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RESPONSE

Integrated Solutions for Positive Energy and Resilient Cities

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Deliverable D1.5

Master City Plans for TA#3 Sustainable Energy Storage

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Glossary

Abbreviation	Full form
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
DH	District Heating
DHW	District Hot Water
DM	Dijon Metropolis
EMS	Energy Management System
ESaaS	Energy Storage as a Service
EV	Electric Vehicle
FC	Fellow City
GHG	Green House Gases
IE	Innovative Element
IS	Integrated Solution
LHC	LightHouse City
LVAC	Low Voltage Alternative Current
LVDC	Low Voltage Direct Current
PCM	Phase-Change Material
PEB	Positive Energy Building cluster
PED	Positive Energy District
PV	PhotoVoltaic
RES	Renewable Energy Sources
TYS	Turun YlioppilaskyläSäätiö - Turku Student Village Association
V2G	Vehicle to Grid
WP	Work Package
ZnR	Zinc-Air

Executive Summary

This report is part of the Horizon 2020 Smart city project RESPONSE and is an outcome of *Task 1.5: Master City planning for Sustainable Energy Storage (TA#3)*. It documents the implementation and replication plans for 'Integrated Solutions' in the cities of Turku (Finland) and Dijon (France). These solutions pertain to electricity and heat storage systems. Storage of energy introduces an element of flexibility in the operation of the local electric systems as well as of space heating, cooling, and water heating. By using this flexibility, the system operators can choose to pursue various targets, such as reducing the peak demand, improving the overall system efficiency, increasing the share of local production consumed locally or a combination of some of these.

In terms of electricity storages, the city of Turku will implement two 50 kWh battery storage systems. The first one will be assembled from second life batteries, recovered from electric vehicles. The second will be composed of lithium-ion batteries. They will both be used to reduce the local PV production or the consumption peaks, while the second will also provide increased robustness and power quality in the local network.

Regarding heat storages, the city of Turku will implement six units of a novel Phase-Change Material (PCM) heat storage with a total capacity of 84kWh. In addition, the city will implement a multi-temperature district heating system in which a storage provider will offer PCM heat storage capacity, following the concept of "storage-as-a-service", where the service provider delivers the heat storage capacity to an agreed yearly payment. In Dijon, the plan is to implement residential PCM storage units to increase self-consumption and reduce heat losses, an industrial hot water buffer tank to reduce the peak gas demand, and finally a collective hot water tank will be installed alongside a building energy management system to increase the self-consumption of the solar production.

Both cities have identified areas in which some of the solutions developed could be replicated, both for electricity and heat storages. In addition, six other cities have expressed interest in the solutions that will be implemented. They have identified areas and conditions where some of those solutions could be replicated after the completion of the RESPONSE project.

Further technical and detailed planning for Turku and Dijon will build on the T1.3 master planning results and continue in both cities. The updated plans will be documented in WP6 T6.1 "Dijon Smart City Diagnosis and dynamic Master Planning for TA#1-TA#3" for Dijon and in WP7 T7.1 "Turku Smart City Diagnosis and dynamic Master Planning for TA#1-TA#3" for Turku. The replication planning in the six other cities will continue in WP8 "FCs Replication Plans and 2050 Bold City Vision".

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Integrated Solutions for Positive Energy and Resilient Cities

Chapter 1

Introduction

Chapter 1 - Introduction

RESPONSE aims to turn energy sustainability into a do-able vision by solving the energy trilemma (security, equity/affordability, and environmental sustainability) at building, block and district levels in smart cities. RESPONSE builds upon intelligent integrated and interconnected energy systems coupled with demand-oriented city infrastructures, governance models and services that foster energy sustainability. To achieve this goal RESPONSE is built around an energy sustainability and climate change conscious perspective to form innovative and scalable solutions in five Transformation Axis (TA#1- TA#5) that directly contribute to the United Nations' 2030 Agenda for Sustainable Development and the associated Sustainable Development Goal 11 (SDG11) and provide energy security, energy equity and environmental sustainability. Each of these axes, contains a number of innovative elements (or technologies) that contribute to each of the TA targets, as well as the global goals of RESPONSE.

1.1 Objectives

The objective of this deliverable is to explain the plans related to TA#3: Sustainable Energy Storages. In order to keep the electricity systems balanced and running smoothly, the production and consumption need to be equal at any given time. The traditional way to achieve this is to modulate electricity production in order to follow the consumption. Energy storages introduce flexibility by stocking some energy to be used later. Adding a degree of flexibility allows for a better optimization of all aspects of energy production, transport and distribution. It however comes at the cost of energy losses. Nonetheless, it can be seen as preferable to use previously produced energy from a local renewable energy source than to force instant production in a distant plant.

In cases of a limited energy production supply, as is often the case for heat production, storage also allows for a better use of the production capacity and reduces the required size of the installation.

Energy storage enables the optimization of supply and demand, helps mitigate grid infrastructure constraints and assists in the seamless integration of renewable energy. The solutions studied focus on reducing grid stress while avoiding load and generation curtailment, supporting self-consumption over grid export and enabling the penetration of a higher share of Renewable Energy Sources (RES) without affecting system stability. The solutions implemented in RESPONSE are grouped into two Integrated Solutions (IS), as presented in Table 1.

T1.5 aims to define the exact measures for demonstrating, rolling out, transferring and replicating Integrated Solutions of the TA#3 by comparing the conditions before the demonstration and performance of the Positive Energy Buildings and Districts (PEBs and PEDs) of the two Lighthouse Cities (LHC) with their conditions after the envisioned demonstrations by the cities. This review will help in the successful implementation of the ISs defined for TA#3 as well as the development of a solid structure for facilitating the transferability of the ISs not only within the project's participating cities, but also across the EU.

Table 1 - TA#3 - Integrated Solutions for PEB/PEDs

TA#3: Sustainable Energy Storages		
Integrated Solutions	IS 3.1	Novel electricity storage providing flexibility to the energy systems
	IS 3.2	Novel heat storage providing flexibility to the energy system

1.2 Relation to other WPs and tasks

The Lighthouses Cities (LHCs) of Turku and Dijon, the Fellow Cities (FCs) and the other partner companies have exchanged knowledge and experience about the best possible integration potential for the RESPONSE solutions. This work is strongly related to work packages WP6 (LHC Dijon), WP7 (LHC Turku) and WP8 (FCs of Brussels, Zaragoza, Botosani, Ptolemaida, Gabrovo and Severodonetsk). The results of this WP and task will feed into WP6 and WP7 for the demonstration activities and WP8 for replication activities in the FCs.

Information from Task 1.5 will also be utilized in WP2 Smart Cities Performance Monitoring Framework and Governance which will define, plan, conduct and coordinate project monitoring activities for TA#3. Similarly, WP4 activities include open innovation competitions such as ideathons and hackathons launched in the LHCs during which start-ups, businesses, and students can build impactful, creative products and services in response to challenges identified by the cities in relation to TA#3.

1.3 The structure of this document

The structure of the deliverable is as follows:

- Chapter 1 introduces the objectives and scope of the deliverable.
- Chapter 2 describes the adopted methodology to collect and compile the available information.
- Chapters 3 and 4 present the areas chosen for the implementation and the plans as they exist for the implementation of the different Integrated Solutions (IS) respectively in Turku and Dijon.
- Chapter 5 compiles the planned replication activities in 6 Fellow Cities .
- Chapter 6 concludes the document, presenting the lessons learned at this stage of the project as well as the upcoming work to be realized.
- The appendices contain more detailed information about the various IS implementation plans for Turku and Dijon

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Chapter 2

Methodology

Chapter 2 – Methodology for information collection

2.1 Approach to the definition of Master City planning

The development of each LHC city's master plan (along with the initial plans of FCs) necessitates close cooperation among local partners, involving all relevant stakeholders: energy utilities, industrial and research partners, policy making bodies, citizens, and representative citizen groups.

In this regard, high- and low-level input from key players (such as technology providers and/or implementers), information related to the current status and expected actions, as well as information regarding regulatory concerns, needed to be collected. This deliverable presents the pieces of information collected which pertain to the implementation of energy storage solutions. The intentions for replication of these solutions by both the Lighthouse and Fellow Cities are also included.

RESPONSE's management structure was used to gather the essential details from both Lighthouse and Fellow Cities. To that end, under the umbrella of WP1 the Task leaders of each respective Task (T1.3-1.5) worked with the LHC/FC managers to define the relevant information. The managers worked with the respective Transformation Axis (TA) and Integrated Solution Leaders (IS) for the two LHC to gather the requisite information for the different Innovative Elements that will be introduced under the relevant TA-IS. The information was then checked and consolidated in the deliverable by the respective Task Leader. The process was repeated until all the participants were satisfied with the relevance and completeness of the information. The whole process is identical for Tasks 1.3 to 1.5 and is schematically presented in Figure 1.

Figure 1 - Methodology loop for collecting the required information from local partners in LHC.

2.1 Data collection methodology

The objective of this work was to define a preliminary plan to pave the way for the actual implementation. For that reason, the data collection started right at the start of the project. A set of questionnaires was deliberated with the LHC and FC managers and, after some revising, the final forms were completed.

Focusing on the LHC cities, two groups of Questionnaires were created:

The first one describes the PED/PEB, their current-status and an overview of IS's relevancy for each LHC city. Following questions were asked:

- What is the detailed description and current status of the demonstration areas?
- What are the technological elements already in place?
- What are the problems, motivation, restrictions, and barriers related to each Integrated Solution (IS) for the demonstration areas?

The second questionnaire focused on each IE. Following questions were asked:

- What are the general problematic and challenges that this IE wants to address?
- How the IE provides innovation and solves the challenges? What is its technical description?
- Was the IE pre-piloted and where? What are the lessons learnt from the pre-pilot?
- How the IE relates to RESPONSE's specific demonstration areas (PEB/PED)?
- What are the technical specifications, dimensions, implementation area etc. of the IE to be demonstrated?
- Will the IE be replicated and where exactly? What would be the benefits for the local replication ecosystem? What are the potential barriers?

Another set of questions, referring to replication activities was shared with the FC managers as well to retrieve their respective up-to-date vision. Figure 2 presents the timeline for T1.3 – 1.5 activities from M1 to M12 (deliverable ready for submission).

The entire process was supported by both monthly WP meetings and task-related meetings with the LHC managers and coordinating TA and IS leaders to clarify the process and the status of the questionnaires.

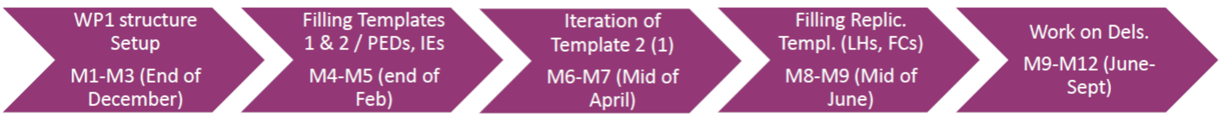

Figure 2 - Timeline for WP1 - T1.4 activities

2.2 Data collection templates

The templates completed by Turku and Dijon are presented respectively in Appendix A and Appendix B.

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Chapter 3

Turku Lighthouse City

Chapter 3 – Demonstration and replication plans in Turku

Turku will turn 800 years in 2029 –a date chosen as an objective for reaching carbon neutrality. According to Future of Today Institute's report of 2019, Turku was ranked as the 7th smartest city in the world[1]. The city aims at being resource-wise by 2040, which means zero-emissions, no waste and with sustainable use of natural resources. The operating commitments are based on shared values of responsibility and tolerance, regeneration, and cooperation, as well as being resident oriented.

Turku strives to prevent geographical segregation and social exclusion, diversify its economic structure, and improve the employment situation, make broadly available digital services, provide convenient and sustainable transport solutions as well as urban culture. With over 190 000 residents and estimated population growth of 20 000 new inhabitants by 2040, Turku is the 6th largest city and the 3rd largest urban area in Finland. The city has 2 universities and 4 higher education institutions with over 40 000 students.

On June 11th, 2018 Turku approved its sustainable energy and climate action plan 2029 which includes climate change mitigation and adaptation plans. The city's strategic vision is a carbon neutral city area by 2029. This objective is one of the most ambitious in the world, and Turku is well on its way towards achieving it. To meet its goal, Turku strives to reduce greenhouse gases by 80 % compared to the 1990 level by 2029. This target will be reached through milestones that are set for each council term:

- by 2021, reducing emissions by 50% compared to the 1990 level
- by 2025, reducing emissions by at least 65-70%
- and finally, by 2029 at the latest, reaching carbon neutrality and entirely compensating for any remaining emissions left.

Energy storage solutions are being explored and developed as a part of various initiatives involving the city of Turku and key actors in the field: Turku Energia, universities and local SMEs. For example, several projects related to energy storage for e-mobility applications, integration of renewable energy to the smart grids or heavy-duty batteries production and charging are currently running at the New Energy Research Center of TUAS.

