight into the work, LSW wants to give a short description. For each asset type, LSW needs to realize a prototype to proof its availability to connect with Digital Platform. LSW uses its own hardware, called L.Box, for data sourcing and thus has to find a way to connect the L.Box to this controller of the asset or the meter etc. When this is done, LSW can rollout the solution to connect all assets of the same kind. The data transmission is standardized; LSW uses MQTT and HTTPS and stores the telemetry data in a time series database. Once LSW has the data, LSW has to clean it up, meaning: fill out gaps, cut spikes, and calculate mean values, to have a sound basis for data analysis. Only on this basis, LSW can forecast and optimize the system. LSW assumes that for each kind of data LSW must find a new way to pre-process it (values in watt behave in a different way as in hertz).

Economically reasonable integration of open and standardized sensors and systems

In Leipzig West, the project partners plan to realize a smart district. That means collecting data, using the IoT device of Leipziger Stadtwerke (L.Box) for assets of energy consumption and generation. For some other kind of data, this hardware is not useful (e.g., waste disposal, car parking spot sensors, weather data).

Planning to build up a LoRaWAN net in the district of Leipzig West and collect data, which is needed for some municipal use cases (waste disposal, public parking spots or air quality) and energy related use cases (measure weather data, such as air humidity, radiation). On basis of this data, it is possible to design models for forecasting air quality and energy usage or generation or set up other smart services, for example parking spot management for third parties.

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

LSW intends to develop an innovative solution "zero carbon community" (externally controlled power outlet) that enables customers to actively participate in the energy market. It would be necessary to install the solution in the housing units. One goal of the solution is, that the user can increase the share of RES for their energy consumption. During the project time, LSW

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

plans to test and modify the solution according to customer's needs. WSL/LWB supports LSW in the selection of possible customers in their housing units.

Implementation of a human-centric interface/application

The aim of this task is to develop and deploy universal behavioural change framework focusing on the discovery, quantification and revelation of energy-hungry behaviours of residential electricity consumers, aiming to convey meaningful energy-use feedback to occupants and engage them into a continuous process of learning and improvement. It will follow a stepped approach to reveal energy patterns and reshape sustainable energy efficient behaviours by utilizing extrinsic and intrinsic motivation means. Energy will be conserved through the progressive improvement of user behaviours.

The planned application will enable:

- Providing an overview of consumption, billing, and environmental impact per apartment.
- Visualisation of historical energy consumption data, billing and environmental impact.
- Based on metering equipment to be made available, display a distribution of consumption between appliances.
- Based on the sensors to be made available, apartment and room specific information, such as temperature, humidity, luminance, etc.
- Providing super user capabilities to the building manager, for aggregated building information and overview.

Visual metaphors and constructs/ dashboards for energy footprint analysis

Demonstration of Energy Behavioural Profiles, revealing the energy related aspects of behavioural profiles and allowing for self-evaluation and normative comparison of energy behavioural patterns. Such visual metaphors and constructs/dashboards will enable the energy footprint analysis to identify energy wastes and possible actions that can bring sizeable energy savings.

The application to be developed will allow:

- Comparison of consumption with similar peers (neighbours, best/average/worst consumers, etc.) to motivate a change towards lower consumption.
- Visualisation of the current performance vs. similar peers via a ranking.
- Check of historical performance and rankings achieved.
- Providing super user capabilities to the building manager, for aggregated building information and overview related to ranking achieved per peer group.
- Further actions within the Virtual Positive Energy Community include the evaluation of the potential of Blockchain.

Conceptualization and application of a public Blockchain for transactions between energy consumers, producers, service providers and grid system operators in a microgrid

It will be demonstrated how blockchain technology helps to tackle the core challenge when it comes to energy distribution: the integration of millions of small-scale distributed energy resources in an energy system that is currently not designed for having a large amount of individual market participants. Focus of the demonstration activity will therefore be on the conceptualization and application of a public blockchain for transactions between energy consumers, producers, service providers and grid system operators in a microgrid. Stadtwerke Leipzig decided to build up a Digital Platform (see Action L9-1) based on decentralized IoT

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

devices. These devices provide the LSW with the capability to make any existing asset "smart", that means being able to communicate with the community and know their state at any time.

In smart cities, many smart assets- in the energy grid have to be balanced in an optimal way. It means dealing with very big amount of information from all devices simultaneously and finding a way to balance the grid. Blockchain technology can help doing it, because it gives one the opportunity to securely share and store information with all partners (or in this case) assets.

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

This intervention takes on the task of understanding and predicting the behaviour of energy system participants. The reliable integration of the planned "community energy storage" (CES) and "community demand response" (CDR) represent possible business cases for a successful system transformation at the municipal level. The mathematical optimization model, as a mixed-integer linear programming, will allow a policy-oriented, technology-based, and actor-related assessment of varying energy system conditions in general, and innovative business models in particular. The integrated multi-modal approach is based on a novel six layer-modelling framework, which builds on existing high-resolution modelling building blocks.

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

4. SPARCS ICT ECOSYSTEM

The role of the SPARCS ICT Ecosystem (Figure 1) is to securely access data from different open and proprietary data sources and files from the distributed systems of SPARCS lighthouse and fellow cities, to map these onto a common information model, analyse them, and to visualise the information using the SPARCS Data Visualisations Framework. This will allow for visualisation of city data, city KPIs, and furthermore offer comparative city visualisations.

This section introduces the SPARCS ICT Ecosystem and its two main components: SPARCS Data Management Platform, and SPARCS Data Visualisations Framework. Interaction mechanisms, key services, and tangible outputs are highlighted.

4.1 Overview

According to ISO/IEC 2382:2015 interoperability is defined as the 'capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units' (ISO/IEC 2382, 2015). Consequently, it can be concluded that interoperability within SPARCS project, refers to the data exchanges and usage of the project's data between the various city/district systems developed for data capturing, management and decision making, enabling the successful transformation to PEDs.

Interoperability among the various existing city systems is a core requirement towards a smart city transformation. When cities support an open approach, its various systems will be also able to seamlessly work together in an integrated way and increase their overall collective power towards the fulfilment of their smart objectives. Such an event will enable smooth data exchanges at any level of a city's urban infrastructure, which in turn can be correlated to optimise various aspects of its existing infrastructure. As a result, the need for an interoperable data management "infrastructure" is emerged. Such an "infrastructure" should be capable of integrating data from diverse sources and of various interfaces, organizing the data storage and processing the data in an efficient manner, thus enabling interoperability and interconnection. Moreover, such a solution should deploy appropriate access policies mechanisms to ensure security and privacy (GDPR) is met; while stopping any illegitimate data exchanges.

Under this context, the SPARCS ICT Ecosystem is introduced (see *Figure 2*), which will be responsible for the processing and managing of the data coming from the various distributed information systems of the Lighthouse and Fellow cities; enabling finally the refinement and consumption of these data and information. The two main components forming the SPARCS ICT Ecosystem (i.e., the SPARCS Data Management Platform and the SPARCS Data Visualisations Framework) each one designed with a distinct role, a distinct scope and a distinct set of core functionalities which are described in the following paragraphs, providing also the envisioned input/output connections and parameters.

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

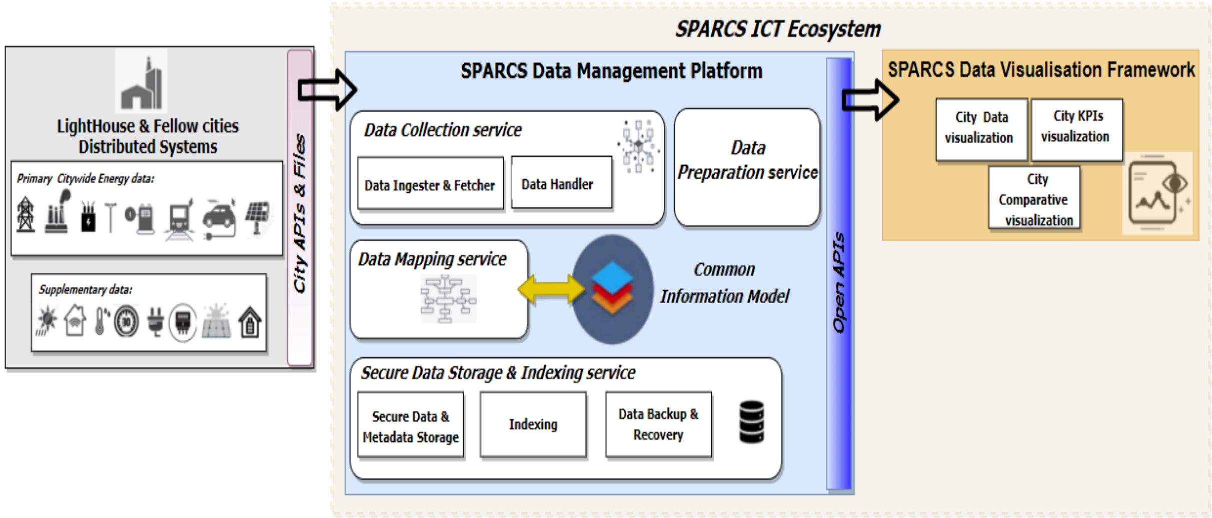

Figure 2 SPARCS ICT Ecosystem: High-Level architecture

4.2 SPARCS Data Management Platform

The **SPARCS Data Management Platform** (comprising the foundation of the SPARCS ICT Architecture) will support the seamless sharing of information and functions to the city's stakeholders and targeting at the realization of the SPARCS objectives. The main responsibility of the SPARCS Data Management Platform will be the collection and management of all types of data coming from the various sensors, submeters and energy components of the distributed information systems deployed in the Lighthouse and Fellow cities. Towards supporting standard interfacing with the platform, it will offer various ways of ingestion for the various types of data coming from the cities, such as file uploading, acquisition through the cities' local management systems, APIs, etc. Through its provided services the developed platform will facilitate the mapping of the various data elements to the concepts of a Common Information Model to enable the interoperability and homogeneity of the ingested data and it will finally store the data in its secure data storage space. The Data Management Platform will consist of different services and components that will perform the different necessary data management processes, so that the collected data can then be utilised for the operations of the SPARCS Data Visualisations Framework, as well as for the evaluation and optimization of cities' strategies and the cities' applications.

Towards enabling access and connection with the SPARCS Data Management Platform an intuitive user interface (UI) will be also provided, offering users a collection of features relating to user actions and usage over the Data Management Platform. In more detail, the provided UI**,** will offer the necessary mechanisms for user registration, authentication, login and analysis of the actions they perform over the different sub-components involved in the SPARCS Data Management Platform, while allowing for the specification of different user roles and groups in the SPARCS Data Management Platform. Moreover, appropriate authorization and access control functionalities for the verification of users' access rights over specific datasets will be provided, enabling the data providers to enforce restrictions on their datasets. This will enable the assignment of specific rights to the different users of the SPARCS Data Management Platform for accessing the data that are stored and are made available through the platform, ensuring in parallel that no data will be accessed by a non-authorized user or user type. Utilising the SPARCS Common Information Model, the Data Mapping service will enable the mapping

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

of the elements of the ingested datasets to the equivalent concepts of the CIM, facilitating in this way further processing of data for analytical and other purposes.

4.2.1 Data Collection Service

The **Data Collection service** is responsible for the timely and successful retrieval of data of different formats and from different sources in the SPARCS Data Management Platform. It allows the import of open data that may come from various external open data sources by providing the necessary mechanisms to connect and retrieve the corresponding datasets based on the provided configuration. Through a user-friendly interface, the Data Collection service enables data providers to select the desired options for the data collection process. The Data Collection service enables collection of data either through uploading of files (e.g., uploading historical data in the SPARCS Data Management Platform) or through Application Programming Interfaces (APIs) that will be offered by the distributed information systems of the Lighthouse cities. Pub/Sub messaging may also be envisaged depending on the specificities of each Lighthouse city. In addition, the Data Collection service undertakes the configuration of quality checks and performs the necessary curation of any erroneous data.

The different functionalities of the Data Collection service are described below:

- ***Data collection process definition through a user-friendly way***: The Data Collection service enables the data providers to configure the data collection process in the desired way through a simple user interface. Data providers are provided with various data configuration options, for example they can select the desired collection options, the retrieval schedule, the authentication specifications and other related details.
- ***Configuration management of data collection process***: The Data Collection service facilitates the creation of a configuration file for each different data collection process, which contains all the data collection details as selected by the data provider. As long as the configuration file is not finalized, the data collection details can be modified freely by the data provider. However, after the finalization of the configuration file only specific details can be updated so that the data collection process is performed in a seamless way.
- ***Data ingestion through file uploading***: The Data Collection service enables uploading of various files formats, such as tabular (e.g., CSV, TSV), non-tabular (e.g. XML, JSON) and other formats. The uploading of data samples of files is also provided, which drives the creation of the configuration files, including the data collection details defined by the data provider.
- ***Data acquisition through APIs***: The Data Collection service enables the collection of data through the APIs that will be offered by the local platforms and legacy systems of the cities by providing a comprehensive interface for the definition of the API details, such as the method, the path and the retrieval settings. Moreover, the already configured API connection is tested and in case of success, sample data are collected. Moreover, the scheduling of data updates through the APIs, is facilitated by configuring the related details (e.g., time rule-based updates, event rule-based updates, etc.).
- ***Management of API authentication details***: The Data Collection service allows the data provider to define the authentication details of an API connection by setting the type of authentication and the related information, such as tokens or credentials. The Data Collection service uses these authentication details to verify the API connection, while saving any sensitive information for future API calls in a secure repository.
- ***Option for storage of specific data:*** The Data Collection service allows the data provider to define during the data collection the desired part of the data sample that s/he would like to be stored in the SPARCS Data Management Platform. In that context, only the

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

chosen data will be further processed, while the rest of them will be rejected and not be stored eventually in the SPARCS Data Management Platform.