Among the previously completed projects was LÄMPÖÄ which investigated the utilization opportunities of thermal energy storage through multisectoral cooperation. Its core focus was to research all-year storage of thermal energy in the ground by using energy piles and the utilization of these stocks as a source of additional energy for properties.

[1] Turku Climate Plan 2029. The City of Turku Sustainable Energy and Climate Action Plan 2029. Turku City Council 11 June 2018 https://www.turku.fi/sites/default/files/atoms/files/turku_climate_plan_2029.pdf

Partially as a result of this cooperation, a new ambitious construction project for Toriparkki was developed, as a part of the renovation of the Turku Market Square. Toriparkki, completed in December 2020, is a two-storey underground parking garage with more than 600 parking spaces, 20 of which equipped with electric car charging points. It is also aspiring to be a zero-energy parking garage, where the heating solution utilizes the solar heat collected from the surface of the market square. The recovered thermal energy is estimated to correspond to the annual heat consumption of about 560 detached houses, which at the same time makes Toriparkki one of the largest solar thermal energy storage systems in the world.

3.1 Positive Energy District in Turku

The Positive Energy Building cluster (PEB) that is implemented in Turku consists of several buildings located in the heart of the Student Village area in the North-eastern part of the city. The buildings are mainly used as housing for students and families, provided by the Turku Student Village Foundation (TYS). Two of them also include tertiary premises for grocery and retail shops, offices, restaurants and sport facilities. The PED also includes a city bike-sharing station (the most actively used of 41 stations in the city) and an e-vehicles charging station.

The selected PEB is composed of buildings of varying ages and uses with a net floor area of 40 543 m^2 (see Figure 3). It includes residential apartment buildings constructed in 1971 (cluster B4), 2004-2007 (cluster B5), 2011 (Ikituuri, B2), 2019 (Aitiopaikka, B1) and 2021 (Tyyssija, B3). Cumulatively, they are currently inhabited by 1024 occupants, which is to be increased by another 250 upon Tyyssija's completion.

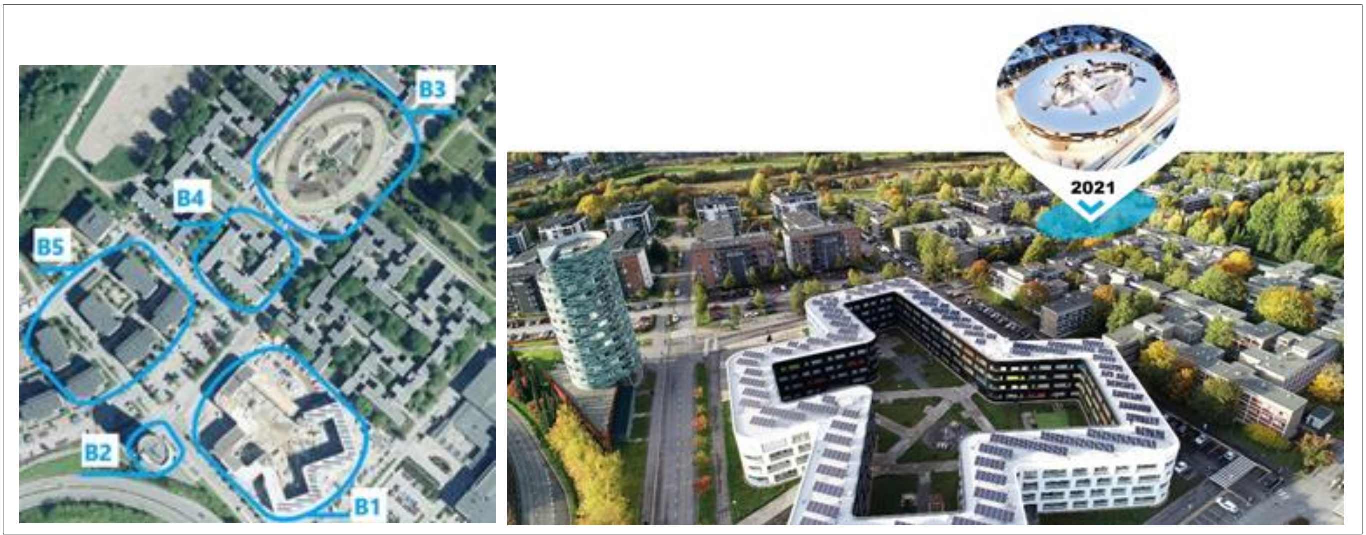

Figure 3 - Aerial view of the Turku PEB

The city of Turku is currently experiencing a shortage of student accommodation. More students continue to arrive. They currently represent about one fifth of the growing population of the city. This situation leads to an increased demand for affordable and sustainable dwellings. TYS offers housing for 25% of the students. The new buildings developed for that purpose are designed as forerunners for environmentally friendly construction. In addition, older premises are also renovated and maintained to increase their attractiveness and sustainability.

3.1.1 Inhabitants

Information about the residents is available only for the existing and inhabited building, therefore Tyyssija, which is currently under construction, is not taken into account.

The total number of PEB residents in Feb 2021 is 1024. Nationality-wise, 919 (90%) of the residents declared to be Finnish, 84 (8%) - of other nationality, and for 21 residents (2%) the nationality is unknown.

The age division is shown in Table 2.

Table 2: Age distribution in Turku's PEB

Age	Number	Percentage
< 18	17	1.7 %
18-25	545	53.2 %
26-40	431	42 %
41-55	20	1.9 %
56-70	1	0.1 %
> 70	2	0.2 %
Unknown	8	0.8 %

The rent level of the TYS student and youth housing in the PEB is 14.44 € / person-m² / month (including electricity, water charges and the data network). It is slightly higher than the TYS average rent, including all other locations of the housing company, which in 2019 was 12.60 € / person-m² / month. Buildings-wise, the most expensive rent is in Aitiopaikka – 16.86 €, followed by Ikituuri – 15 €, B4 block – 14.59 € and lastly B5 block – 13.65 € / person-m² / month.

The occupancy level of the PEB, as of February 2021, was on average 97.83%. The highest occupancy levels are in Aitiopaikka (99.97%) and Ikituuri (99.7%), slightly lower in the B5 cluster (98.34%) and the lowest in the B4 cluster (91.79%).

3.1.2 Energy Production and Consumption

The baseline for energy demand and generation of the PEB as well as the situation after the implementation of the RESPONSE innovative elements is presented in Table 3.

Table 3: Energy demand and production in the Turku PEB

		Baseline (kWh/a)	RESPONSE Solution (kWh/a)
Energy Demand	Space heating, cooling, and AC	2 607 340	1 170 529
	Hot water	1 419 005	972 650
	Lighting	243 258	243 258
	Appliances	2 016 457	2 820 292
	Total demand	**6 286 060**	**5 206 729**
RES Production	Photovoltaic	175 000	562 058
	Upcycling heat pump, heat	-	3 127 320
	Upcycling heat pump, cool	-	2 098 596
	Geothermal	337 600	337 600
	Total production	**512 600**	**6 125 574**

3.1.3 Equipment already installed

TYS has been testing the transfer of excess heat and electricity produced by RES between the buildings in the Student Village area. The transfer of excess heat is facilitated by the local low temperature District Heating (DH) network (75-55 °C), which is managed by TYS. The work requires more sensors and smart solutions to be expanded to the block and district levels.

The residential building “Ikituuri” has a hybrid heating system that uses both geothermal energy and district heat. The district heat is used to complement the geothermal heat pumps during peak demand. 20 geothermal wells with a depth of about 220 meters have been built in 2010 below the parking area of “Aitiopaikka” building. The building has a mechanical ventilation with heat recovery to increase the energy efficiency. It is also possible to cool the supply air during summertime.

The residential building “Aitiopaikka” has a solar park of 516 photovoltaic panels on its roof generating about 175 000 kWh yearly. The building is also equipped with heat recovery systems in each apartment.

The ongoing construction project “Tyyssija” (to be completed in 2021) will include an innovative energy upcycling heat pump using the city district cooling network of Turku as a heat source.

3.2 Description of the Integrated Solutions in Turku

3.2.1 IS 3.1 – Novel Electricity Storage Providing Flexibility to the Energy Systems

In order to provide flexibility to the energy systems, the Turku PEB will install two new electricity storage solutions:

- A 50 kWh second life Battery Energy Storage System (BESS) will be installed in the Aitiopaikka building, which already has 150 kWp of photovoltaic (PV) power installed.
- A 50 kWh lithium-ion BESS with micro-grid support will be coupled to the Low Voltage DC (LVDC) microgrid in the Tyyssija building.

Both BESS will be used to absorb part of the excess PV production and to reduce the peaks in consumption. In addition, the second will be used to reduce the gradients of power taken from or delivered to the common DC link, in order to increase the robustness of the innovative electrical energy distribution system and expand the term reliability of the LVDC. Those tasks require a higher Power to Energy ratio P/E for the selected BESS than in classical applications. It means that standard commercial solutions have to be modified and tested in specific conditions. For that reason, the BESS, along with the microgrid's Energy Management System (EMS) will be tested first in a Hardware-In-the-Loop (HIL) environment.

More information about the exact plans for each of these Innovative Elements (IEs) can be found in Appendix 1.

Risks

A possible risk to the installation of the second BESS is a delay in the construction process of the the Tyyssija building. It is however seen as unlikely because the construction process is currently ahead of schedule.

Opportunities

The integration of two different battery systems (novel DC-coupled and second-life AC-coupled) in a common project will give the opportunity to compare both solutions technically, in terms of cost, reliability, efficiency and environmental impact.

The Battery Energy Storage System (BESS) and the Low-Voltage Direct Current (LVDC) microgrid will enable the development and testing of business models regarding system capacity optimization (peak power shaving, load shifting) and cost optimization (energy spot price vs. CAPEX etc.).

The 2nd life BESS represents huge future business possibilities with the increasing number of Electric Vehicles (EV) in the coming years. There is a lot of value still left in decommissioned EV batteries.

A LVDC grid is a merging technology with clearly identified advantages in electrical energy distribution in comparison to the classical Low Voltage Alternative Current (LVAC) technology when Renewable Energy production needs to be integrated locally. One key aspect is the move from solving problems at the system level to solve them at components level. Once validated on real demonstration sites, those advantages will turn into strong marketing advantages for this technology, opening the door to new business opportunities.

Investments required for new energy distribution infrastructures and local storage will be compensated by cost reduction due to higher efficiency, reduced energy transfers, reduced peak capacity and higher robustness. The same is valid for the assessment of the sustainability of the solutions and of the equipment used on the site.

3.2.2 IS 3.2 - Novel Heat Storage Providing Flexibility to the Energy System

In order to provide flexibility in the provision of heat to the PEB, two Phase-Change Material (PCM) heat storage systems will be installed:

- Six units of a novel Phase-Change Material (PCM) heat storage with a total capacity of 84kWh (Figure 4) will be installed in the Tyyssija building where it will be coupled with an upcycling heat pump as well as with the building’s Domestic Hot Water (DHW) systems.
- A district-scale PCM heat storage will be implemented using a multi-temperature approach where the different phase change materials make an artificial stratification 43-58-70 °C suitable for the low-temperature district heating networks. This approach balances the charging mass flows in the system when the tubes in the storage are connected in a counter-flow configuration and reduces the thermal losses of the storage. The storages will be installed in between the city´s high temperature district heating and the local DH network of the PEB to serve a set of 4 renovated buildings (B4) as a block level solution to increase the flexibility of the district heating. An industrial “storage-as-a-service” concept will be demonstrated, where the service provider delivers the heat storage capacity to an agreed yearly payment. The total capacity of the storage will be 0.4 MWh and the peak load 0.5 MW. The storages will be charged by the high temperature district heating network and discharged to the local low-temperature network of the block.

More information about the exact plans for each of these Innovative Elements (IEs) can be found in Appendix A.

Figure 4 - PCM heat storage unit to be installe in the Tyyssyja building

Risks

A possible risk to the installation of the second BESS is a delay in the construction process of the the Tyyssija building. It is however seen as unlikely because the construction process is currently ahead of schedule.

Opportunities

Thermal storages increase the flexibility in the heating system operation of buildings and the district heating management. They further increase the self-sufficiency from renewable energy sources and participate in shaving the peaks during the peak load hours.

Compared to the systems where the water is where the heat is stored, PCM systems are more compact and reduce the risk of legionella growing in the system.

The service provider business model offers a facility to benefit from the advantages of an energy storage system by entering into a service agreement without purchasing the system. ESaaS (Energy Storage as a Service) combines an advanced storage system, an energy management system and a service contract that delivers value to a business providing thermal power more economically.

3.3 Replication of Innovative Solutions and Integrated Elements in Turku

Table 4 summarises the intentions expressed by the city of Turku regarding the possible replication of the Integrated Solutions that will be implemented in the RESPONSE project.

Table 4: Summary of the replication plans for Turku

IEs	Innovative Element	Area	Needs	Objectives	Financial features
IE 3.1.2 and IE 3.1.4	2nd life Battery Storage System and DC coupled Battery Storage System	Turku Science Park	High share of solar PV production	Facilitate energy transformation and decarbonization	Capacity optimization services (peak shaving, load shifting)
				Increase energy security	
				Improve energy affordability	
				Maximize energy harvesting	Expected high availability of 2nd life or decommissioned EV batteries
				Promote the technologies and products	
IE 3.2.5	District heating PCM heat storage-as-a-service	Koroinen substation	Optimize the operation of a geothermal plant for district heating	Facilitate energy transformation and decarbonization	The service is provided to the plant operator without requiring them to purchase and install the equipment
				Increase energy security	
				Improve flexibility in production	Combine a storage system, an energy management system and a service contract that delivers thermal power more economically
				Promote the technologies and products	

3.3.1 Description of the Turku Science Park (Kupittaa-Itäharju)

The significance of the further development of the Science Park (Figure 5) area became evident during the update of its strategy in 2018. The City of Turku nominated Science Park as one of its three spearhead initiatives (alongside with the City Centre and the Smart & Wise Turku). The goal is to strengthen the district's attractiveness and competitiveness as an international centre of excellence through the utilisation of digitalisation and smart solutions, development of transport and operational integration of the area with the city centre, implementation of a new way of spatial thinking regarding working and creation of an all-year and 24-hour urban environment.

Figure 5 - Architectural vision from Masterplan 2050 – Science Park visible in the top right corner

Figure 6 - Itäharju area development vision

The district is currently expanding from Kupittaa to the other side of the highway, the Itäharju area (Figure 6, now mainly consisting of low individual housing buildings and brownfield sites; population 2 684 in 2016), so that by 2050 there will be more than 20 000 new homes and more than 10 000 new jobs. The new Turku Science Park will be densified with construction of high (up to 40 stories) buildings, allowing reduced use of private cars and energy consumption, as well as efficient services.

Masterplan 2050 foresees that the Science Park (Figure 7) will consist of several campuses, thus bridging the pilot PED (Student Village – Student Campus) with the replication PED (Business, UAS and New Campuses). The area thus aims at becoming the best student district in Finland, providing jointly modern learning environments, affordable and sustainable student housing and versatile exercising and sport facilities.

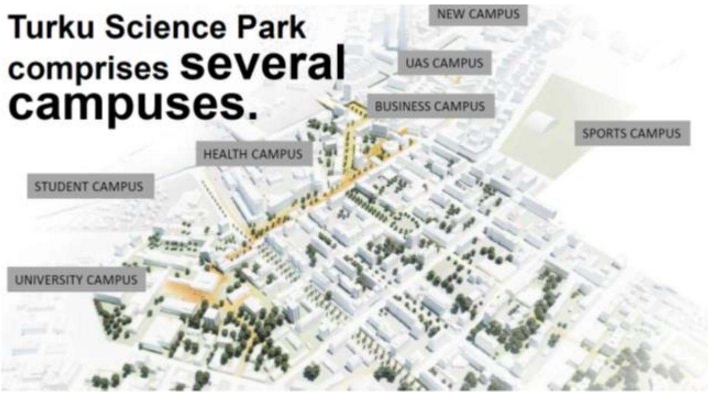

Figure 7 - Turku Science Park campuses according to Masterplan 2050 vision

3.3.2 Description of the Koroinen substation

In the autumn of 2019, Turku Energia and Turun Seudun Energiantuotanto Oy have applied for an action permit to drill two 7 000 m-deep heat wells in the Koroinen area for a geothermal plant. To produce geothermal energy, cold water is pumped from one well deep into the earth’s crust. There, the water heats up and is collected from the second well. The heat energy contained in water is usually collected in the pumping station via a heat exchanger. In this case, the goal is to heat the water enough for it to be used directly for district heating. The final decision about building a geothermal plant will be made after the first geothermal plant by St1 has been built and is in operation in Espoo. No new buildings are foreseen as the currently operating facilities at the Koroinen substation (Figure 8) are deemed to be sufficient. The new processing equipment is also planned to be installed there. Connected to the Koroinen substation is one of Turku Energia's district heating backup and peak production plants.

Figure 8 - Turku Energia substation in Koroinen. **Photo: Akseli Valmunen.**

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Integrated Solutions for Positive Energy and Resilient Cities

Chapter 4

Dijon Lighthouse City

Chapter 4 – Demonstration and replication plans in Dijon

Dijon is in Eastern France in the heart of the Paris-Lyon-Strasbourg triangle and is the capital of Burgundy Franche Comté Region. Dijon Metropolis, crowned with the label "City of Art and History", was home of the Dukes of Burgundy from the early 11th until late 15th century and has a vast protected area of 97 hectares where the palace of the Dukes and States of Burgundy are located. Dijon is an attractive metropolis with 250 000 inhabitants, composed of 23 cities, the biggest of which (Dijon), counts more than 155 000 inhabitants. Famous for its typical culinary specialities (i.e. mustard, blackcurrant cream), Dijon has always been a wine-growing town whereas the vineyards of Burgundy, existing for more than 2000 years, are included in the World Heritage List of UNESCO.

Dijon Metropolis (DM) is highly committed to achieving the necessary energy transition. In 2017, the total renewable energy produced within DM increased by 83% since 2010, reaching 380 GWh/year. The city of Dijon was one of the first public authorities to join the Covenant of Mayors. The DM's Sustainable Energy Action Plan was adopted in 2011 and applies to 23 municipalities. In 2018, Dijon signed the new Covenant of Mayors for Climate and Energy initiative and has been working on plans since, according to which a short-term goal of reducing GHG emissions by 40% until 2030, and a long-term goal of being carbon neutral by 2050, have been set. In September 2019, Dijon voted new local climate and energy objectives including reduction of Green House Gases (GHG) emissions by 95%, improving energy efficiency by 59% and increasing the share of renewables by 69% compared to 2010 levels. Eventually, 31,000 tCO_{2eq} of the remaining emissions will be compensated with local carbon sequestration, leading to carbon neutrality.

4.1 Positive Energy District in Dijon

The Positive Energy District (PED) of "Fontaine d'Ouche" is a district of Dijon located in the southwest part of the city. The density of the district is 185 dwellings per hectare. The average household size is 2.4 persons. In 2012, 37.5% of the households in PED were living below the poverty line, compared to 13% in the Dijon metropolitan area. An ambitious program is ongoing in the 2018-2024 period, including the French State as a co-financer. It includes the demolition of 122 homes, the energy renovation of 5 blocks of low-rent housing (1,219 housing units), support for the thermal renovation of 3 condominiums (984 dwellings) and the construction of 300 homes for homeownership. This ambitious project has led Dijon Metropolis (DM) and the City of Dijon to engage in an extensive process of development.

The Positive Energy Buildings cluster (PEB1) represents a wide variety of uses and has a net floor area of 17 316 m2, including a sport centre, two residential apartment buildings (social housing) consisting of 83 and 56 dwellings respectively, a kindergarten and a primary school and two car parks serving the needs of the citizens. The key objective is to aggregate the energy production and consumption of all these buildings into a single experiment in order to show that the PEB can export part of its production to other buildings. To regulate the energy flow, storage solutions will be implemented and their management system upgraded gradually with a slow optimization (Super EMS). Three Vehicle to Grid (V2G) charging stations and one collective water tank will be installed.

The PEB1 consists of 7 buildings:

- PEB1_B1: Sports center
- PEB1_B2: Car park
- PEB1_B3 and PEB1_B4: residential building “Ile de France”
- PEB1_B5: School of Colette
- PEB1_P1 and PEB1_P2: Car parks

The second Positive Energy Building cluster (PEB2) has a net floor area of 16,923 m2, including three residential apartment buildings (social housing) consisting of 40, 62 and 44 dwellings respectively, two kindergartens, two primary schools and a recreation center (within Anjou School), two car parks and a bleacher from a soccer field. The objective is also to aggregate the production and consumption of all these buildings into a single experiment in order to show that the PEB can export part of its production to other buildings.

The PEB2 consists of 8 buildings:

- PEB2_B1, PEB2_B2 and PEB2_B3: Residential buildings “Ilot Franche Comté”
- PEB_B4 and PEB_B5: respectively Buffon and Anjou schools
- PEB_P1 and PEB_P2: Car parks
- PEB_P3: Step stadium

4.1.1 Inhabitants

Fountaine d’Ouche is a district of Dijon, the population density is about 2 170 inhabitants per km^2, the total number of inhabitants is 18 620, of which 40 % are under 25 years old, 43 % between 26 and 59 years old, and 17 % are over 60 years old, the average age is 40 years old. Regarding the education level, 78 % of the 15-year old and over are either out of school without a diploma or below the Baccalaureate. The unemployment rate is 14 % and the income level is 24 500 euros.

4.1.2 Energy Production and Consumption

The energy produced and consumed for each building in the PED is shown in Table 5. The production is attributed to local PV systems (1 104 MWh/y in PEB1 and 899 kWh/y in PEB2) on some of the buildings themselves, biomass production from a nearby plant, waste heat recovery systems and biogas through Green Certificate Contracts.

Table 5 - Energy production and consumption per building in the Dijon PED (in MWh/y)

	Building	Consumption	Production
PEB1	B1	272	491
	B2	5	144
	B3	750	618
	B4	520	355
	B5	303	220
	P1	-	127
	P2	-	336
	Total	**1 850**	**2 291**

	Building	Consumption	Production
PEB2	B1	362	302
	B2	532	412
	B3	347	234
	B4	257	368
	B5	307	343
	P1	-	130
	P2	-	250
	P3	-	64
	Total	**1 805**	**2 103**

4.1.3 Equipment already installed

The Dijon smart city project, a 105M€ contract financed by DM, the Region of Bourgogne Franche-Comte and the ERDF made Dijon Metropolis the first fully digital public administration in France. Sensors for air quality, temperature, mobility are gathered through an IoT communication bus, based on Apache ActiveMQ, and are inserted into a data lake based on Apache Cassandra exposed with APIs using a NodeJS server.

OPTEER Climate, Air and Energy Platform: The OPTEER platform (developed by UB/THema and ATMO-BFC) is the reference observatory at the scale of the Bourgogne-France-Comté area for air quality. Between 2010-2017, it was used by more than 600 users to support the planning of more than 80 plans and is used to track the targets of the regional master plan.

Predictive models of air quality and Urban Heat Islands: The measurements of the air quality stations of Dijon are supported with the ADMS Urban model developed by ATMO. Day-ahead forecast of air quality are displayed in a public website and in the free smartphone application “air to go”.

Mustard network: The MUSTARDijon urban climate network was firstly conceived as a seasonal instrumental campaign, with the deployment of 50 sensors measuring air temperature and humidity every hour in June 2014. These sensors recorded measurements on internal memory cards, requiring recurrent data retrieval in each station.

Heating district network -–CORIANCE: Sodien, a subsidiary of Coriance, manages the district heating network in Dijon, which measures 62 km, serves 32 400 housing equivalents through 385 sub-stations, avoids 44 400 tonnes of CO_2 emissions per year, its resource is 50% biomass, 20% natural gas and 30% from incineration plants

4.2 Description of the Integrated Solutions in Dijon

4.2.1 IS 3.1 – Novel Electricity Storage Providing Flexibility to the Energy Systems

In order to provide flexibility to the energy systems, the Dijon PED will install three new electricity storage solutions:

- A Zn-Air (ZnR) battery system in the school Buffon (PEB2_B4) in order to increase the district's self-consumption ratio. The system would have had a capacity of 450kWh, with an optimal charge duration of 6 hours and a discharge duration between 4 and 12 hours. A Building Energy Management System (BEMS) was also to be implemented on this battery in order to pilot the flexibility and improve self-consumption. It is known at the time of this deliverable that this solution is not going to be implemented in the RESPONSE project. Alternative possibilities are being considered to replace it, similar in spirit, relevance and budget. They cannot however be included in this deliverable before they are officially confirmed.
- A flexible and scalable second life battery storage system based on salvaged from used electric vehicle batteries. The system implemented will be a 60 kWh battery with a power converter of 60 kW. It will be equipped with a programmable logic controller which can be operated by a separate third-party energy management system. Due to the original supplier stopping their operation, a call for tenders has been issued. At the time of this deliverable, a preselection has been made, but the choice has not been officialised yet.
- Vehicle to Grid (V2G) storage system coupled with Li-Ion batteries (not included in this deliverable, but covered in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*.) It is also known at the time of this deliverable that the Li-Ion batteries won't be implemented. Mitigation plans are being considered.