- ***Elaboration of data ingestion status messages***: The Data Collection service sends the appropriate feedback messages in order to communicate the status of the data collection processes (e.g., failed API connection due to wrong credentials).]3
- ***Quality checks and cleaning of data***: The Data Collection service offers an intuitive interface that enables the data provider to select the desired validation checks that will discover any erroneous or inconsistent data in an ingested dataset. Subsequently, if any errors are found, the cleaning of the data is performed in order to have curated datasets in the SPARCS Data Management Platform.

Input Connections & Interfaces	It will be connected through various means (APIs, Pub/Sub messaging, etc.) with the cities' management systems
Output Connections & Interfaces:	It will send its output to Data Mapping component.
Input Parameters:	TBC
Output Parameters:	The input parameters will be sent after data collection to the Data Mapping component.
Software Development Language:	Python (TBC)
Communications	• APIs, Pub/Sub messaging, etc. with the distributed information systems of the cities. • Internal APIs with Data Mapping and Data Storage components.

4.2.2 Common Information Model

In the context of the SPARCS Data Management Platform development activities, the SPARCS **Common Information Model** (CIM) will be also developed, in order to semantically model all the necessary information regarding the development, installation, deployment and operation of the SPARCS solution. The SPARCS CIM will act as a common language for all the different datasets that will reside in the Data Management Platform, enhancing their alignment and interoperability.

The datasets that will be gathered from the various distributed information system of the cities by the SPARCS Data Management Platform should be finally stored in an interoperable and standardized way, in order to be available for visualisation purposes. Therefore, the intended Data Management Platform will be based on the design and development of the SPARCS CIM comprising the common language for all the various datasets that will be ingested, pre-processed and stored in the Data Management Platform. The design of the SPARCS CIM will be based on analysis of the datasets provided to the Data Management Platform Overall, while aligning with open data models and standards for smart cities communication and interoperable information exchange. In general, the SPARCS CIM will constitute the cornerstone of the Data Mapping service, since all the elements of the ingested datasets will be mapped against the equivalent concepts and attributes of the CIM, thus enabling homogeneous data forms to be stored in the SPARCS Data Management Platform.

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

4.2.3 Data Mapping Service

The **Data Mapping service** is responsible for the mapping of the elements of the collected datasets to the equivalent concepts of the SPARCS CIM, thus enabling the elaboration of interoperable, homogeneous and consistent datasets that can be easily understood by the various SPARCS users and utilized for further analytical processes towards producing meaningful outcomes. As previously mentioned, the SPARCS CIM will be developed by analysing and extracting the different entities from the various datasets coming from the various distributed information systems of the cities and will be updated, as long as new elements are needed to be mapped. The overall functionalities that will be offered by the Data Mapping service are described below:

- ***Exploitation of various matching techniques for automated mapping predictions:*** The Data Mapping service as its name entails, maps the data elements of the various ingested dataset to the related concepts of the SPARCS Common Information Model. The automated mapping predictions are executed using a series of fuzzy matching techniques.
- ***Manual configuration of proposed mapping predictions:*** Through a user-friendly interface the Data Mapping service enables the data provider to check the proposed automated mappings and select whether they should be maintained, updated or deleted. Moreover, any unidentified concepts can be mapped manually (from the data provider) to related concepts of the SPARCS CIM. Additionally, the data types, measurement units and any other data transformations may be specified. At the end of this process, all the final mapping selections are saved in the configuration file.
- ***Spontaneous exploration of the SPARCS CIM:*** The Data Mapping service enables the data providers to explore the SPARCS CIM, view its structure and get deeper understanding of its concepts/attributes; this in turn allows them to choose if any manual mappings are more suitable for the data elements of their dataset.
- ***Life-cycle management of the SPARCS CIM***: The Data Mapping service allows the data providers to propose additions and updates of the data concepts of the SPARCS CIM through an intuitive user interface. All these additions will be handled accordingly by the SPARCS CIM administrator.
- ***Option for storage of specific data:*** The Data Mapping service enables the data providers to specify during the data mapping process which data they would like to store in the SPARCS Data Management Platform. As only the mapped data elements of a dataset to the SPARCS CIM will be further processed, the remaining unmapped elements will be rejected and not stored eventually in the SPARCS Data Management Platform.

Input Connections & Interfaces	It will receive input from the Data Collection component.
Output Connections & Interfaces:	It will send its output to the Data Storage component
Input Parameters:	They will be the output parameters of the Data Collection component
Output Parameters:	The input parameters that will have been mapped to the concepts of the Common Information Model.
Software Development Language:	Python (TBC)
Communications	Internal APIs with the Data Collection and Data Storage components.

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

4.2.4 Data Storage Service

Notably, the lack of a centralised storage location where city-wide are data often distributed across many organisations or kept in private silos with the majority of the information not accessible to all relevant stakeholders, poses one of the most significant challenges faced towards a smart city transformation "journey". Towards addressing this data storage question, the ***Data Storage service*** provided in the context of the SPARCS Data Management Platform is introduced. The main responsibility of the Data Storage service is the storage of the data coming from the various distributed information systems of the Lighthouse and Fellow cities. Once the data collection process is complete and the collected data are mapped to the SPARCS CIM, these will be stored in a secure storage space in the SPARCS Data Management Platform.

For the design of the Data Storage service, a multi-persistence architecture is considered, where several databases are utilised from a single application instance, while the selection of the most appropriate database is tailored to the specific needs and types of data. The Data Storage service will be built on traditional SQL, NoSQL and time-series storage engines, offering increased performance and productivity, also providing data indexing capabilities for increased search performance. The overall functionalities to be provided through the Data Storage service are described below:

- ***Storage of data collection tasks and related configurations:*** The Data Storage service will enable storage of the various properties of the data collection task, along with the corresponding settings of the configuration file generated during the data collection configuration process.
- ***Data perseverance***: The Data Storage service stores the dataset along with the data sample, as soon as the data collection and data mapping process have been completed.
- ***Metadata storage***: The Data Storage service will also enable storage of the dataset's metadata, thus maintaining the necessary relation between the stored data and their corresponding metadata.
- ***Data indexing***: Following the storage of data, the Data Storage service will create the necessary indexes for the stored data, in order to enable faster data searching capability.
- ***Metadata indexing***: Following the storage of metadata, the Data Storage service will create the necessary indexes for the stored metadata in order to optimize metadata searching.
- ***Intermediate data storage***: The Data Storage service will offer a temporary storage space where the intermediate configuration and data files generated during the data collection and data mapping processes are stored, enabling this way the pause and continuation of these processes. This approach enhances the fast resuming of these processes and supports traceability in case the data collection or data mapping process fails.
- ***Secure data storage:*** The Data Storage service will also provide a distinct secure space where the sensitive information of API connections (such as tokens and credentials) will be stored ensuring data privacy and security.

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

Input Connections & Interfaces	It will receive input from the Data Mapping component.
Output Connections & Interfaces:	It will send input to any internal component that needs to further process data, (e.g., Data Visualisations Framework)
Input Parameters:	These will be the output of the Data Mapping component
Output Parameters:	All the data that will have been stored after the data mapping process to the Data Storage component.
Software Development Language:	Python (TBC)
Communications	Internal APIs with the Data Collection and Data Mapping components and any other component that needs data for further processing, (e.g., Data Visualisations Framework)

4.3 SPARCS Data Visualisations Framework

Towards increasing transparency to the wider public and any other interested stakeholder (e.g., City Leaders, Decision Makers, project's partners, etc.), the **SPARCS Data Visualisations framework** is introduced encapsulating the visualisation applications (i.e. dashboards); which will provide end-users with features for creating visual representations of the data managed by the SPARCS Data Management Platform.

The main advantage of a using a dashboard is that it can provide results by aggregating and extracting value from the data provided. Within the context of Smart Cities, dashboards are widely used to visualise various integrated city data, such as energy consumptions, mobility data, energy generation data, etc. delivering a powerful tool that allows a better management and enables decision makers to take wiser decisions. In their research (Brath and Peters 2004), consider dashboards as "cognitive tools that improve the user's span of control over a large repository of voluminous, varied and quickly transitioning data and enable a user to explore the characteristics and structure of datasets and interpret trends without the need for specialist analytics skills simplifying data into more manageable chunks of visual information that allows to see in a single place". In addition, as explicitly stated in the DoA, the SPARCS Data Visualisations framework shall focus on providing an appropriate visualisation environment enabling Lighthouse and Fellow cities to measure the performance of its Positive Energy Districts/Blocks, and in the long term, enable cities to monitor their urban transformation progress and corresponding implementation process of the underlying measures to achieve the city vision.

Under this context, the main scope of the SPARCS Data Visualisations framework (forming part of the SPARCS ICT Ecosystem) is to manage, display and disseminate data from the project's Lighthouse and Fellow cities, providing a virtual tool for disseminating city/district-wide information. Data visualisations will be available for project's use, towards monitoring the project's ongoing progress, cities' performance (through comparison of historic and present data KPIs), but also to be used by the city leaders to track the performance of their planned interventions or used by the partners for any further processing and analysis purposes.

Beyond the specific project's needs, the dashboard(s) aim also to be used by the cities and their citizens, in order to monitor the achievements and the impacts of the planned interventions.

The information visualized through the dashboards can be used by the cities to acquire a better knowledge of the supply/demand energy needs of their citizens and districts; providing an efficient tool for decision support. Moreover, the dashboards to be developed are intended for public usage; having an educating role through the integration and visualisation of various sources of information, will aim to inform the citizens, e.g., by showing their carbon footprint, various energy efficiency indicators, etc. thus motivating them to take environmentally and energy conscious decisions regarding their daily energy needs.

Forming part of the overall SPARCS ICT Ecosystem, the SPARCS Data Visualisations framework provides a decentralised tool able to utilise the data coming directly from the SPARCS Data Management Platform. In more detail, the ***Data Preparation service*** (forming part of the SPARCS data Management Platform) will be responsible for identifying and formulating the various elements/data that can be linked towards communicating information provided through the various data sources while enabling access, reporting and visualisation of these data to the authorised users.

A flexible and adaptable Data Visualisations framework is being created, able to handle and visualize various types of KPIs, while being capable to accommodate any future adjustments that may be required during the project's implementation. At the time of writing this document, the data needed per intervention is being ingested into the SPARCS Data Management Platform, to be used as the basis for fine tuning the design of the KPIs and their visualization.

As at the time of writing this document, the nature/types of the KPIs data to be shared and captured in the Data Visualisations framework is not yet finalized, the development of the framework will be made flexible in order to accommodate any future adjustments that may be required during the project's implementation. As a starting point for identifying what data each city utilizes; or will utilise in the future in order to implement the planned interventions; as well as for the evaluation of which data will be available for the KPIs definition and consequently be presented in the dashboard(s), a "Data needs per Interventions" spreadsheet was initially created. This will be circulated among all potential data providers/consumers to identify all the required/foreseen data needs, their granularity (i.e., yearly, monthly, etc.), their type/format (i.e. csv., DB, txt., etc.) and the availability of any historical data. Such information will be also enriched upon discussion and feedback received from the activities performed and the prioritization criteria determined during the city diagnosis phase (T1.1) where a performance measurement system will be developed enabling the calculation and the evaluation of the final KPI's.

Through user-friendly dashboards, designed upon agreement of a common structure by the partners, city/district-specific information will be visualized enabling the monitoring and understanding of city/ district energy level behaviours and urban energy flows that can lead to the achievement of energy savings and realization of PED's.

Overall, the SPARCS Data Visualisations framework will consist of multiple dashboards, or a common dashboard developed as a web-based application presenting to the user the following:

- **City Data visualisations**; will provide visuals of various raw data/metrics deriving from the various sensors/submeters/actuators deployed in the Lighthouse and Fellow cities, enabling near-real time monitoring of the city's performance and identifying potential energy savings. Utilising such a dashboard, the citizens will be given access to various near-real time information, so as to be informed for example about their city's air pollution, the weather conditions, electricity demand, etc. Such visualisation of city-wide data will provide citizens with city insights, empowering them in their everyday living and decision-making, towards more sustainable choices.
- **City KPIs visualisations**; will aim to capture, manage and visualize KPI related data, in line with the overall structure of the SPARCS Holistic Impact Assessment Methodology and KPIs developed under the activities of T2.2 "Ex-Ante Lighthouse Demo Analysis and

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

Detailed Baselining" and documented in deliverable D2.2 "Definition of SPARCs Holistic Impact Assessment Methodology and Key Performance Indicators - updated version".

The data gathered for each KPI, will be utilised to produce suitable graphs delivering a visual representation of the captured data, while users will be able to apply various filters, selecting the data they require.

Moreover, and towards providing a "learning" content, the dashboard's user interface except from displaying current and historical data enabling the conceptually composition of data towards the presentation of KPIs related to the performance of the project's planned interventions; it will enable users to interact with a variety of data summaries and visualisations presenting the KPI data in a simple and understandable format.

- **City Comparative visualisations**; will enable a direct comparison between user-selected metrics related to the performance of the Lighthouse and Fellow cities. The overall scope of this dashboard is to inform users (such as decision makers) of their city's ranking against top-performing cities or of similar status. By presenting specific metrics of multiple cities one next to each other, it will provide the means for the users, to compare their city's dynamics, identify differences and similarities, as well as areas for improvement.

Input Connections & Interfaces	It will receive input from the Data management Platform.
Output Connections & Interfaces:	As a visualisation application, it will not provide any output to other components.
Input Parameters:	TBC
Output Parameters:	As a visualisation application, it will not provide any output to other components.
Software Development Language:	Vue3 (JavaScript), Apexcharts
Communications	Internal APIs with the Data Management Platform

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

5. REFERENCE ARCHITECTURE FOR INTEROPERABLE ICT PLATFORMS AND INTERFACES FOR POSITIVE ENERGY DISTRICTS

As more and more data sources become available through different heterogenous systems, and the desire to optimise energy demand-supply in buildings, districts, and cities to ensure carbon neutrality in cities increases, there is a need to ensure seamless connection and operability between these solutions to deliver actionable intelligence and value-added services to ensure an urban energy transformation towards positive energy buildings, districts, and cities (Girtelschmid, et al, 2013). This section presents a generic ICT reference architecture (positioning framework) for interoperable ICT platforms and interfaces for PEDs. It supports clearer understanding of the planned ICT-based interventions in the Lighthouse cities and serves as a basis for other cities to better understand, plan and replicate similar interventions.