The batteries are connected to the GeneSys system which encrypts energy data and assures the communication between assets and the "Super EMS" to pilot batteries in order to maximize self-consumption rate.

More information about the exact plans for each of these Innovative Elements (IEs) can be found in Appendix 2.

Risks

The complete concept change for the ZnAir batteries and the change of supplier for the second-life batteries have introduced delays in the planning. The expectation is that the implementation of the Integrated Solution will be back on track for the next round of the planning phase, which will be opening the work in WP6.

Opportunities

Battery storage is a key technology for the energy transition. It helps decarbonizing both the transport sector (with electric mobility) and the energy sector (by balancing renewables). The lithium-ion battery demand for electric mobility is forecasted to increase from 142 GWh in 2018 to 2333 GWh in 2030. This growth in battery manufacturing facilities, particularly in China, drives the global demand for lithium. Electric vehicle batteries are dismantled once the capacity decreases down to 75%. Reusing electric car batteries in less restrictive applications enables to take advantage of the 75% remaining capacity and prolongate the battery lifetime. It decreases the overall impacts of the battery lifecycle and delays recycling to a later period of time when recycling processes and regulations will be more mature.

4.2.2 IS 3.2 - Novel Heat Storage Providing Flexibility to the Energy System

In order to provide flexibility in the provision of heat to the PED, three different heat storage systems will be installed:

- Small decentralized phase change material (PCM) tanks to store the excess of solar production, increase the self-consumption ratio and reduce the heat losses induced by the heating of a hot water loop temperature in collective housing. Eight PCP50 tanks (one per supplied apartment) will be installed in building 55 for the production of hot water and will be connected to the heating network. In order to charge it, the heating water will circulate through one of the internal heat exchangers to melt the PCP50. The heating fluid will circulate at 55°C, thus reducing heat losses. Whenever hot water is used in a flat on the same floor, fresh water will flow through the second heat exchanger to directly supply the end-user.
- An industrial hot water buffer tank used for intraday heat storage to reduce peak supply from gas boilers will be used to heat the district heating network. One sensitive heat storage (buffer tank) will be designed and installed accordingly on the production plant within the PED.
- Collective hot water tank with a dedicated BEMS, on a building level in order to optimize the self-consumption ratio. It will be installed for the 2 buildings of “Franche-Comté” block and one for the “Ile de France” block with an electric resistance to heat the water used for sanitary needs of the residents (using own funding), demonstrating a Power-to-Heat storage solution.

More information about the exact plans for each of these Innovative Elements (IEs) can be found in Appendix 2.

Risks

The small PCM tanks may encounter technical issues, as the hot water service in the targeted building is old-fashioned.

The technical and financial feasibility of converting former fuel tanks to hot water storage is being studied.

Opportunities

The expected energy saving by the PCM tank for hot water production is 35%.

A buffer tank of 1 200 m^3 will be used for thermal storage. By storing heat produced from the use of biomass, the gas consumption can be reduced during the peak load periods. The estimated natural gas reduction at those times ranges from 1 to 3 GWh/y.

The capacity of the Collective hot water tanks with a dedicated BEMS is about 10 m^3 for “Ile de France” Island and 6 m^3 for the “Franche-Comté” island.

4.3 Replication of Innovative Solutions and Integrated Elements in Dijon

Table 6 summarizes the intentions expressed by the city of Dijon regarding the possible replication of the Integrated Solutions that will be implemented in the Response project.

Table 6: Summary of the replication plans for Dijon

	Innovative Element	Area	Needs	Objectives	Financial features
IE 3.1.1 and IE 3.1.2	Zn-Air battery and 2nd life Battery Storage System	CHU and University Districts	Battery storage (450kWh) + 2nd life battery storage	Maximize energy harvesting	To be defined based on expected costs
				Grid flexibility and stability	
			Promote solution based on circular economy	Facilitate energy transformation and decarbonization	
				Empower citizens in the energy transition	
IE 3.2.3	Collective hot water tank with a dedicated BEMS	Buildings of Grand Dijon Habitat and Orvitis	The tank size will depend on the dimensions of the rest of the installations	Improve energy efficiency and maximize RES harvesting	Included in broader renovation plans
				Grid flexibility and stability	
			Promote solution based on circular economy	Facilitate energy transformation and decarbonization	
				Empower citizens in the energy transition	

4.3.1 Description of the Dijon replication areas

Fontaine d’Ouche is a residential district of 18 000 inhabitants who mainly live in social housings. Thanks to RESPONSE, parts of the district are going to be refurbished and a collective self-consumption plan is deployed for 1 000 inhabitants.

Figure 9 - Fontaine d’Ouche District

CHU & University is a very dynamic east district of Dijon built in 1960s. There are plans to renovate buildings through an energy efficiency plan. The population is young and mostly committed in global energetic transition, making a collective self-consumption scheme easier to develop. Moreover, over 7 000 persons work in this area (highest rate in Bourgogne Franche Comté County), developing a huge potential in electric mobility and V2G linked with self-consumption optimization.

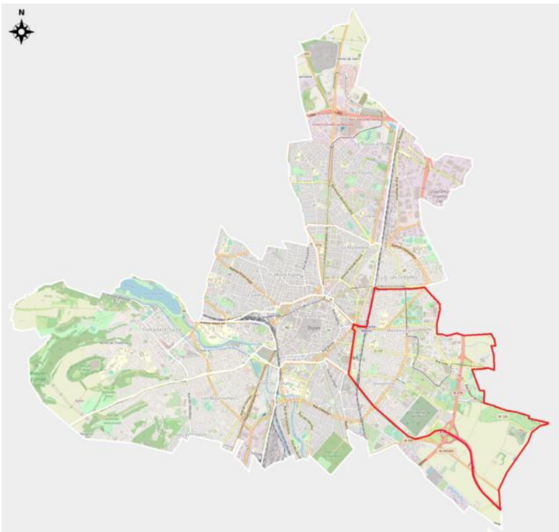

Figure 10 - CHU University District on Dijon Map

There are 23 431 social housings in Dijon Metropolis. Grand Dijon Habitat and Orvitis are the two main social housing owners (39% and 20% respectively), anchored throughout the territory. In the RESPONSE project, Social housing owners will test in Fontaine d'Ouche collective self-consumption scheme in their buildings (solar production on roofs, BIPV balustrades, …) and their tenants will consume this energy. If the business model were reliable and viable, social housing owner would be ready to develop renovation plans to their buildings in Dijon, including collective self-consumption. Dijon has already equipped public buildings with PV on roofs (only to sell back produced energy):

- Beaumarchais School
- Gaston Gérard Stadium
- Olympic Swimming Pool

In 2025, Dijon must sign a new energy performance contract. Thanks to the RESPONSE demonstration in Fontaine d'Ouche, it could design a policy to install renewable production on public buildings and sites welcoming public (not precisely defined yet) in order to implement collective self-consumption.

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Chapter 5

Replication Plans of Fellow Cities

Chapter 5 – Replication Plans of Fellow Cities

5.1 Brussels

The City of Brussels is the capital of Belgium and has a population of 181 726 inhabitants spread over 33.1 km2. 27 345 buildings and 83 870 residential units are registered in the City of Brussels (as of 2014), including 7,809 social housing units. 38% of housing has been built before 1919, while an overwhelming majority of buildings were built between 1900-1945. Major redevelopment projects such as the redevelopment of the Canal Zone, or the NEO51 project on the Heysel Plateau aim at constructing energy-efficient buildings. Tivoli GreenCity is a newly constructed neighborhood; served by a district heating network, renewables, PV panels while an experimental greenhouse installed at the first floor of one of the buildings will be used for educational purposes. Brussels together with the Public Welfare Centre have already constructed more than 2,000 energy-efficient and passive homes and plan to develop 750 additional housing units.

According to 2017 statistics, the main energy-consuming sector was housing, accounting for nearly 38% of final consumption, followed by the tertiary sector (35%) and transport (22%). As for greenhouse gas emissions, mostly CO2, buildings' heating accounts for 61%, followed by transport with 29%.

5.1.1 IS 3.1 - Novel Electricity Storage Providing Flexibility to the Energy Systems

Some ideas about energy generation are starting to be explored in Brussels. Those are located in diverse areas of the district. For hydro-energy, the canal area will be assessed. In the same area, waste heat and possibilities from industries will be explored. Geothermal energy is also possible near the Maximilan Park area. Furthermore PV would be integrated to the buildings mentioned in *m* Electricity storage solutions would be located near the mentioned places.

The current plans regarding electricity storages are to first map the existing systems within the PED perimeter and, as a next step, to realize feasibility studies for battery systems in the locations where a surplus of production would be identified.

It should be noted that if the installation containing battery storage systems needs to follow certain norms and regulation, in most cases, the solution should be implemented at the conception of new buildings or during retrofitting projects.

5.1.2 IS 3.2 - Novel Heat Storage providing flexibility to the energy system

During the project, the City of Brussels is going to explore the implementation of a district heating system within the PED (as described in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*). The heat storage solutions implemented in the Lighthouse Cities will be integrated in the design of the new system.

5.2 Zaragoza

Zaragoza is the capital city of the Zaragoza province and the Aragon Region (Spain). Zaragoza, divided in 15 districts, is one of the largest municipalities in Spain (about 1 000 km²) being the fifth city in terms of citizens in the country and its municipality is home to more than 50 percents of the Aragonese population.

The proposed use case is the neighbourhood of Balsas Ebro Viejo, within the Picarral district. It encompasses a total of 1 350 households in 130 buildings.

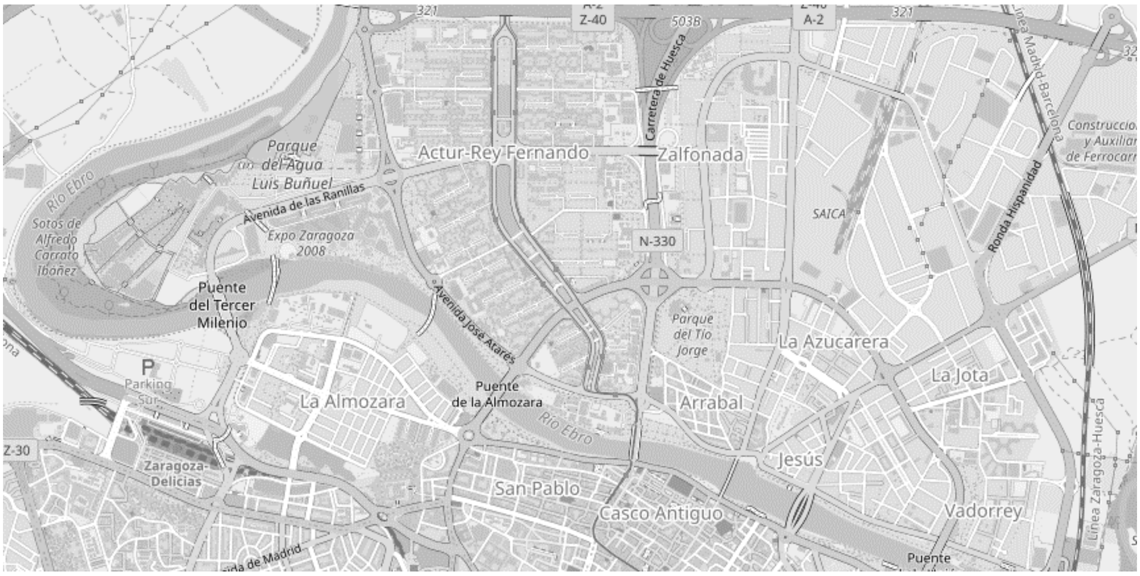

Figure 11 - Location of Balsas de Ebro Viejo in Zaragoza

In deliverable *D1.3: "Master City Plans for TA#1 Positive Energy Building Systems"*, an energetic rehabilitation program is described for the neighbourhood. If that development is successful, the intention is to perform feasibility studies for stational heat storages within the neighbourhood and centralize the heat, starting from the air source heat pumps and working up to the building and block levels.

Balsas de Ebro Viejo is part of 21 urban interest sets in the city and its structure (in terms of age and type of housing and communities) shares similitudes with many similar neighbourhoods in the country. However, the solutions proposed require a high investment cost, which may be a barrier for the local aging or vulnerable population. For that reason, the plan contemplates a 100 % grant recovery plan and a study about the effect of the solution of the population's vulnerability.

5.3 Botosani

Botoșani is the capital city of Botosani County, situated in the Northeast of Romania. According to the 2011 census, Botoșani has a population of 106 847 inhabitants. Botosani has a warm summer continental climate. Heating and hot water services are provided by a single entity called Modern Calor S.A. In mid-2000s, a large improvement project has been run in the city, leading to the installation of a state-of-the-art CHP plant, two heat-only boilers and the replacement of some transmission and distribution lines.

The replication area considered consists of blocks of habitations within the Owners Association no.47, the recovery hospital "SF. Gheorghe" and the "Alexander the Good" high school. More information about the renovation of the district heating network as well as of the various buildings in the area can be found in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*.

The *IE 3.2.4 – PCM Heat Storage Tanks for DHW buffering* is suitable to store the excess of solar production, to increase the self-consumption ratio and to reduce the heat losses induced by the heating of a hot water loop temperature in collective housing and the hospital in that area. The Municipality of Botosani is interested in the PCM technology and possibilities of using this technology in the DHS as either storage or buffer tanks in order to improve the overall energy distribution efficiency and smart energy management.

Hospital buildings, schools and homes are present in all areas of the city, as well as in all cities. The implementation of projects on these buildings will generate a major interest and, hopefully, large-scale replication of them in other areas and cities.

5.4 Ptolemaida

Ptolemaida is a city in Nothern Greece and since 2011 is the capital of the municipality of Eordaia, in Kozani Regional Unit of Western Macedonia Region. The municipality has a population of 45 450 residents whereas the population of the city of Ptolemaida was 32 142 residents, occupying an area of 57 508 km².

The city's space heating and domestic hot water demands are mainly covered by a district heating network (approximately ~98%), operated by the municipal District Heating Company of Ptolemaida (DETIP). The network was constructed in 1993 and is connected to the Public Power Corporation's (PPC) thermal power plant "Kardia" (Units III and IV, about 100 MW_{th}) while it is expected to be connected to the new PPC's thermal power plant "Ptolemaida V"). The heat consumption in the Ptolemaida district heating network amounts to 200 807 MWh. To ensure the energy efficiency and to cover the peak load, DETIP has installed three thermal storage tanks (buffers) of 3 800 m^3 and a back-up oil-fired boiler of 25 MW_{th}. By 2023, however, PCC has taken the decision to shut down most of their coal fired plants. For that reason, the Municipality of Eordaia is considering alternative options regarding its district heating. More information about the district heating system in Ptolemaida and its upcoming changes can be found in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*.

In this regard, they are going to investigate the possibility of additional industrial hot water buffer tanks (IE 3.2.2) and of heat storage tanks for DHW buffering (IE 3.2.4) in the existing district heating system.

5.5 Gabrovo

Gabrovo is situated in the North Central Region of Bulgaria, along the Yantra River, at the foot of the Balkan Mountains. The municipal territory, consisting of Gabrovo and 133 villages spans over 555 579 km² with a population of 62 763 people.

In its PED area, the municipality of Gabrovo intends to install new PV production capacity. The overall idea is to make use of public spaces (including parking shades) to generate electricity for the needs of public and façade lighting in the Gabrovo central square and the surrounding public buildings as well as to use the locally generated RE electricity to charge EVs. More details about these plans can be found in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*.

The municipality of Gabrovo intends to realize feasibility studies, based on the results in Turku and Dijon, about the addition of electricity storage units (Zn-Air batteries, 2nd hand batteries or others) to store the excess of electricity production. The specific location of the installations as well as their dimensions would be the result of such feasibility studies

5.6 Severodonetsk

Severodonetsk is a regional centre of the Luhansk Oblast, located in the east of Ukraine. The city has a population of about 113 616 inhabitants (January 1, 2019) spread over 58 km².

5.6.1 IS 3.1 - Novel Electricity Storage Providing Flexibility to the Energy Systems

Since 2015, the city has implemented a system of daily monitoring of energy consumption (on-line program "Energy Balance") at 57 sites with a total area of 212 600 m². It is a reliable metering and monitoring system for energy consumption, followed by data analysis, which helps to identify weaknesses in a timely manner, notice the effectiveness of energy efficiency measures and report on the reduction of energy consumption.

As described in *D1.4: "Master City planning for Local Energy Supply – Low Carbon & High Share of Renewables"*, Severodonetsk is interested in installing a cloud-based Smart Energy Management System in the Educational and Laboratory Building of the V. Dahl East Ukrainian National University. The building has an average energy consumption of 14.54 kWh/m² and a maximum energy consumption of 28 kWh/m². The results of the implementation of *IE 3.1.2: 2nd life BESS* in Turku and Dijon will be used to assess the feasibility of installing that type of storage system in the University building and of sharing its capacity with other nearby buildings

5.6.2 IS 3.2 - Novel Heat Storage providing flexibility to the energy system

A complete renovation of the public heating networks is foreseen. There are two main heat suppliers, the "Severodonetsk-teplo-commun-energo" with a total length of heating pipes network of 63 km and State Enterprise "Severodonetsk TEC" with a total length of heating pipes network of 110 km. These two enterprises use gas boilers to generate energy, while "Severodonetsk TEC" can operate both gas and oil.

Severodonetsk is also interested in biomethane injection produced from sewage sludge (as a prospective technology), Green Certificates Contracts and two-way consumer/prosumer district heating connection with Green Certificates Contracts. In the future, the development of local energy markets is also envisioned.

In this context, Severodonetsk will study the installation of PCM heat storage tanks for DHW buffering (IE 3.2.1).

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Integrated Solutions for Positive Energy and Resilient Cities

Chapter 6

Conclusion

Chapter 6 – Conclusion

This deliverable presented the first version of the Master planning for the energy storage related demonstrations of the Innovative Solutions in Lighthouse cities Turku and Dijon. It introduced the districts and the systems that will be implemented in them. Each city will see the installation of two different electricity storages, with their management systems. Their heating systems will be improved with the integration of Phase-Change Material heat storages. The system in Dijon will also be aggremented with an additional hot water industrial scale storage tank.

The expected outcomes from the introduction of energy flexibility in the districts are to reduce peak power consumption or production, reduce the costs of energy provision and the promotion of a more circular form of economy.

7.1 Lessons learned

The questionnaire-based approach to collect detailed information about the innovative elements proved to be a suitable method. The iterative nature of the process improved the quality of the information collected with the questionnaire templates as the questionnaire circulated between the task lead, IS-leader and the technology provider several times. The uniform approach selected for all WP1 master planning tasks (1.3-1.5) also streamlined the process for the lighthouse managers.

The replication plans show us that there is interest for cities and municipalities to implement energy storage solutions, especially when they are in the process of renewing their energy supply installations.

For projects of this scale, the planning and implementation of the various solutions takes time and requires to constantly change and adapt the plans to the circumstances. This deliverable is therefore more of a still image of the plans as they currently stand than the motion picture of the different Integrated Solutions as they are actually progressing.

At such an early stage in the development, it is difficult to expect the Fellow Cities to have much more than expressions of interest. They will require more information about the results of the implementation in order to further their plans and to eventually launch replication actions.

7.2 Future work

This Master Plan is set to be followed as a part of WP6 and WP7 work, in particular tasks *T6.4 and T7.4 Dijon/Turku Sustainable Energy Storage (TA#3) implementation*. Based on the needs and conditions of the on-site work, it is also foreseen that the Master Plan will be reviewed, updated and adjusted in the framework of carrying out tasks T6.1 and T7.1 devoted to Smart City Diagnosis and dynamic Master Planning for TA#1-TA#3.

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Appendixes

Appendixes

Appendix A. Additional Information about the Turku PEB, IS and IE

In order to keep this deliverable clear and concise, not all the collected information was included in its main part. The additional information collected is presented in the following annexes.

a. Demonstration Area and Geographical Overview

The Student Village PED (Figure 12) is located in northeastern part of Turku, embraced by the meander of Aura river in the west and north, bordering the Nummi district in the southeast and the University of Turku campus in southwest. It mainly consists of housing for students and families provided by the Turku Student Village Foundation (TYS), but also includes residential buildings and private detached houses. There is a shop in the area, a spa-hotel, several daycare centers and schools, a cemetery and a Lutheran church. The area offers good opportunities for both outdoor and indoor sports, as there are hiking trails and facilities for activities such as swimming, tennis, volleyball and basketball.

The area is well connected within the public transport system with both buses (lines 50, 51, 54, 55, 220, night line 36) and the city bike sharing system (two stations are within the PED). In fact, the first bike sharing station at Ikituuri is the most actively used one among the 41 currently existing in the city. Tenants of TYS have the possibility to rent out two shared cars in the Student Village – this service is provided by operator 24rent. There are also 3 electric vehicles charging stations – one nearby the city-bikes station, and two on the parking in front of the spa-hotel.

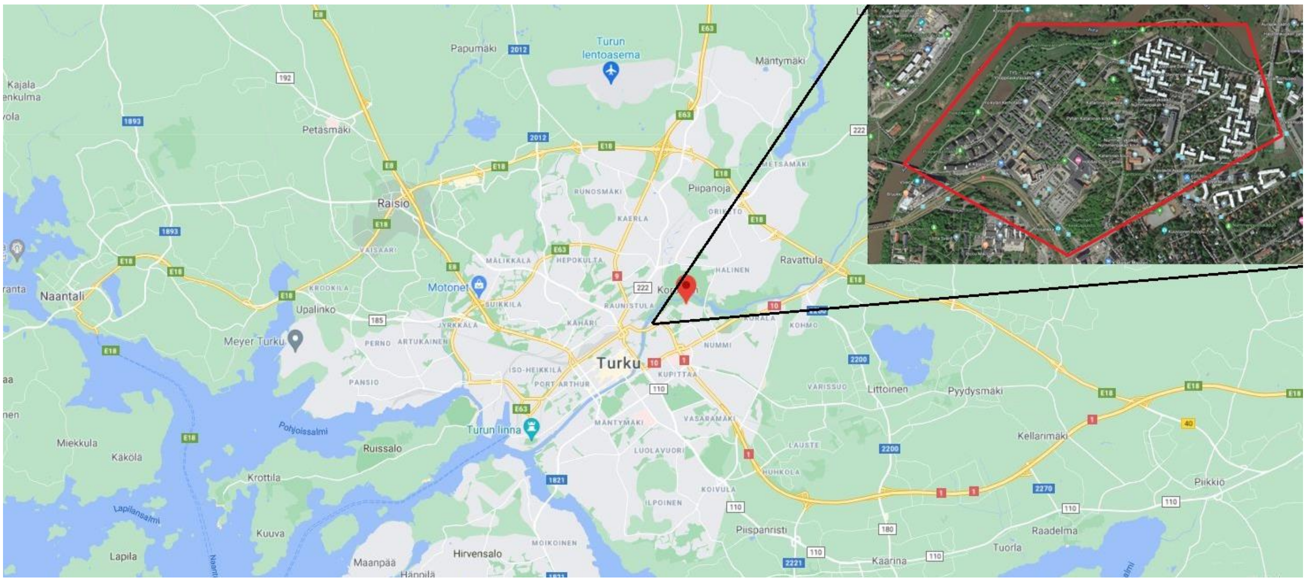

Figure 12 - PED location on the greater map of Turku

The joint goal of the higher education institutions of Turku is to be Finland's best student city. Active student life, easy and well-functioning public transport, and affordable housing are Turku's great assets. Consequently, one fifth of the growing number of residents in Turku are students, and TYS offers housing for 25% of them. Currently there is a shortage of student accommodation in the city and in the view of growing number of citizens, incl. students, the situation leads to increased demand for affordable and sustainable dwelling. Due to its size (being the largest single student housing complex in Finland) and proximity to the University of Turku and Åbo Akademi University campuses, Student Village can be considered the main housing area of TYS. Majority of TYS buildings in PED have been constructed during the 70-80s, some of the most recent ones – in 2011 and 2019.

The Student Village will form an integral part of the new campus area, and contribute to the lively atmosphere, convenient services and sustainable ways of life. Its proximity to the Science Park area – the city's most significant growth center of know-how and high technology jobs covered by the strategic spearhead initiative – further emphasizes the importance of Student Village area as one of Turku's priority districts for smart solutions development, testing and adoption.

b. IE 3.1.2 - 2ND LIFE BATTERY STORAGE SYSTEM (BESS)

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

Battery storage is a key technology for the energy transition. It helps decarbonizing both the transport sector (with electric mobility) and the energy sector (by balancing renewables). Lithium-ion battery demand for electric mobility is forecasted to increase from 142 GWh in 2018 to 2333 GWh in 2030. This growth in battery manufacturing facilities, particularly in China, drives the global demand for lithium. Electric vehicle batteries are dismantled once the capacity decreases down to 75%. The EU Battery Directive states that at least 45% of all the EU's used batteries must be collected by 2016, of which at least 50% must be recycled. Thus a maximum of 77.5% of all the EU's used battery components are likely not recycled.

Reusing electric car batteries in less restrictive applications enables to take advantage of the 75% remaining capacity and prolongate the battery lifetime. It decreases the overall impacts of the battery lifecycle and delays recycling to a later period of time when recycling processes and regulations will be more mature.