5.1 Reference Architecture

The need for ICT architecture(s) to support interoperability and integration between heterogenous data formats and legacy systems is not new per se and has been discussed in scientific literature for quite some time (Mamkaitis et al, 2016; Da Silva et al, 2013, Rodríguez-Molina, 2013, Anthopoulus and Fitsilis, 2010). The key stakeholder requirements, ICT platform requirements, city data requirements, and energy data specifications for an ICT platform to support PEDs are described in Section 2 of this document.

The SPARCS reference architecture has been designed to ensure that all SPARCS lighthouse city's (Espoo and Leipzig) identified use cases and intervention actions can be easily understood, realised, and where relevant replicated. This multi-tiered architecture also serves as a basis for the SPARCS ICT Ecosystem (see: Section 4) and supporting applications and services. It serves as a mapping mechanism for identifying the various data sources, applications, etc., when defining, planning and implementing the require lighthouse city interventions in terms of what exists and what needs to be implemented in a simple and yet systemic manner.

The main concept behind the reference architecture is to demonstrate a mechanism to visualise the capture of data from different (distributed) data sources and legacy applications, to use these to build new applications and services, and to then present them to different stakeholders to support value-creation. The reference architecture is composed of three tiers: secure data, communication, and value co-creation. In short, it provides a mechanism to securely access data from multiple sources (open data, legacy applications, etc.), to communicate it using standard communication protocols, and to then enable value co-creation through different applications and visualisation tools. Overall, the reference architecture has eight layers that cover: data storage, services, access control, communication, interoperability, applications, shared services, and interaction (Figure 3).

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

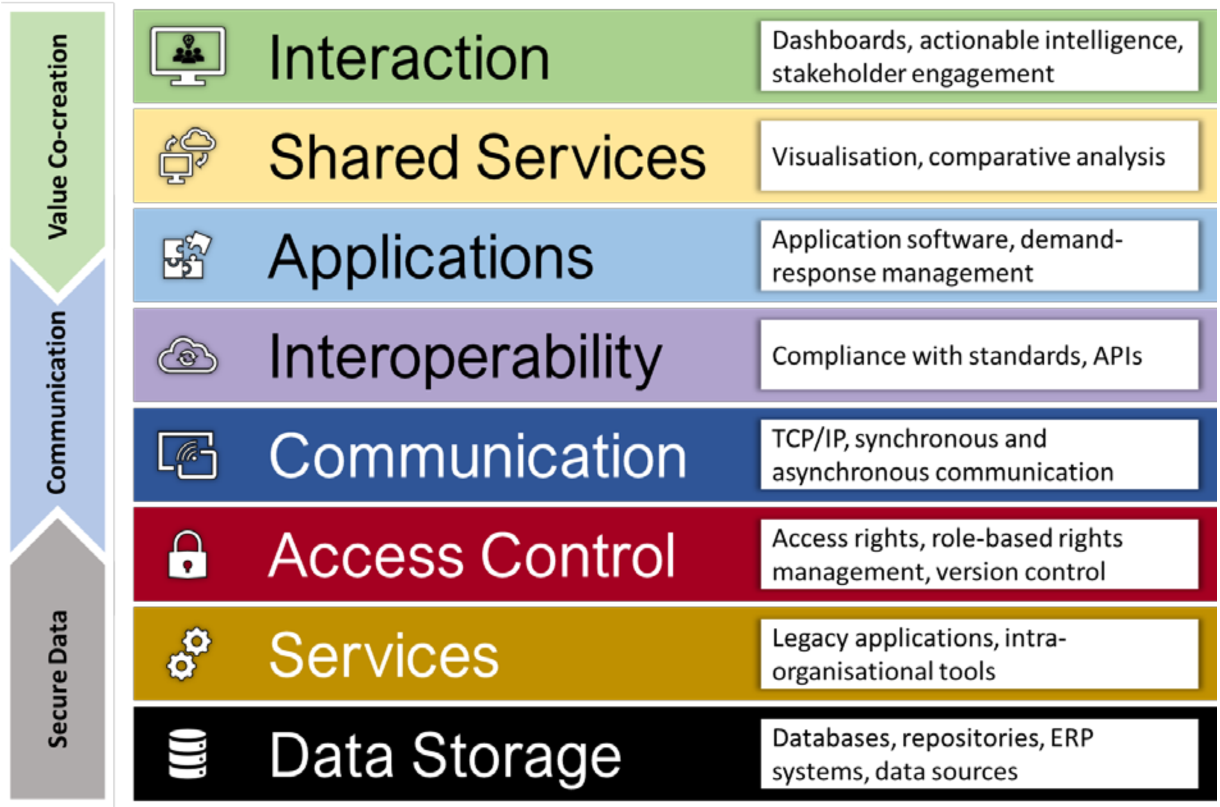

Figure 3: SPARCS ICT Reference Architecture (Positioning Framework)

5.1.1 Secure Data

The first tier of the SPARCS ICT reference architecture (positioning framework) covers access to secure data. It supports secure, role-based access to different legacy applications and corresponding data storage systems.

- ***Data storage:*** This layer may be viewed as the data black-box. It is here that all organisational data bases, repositories, ERP systems, and different data types and sources are stored in a secure environment.
- ***Services:*** The services layer essentially operates on the data from the data storage layer. It includes different types of legacy applications, intra-organisational tools, document management tools, model management tools, workflow management, etc.
- ***Access Control:*** The access control layer manages security hierarchies, access rights, role-based access, version control and other data and application security protocols. It serves as the gatekeeper to any data or information that is made available from an organisation to other entities.

5.1.2 Communication

The second tier of the SPARCS ICT reference architecture (positioning framework) covers communication between different ICT systems (within an organisation, and across organisations) using communication standards and protocols.

- ***Communications:*** This layer enables communications between the ICT systems of an organisation and the shared data/application environment of different entities (e.g., SPARCS data management platform). It relies on different data transfer protocols such

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

as TCP/IP and based on established standard communication protocols and commonly available technologies.
- ***Interoperability:*** The interoperability layer ensures data mapping and translation of application/organisation specific data into a form that is usable by other applications and shared services. APIs, data exchange formats, semantic and syntactic mapping, etc. are part of this layer. As an example, the SPARCS data management platform (Section 4.2)makes use of this layer to provide data mapping services to develop a shared information model.

5.1.3 Value Co-creation

The third tier of the SPARCS ICT reference architecture (positioning framework) covers focuses on value co-creation for different stakeholders. This is where purpose-built applications utilising the accessed data provide a particular application/service (e.g., KPI analytics), which can then be shared in different forms to different stakeholders for informed decision making based on actionable intelligence.

- ***Applications:*** This layer mainly includes different types of purpose-built applications that utilise data from different distributed and heterogeneous sources to deliver a particular application/service (e.g., energy demand-response management).
- ***Shared Services:*** The purpose of the shared services layer is to provide access to and management of shared repositories, applications and services. A good example of this is the SPARCS data visualisations framework (Section 4.3) that visualises different building/district/city level KPIs and provides a mechanism for comparing PED implementation strategies and outcomes in different cities.
- ***Interaction:*** This layer provides the main interaction interfaces for different stakeholders to shared services and applications. Different stakeholder / purpose specific dashboards provide value-added information on whose basis informed decisions/choices may be made. It also provides for stakeholder engagement and interaction.

5.2 Reference Architecture as a Positioning Framework – SPARCS Use Case Mapping

The SPARCS ICT reference architecture serves as a positioning mechanism to easily map different key ICT-related elements of a use case (intervention) in a simple manner to allow for better understanding of the development requirements for delivery of the mapped use case. It furthermore illustrates for others in a visual form what they would need to do in order to define, describe and potentially replicate a similar use case (intervention). Furthermore, it allows clear visual identification of the different systems/components from different providers needed to enable a particular PED solution/intervention.

The role of the SPARCS reference architecture (positioning framework) is best understood through examples demonstrating how a planned intervention can be easily visualised. Three cases from the City of Espoo and two from the City of Leipzig are presented to show this.

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

5.2.1 Espoo Use Cases

Case: Optimisation of the NZEB energy system

The target of the *Optimization of the NZEB energy system* is to achieve Lippulaiva as NZEB with integrated RES and purchased certified renewable electricity with utilizing on-site excess heat, smart control strategies and smart thermal energy storage system. This is done with integrated RES and Virtual Power Plant (electricity contracted via Nord Pool) based on big data and predictive building control strategies.

The heating and cooling demand in Lippulaiva shopping centre is mainly covered with on-site geothermal heat with heat pump (system by Adven). Beside the heat pump system, Lippulaiva has district heating connection and electric boiler for back-up heating system and for peak heat demand. The on-site excess heat is utilized. Electricity demand is covered with PV panels (roof and façade) and certified renewable electricity.

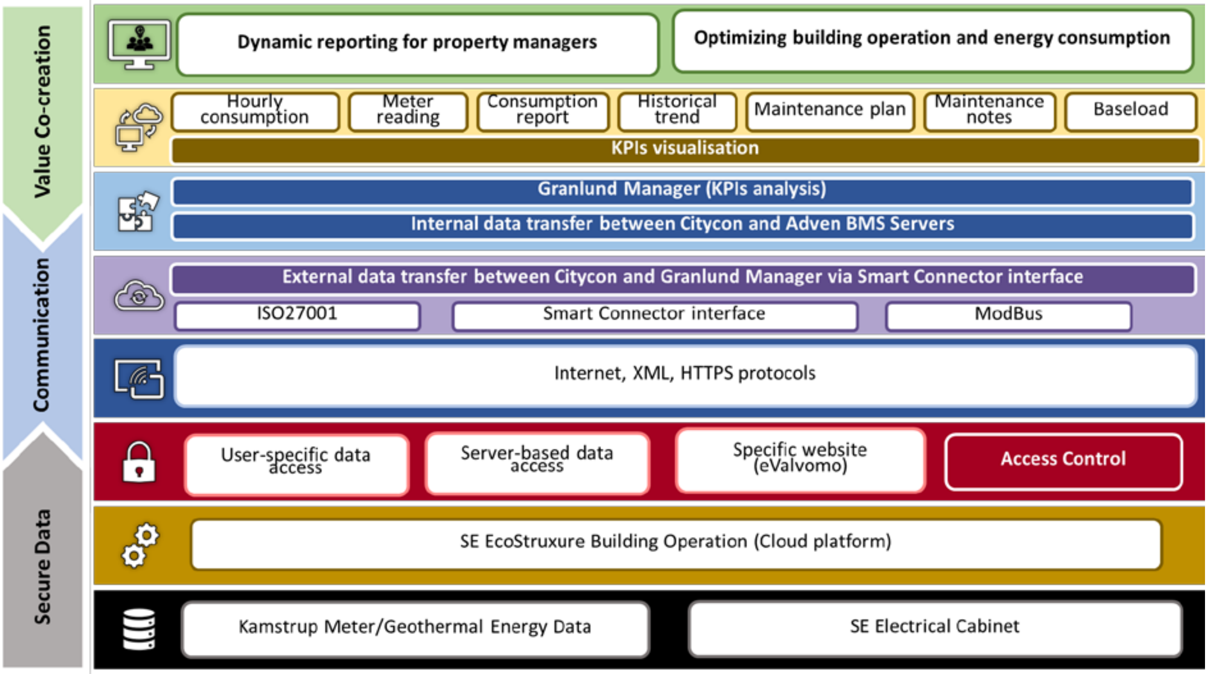

Figure 4: Use Case optimisation of NZEB energy system mapping on to SPARCS reference architecture/positioning framework

Secure Data tier:

- ***Data storage:*** Geothermal energy data is recorded by physical meters provided by Kamstrup. The data then is transferred to Schneider Electric Electrical Cabinet, which is located locally on-site via ModBus system. By using Ethernet-IP, data is uploaded to cloud.
- ***Services:*** Schneider Electric EcoStruxure Building Operation (so called eValvomo) is a cloud platform service that acts like a virtual power plant. Over there, the diagram of the plant is display, together with real-time performance (live data from meters) in order to give a full understanding of the operations.
- ***Access Control:*** Only authorised personnel are given access to eValvomo, and different rights is assigned according to the need of that person. To enter the system, user must go to a specific website, which indicates a specific server to Adven's geothermal plants.

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

Communication tier:

- ***Communications:*** Communication follows standard protocols.
- ***Interoperability:*** The system is built according to ISO27001 security certificate, an international standard to manage information security. From physical meters to enter the virtual control room, ModBus is used. It is an open, widespread and well-established serial communication protocol used within building automation. In addition, Schneider Electric offers Smart Connector as a solution to create bridge between their own Building Management Systems and third-party systems.

Value Co-creation tier:

- ***Applications:*** Because both Adven and Citycon use Schneider Electric Building Managements Systems, internal data transfer between them is done easily. The meter data is logged into a trend, which will help to study long-term behaviour. That similar piece of information continues to flow into Granlund Manager (third-party) for KPIs analysis purpose.
- ***Shared Services:*** Visualisation and analysis is done at Granlund Manager platform. Meter reading and hourly consumption are displayed based on user's selection. Consumption report and historical trend are drafted in both numerical and graphical ways.
- ***Interaction:*** All of the above provide a powerful tool for property managers. With dynamic report, they can start with a ready-to-use, easy-to-understand template to customize reports based on interest of different viewers.

Case: Building Automation Steering System

The aim of this case is to optimize 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 utilization of weather forecasts. Case Lippulaiva act as pilot in this case. Target is to connect building automation to Adven energy production automation to produce energy more efficiently production and minimize expenses and CO_2 emissions.

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

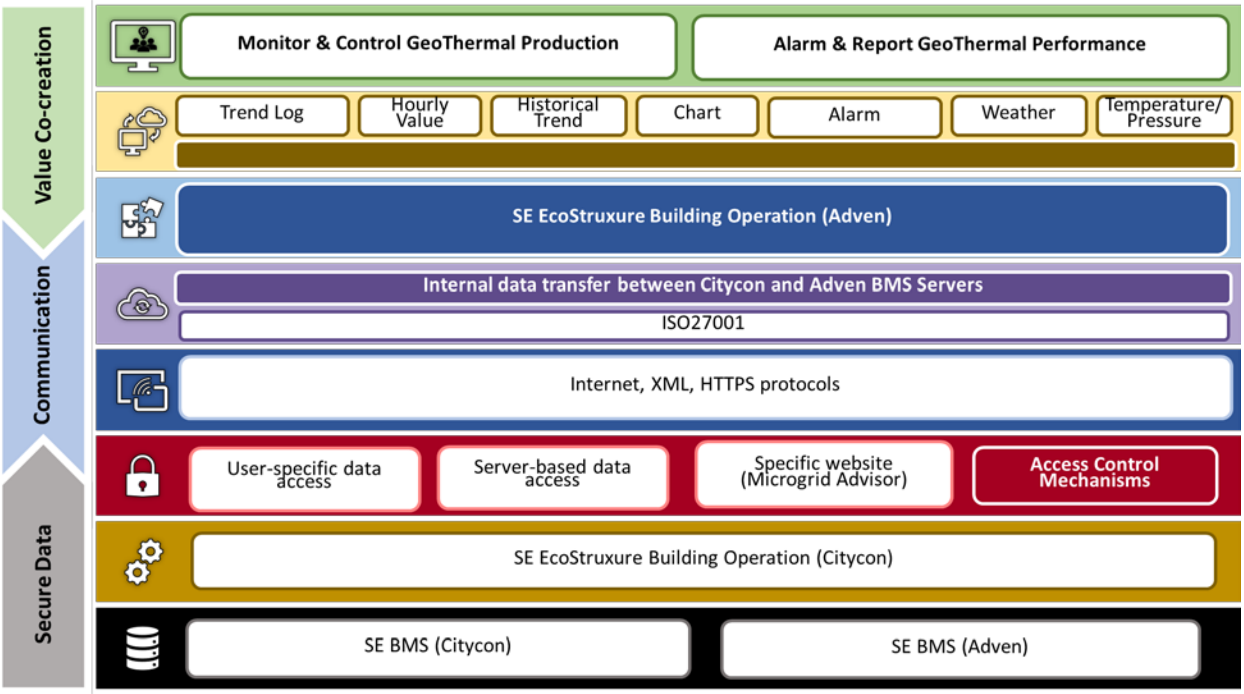

Figure 5: Use Case Building Automation steering system mapping on to SPARCS reference architecture/positioning framework

Secure Data tier:

- ***Data storage:*** Information of Building automation steering system is recorded by Citycon's Building Management System (Schneider Electric). It is then merged together with Geothermal information in Adven's system.
- ***Services:*** Information is presented at Schneider Electric EcoStruxure Building Operation platform.
- ***Access Control:*** Similar to the previous case, the platform is accessed by limited users with rights only enough to serve their needs. Also, a specific website which indicates Citycon's server is given in order to access the platform. In Microgrid Advisor, users can see the Power Flow (HVAC, PV Solar, Lightning, Electric Battery...) as well as Electrical Highlights and Weather info such as temperature, cloud coverage, and wind speed. The overview picture can be display in different time periods (real time, this week, last week, this year etc.).

Communication tier:

- ***Communications:*** Communication follows standard protocols.
- ***Interoperability:*** Internal data transferred is done securely between Citycon and Adven's Building Management Systems following ISO27001 standard.

Value Co-creation tier:

- ***Applications:*** The data of HVAC system ends up at Adven's site, where geothermal energy production information is located.
- ***Shared Services:*** Trend log, hourly value, historical trend as well as chart are available to provide additional insights for energy production. Moreover, instant display of temperature and pressure in the pipes indicates the current status of the geothermal plant, in accordance with the outdoor temperature, which is collected from on-site sensor. Alarms are set to based on concept design and operation experience.

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

- ***Interaction:*** The valuable insights help in the work of monitor and control geothermal production to the optimal level.

Case: Thermal and Battery Storage Prediction

This use included developing thermal prediction model for Sello and how to lower CO2 emissions of local district heating system by enabling Sello to become active part of the energy sector. In this use case Sello provided thermal flexibility and using building as a thermal battery. District Heating flexibility demand were carried out by Siemens platform, which adjusts the required flexibility based on the consumption at the time.

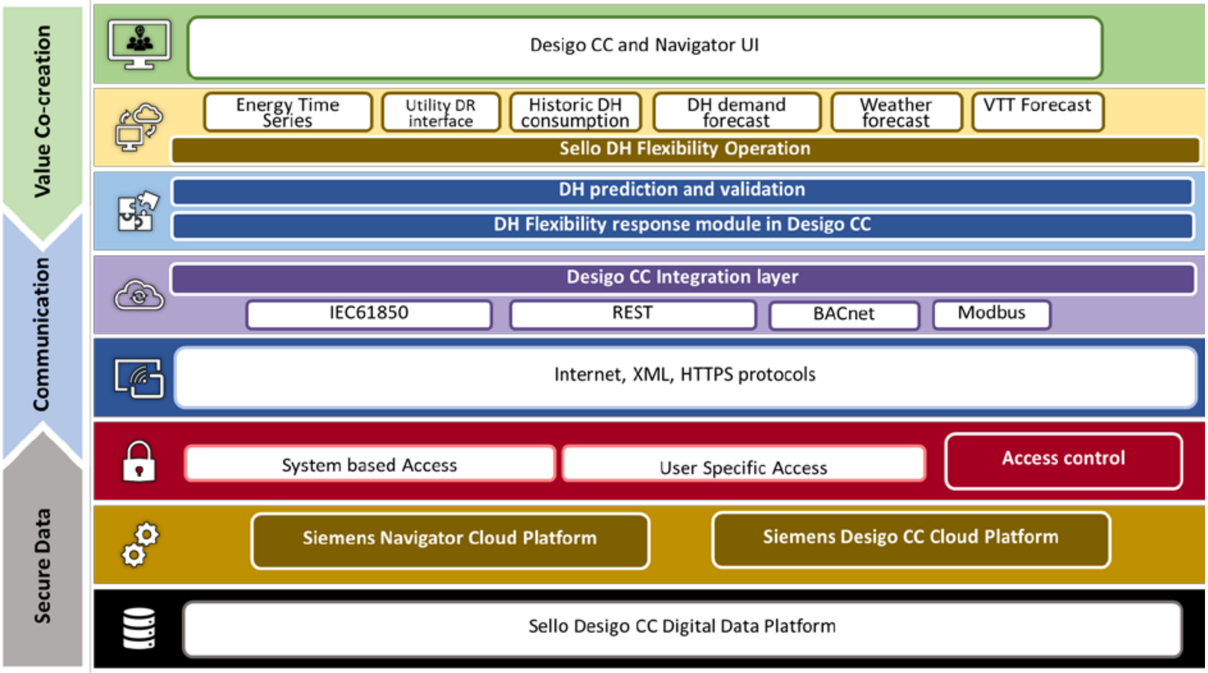

Figure 6: Use Case providing flexibility to district heating network

Secure Data tier:

- ***Data storage:*** Desigo CC in private cloud, acquires data from distributed assets such as energy meters, valves, temperature sensors, PLCs, energy procurement information and stores the data in Desigo CC private cloud server.
- ***Services:*** Desigo CC together with Navigator platform, are used for data quality validation, processing and analysis of the data, improve energy efficiency by tracking consumption patterns and establishing benchmarks and key performance indicators.
- ***Access Control:*** In the Desigo CC and Navigator, access can be prohibited or restricted to part(s) of the installation, applications and event categories based on the roles and responsibilities of the user.

Communication tier:

- ***Communications:*** Communication follows standard protocols.
- ***Interoperability:*** Desigo CC is using RestFul API for communication with District heating network operator. Desigo CC is using BACnet and Modbus for communication with field devices and IEC61850 for power monitoring.

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

Value Co-creation tier:

- ***Applications & Shared Services:*** Real time and historical data from Desigo CC and Navigator are shared with DH utility company and VTT, that use the data for visualization, prediction, and deployment of Sello's flexibility.
- ***Interaction:*** Navigator and Desigo CC user interfaces are used by multiple stakeholders among others Sello's Energy Engineers to verify the flexibility provided, real time and past consumption, deploy machine learning algorithms for fault detection and diagnosis. Control of the flexibility limit set-points and monitoring real time values measured by field devices.

5.2.2 Leipzig Use Cases

Case: Citywide Virtual Power Plant

The power generation assets in Leipzig are designed not only to generate and distribute electricity to meet the energy needs of the city, but also to improve the integration of renewable energy resources. The virtual power plant is a tool to help optimize this attempt. It consists of a variety of distributed assets, many sources of renewable energy, including rooftop photovoltaic plants and cogeneration plants. These assets are connected and controlled through the virtual power plant. In the operation of the virtual power plant, LSW employees monitor the current status of energy demand and supply and trigger incentive programs to align those. The purpose of the virtual power plant is to ensure that Leipzig has a reliable source of electricity and to optimize the use of available energy resources, with a focus on improving the integration of renewable energy into the city's energy mix and most importantly, to enable LSW operators and users to dynamically optimize the energy demand and consumer behaviour in the virtual energy community.

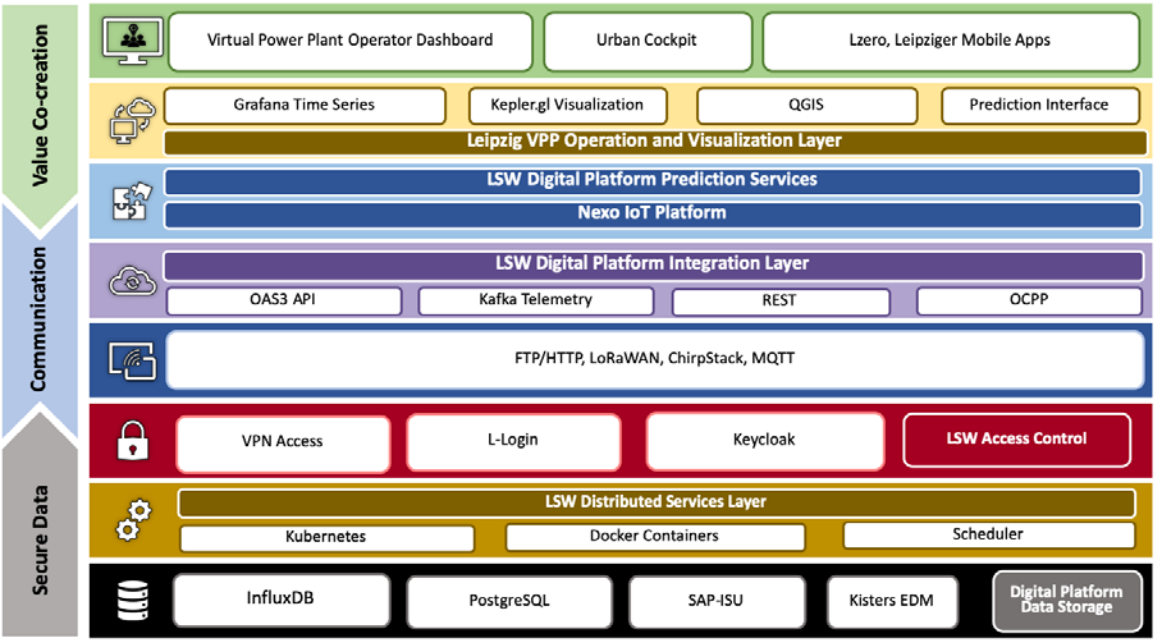

Figure 7: Use Case VPP mapping on to SPARCS reference architecture/positioning framework

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

Secure Data tier:

- ***Data storage:*** The LSW data storage system constitutes a platform that connects distributed assets, such as energy assets, metering devices, sensors, and consumers, and integrates telemetry and master data from these assets. The system uses a combination of SQL, InfluxDB, and Kisters EDM to manage and analyse the data, with SQL being used for managing and organizing data in databases, InfluxDB being used for storing and processing large amounts of time-stamped data, and Kisters EDM being used for managing and analysing master data and integrating data from multiple sources. This system is designed to efficiently manage and analyse data from distributed assets, enabling data-driven decision-making and enabling your company to make informed decisions based on real-time data.
- ***Services:*** LSW uses a distributed system with Kubernetes, Docker containers, and scheduling functions to provide services for the management and analysis of energy-related data. LSW packages their data analysis tools and applications in Docker containers and use Kubernetes to deploy and manage the containers in a distributed system across a cluster of machines. The Kubernetes scheduler can then ensure that the containers are placed on the appropriate machines in the cluster and that the necessary resources are available to the containers to handle the processing and analysis of the energy data. By using a distributed system, LSW can efficiently manage and analyse large amounts of data, enabling them to make informed decisions and provide valuable insights to their customers.
- ***Access Control:*** LSW is utilizing Keycloak and a virtual private network (VPN) to ensure secure access to its critical applications and to manage user identities, roles, and permissions. Keycloak, an open-source identity and access management (IAM) system, allows the company to set up user groups and assign specific permissions to each group, ensuring that only authorized employees are able to access certain applications. The VPN, meanwhile, establishes a secure, encrypted connection between an employee's device and the company's network, allowing them to access company resources as if they were on the internal network. This way, LSW can effectively control access to its critical applications and ensure that they are only controlled by designated employees and users.