The IE is designed and developed specifically to integrate electric vehicle batteries for them to be used in an environment (stationary storage) which is technically very different from the original usage (within a vehicle). The IE is a 2nd life battery storage system for stationary applications. The system is composed of 1) batteries designed for and previously used in electric vehicles, 2) a tailored power conversion unit connectable to any power grid and 3) a programmable logic controller which manages charging and discharging of the batteries.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

Pre-pilots of the 2nd life battery storage system have been developed and deployed within the H2020 ELSA project. Six pre-pilots have been installed in four EU countries in order to cover all the relevant applications for distributed storage from an office building to a university R&D center or a local grid with solar energy generation:

- Ampere Building - Location: Paris, France - Category: Building – Batteries: 8 Kangoo (96kWh)
- Gateshead College - Location: Sunderland, United Kingdom - Category: Building – Batteries: 8 Leaf (36kWh)
- Nissan Europe Office - Location: Paris, France – Category: Office Building – Batteries: 12 Leaf (144kWh)
- Aachen University - Location: Aachen, Germany – Category: District - Batteries: 6 Kangoo (72kWh)
- City of Kempten - Location: Kempten, Germany – Category: Distribution System, District - Batteries: 6 Kangoo (72kWh)
- City of Terni - Location: Terni, Italy - Category: Distribution System - Batteries: 6 Kangoo (72kWh).

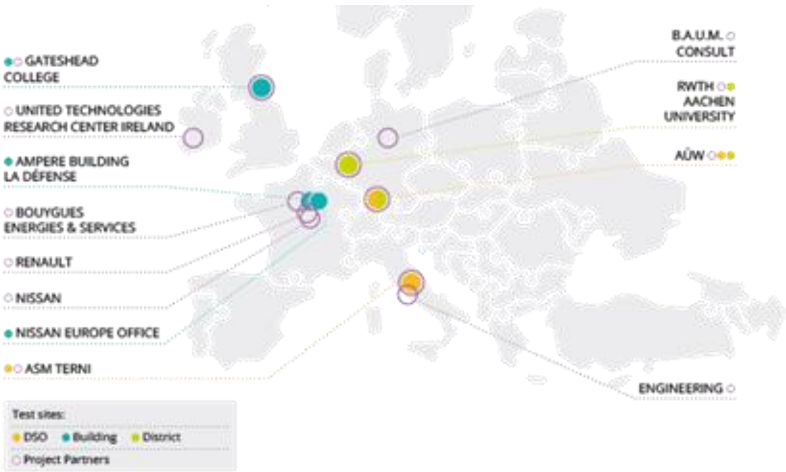

Figure 13 - Locations and battery storage construction for the H2020 ELSA pre-pilots

Technical specifications of the IE as pre-piloted?

Pre-pilots deployed within the H2020 ELSA project (Figure 13) have a capacity of 36kWh to 144kWh due to the modularity of the system. Integrated batteries are mostly Kangoo batteries from Renault, based on Manganese Laminated Lithium-Ion with a remaining capacity of 15 kWh (available capacity being 12 kWh), dimensions (W/D/H) of 1210 x 800 x 300 mm and a weight of 265 kg. Up to 8 batteries can be connected to each power conversion unit. Power conversion units are developed and supplied by ABB, with several existing sizes of 24 kW, 48 kW, 72 kW and 96 kW, dimensions (W/D/H) of 600 x 600 x 2132 mm and a weight of 200 kg. The system is controlled through the programmable logic controller by an Energy Management System (EMS) developed and implemented by a third party.

Figure 14 - Batteries and conversion units

Technical improvements achieved

Significant technical improvements of the pre-pilot have been made in order to industrialize the solution. From a prototype integrating an electric car charger and a PV inverter to charge and discharge one battery, the final version of the pre-pilot integrates a power conversion unit developed by ABB which can control up to 8 batteries of 12 kWh.

Energy savings, increase of overall efficiency, performance data, power generation etc ?

The efficiency of the power conversion system is above 95%, which is similar to typical stationary storage power conversion systems using 1st life batteries. To evaluate the overall efficiency of the 2nd life battery storage system, measurements were performed by charging and discharging entirely the system at different loads. Results showed an overall efficiency of 85.5-90.3%. The maximum efficiency was reached at 50% load (charging and discharging at 72 kW for a system of 144 kW), decreasing to 87.8% at 100 % load (144 kW) and 85.5% at 20% (29 kW). The standby consumption of the 144 kW system was between 300 W and 400 W.

Socioeconomic benefits reached (citizens acceptance of solution, improved experience, and standard of living; both qualitative and quantitative info can be provided if available)?

The IE is based on the reuse of batteries which are no more able to deliver the required performance in an electric vehicle. Circular economy is the key aspect of 2nd life battery storage systems, with socioeconomic benefits being also the higher citizens acceptance and the lower price of 2nd life batteries.

Restrictions and problems encountered (regulations, citizen, technical) and mitigation actions?

Technical, supply and price problems were encountered. Technical problems were related to bugs of the system and were resolved through corrective actions. Supply problems were related to the lack of availability of specific components of the power conversion unit. Because of the tailored development of the system, the IE supply is fully reliant on ABB who has very long delivery times above 4 months. A mitigation action has been to reuse an existing pre-pilot. At last, the expected lower price of 2nd life battery storage systems is not obvious because of two effects: 1) the tailoring of the power conversion unit makes it more expensive than mass-produced products, 2) the increasing compactness and decreasing price of new battery technologies make 2nd life batteries less attractive.

IE 3.1.2 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

PEB1 is composed of a wide variety of constructions: University Aitiopaikka, offices, Restaurant, grocery, sport areas, Student accommodation and car parks. It has the particularity to produce more energy (2,103 MWh/year) than it consumes (1,805 MWh/year), thanks to solar panels, a nearby biomass plant, waste heat recovery and biogas through Green Certificate Contracts. A unique collective experimentation will be deployed to maximize self-consumption at the scale of PEB2. Because the production and consumption needs cannot not match at any time, energy storage is required in this experimentation. The IE is trying to solve the challenge of getting the best out of battery storage (grid flexibility) without its disadvantages related to environmental issues.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

By reusing electric car batteries for stationary storage, the IE will solve both grid flexibility and environmental challenges of PEB2. The IE will be controlled at the scale of PEB2 by taking into account the overall production and consumption needs to maximize collective self-consumption. Circular economy within this IE enables to get grid flexibility without environmental issues related to lithium-ion batteries.

Innovation in the proposed IE?

The IE is designed and developed specifically to integrate electric vehicle batteries for them to be used in an environment (stationary storage) which is technically very different from the original usage (within a vehicle). The IE is a 2nd life battery storage system for stationary applications. The system is composed of 1) batteries designed for and previously used in electric vehicles, 2) a tailored power conversion unit connectable to any power grid and 3) a programmable logic controller which manages charging and discharging of the batteries.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

The IE consists in a 2nd life battery storage system of 50kWh. Integrated batteries are recycled batteries from electrical vehicule, based on Lithium-Ion. The battery is mounted on racks with a dedicated part for the BMS directly on racks as well . Batteries are connected to a power conversion unit of 50 kW. The system also integrates a programmable logic controller, which include an Energy Management System (EMS).

In addition, two energy meters are supplied and connected to measure the Electricity production coming from the photovoltaic installation and to measure the consumption of the buildings. Then the EMS is able to define the storage or supply mode according to the various profile between production and consumption. The layout of the system integration in the existing sites is showed in Figure 15.

The supplier for the batteries has not been confirmed at the time of this deliverable.

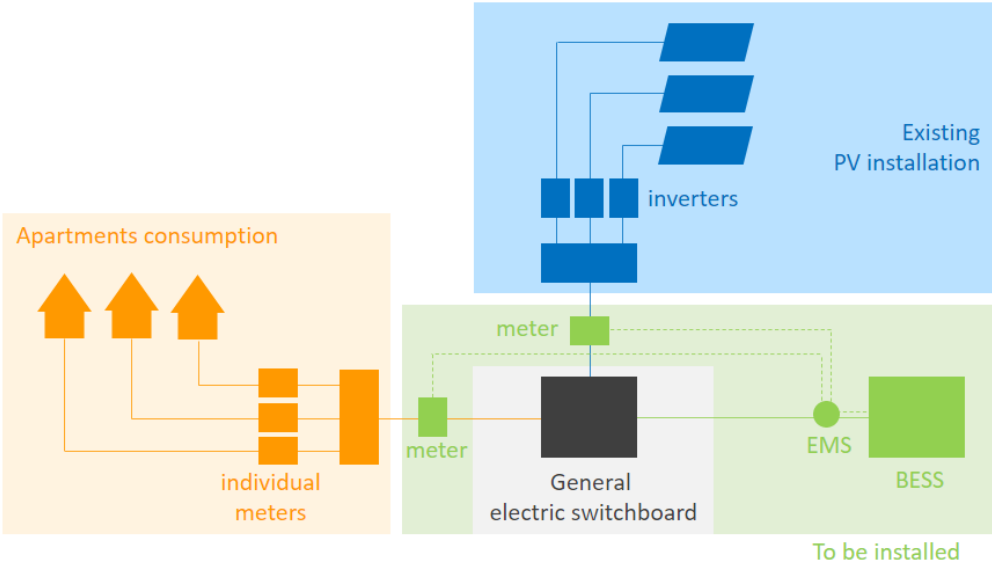

Figure 15 - Integration of the BESS and EMS in the existing installations

Area of implementation and positioning of the IE in the PEB/use case?

The 2nd life battery storage system will be installed in the University Aitiopaikka own by Turun Ylioppilaskylasaatio (TYS) (see Figure 16 to Figure 18).

The implementation of the battery container will be set on the north part of the area next to car park on the ground.

The total capacity is 50kWh of storage.

It will be connected electrically to general electrical switchboard of the main building. The integration to PEB1 will be performed through the diagram mentioned in paragraph 9 and will be installed as follows:

- The battery pack will be positioned on a dedicated foundation provided by TYS to support a 10 feet container with the weight of 2 000 kg (external dimensions: L 2991mm, l 2438 mm, H 2591mm).
- The connection cable to the Aitiopaikka building, will be installed trough an underground buried connection by the electrical company. The internal wiring and connection will be performed by Bouygues Construction and the commissioning with the support of the battery supplier.
- The delivery and installation will be planned between July and October 2022 (To be confirmed by planning works)

Figure 16 - General perspective of Aitiopaikka building

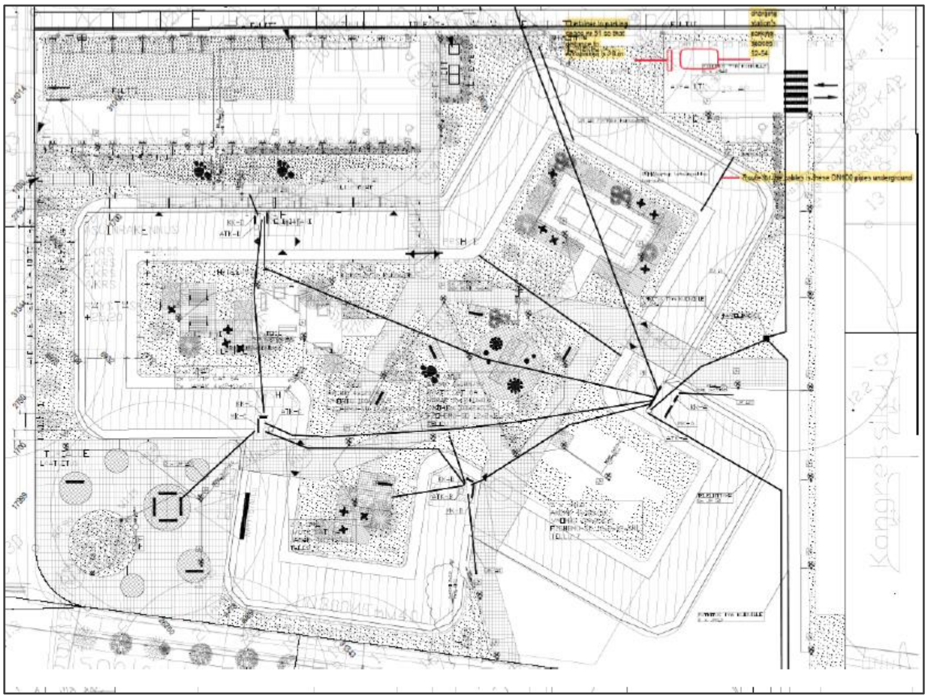

Figure 17 - Site plan - Aitiopaikka building

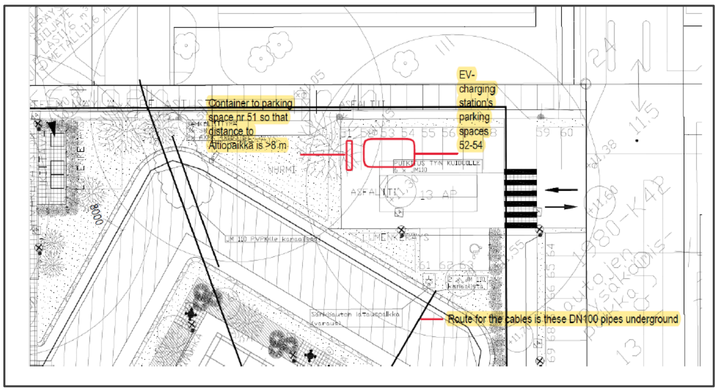

Figure 18 - Detail of implementation area for 2nd life Battery Container

Important stakeholders to be involved in the process of deployment of the IE.