Communication tier:

- ***Communications:*** LSW is using the LoRaWAN protocol for communication between IoT devices and a central platform, with MQTT for messaging and ChirpStack for the underlying network infrastructure. LoRaWAN is a wireless communication protocol designed for low-power IoT networks that can transmit data over long distances while consuming minimal power, and ChirpStack is an open-source network server that implements the LoRaWAN protocol and provides the necessary infrastructure to build a complete LoRaWAN network. Together, these technologies enable LSW to establish reliable communication between IoT devices and its digital platform.
- ***Interoperability:*** LSW maximizes interoperability in the communication and coordination of distributed devices, assets, and electric vehicles by using appropriate standards. OCPP is used to manage the electric vehicle's charging stations, REST APIs are used to access data or functionality from the digital platform, OAS3 is used to define the structure and behaviour of the APIs in a standardized format, and Apache Kafka is the foundation to build real-time data pipelines and streaming applications to process

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

and analyse the data. This enables LSW to maintain a connected, flexible, and scalable system for managing and coordination of distributed assets.

Value Co-creation tier:

- ***Applications & Shared Services:*** The digital platform uses a variety of tools and libraries for data visualization, prediction, and deployment, including Grafana for displaying energy time series data, Kepler.gl for visualizing and analysing geospatial traffic information, QGIS for monitoring critical grid infrastructure, PyTorch and Keras for prediction model training, MLFlow and BentoML for packaging of these models and Kubernetes and Kubeflow for deploying them as applications and services in containerized environments.
- ***Interaction:*** The Leipzig virtual powerplant uses a central operator dashboard to monitor and manage a virtual power plant. The dashboard is based on the Nexo Energy IoT platform and LSW digital platform, which integrate distributed devices and assets and allow for the collection of telemetry data. This data is used to monitor the power generation of renewable energy plants, simulate the net-load and enumeration of peer-to-peer energy trading with the Baumwollspinnerei microgrid, and track the storage potential of the BMW battery farm. The operator can also use machine learning services to predict generation, demand, and future events. The dashboard also allows for the control and management of L-Zero smart plugs (and mobile application) for demand response and electric vehicle fleet management, allowing the operator to use data from the grid and spot market to incentivize behaviour changes within the virtual energy community.

<u>Case: Implementation of a human-centric interface/application</u>

This use case focuses on implementation of a human-centric interface/application for end users (apartment/home owners, and building managers) to support information access and visualisation in a systemic way. These are enabled through a series of apps/dashboards that support:

- an overview of consumption, billing, and environmental impact per apartment.
- visualisation of historical energy consumption data, billing and environmental impact.
- use metering equipment to be made available, display a distribution of consumption between appliances.
- based on the sensors to be made available, apartment and room specific information, such as temperature, humidity, luminance, etc.
- super user capabilities to the building manager, for aggregated building information and overview.

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

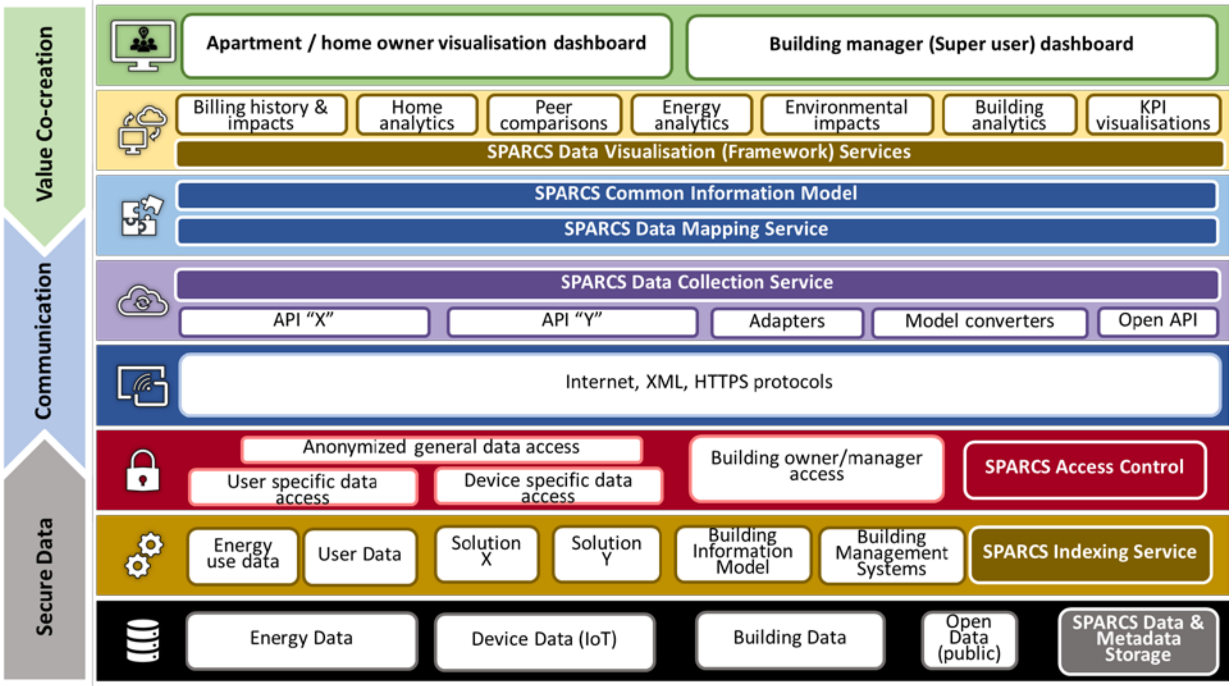

Figure 8: Use case implementation of a human-centric interface/application

Data is stored, and made available for secure access through the **Secure Data** tier:

- ***Data storage:*** This is where data is stored in different databases, ERP systems, and even as files. For this particular use case, this would include energy data (stored in ERP systems of energy providers, device specific IoT data stored on the cloud, building information data stored in a product model server, etc. These are most likely stored at different locations (e.g., ESCO, IoT device providers cloud, building owner systems, etc.) This layer also is where SPARCS data and metadata are stored.
- ***Services:*** There is a need for specific services/interfaces to access data from the different data storages / legacy systems. As an example, a service to extract energy data, the energy data for a specific homeowner, IoT data for a specific device, building information model, buildings management systems, etc. SPARCS makes use of this layer for indexing relevant data.
- ***Access Control:*** Even though data may have been extracted from the storages and legacy systems using different services, there is still a need to securely access this data. Each application / organisation would have its own specific access control mechanisms – e.g., user specific data, anonymised but secured data, etc. SPARCS also has a specific mechanism to ensure access control of data.

Data is securely communicated using the **Communication** tier and access through the SPARCS Data Collection Service:

- ***Communications:*** Data is securely communicated outside of organisation through standard data transfer protocols such as TCP/IP using the internet, XML, and secure https protocols.
- ***Interoperability:*** Even though mechanisms to secure and make data communicable may exist, this does not imply that the data is truly accessible. This is where the role of the SPARCS data collection service is of paramount importance. The SPARCS data collection service makes use of relevant API (application programming interface), adapters, (model) converters, to securely collect (extract) the required data.

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

Data is mapped, modelled, and visualised in the **Value Co-creation** tier and presented to relevant stakeholders in a meaningful form to allow for informed decision making based on actionable intelligence:

- ***Applications:*** The SPARCS data mapping service makes use of the collected data and maps it to a common information model for the data. This serves as a basis for developing different analytics, visualisations, etc.
- ***Shared Services:*** The SPARCS data visualisation framework (service) access data from the common information model to allow for development of specific applications, e.g., energy data analytics, comparing data between peers, billing history visualisation, building level KPI analytics, etc.
- ***Interaction:*** The main added value for different stakeholders is visible in the interaction layer. User specific (homeowner, building manager, etc.) are provided with dashboards containing different visualisations, comparative analysis, recommendations on energy optimisation, etc.

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

6. Implementation, Replicability and Scalability of Interoperable Distributed Energy Applications

6.1 Implementation

The implementation process of an interoperable platform for distributed energy applications is a complex and multidimensional task. When developing a smart integrated platform for energy services, the level of interoperability achieved will play a vital role in enabling its functionality and associated benefits.

The key issue is that while a successful implementation of an interoperability process will surely lead to a virtuous circle that encompasses acceleration of technology adoption via decreasing costs, thereby reducing investment risk and boosting innovation, a potential failure will instead contribute to reducing investment and contain synergies, limiting the eventual benefits of an interoperable and thus, causing an expensive and time-consuming redesign and reconstruction process.

According to the Smart Grid Policy Centre White Paper *Paths to Smart Grid Interoperability*[4] there are 6 key aspects making the implementation of interoperable platforms a particularly complex process and that should be taken into consideration in advance:

1. **The energy grid is a "Complex System of Systems"**. Traditionally the energy grid has a high number of domains (e.g., generation, transmission, distribution, customers, markets, operations, service providers, etc.) with its own features, applications, practices and infrastructures. Such complexity must be supported and accommodated by the platform to be created.
2. **The need to accommodate multiple communications layers.** Communication systems are typically composed of multiple sequential layers providing similar functions, with its own protocol. For the implementation of a digital integrated platform, an appropriate set of protocol layers will be needed, its complexity dependent on the number layers covered. Achieving interoperability an appropriate level of standardization is required.
3. **The disproportionate development of parts of the energy grid.** The nature of the energy infrastructure is changing. The traditional hierarchical power system is increasingly being replaced by a distributed network that enables the accommodation of distributed energy sources, renewables and vehicle charging. As this transition accelerates, it also increases the demand for adequate portfolio standards. However, in some cases, certain technical and technological solutions cannot wait for the lengthy standards development process, leading to a situation where the timing priority is conceded to technology decisions that require near-term resolution while others are left to a later stage of the development process. Considering that investment in a smart integrated and interoperable platform requires a set of sequential decisions, the setting of standards should improve the overall effectiveness of the investment process and reduce risk through encouraging innovation and learning.
4. **The different interests of the stakeholders involved.** Apart from the disparate geographic location, dissimilar regulatory jurisdictions and fluctuating commercial

[4] Gilbert, Erik, Violette, Daniel and Rodgers, Brad (2011), "Paths to Smart Grid Interoperability", *Smart Grid Policy Center* (https://www.smartgrid.gov/files/documents/Paths_Smart_Grid_Interoperability.pdf).

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

interests, the many stakeholders in the energy value chain have different motivations for participation, deviating from what the platform should be, making the alignment of perspectives and interoperability even more difficult.

5. **The new security and privacy challenges.** Like in any other types of platforms, cyber security and customer privacy are key transversal issues in a smart integrated energy system. From the cyber security point of view, the platform should address not only potential issues related with terrorism, espionage, etc., but also possible problems caused by user errors, natural disasters or equipment failure. Furthermore, as the system will further expand the availability and granularity of consumption and grid system data, it will also pave the way for general invasions of privacy, raising the need for the adoption of clear privacy policies.
6. **The need to balance certainty and flexibility.** In order to enable innovation, the smart energy platform should be able to find the right balance between certainty and flexibility. In this process, the standards to be established are key. While excessively prescriptive standards may result in the desired interoperability but obstruct the advancement of the grid to incorporate new business models or technologies, too flexible ones may not ensure the desired levels of interoperability needed.

Apart from the above-mentioned key issues, there are other basic aspects that need to be met regarding the implementation of an interoperable platform. Among these are:

- The existing infrastructure and the possibility to integrate the different sources.
- The existing level of connectivity for enabling the deployment of a platform.
- The technical capacity and digital literacy of the human resources dealing with the platform.
- The viability of the implementation timespan and the existing temporary management solutions.

Taking into account all these aspects, a customized peer-to-peer interoperable ICT platform is a fundamental tool for the development of a Positive Energy District, facilitating the implementation of integrated concrete solutions, pursuing replicability and scalability aims and ensuring a vertical type of interoperable integration (reusable services) rather than a horizontal one (in between platforms). In this context, data sharing (among users and groups of stakeholders) and openness (with other cities and districts) represent some of the ground conditions upon which PED will be developed, allowing adequate interactions between citizens, buildings, district energy systems and larger scale energy systems.

In this context, there are several kinds of activities that are needed for a successful implementation of the interoperable platform, very much related to processes of awareness raising, capacity building, multilateral knowledge and technical know-how transfer and exchange. These activities will provide actionable information for the implementation of the interoperable platform and will also contribute to motivating the main target groups to use a new solution that integrates the already existing ones. Having electric mobility and energy storage device interactions as the main topics of interest, the most relevant activities sought to support the implementation of the platform are the following points listed:

- **Awareness raising campaigns** developed at different levels and targeted to specific audiences within the relevant stakeholders' groups, such as city and municipal administrators, relevant city and municipal departments, city services companies, utility providers building owners and citizens and end users. These campaigns will be key in

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 process of informing and raising the awareness of these groups about the specific group benefits of using an interoperable energy platform;

- **Professional training courses** with specific e-learning contents tailored to the needs of key target groups (i.e., civil servants of the municipal departments, city and municipal administrators and utility providers) which will act both as enablers and users of the system to be created.
- **Cooperation models between developers**, allowing the capitalization of the lessons learned from each stakeholder's user experience into new high-profile partnerships, paving the ground for the long-term sustainability, effectiveness and outcomes of the implementation process of the interoperable platform.
- **Costumer-oriented and developers open learning campus, peer learning processes and Massive Open Online Courses** (MOOCs) focused on new energy technologies, interoperable mobile applications and complementary products, big data management and related open standards, cost-benefit analysis and associated investment risk, among others.
- **Capacity building and expert exchange between the stakeholder's groups** (e.g., coaching and mentoring activities, stakeholders pairings, peer-to-peer learning, etc.) provided by the more experienced stakeholder groups to the less experienced ones;
- **Joint events** (e.g., workshops, webinars, hackathons, etc.) through which best practices will be shared by stakeholders using similar platforms or interesting relevant digital applications/functions cities and operators.
- **Utilisation of social media audiences and tools** (i.e., press releases, YouTube, Facebook, LinkedIn and Twitter pages, etc.), as well as other online publishing platforms (e.g., SlideShare, Issuu, among others) to fostering the end-user acceptance and ensuring the uptake of the platform as a digital solution to be used.

At this point it is important to note that the different stakeholder groups – i.e., city and municipal administrators, city and municipal departments, city services companies, utility providers, building owners, ordinary citizens and end users - have different motivations underpinning the possible use of a smart integrated and interoperable platform. Such motivations are very much connected to the requirements of each one of the groups, ranging from the optimization of energy consumption to the savings associated to its usage, going through the significant simplification of the energy management process, efficiency gains, real time management and visualisation of the energy performance and consumption, remote monitoring of applications and devices, detailed information of the demand curve, instant identification of the energy system flaws, leaks, malfunctions, trade-offs and risks, among others.

In the process of engaging the target stakeholders to use a smart integrated digital platform, the concept of gamification is of particular interest: the application of game theory techniques and concepts to non-game activities, specific to the energy management field. With the mainstreaming of social media, interactive web technologies and devices such as smartphones and touchscreens, gamification offers an opportunity to create a state-of-the-art consumer experience and encourage conservation behaviour in the energy field.

According to Dexma Energi Intelligence[5], gamification is a very relevant upgrade in the energy management area as it contributes to the development of an energy saving mind-set by "(…) involving the user in a game-oriented way". Either via "(…) cooperation and competition, the

---

5 Dexma Energi Intelligence, "What Gamification means for Energy Management" (https://www.dexma.com/blog-en/gamification-means-energy-management/).

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

applications motivate the users in order to achieve the energy efficiency goals". Building upon this, Intellias Intelligent Software Engineering[6] states that a game-like approach will support innovation and business model transformation in the utility providers' side, while helping the addressing some of the main areas of concern in its relationship with users, as listed below:

- Getting the attention of consumers and making them receptive.
- Presenting information about consumption and conveying its meaning to users.
- Encouraging collective energy savings.
- Increasing consumers' awareness of energy-saving problems.
- Illustrating options to change consumption behaviour.
- Encouraging and sustaining eco-friendly changes in behaviour.
- Educating and motivating employees towards reducing energy consumption at work.

Finally, smart interoperable platforms can play a key role in supporting urban transformation at different territorial scales and levels of intervention. However, since the concept of urban transformation is much broader concept, operating at a multi-level and multi-dimensional scale (i.e., not just about implementing technical or technological solutions in a particular issue area), the development of the integrated digital platform can only be understood as one of the drivers of change contributing to the structural process of urban transformation.

The implementation of an interoperable platform for distributed energy applications will be based upon a tailored-made city diagnosis, data collection, and preliminary analysis (T1.1) that are also the base for the city vision processes. As a dynamic and non-linear process, Urban Transformation is not entirely predictable *a priori*. However, by virtue of using processes such as visioning, forecasting, and back casting (developed under Task 1.7) a roadmap towards achieving urban transformation at the city level will be developed, in which digital interaction, together with data storage and management for information exchange will play a critical role. Such a tool acquires an increasing relevance in present times, particularly in addressing the challenges imposed by the continuously changing global trends and uncertain contexts, such as the current pandemic situation. In this context, the ICT platform is considered not only a necessary tool but also a prerequisite to enable remote management and communication among the various stakeholders in the energy grid value chain, an essential dimension of urban transformation processes.

6.2 Replicability

The SPARCS project addresses the smart cities challenges by implementing sets of integrated solutions that produce Zero Carbon Positive Energy Districts. Replication means "repeating successful smart city initiatives in another locale or replicating the same type of smart city in other cities"[7]. In the SPARCS project case this concept must be adapted to the holistic nature of their implementation. That is, the solutions have value per se (individually), and also have value from their conjoint impact, that is more than the linear sum of the individual impacts – it is holistic. This creates some difficulties in the evaluation of their replication potential, as if we

[6] Intellias Intelligent Software Engineering, "How Utilities Use Gamification to Engage Customers and Change Consumption Behavior" (https://www.intellias.com/how-utilities-use-gamification-to-engage-customers-and-change-consumption-behavior/).

[7] https://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pdf

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

were facing a one-of-a-kind solution and not a scalable concept. To solve this conundrum, we propose a structured step by step approach as listed below:

1. Separation of the integrated solutions in its components (D1.7[8]).
2. Evaluation of the components of the integrated solutions:
    a. Technical characterisation (see D3.1[9], D4.1[10] and D1.7)
    b. Impact evaluation (see D2.1[11] and D1.7)
    c. Main stakeholders (see D1.7)
    d. Requirements for their implementation (see D1.7)
3. Characterization of the city (target city) – evaluation of city needs, and potential regarding the components of the integrated solutions (in SPARCS D1.7).
4. Assessment of the solutions applicability - individually - in the city for the current date
5. Assessment of the solutions applicability - individually - in the city within 10 years from now
6. Solutions gaps and opportunities
7. Solution's prioritization
8. Replicability evaluation of the aggregated – holistic – impact of the solutions for the specific city
    a. For the current date
    b. Within 10 years from now

Steps 01, 02 and 03 are exemplified in the related documents.

Steps 04 and 05 are detailed in D1.7. They encompass a thorough evaluation of all solution's pre-requisites that need to be in place, so the solution can be effectively implemented. Here there will only be a short version of them.

For each solution there is a prerequisite list that includes technical and social ones, there are also general social prerequisites.

Table 8: PED Technologies and Technical Requirements

Technology	Technical requirements
Renewable energy - PV	PV: 1. Site with at least 2000 hours of sun per year[12] 2. Area of around 2 m^2 per panel available
Renewable energy - Wind	Wind:[13] 1. Average wind speed of more than 5 m/s – in this case small wind turbines can be a good alternative to PV panels 2. No obstacles nearby the turbine that may interfere with wind speed

[8] D1.13 Strategy for Developing Interoperability and Ecosystems for Positive Energy Districts
[9] D3.1 Detailed plan of the Espoo smart city light house
[10] D4.1 Detailed plan of the Leipzig smart city light house
[11] D2.1 Definition of SPARCS Holistic Impact Assessment Methodology and kPIs

[12] Considering a payback period of 5 years

[13] Source: https://news.energysage.com/small-wind-turbines-overview/

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

	3. Availability of at least one acre of clear land, i.e., around 4000 m^2, recommend by most installers
Renewable energy – Geothermal- Low enthalpy	Geothermal Low enthalpy: 1. Availability of temperatures in the range (20°C to 150°C) to provide **direct** heat for residential, industrial, and commercial uses
Renewable energy – Geothermal – high enthalpy	Geothermal high enthalpy: 1. Availability of temperatures in the range (150°C to 370°C) to provide high enthalpy fluid for geothermal electricity generation 2. Distance of the geothermal reservoirs bellow 3 km – since electricity production demands a close to the earth surface
Renewable energy - Geothermal	Geothermal: 1. For geothermal heat pumps existence of excavations of around 2 meters for the installation of the coiled pipes. Geothermal heat pumps take advantage of the soil moderate temperatures both in winter and summer to cool or heat houses. So, these systems do not require geothermal reservoirs, but will require excavations of around 2 meters for the installation of the coiled pipes. 2. Distance of the geothermal reservoirs bellow 3 km – since electricity production demands a close to the earth surface
Virtual power plants	1. Existence of EMS, sensors and actuators 2. Existence of a VPP controller 3. Existence of regulation and contracts with prosumers 4. Existence of a transparent, accountable, fair transaction ledger system
Energy storage	1. Does the battery increase the PV self-consumption in about 50% and simultaneously the battery system represents less than 50% of the total investment cost (PV + battery)? If so, that's a GO situation for battery acquisition 2. Available space: about 1 to 2 m2 of wall area (usually batteries are placed in the wall)
Demand response	1. EMS and at least 3 kW of controllable loads (examples washing machine, dishwasher machine, water heater, heating/cooling devices, etc)
Microgrids	1. Grid that allows independent blocks operation 2. Microgrid controller 3. Existence of regulation and contracts
Energy infrastructure planning	1. Energy infrastructure planning developed with relevant stakeholders– Stakeholders identified, existing communication channels 2. Integration of the outputs of the work with relevant stakeholders in the Energy infrastructure planning
EMS (Energy Management Systems)	1. Existence of EMS, sensors, actuators

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

Table 9: PEDs – Social Requirements

Technology	Social requirements
Positive Energy Districts	1. Policies and regulation frameworks to support PED conceptualization, implementation and stakeholder's engagement, including co-creation 2. Incorporation of innovative investment valuation methodologies such as: Dynamic evaluation[14], scenario analysis, or at least cost-benefits analysis, risk analysis and RoI (Return on Investment), all integrating social impacts. 3. Community energy initiatives leaded by citizens and households 4. Community energy initiatives funding 5. Transparency, openness and inclusiveness in the decision-making process and procedures to guarantee trust/fairness in the technology implementation and in the decision makers/relevant stakeholder relation 6. Existence of short-, medium- and long-term strategies at city level that involve local community in planning PED projects.

Table 10: Mobility Technologies and Technical Requirements

Technology	Technical requirements
E-mobility	1. Existence of fast charging capabilities (around 300 kW) 2. Existence of sufficient parking space for charging 2 to 4 vehicles and preferably near a transformer substation (less than 50 meters) 3. Existence of EV charger equipment that is universal and compatible with most automobile brands 4. Existence of Contract with energy retailer for the supply of the charging station
Mobility hubs	1. Identification of the spots where is more interesting to install EV charging stations, example railway stations, light rail stations. 2. The mobility infrastructure works in an integrated way in terms of connections between public transportation (light rail, boats, buses, etc) and their schedules 3. Integration of public transportation, car sharing and last-mile electrification 4. Discounts for integrated passes of public transportation 5. Management of the electric scooter's logistics to the places/stations with higher demand
V2grid	1. Cars equipped with V2G technology (bidirectional vehicles) 2. Existence of V2G regulation and contracts 3. System integration with VPP controller or DSO 4. Adequate V2grid infrastructures (charge points) at the city level

[14] Mazzucato, *Mission Economy A Moonshot Guide to Changing Capitalism*, page 179, Allen Lane, Dublin, 2021.

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

EV integration in VPP	1. Cars equipped with V2G technology (bidirectional vehicles) 2. Existence of V2G regulation and contracts 3. System integration with VPP controller or DSO
Last mile electrification	1. Availability of well-located charging points 2. Existence of safe roads and dedicated lanes for soft mobility

Table 11: Mobility – Social Requirements

Technology	Social requirements
Mobility	1. Policy frameworks and political commitment at the city level to directly promote e-mobility 2. Policy frameworks and political commitment at the city level to support the V2grid infrastructures 3. Foster user acceptance for electric vehicles through engagement activities focused on advantages/benefits/positive externalities (environmental sustainability; cost effectiveness, etc.) 4. Develop end-users (citizens) profiling (e.g., surveys; questionnaires) related to environmental/technology-friendly driving, behaviours and preferences to adequate the offer (complying with the GPRD). 5. Orography of the District (important for the e-bikes and e-scooters) 6. Transport infrastructure (Km of roads for cars, bicycles, etc.) 7. Transport infrastructure (Public transportation lines, # of stops) 8. Stock of vehicles (Cars, Motorcycles, Bikes, Buses, etc.) 9. Modal Split; the distribution of transport over the modalities of public and collective transport, private vehicles, biking and walking.

Table 12: New Economy – Solutions and Requirements

Solution	Requirements
Smart business models	1. Literacy regarding New Business 2. Users engaged – users identified, efficient and effective communication channels 3. Regulation on New Business
Smart governance models	1. Literacy regarding Urban transformation 2. Urban transformation co-creation – users identified, existing communication channels 3. Urban transformation financing models 4. Urban transformation governance models 5. Urban transformation procurement 6. Regulation on smart governance models 7. Coordination mechanisms for networked urban development 8. Promotion of direct social engagement activities involving local communities in planning, implementation of smart governance models

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

Engaging users in new business	1. Literacy regarding New Business 2. Existence of a Peer-to-peer energy marketplace 3. Existence of personalized Informative billing using real-time energy prices 4. Existence of a benchmarking informative system to compare user consumption.
Co creating new business models	1. Literacy regarding New Business 2. Users engaged – users identified, efficient and effective communication channels 3. Regulation on New Business 4. Urban transformation co-creation – users identified, existing communication channels 5. Develop new financing models through partnerships involving community-cooperatives/public/private sector.
Bankable smart cities solutions	1. Existence of a catalogue with bankable solutions encompassing user-centric, carbon-free buildings, smart technologies applied to the district and to mobility and all connected services 2. Existence of an innovation ecosystem enabling the development of the bankable smart city solutions to be worldwide replicated 3. Promote dissemination activities focused on bankable smart cities solutions reaching out hard-to-reach group
Smart local sustainable businesses	1. Existence of an ecosystem enabling the creation of smart local sustainable businesses: market potential, prospective businesses plan, municipal support, joint procurement
V2grid monetization	1. Existence of grid connection points permitting the bidirectional charging of vehicles 2. Existence of a metering system enabling the electrical bidirectional flow quantification 3. Regulation allowing the electricity grid charging and monetization 4. Existence of a demand response system facilitating V2G flexibility use 5. Existence of a life cycle cost evaluation of the V2G operation 6. Clear definition of the V2G overall costs (OPEX, CAPEX) allocated
Dynamic pricing of EV charging	1. Existence of grid connection points permitting the bidirectional charging of vehicles 2. Regulation allowing the electric vehicle charging and dynamic pricing 3. Existence of a demand response system facilitating V2G flexibility use 4. Existence and application of dynamic pricing models for electric vehicle charging and price of electricity depending on the flexibility resource the EV can bring.