- Building owner: Turun Ylioppilaskylasaatio (TYS) determines the exact location and date of the installation, as well as manages the preliminary works to allow for the installation of the IE
- Electrical integration: TYS implement the IE of PEB1 to maximize collective self-consumption
- 2nd life battery system provider: To be selected by Bouygues through a call for tender
- Other technology provider (same location and same controller): Redox Battery supplier with a dedicated container positioned next to the 2nd life battery container
- Installer: To be selected by TYS through a call for tender and in charge of the preliminary works

c. IE 3.1.4 - DC coupled Lithium-ion Battery Storage System

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

Efficiency of the BESS will be increased as unnecessary DC/AC and AC/DC conversion steps are eliminated. Round Trip Efficiency of the energy storage is key element on sustainable RES. As most of the RES components are operating in DC, it is more efficient to stay in DC between each element. However, in conventional RES systems there still is multiple DC/AC and AC/DC conversions. By eliminating these steps, efficiency can be increased, and system simplified.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

ELCON has been providing conventional backup power systems for 15 years. During this time, we have delivered over 2000 units to more than 70 countries. This background gives ELCON a strong understanding of the requirements of the customers and systems, when novel DC coupled BESS is developed. FERROAMP has developed converters for DC coupled BESS several years now and several systems has been delivered for customers in Sweden. TUAS has developed a model of DC micro grid based next generation e-Bus charging hub with a DC coupled Li-Ion battery storage system.

Technical specifications of the IE as pre-piloted?

Most ELCON systems include lead-acid batteries, chargers, DC-distribution fuses and a system controller.

Our customers often need backup power for equipment which operates on standard DC voltages (24V, 48V, 110V, 125V, 220V). Consequently most of the delivered systems are DC systems. We also equip the systems with inverters if AC output is required. If there is a need for several DC voltages, DC/DC converters can be installed.

The cabinet in Figure 19 is a typical ELCON DC system. It is a compact single cabinet system including three switch mode rectifier modules with total 13.2 kW continuous output power, 110 V 200 Ah sealed lead-acid battery bank with low voltage disconnect, 24 miniature circuit breakers for DC output and a system controller.

Figure 19 - Cabinet for a typical ELCON DC system.

FERROAMP has developed and integrated converters for several Li-ion battery vendors and has gained experience on integration of the DC7DC converters for the BESS. FERROMAP can support ELCON at integration of the BESS for local DC Micro Grid.

Figure 20 - FERROAMP Converter Cabinet

DC micro grid-based Hardware-In-the-Loop –model was developed in TUAS at SeBNet project. This laboratory demonstrator emulated an Energy Hub for fast e-Bus charging station. The 3kW down-scale demonstrator included an Active Front End interface to the LVAC grid, an Energy Storage System, an e-Bus charging station, and PV plant emulator all directly connected via a 750 VDC bus. An advanced Programmable Logic Controller

(PLC) monitored electrical values and integrated protections of the whole system. The PLC also interfaced the system with an Energy Management System (EMS) hosted in a HIL controller.

Figure 21 - TUAS DC micro grid-based Hardware-In-the-Loop –model

Technical improvements achieved

ELCON has acquired a lot of experience in building conventional battery systems and has excellent understanding of customer's needs. FERROAMP has developed solid understanding of DC/DC converters in DC micro grids and integration of the DC/DC converters for different battery vendors. TUAS has gained comprehensive understanding of the protection challenges in multi domain energy systems.

Energy savings, increase of overall efficiency, performance data, power generation etc ?

Savings to end customers typically come from keeping critical processes running during power outages. In some industrial applications these can be very significant.

Socioeconomic benefits reached (citizens acceptance of solution, improved experience, and standard of living; both qualitative and quantitative info can be provided if available)?

In addition to cost savings, Elcon systems often back up vital security systems ensuring human safety.

Restrictions and problems encountered (regulations, citizen, technical) and mitigation actions?

Run-time on battery power is limited. Although batteries have quite long working life, they are the component to first need replacement.

IE 3.1.4 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

Production from solar PV generator is intermittent and consumption in the buildings and EV charging is not always concurrent with production. This results in energy being sold when there is excess production and bought back at a higher price when consumption exceeds production.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

As an electrical energy buffer BESS provides a means to balance production and consumption. It is also possible to achieve savings by using stored energy when the price of electricity is at its highest.

Innovation in the proposed IE?

DC-coupled battery storage system will eliminate unnecessary energy conversions and thus improve efficiency and simplify the system.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

A Li-Ion battery storage system 50 kWh / 50 kW will be installed for the technical room at the ground floor of the Tyyssija building. FERROAMP's Energy Hub central converter will be installed at the same location. The BESS will be connected to the DC Micro Grid that is maintained by Energy Hub.

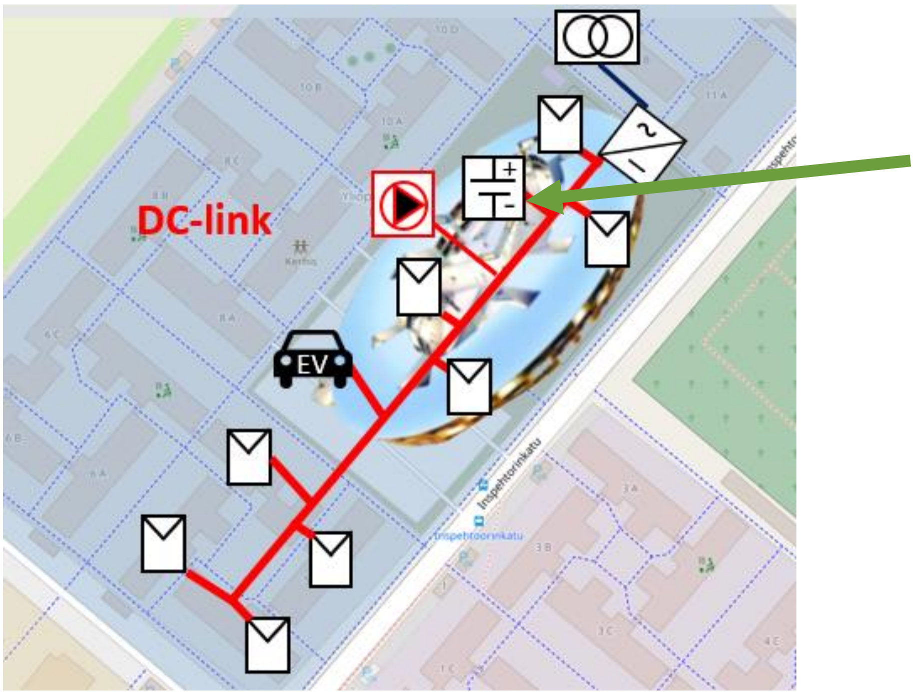

Figure 22 - Location for the installation of the Li-Ion BESS in the Tyyssija building

Figure 23 - Location for the installation of a BESS in theDC microgrid maintained by Energy Hub

Area of implementation and positioning of the IE in the PEB/use case?

The BESS is located in the Tyyssija Building, connected to the retrofitted buildings by a LVDC microgrid

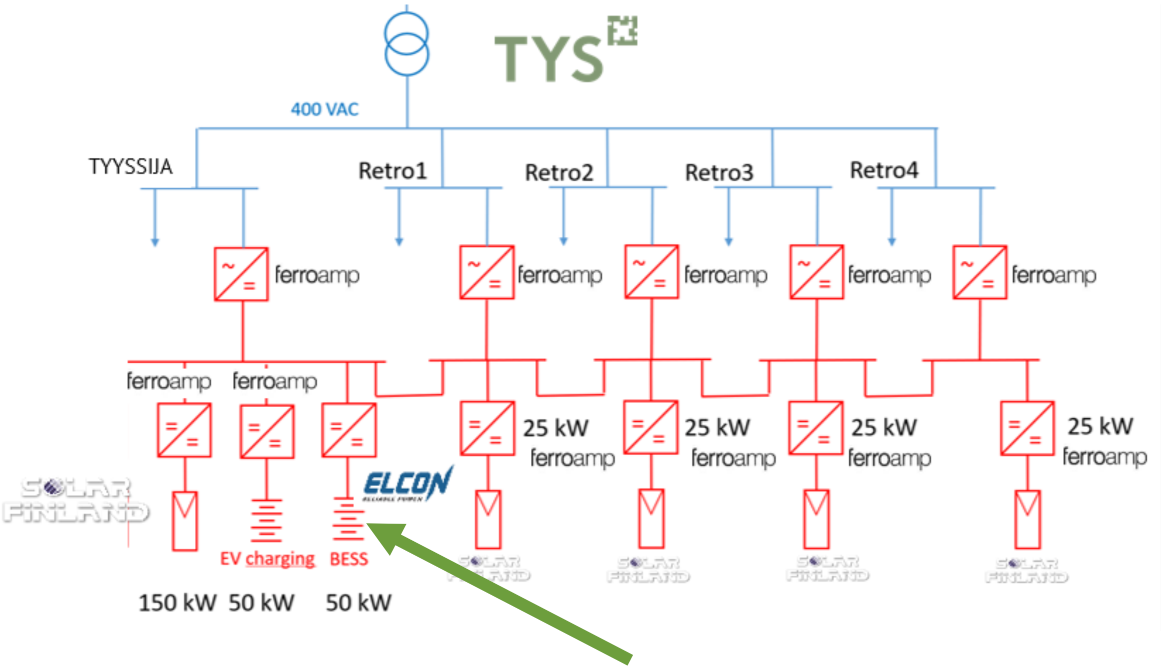

Figure 24 - Location of the BESS in the Tyyssija building's LVDC microgrid

Important stakeholders to be involved in the process of deployment of the IE.

- FERROAMP provides the equipment that creates connection to the local DC microgrid.
- TYS provides boundary conditions and facilities for the installation of the system.
- TUAS provides technical support for the development and testing of the system.

d. IE 3.2.4 – Novel PCM Heat Storage for District Hot Water (DHW)

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

General problem: thermal energy (heating and cooling) is by far the largest final energy consumption in domestic and commercial environments. Despite all the hype for electrical storage, thermal storage is key to maximize the usage of renewables and to decarbonize hot water, space heating, and space cooling in building. Unluckily, the thermal storage technology has not changed in centuries, with water tanks being the state-of-the-art for it. Main problems of such technology are: 1) they are big, bulky, and heavy: while the sources of heat e.g. boilers, heat pumps, etc. are getting smaller and smaller, water tanks cannot shrink and it will always be challenging to accommodate them in buildings that were not designed for them; 2) they can carry lethal bacteria: legionella grows in water at temperatures that are common for domestic hot water applications. Legislation mandates, in fact, that water tanks are brought above 60°C regularly to kill the bacteria (pasteurization), but this has a significant impact on the energy consumption of such tanks; 3) they are dangerous: tens to hundreds of litres of water stored in an unvented cylinder and recharged by integrated resistance heating elements can be catastrophic in case their temperatures go above 100°C. This would require a malfunction of the tank and its safety ancillary devices, but the risk is not intrinsically avoided.

Phase change material (PCM)-based heat batteries (HBs) solve all these problems: 1) they are compact, and the installed weight is lower than the equivalent water tank. This is achieved through the use of PCMs, materials with high energy density; 2) water is not used in heat batteries to store the heat but only to transport the heat in and out from them. Therefore, the volume of water into the storage units is multiple times lower that in the equivalent water tanks. While it cannot be claimed that the risk of growing legionella is zero, it can be claimed that it is much less risky than water tanks, for the following reasons: i) the little amount of fresh water in the units is completely changed every time a small amount of water is used in the house, there is no time for the bacteria to grow; ii) heat batteries are usually kept at temperatures high enough to kill the bacteria i.e. 65-75°C. Even if, for any reasons, they were kept at a lower temperature, the pasteurization process of the small amount of water is less energy eager than in the equivalent water tanks; 3) as per point 2), having a little amount of water in the unit results in an intrinsically safe technology that does not explode if, as results of malfunctions, reaches temperatures above 100°C.