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

Table 13: Urban Innovation – Solutions and Requirements

Solution	Requirements
Engaging users	1. Literacy regarding Urban innovation 2. Urban innovation user involvement in co-creation– users identified, existing communication channels
Sustainable lifestyle	1. Definition by the municipality of a Sustainable lifestyle roadmap 2. Literacy regarding Sustainable lifestyle (includes the adoption by the municipality of a Sustainable lifestyle definition) 3. User involvement in Sustainable lifestyle – users identified, existing communication channels (includes the implementation by the municipality of a Sustainable lifestyle paradigm) 4. The Sustainable lifestyle roadmap should include solutions for optimizing people's flow (urban) regarding energy and user experience, should identify benefits and the added value for citizen and other stakeholders in different district lifecycle phases. 5. The Sustainable lifestyle roadmap should 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 the nearby green areas.
Cocreation for PEB developments	1. Existence of an established PEB/PED methodology to which all players agree to abide. PEB/PED should encompass energy, mobility, and service solutions based on digital platforms and networks 2. Stakeholders involvement in PEB/PED co-creation, guaranteeing that their inputs are considered in new development areas– users identified, existing communication channels orchestrated by the municipality or other governing institution. Should include all relevant stakeholders such as: industry, SMEs, citizens, among others.
Induce citizens behaviour towards energy positiveness	1. Literacy regarding Energy Positiveness 2. Stakeholders involvement in energy positiveness, guaranteeing that their inputs are considered – users identified, existing communication channels orchestrated by the municipality or other governing institution. This must be supported by an *Idea Management* and/or *Open Innovation* system and/or a *Desk Support*. In these systems citizens are engaged in the discussion of ideas/projects to improve positiveness in urban sustainability, as well as they are invited to participate in adopting sustainable behaviours. 3. Existence of a system – APPs and eParticipation tools to allow bi-directional communication between users and the municipality. 4. End-users (citizens/owners) characterization (preferences/expectations/behaviour) in order to adapt the technology (e.g., through surveys; questionnaires, etc.)
Optimize people's flow	1. Existence of data regarding citizens' preferable future multimodal mobility habits, schedules and routes to optimize the people flow from energy and user experience perspectives

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

	2. Use of the data on people's mobility to optimize the people flow from energy and user experience perspectives
City planning district development	1. Existence of inclusive management, cooperation and planning models (includes the participation of companies, city planning departments, citizens and research organizations) 2. Definition by the municipality of the smart city paradigm 3. Stakeholders' involvement in co-creation models for smart city planning, guaranteeing that their inputs are considered – users identified, existing communication channels orchestrated by the municipality or other governing institution 4. Clear political commitment with the local community 5. Public accountability involving policy makers at different levels of governance/government.
Promotion of soft mobility	2. Existence of data regarding citizens' preferable future multimodal mobility habits, schedules and routes to optimize the people flow from energy and user experience perspectives 3. Use of the data on people's mobility in city planning optimizing people flow (from energy and user experience perspectives) 4. Existence of integrated sustainable strategies connecting Metro and e-bicycle modes, to boost e-mobility in the district

Table 14: ICT – Solutions and Requirements

Solution	Requirements
ICT for PEB	1. Digital platforms availability 5. Availability of historical data, consumption, generation, etc. 6. Availability of data streams 7. Data analysts 8. Internet connections and mobile phones 9. 5G infrastructure availability 10. Blockchain infrastructure availability
Smart business models	1. Business model's creation expertise 2. Budget for engagement activities 3. Engagement tooling 4. City wide ecosystem with local SME and start-ups 5. Regulatory incentives for new services and models
Virtual power plants	1. Availability of controllable flexible loads 2. Minimum capacity of flexibility according to the national energy market rules 3. Aggregator business model availability 4. Historical data for controllable flexible assets 5. Continuous data collection infrastructure
Virtual twins	1. Digital twin platform populated with city models to simulate complex real scenarios

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

	2. Historical data regarding city assets operation 3. Detailed models for city evolution

Table 15: All Solutions – General Social Requirements

Social requirements
1. Population – number of people that enable the feasibility of the solutions 2. Social economic level of the population 3. Population literacy on PED, e-mobility, New Economy, Urban innovation 4. Inclusion of ethical requirements/social objectives & priorities (e.g., improve health conditions; include hard-to-reach groups, etc.) in contracts with end-users (citizens/owners) 5. Social acceptance (perception of advantages/positive externalities - in terms of environmental sustainability, cost effectiveness, risks - from technology implementation) 6. Technology's flexibility to address user's (citizens) needs 7. Friendliness of ICT technologies 8. Integration of privacy/security mechanisms for end-user's data treatment on energy consumption **9.** Existence of support for the solution/product through its life.

Each requirement is evaluated in a scale from 0 to 3. The result is produced either from qualitative scales, via a Likert conversion, or from an on/off scale via a conversion. To integrate the different components of each requirement, a methodology was provided for each one of them (see D1.7 for further details). In all requirements, the ON/OFF components were translated into an absorbing element (thus multiplicative), whereas the qualitative components were directly obtained via a Likert conversion.

From the application of the detailed methodology, we would obtain a visualisation as shown in Figure 5 – for the city as it is now. As of today's this, is still an illustrative example since we have not yet applied the detailed methodology to a real city (expected to be done in the coming weeks).

The graph thus obtained allows us to finalise *Step 6 Solutions gaps and Opportunities*, in which the solution's potential (red dots) are opposed to the city's potential for their implementation (blue dot) resulting in the expected impact for the specific city (yellow dot).

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

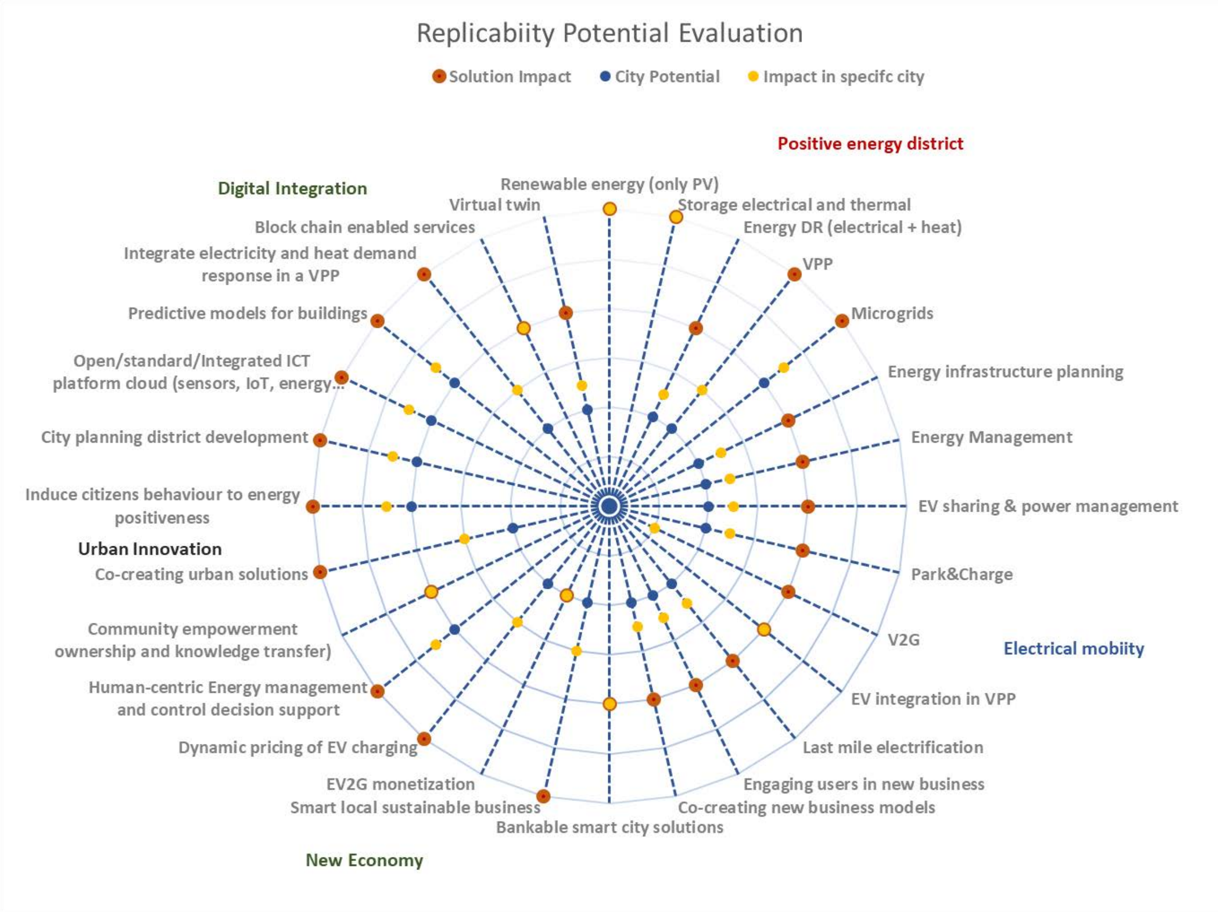

Figure 9: Replicability Potential of Positive Energy Block on a City (example)

Example: the renewable energy potential impact for PV is high (red dot) – that is it can contribute highly to the energy positiveness and carbon neutrality- and the city potential to apply it is also high (blue dot), thus expected impact for the specific city is high (yellow dot). In the case of Energy demand response (DR), its potential impact is medium (red dot), the city potential to apply it is low (blue dot), thus resulting in a below average expected impact for the specific city (yellow dot). All solutions are depicted as an abstract example

Step 7 Solution's Prioritization, from the above figure, the city can know prioritize the solutions to implement. If the data in the picture would be real, then the prioritization list should be as follow:

1. Renewable energy (only PV) Very interesting
2. Storage electrical and thermal – Very interesting
3. Microgrids– Very interesting
4. Human-centric Energy management and control decision support – Interesting
5. Induce citizens behaviour to energy positiveness– Interesting
6. City planning district development– Interesting
7. Open/standard/Integrated ICT platform cloud (sensors, IoT, energy data, dashboards, visualisations) – Interesting
8. Predictive models for buildings– Interesting
9. EV integration in VPP – Average interest
10. Bankable smart city solutions– Average interest
11. Community empowerment ownership and knowledge transfer) – Average interest

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

12. Block chain enabled services– Average interest
13. VPP – Below average interest
14. Smart local sustainable business – Below average interest
15. Dynamic pricing of EV charging– Below average interest
16. Co-creating urban solutions– below average interest
17. Integrate electricity and heat demand response in a VPP– below average interest

As of now, we have executed the steps 1 till 7 of the *"Replicability structured step by step approach"*. In *Step 8 Replicability evaluation of the aggregated – holistic – impact of the solutions for the specific city*, the chosen solutions will be integrated, that is their implementation will be evaluated in a holistic approach. Here we will be demonstrating only for the PED solutions, for which we have used an "*Integrated solutions evaluation holistic Matrix*". The results of the interactions can be:

- Qualitatively characterised as highly positive, positive, neutral, negative and highly negative;
- Quantitively evaluated by a list of the two most important impacts that can be calculate while considering the co-joint effect of the solutions in the row and column.

	Renewable energy (only PV)	Microgrids	Human-centric Energy manage./control	City planning district development
Storage electrical and thermal	- peak shaving - Less energy imports			
Microgrids	- peak shaving - Less energy imports - CO avoided			
Human-centric Energy management & control decision support	- Less energy imports - Energy bill reduction	- Citizen Energy empowerment (focus on citizen's needs) - Flexible energy management		
City planning district development	- Pollutants reduction - Less energy imports	- Decrease energy import - Decrease energy bills	- Decrease the city energy import - Citizen's rate of control on the energy system	
Open/standard/Integrated ICT platform cloud	- Less energy imports - Energy use optimization	- Batteries use optimization - Batteries grid integration optimization	- Energy efficiency improvement - Citizens assess to energy data	- Increase energy efficiency - Increase the RES contribution

Figure 10: Integrated solutions evaluation Matrix

In next steps there will be a detailed "*Integrated solutions evaluation holistic Matrix*", for each one of the 5 SPARCS areas: PED, Mobility, New Economy Urban Innovation and ICT. Each cell in the "*Integrated solutions evaluation holistic Matrix*", will be evaluated both qualitatively and quantitatively, thus providing the holistic evaluation of the possible solutions combination, that is the objective of this replicability methodology.

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

6.3 Scalability

Scalability can be defined as *"the ability of a system to change its scale in order to meet growing volumes of demand"*[15] , or, in a more demanding statement, *"the ability of a system to maintain its performance (i.e., relative performance) and function, and retain all its desired properties when its scale is increased without having a corresponding increase in the system's complexity"*[16]. The SPARCS scalability will be evaluated applying a scaling methodology adapted to integrated solutions, with its steps listed below:

1. Separate the integrated solutions in its components.
2. For the individual solutions evaluate the influence in scalability of:
    a. Technical factors
    b. Economic factors
    c. Regulating factors
    d. Acceptance and stakeholders related factors
3. Assess the scalability of the integrated solutions for a specific universe.

For the sake of demonstration, we will apply the conceptual analysis to some of the individual components that were already individualised in the previous section. For an exemplification of step 2 see the following tables.

Table 16: Positive Energy Blocks – Technical & Economic Factors

Positive Energy blocks	Technical factors	Economic factors
Storage electrical and thermal	- Storage are modular systems, thus they can be added up, this increases integration requirements, but the positive impact of the replication of storage overcomes the integration issues.	- Financial gains from costs reduction in buying additional storage units, energy bill reduction from widespread use of storage; - Positive spill overs from storage use: renewable integration and improvement of the overall electricity system efficiency There is still need for a better definition of the economical compensation model for the operator of energy storage systems. The value of energy storage is expected to increase with higher degrees of variable RES penetration
Microgrids	- Microgrids are modular systems, thus they can be added up, this increases integration requirements, but the positive impact of the replication of the microgrids overcomes the integration issues. Operation in island mode implies several difficulties: higher fault currents may occur and possible damage protections; issues with start-up of island mode; balancing between generation and load in island mode.	- Financial gains from costs reduction in buying additional microgrid components, energy bill reduction (increase energy efficiency), savings from the avoided investment in centralised power plants; - Positive spill overs: energy consumption reduction, the provision of remunerated ancillary services, the provision of additional ICT services enabled by the grid and ability to operate in "island mode.

[15] Philippe, B.; Hansman, R.J. Scalability of the Air Transportation System and Development of Multi-Airport Systems: A Worldwide Perspective; MIT, Report No. ICAT-2008–02; Massachusetts Institute of Technology: Boston, MA, USA, 2008

[16] Ibidem

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

Human-centric Energy management & control decision support	- Technology facilitates the widespread increase in energy management and control systems, once designed they are easy to copy and apply.	- Financial gains from all the efficiency that the human centric energy management systems will generate. - Positive spill overs from the energy management: optimization of energy in buildings use while maintaining the comfort, among others.
City planning district development	- Technology facilitates the widespread increase in city planning district development, once a supporting system is designed, then it will be relatively easy to copy and apply.	- Financial gains from all the efficiency that the adequate planning will generate. - Positive spill overs from the virtuous district planning: efficient communication routes, “15-minute city”, among others.
Open/standard/Integrated ICT platform cloud	- Platforms can be added up, this increases integration requirements, but the positive impact of the replication of the solutions overcome the integration issues.	- Financial gains from all the efficiency that can be implemented throughout the ICT platform, examples: improvement in mobility, energy use, peoples flow, traffic, among many others. - Positive spill overs throughout society: new sustainable business that can be implemented, IoT that can be used in predictive modelling of traffic, pollution, citizens flow, among many others.

Table 17: Positive Energy Blocks – Regulation Factors and Acceptance / Stakeholder Factors

Positive Energy blocks	Regulation factors	Acceptance and stakeholder related factors
Storage electrical and thermal	There might be caps on the storage volume installed on the grid, on the volume of services that storage can provide, among others. There is still the need for a better definition at EU legislation regarding energy storage. Energy storage is restricted, in some countries, for grid operators and DSOs are not allowed to own and operate storage.	Storage widespread Prosumers: Accept - financial value. Real estate developers Accept - financial value. Energy retailer acceptance depends on the business model. ESCOs Accept - financial value. DSO acceptance depends on the business model.
Microgrids	There might be limits on the microgrid implementation, connections to the grid, on the activities the microgrid can deliver, among others.	The general motivation for microgrids deployment and general acceptance comes from the fact that microgrids can operate in island mode and therefore to ensure energy supply during power outages, apart from the fact that they can supply clean, low-cost energy, especially relevant to remote geographical localities. Energy retailer acceptance depends on the business model.

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

		ESCOs Acceptance - financial value. Prosumers Acceptance - financial value. Citizens Acceptance - financial value. DSO acceptance depends on the business model.
Human-centric Energy management & control decision support	The Human-centric Energy management solutions depend highly on how the national and local legislation support it. Example: Participatory processes on energy regulation, on energy management in districts, among others.	Prosumers accept - financial value. Real estate developers Accept - financial value. Energy retailers' acceptance depends on the business model. ESCOs Accept - financial value.
City planning district development	The scale-up highly depends on regulatory openness towards the city planning district. If there is a structured legal procedure in which the municipalities and their citizens are called to participate in the district development discussions, project and implementation.	Prosumers acceptance depends on the business model. Real estate developers accept - financial value. Energy retailer acceptance depends on the business model. ESCOs accept - financial value.
Open/standard/Integrated ICT platform cloud	As long as the GPRD and general law are abided by the platform, there rea no major restrictions to the scale-up	Prosumers accept - financial value Real estate developers accept - financial value Energy retailers accept - financial value ESCOs accept - financial value DSO acceptance depends on the business model.

In step 3 we would then combine individual solution in order to get their integrated scalability potential.

Table 18: Positive Energy Blocks – Integrated Scalability Potential

	Storage electrical and thermal	Microgrids	Human-centric Energy …	City planning district development
Microgrids	Enhances			
Human-centric Energy …	Can enhance	Can enhance		
City planning district development	Can enhance	Can enhance	Can enhance	
Open/standard/Integrated ICT platform cloud	Highly enhances	Highly enhances	Enhances	Can enhance

From the previous table one can conclude that some solutions potentiate their scalability potential when considered together, for example, when considering microgrids and storage, their scale up potential is highly enhanced: microgrids allow the optimization of storage and vice versa, co-jointly increasing energy savings and the district positiveness.

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

6.4 Expected Impacts

The implementation of PEDs combines aspects of the built environment, energy production, consumption (including heat) and mobility, in order to reduce greenhouse emissions and energy use as well as to increase the well-being of citizens. In all stages of development of PEDs, different perspectives are analysed, and various approaches are combined including regulatory, financial-economic, social and spatial. It is the development of an urban, energy-friendly and net-zero CO_2 emission neighbourhood that requires interaction and integration between buildings, users and stakeholders. Through this interoperable process apart from the district's citizens that are directly impacted from the urban re-design, there are indirect benefits for various stakeholders that are involved in the development and play a key role in achieving energy and climate targets. Municipalities, city and national governors, regulatory authorities, research and innovation institutes, energy suppliers, industry, construction companies and financial institutions are elaborate in PEDs concepts and various benefits are foreseen from their participation.

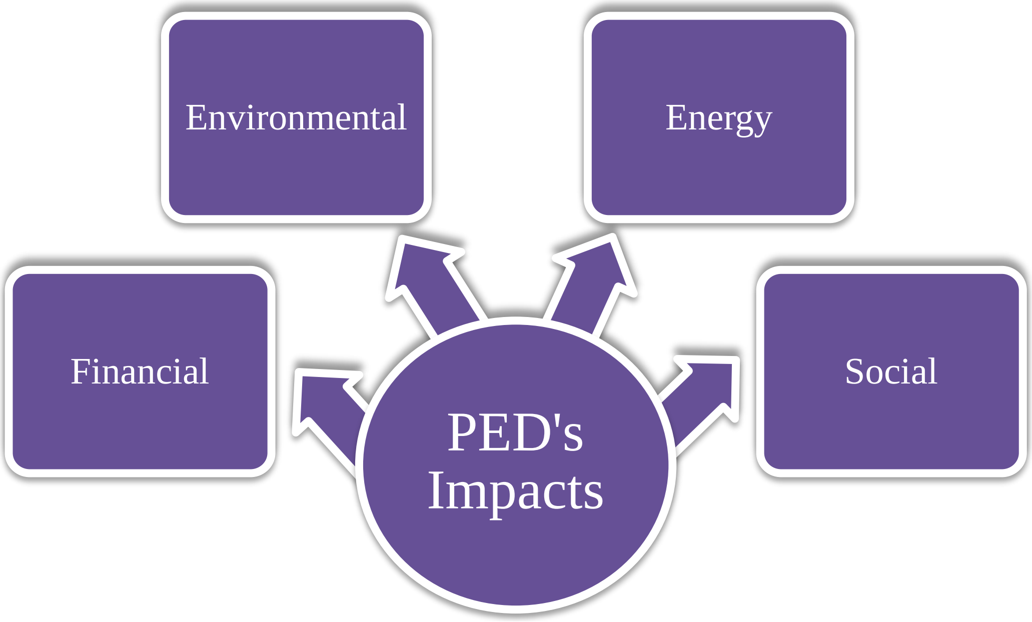

Figure 11: PED Impacts

In a more general context, the transformation of a neighbourhood into a PED requires a wide set of levels of analysis and scales of interventions, with the participation and contribution of various stakeholders. The renewal of the district that turns a run-down neighbourhood into a valued one is challenging and demands affordable and replicable solutions and business models but also brings multiple social and economic benefits for the local community on top of energy and emissions savings.

In the following table the main impact-related categories of PEDs interventions are presented and various foreseen benefits affecting multiple stakeholders are listed.

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

Table 19: PED Impacts and Stakeholders

Category	Impacts	Targeted Stakeholders
Social	• Job creation • Neighbourhood transformation • Property value increase • Improvement of households' income • Crime reduction • Improvement of citizens quality of life, health and well -being • Citizen involvement and engagement • Improvement of transportation • Electromobility development • Energy cost reduction • Mentality shift towards active citizens (demand response, smart buildings, energy sharing, local energy communities, sustainable transportation) • Ecotourism • Improvement of local air quality • Replication strategy in a city's districts • Synergies between different buildings • Procurement of services and technologies not available on an individual building scale • Knowledge exchange • Improvement of innovation capacity • New market opportunities • New policy/ regulatory framework	Municipalities, city and national governors, citizens, R&I institutes, construction companies, regulatory authorities, financial institutions
Energy	• Energy losses reduction • Grid's stability • Installation of cost-effective energy systems • Energy demand reduction • Energy security and reliability • Reduction of energy curtailment	Energy suppliers, industry, citizens, municipalities, consumers
Financial	• Increase investors' confidence • Economic growth • Economies of scale • Cost-effectiveness of transactional energy performances • Investment opportunities	Municipalities, construction companies, citizens, financial institutes, equipment suppliers
Environmental	• Greenhouse emission reduction • Fossil fuels usage reduction • Facilitation of decarbonization targets • Improvement of air quality	Municipalities, city and national governors, citizens

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

7. Conclusions

7.1 Summary of achievements

This deliverable has explored requirements for Positive Energy District ecosystems from the perspective of stakeholder requirements and expectations, technical and functional specifications for an interoperable ICT system and key data requirements and specifications. SPARCS lighthouse city (Espoo, Leipzig) use cases and planned PED interventions have been briefly presented. To support visualisation of different KPIs and comparative city analysis, the SPARCS ICT ecosystem (data management platform and visualisations framework) were defined. Furthermore, for implementation of the interventions (in terms of ICT based solutions), a generic reference architecture (positioning framework) was developed to provide a high-level overview of planned interventions (ICT-based perspective) to support easier understanding and development of similar interventions in other cities. The deliverable elaborates on the benefits of PED implementation from a socio-technical perspective and identifies mechanisms to measure and determine replicability and scalability potentials. Overall benefits and expected impacts are also presented from social, energy, financial, and environmental perspectives.

7.2 Impacts

This deliverable supports the urban transformation of cities through the combination of energy and urban data from distributed and at times, heterogenous data sources and solutions into a holistic PED ecosystem. The key findings from this deliverable are expected to serve as an initial basis for mapping the planned lighthouse city interventions and development of supporting ICT tools. As an example, the tool for optimising and visualising urban energy flows will allow optimisation of energy demand-supply cycles and allow comparisons and analysis of different PED intervention choices and impacts. This will offer valuable insights and actionable intelligence to different stakeholders to make informed decisions that are environmentally feasible, socially desirable, and economically viable.

7.3 Other conclusions and lessons learnt

Interoperability between different heterogenous ICT systems is always a challenge. The challenge is furthermore aggravated when it involves systems and data sharing across multiple organisations. This deliverable has offered a simple and visual reference architecture / positioning framework to show how data from different systems can be securely shared/accessed, combined, and then visualised to support decision makers at different levels through user friendly apps and dashboards. This architecture also serves as a framework for those seeking to replicate some of the PED interventions that are being implemented, validated, and monitored in the SPARCS Lighthouse Cities of Espoo and Leipzig. During replication and scale-up, where needed, different components, systems and data sources can be replaced / inter-changed to suit the particular needs of each fellow city for example.

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

8. Acronyms and Terms

Acronym	Definition
API	Application Programming Interface
BMS	Building management system
CIM	Common Information Model
CSV	Comma-separated Values
DER	Distributed Energy Resources
DoA	Description of Action
DR	Demand response
DSO	Distribution system operator
Dx.y	Deliverable x.y
EV	Electric vehicle
ESCO	Energy saving company
GDPR	General Data Protection Regulation 2016/679
HEMS	Home energy management system
IAQ	Indoor Air Quality
ICT	Information, Communication and Technology
IoT	Internet of Things
IP	Internet Protocol
JSON	JavaScript Object Notation
KPIs	Key Performance Indicators
PCC	Point of common coupling
PED(s)	Positive Energy District(s)
PV	Photovoltaic
RES	Renewable Energy Sources
SPARCS	Sustainable energy Positive & zero cARbon CommunitieS
Tx.y	Task x.y
UC(s)	Use Case(s)
UI	User Interface
V2G (EV2G)	Vehicle-to-grid (Electric vehicle-to-grid)
VPP	Virtual Power Plant
WP	Work Package
WSN	Wireless Sensor Network

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

9. REFERENCES

Anon., 2019 SPARCS Description of Action (DoA) ANNEX 1, Part A

Anthopoulos, L., & Fitsilis, P. (2010). From digital to ubiquitous cities: Defining a common architecture for urban development. Paper presented at the Proceedings - 2010 6th International Conference on Intelligent Environments, IE 2010, 301-306.

Brath, R. and Peters, M. (2004) Dashboard design: Why design is important. DM Direct, October 2004.

Da Silva, W. M., Tomas, G. H. R. P., Dias, K. L., Alvaro, A., Afonso, R. A., & Garcia, V. C. (2013). Smart cities software architectures: A survey. Paper presented at the Proceedings of the ACM Symposium on Applied Computing, 1722-1727.

Girtelschmid, S., Steinbauer, M., Kumar, V., Fensel, A., & Kotsis, G. (2013). Big data in large scale intelligent smart city installations. Paper presented at the ACM International Conference Proceeding Series, 428-432.

International Organization for Standardization. (2015) Information technology — Vocabulary (ISO/IEC 2382:2015)

JPI Urban Europe / SET Plan Action 3.2 (2020). White Paper on PED Reference Framework for Positive Energy Districts and Neighbourhoods. https://jpi-urbaneurope.eu/ped/

Kitchin, R. (2015) The real-time city? Big data and smart urbanism. GeoJournal 79(1): 1-14
Lai, C., Jia, Y., Dong, Z., Wang, D., Tao, Y., Lai, Q., Wong, R., Zobaa, A., Wu, R. and Lai, L., 2020. *A Review of Technical Standards for Smart Cities*.

Mamkaitis, A., Bezbradica, M., & Helfert, M. (2016). Urban enterprise: A review of smart city frameworks from an enterprise architecture perspective. Paper presented at the IEEE 2nd International Smart Cities Conference: Improving the Citizens Quality of Life, ISC2 2016 – Proceedings.

Rodríguez-Molina, J., Martínez, J. -., Castillejo, P., & De Diego, R. (2013). SMArc: A proposal for a smart, semantic middleware architecture focused on smart city energy management. International Journal of Distributed Sensor Networks, 2013

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