The thermal storage units based on phase change material (PCM), namely the heat batteries (HBs), are an innovative technology bringing many benefits compared to the state of the art i.e. water-based storage. The innovative elements are: 1) the use of a chemical formulation (organic or inorganic) to store the heat instead of water; 2) the use of a powerful heat exchanger integrated in the storage unit to exchange heat between the PCM and the heat transfer fluid, usually water; 3) the ability to use multiple PCMs optimized to work at different temperatures to maximize the benefit for the final users; 4) the modular and scalable architecture that allows to quickly adapt the storage capacity to the requirements of each size; 5) the smart control of the units allowing to unlock revolutionary services like heat-as-a-service, demand-side-response, etc.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

A typical pre-pilot project where Sunamp batteries act as a buffer storage for the delivery of hot water from a communal heating loop would be the CORE364 project in Sunderland, in conjunction with Gentoo (Housing association) Engie (energy provider), Kensa (Ground sourced heat pump manufacturer) and Sunamp. The locations of the work are Church and Dock Street, Dame Dorothy, Zetland, Victor, Devonshire and Eglington Tower.

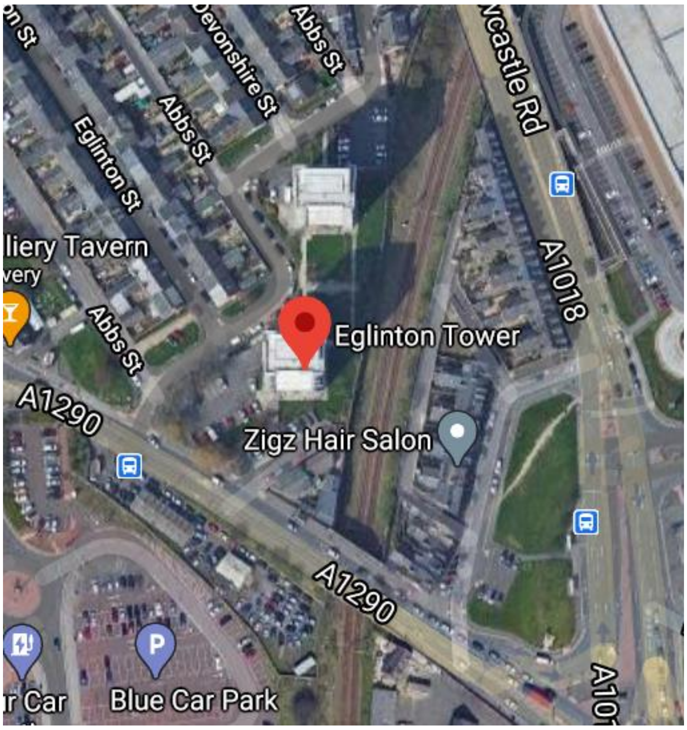

Figure 25 - Location of Devonshire and Eglington towers

Technical specifications of the IE as pre-piloted?

The installation in each of the 364x flats of a UniQ6(58) HW+i that is charged from a Kensa 6kW shoebox heat pump supplied from an ambient shared ground loop array. Figure 26 shows the small space that both Sunamp and Kensa units can be installed into. In addition, the Sunamp thermal battery being charged by the Kensa heap pump, each battery contains an electrical 2.8kW resistive heating element that can be switched on if there is any need to turn-off the heat pump. This provides a level of resilience to the installation that is not normally prevalent on communal and district heating network installations.

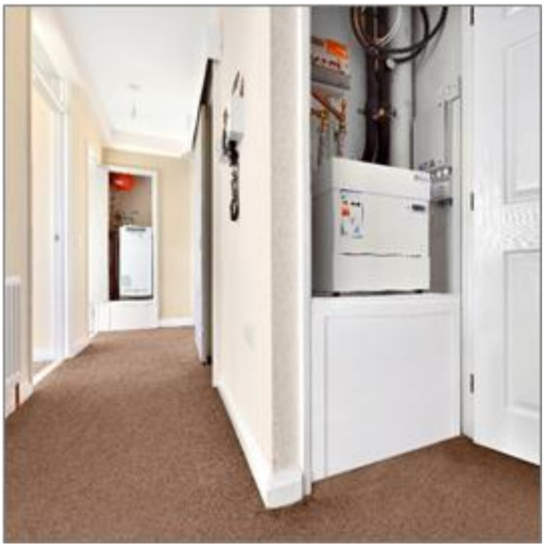

Figure 26 - Illustration of the space required by the Sunamp and Kensa installations

Lessons learned from the pre-pilot

Very easy to install, the occupants did not have to be decanted during the installation phase, saving the housing association £millions.

The installation was quicker than the traditional hot water tank and therefore site time and project overrun risk was reduced.

On-going maintenance will be lower as no annual G3 check for pressurized cylinders will have to be undertaken.

There is no risk from legionnaires disease

Energy savings, increase of overall efficiency, performance data, power generation etc ?

The installation reduced the CO2 emissions by ~70% as compared to the previous individual flat gas central system. In terms of cost it is estimated that the occupants will still pay the same but that they will get more heat and comfort for they same amount of money. Generally in the UK many of the poorest in society live in fuel poverty so any cost reduction is taken up in increased comfort. Typically, the 2-bedroom properties would consume around 9,500kWh for heating and hot water. The cost comparison between heating and electric is detailed in Figure 27.

	2-bedroom flat
Heating and hot water consumption (kWh/pa)	9500
Gas tariff (£/kWh)	£0.0348
Combi boiler efficiency	75%
Gas tariff (£/kWh) after efficiency applied	£0.0464
Standing charge (£/annum)	£90.00
Total cost existing gas combi system (£/kWh)	£530.80
Electricity tariff (£/kWh) (on-peak)	0.1425
COP of heat pump	3
Electricity cost after COP applied	0.0475
Proposed Sunamp and Kensa installation with no DSR - using on-peak electricity (£/kWh)	£451.25
Annual difference (ex VAT)	-£79.55

Figure 27 - Cost comparison between heating and electricity

IE 3.1.4 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

Introduction of new technology requires a demonstration and reference site for trades persons to see and touch. The RESPONSE project will provide the reference site within the Nordic and Baltic region of the EU. In Turku PEB implementation, the PCM domestic hot water storage serves as a buffer heat storage for the hot water system of the new Tyyssija building increasing the efficiency of the energy upcycling heat pump (IE2.2.4).

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

The introduction of distributed storage for hot water on high temperature heating networks will provide benefits to the heat network operator and system. Currently the value of this distributed storage is not known or has been quantified. Particular focus will therefore be on understanding the following:

- Operational savings from reduced pumping
- Operational savings associated with peak shaving on water demand especially associated with morning and evening ablutions.
- Amount of carbon emission savings
- Occupancy experience

Innovation in the proposed IE?

Compared to a conventional water tank domestic hot water storage, the PCM DHW storage achieves the same energy capacity with an improved compactness. This is especially important in applications, where the allocated space is limited.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

Figure 28 shows the current specification data sheet. It is envisaged that the Size 12 will be the model that would be used in the demonstration.

2.5.2 Detailed Specifications

Specification		Size 3	Size 6	Size 9	Size 12	See Note
Heat storage capacity (kWh)	Hot Water Heating with Boiler	3.5	7.0	10.5	14	1
	Hot Water Heating with High Temperature Heat Pump	3.2	6.3	9.5	12.6	2
Water Content (L)	Primary Circuit	1.3	2.4	3.5	4.6	3
	Secondary Circuit	2.3	4.5	6.8	9.1	
Equivalent Hot Water Cylinder Size (L)		71	142	212	284	4
V_{40}, Volume of Hot water available at 40°C (L)		85	185	300	370	5
Standby heat loss rate (kWh / 24h (W))		0.48 / (20)	0.67 / (28.1)	0.77 / (32.1)	0.84 / (34.9)	
ErP Rating class		A+				7
Recommended maximum HW flow rate (L/Min)		6	15	20	25	
Minimum heat source flow temperature (°C)		65				8
Maximum heat source flow temperature (°C)		80				9
Minimum mains supply pressure at inlet of Heat Battery (MPa / (Bar))		0.15 / (1.5)				
Maximum working pressure (MPa / (Bar))		1.0 (10)				
Pressure loss characteristics K_v Values		(Refer to Section 2.6)				
Hot water outlet temperature at design flow rate (°C)		45-55				6
Connected load at ~ 230 V, 50Hz (W)		2,800				
Power supply / Standby consumption (W)		1 PH ~ 230 V / 7				

Table 8: Detailed specifications for UniQ HW +i Heat Battery models

Figure 28 - Product data sheet

Area of implementation and positioning of the IE in the PEB/use case?

The PCM DHW storage will be implemented in the new construction building Tyyssija in the PEB (Figure 29). The storage will be coupled with the domestic hot water system of the Tyyssija building to serve as a buffer storage to the hot water energy consumption.

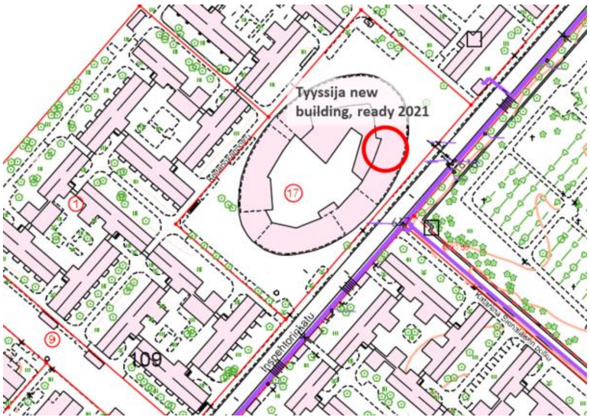

Figure 29 - Location of the PCM DHW storage in the Tyyssija building

Important stakeholders to be involved in the process of deployment of the IE.

For the CORE364 the important stakeholders were the other organizations within the project. As Sunamp's product is not an intrusive item that creates noise or has toxic materials or requires maintenance if it meets the standard electrical and water regulations for the country or municipality then it really is the other project partners that are crucial to the success of the project:

- Sunamp: Responsible partner/project manager, providing the PCM units
- TYS: Building owner
- HögforsGST: Integrating control systems
- VTT and TUAS: Research partners

e. IE 3.2.5 – DISTRICT HEATING PCM HEAT STORAGE-AS-A-SERVICE

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

General problem: thermal energy (heating and cooling) is by far the largest final energy consumption in domestic and commercial environments. Despite all the hype for electrical storage, thermal storage is key to maximize the usage of renewables and to decarbonize hot water, space heating, and space cooling in building. Unluckily, the thermal storage technology has not changed in centuries, with water tanks being the state-of-the-art for it. Main problems of such technology are: 1) they are big, bulky, and heavy: while the sources of heat e.g. boilers, heat pumps, etc. are getting smaller and smaller, water tanks cannot shrink, and it will always be challenging to accommodate them in buildings that were not designed for them; 2) they can carry lethal bacteria: legionella grows in water at temperatures that are common for domestic hot water applications. Legislation mandates, in fact, that water tanks are brought above 60°C regularly to kill the bacteria (pasteurization), but this has a significant impact on the energy consumption of such tanks; 3) they are dangerous: tens to hundreds of litres of water stored in an unvented cylinder and recharged by integrated resistance heating elements can be catastrophic in case their temperatures go above 100°C. This would require a malfunction of the tank and its safety ancillary devices, but the risk is not intrinsically avoided. All of the above, especially point 1), make it difficult a widespread adoption of thermal storage, especially in existing buildings not designed to host them. Unluckily, Heat-as-a-Service (HaaS) can only be effectively enabled by thermal storage. Therefore, the benefits of HaaS cannot be achieved with water tanks.

Phase change material (PCM)-based heat batteries (HBs) solve all these problems: 1) they are compact, and the installed weight is lower than the equivalent water tank. This is achieved through the use of PCMs, materials with high energy density; 2) water is not used in heat batteries to store the heat but only to transport the heat in and out from them. Therefore, the volume of water into the storage units is multiple times lower that in the equivalent water tanks. While it cannot be claimed that the risk of growing legionella is zero, it can be claimed that it is much less risky than water tanks, for the following reasons: i) the little amount of fresh water in the units is completely changed every time a small amount of water is used in the house, there is no time for the bacteria to grow; ii) heat batteries are usually kept at temperatures high enough to kill the bacteria i.e. 65-75°C. Even if, for any reasons, they were kept at a lower temperature, the pasteurization process of the small amount of water is less energy eager than in the equivalent water tanks; 3) as per point 2), having a little amount of water in the unit results in an intrinsically safe technology that does not explode if, as results of malfunctions, reaches temperatures above 100°C. For these reasons, HBs are potentially revolutionary in the field of HaaS: the service provider can recharge the thermal storage units when it is most beneficial for them (low prices) or the community (low carbon), and the storage units can provide the required amount of hot water, space heating, or space cooling when it is required by the final users, who will then pay for the received service (the thermal energy) independently of the source used to generate it, its cost, and its carbon content.

The thermal storage units based on phase change material (PCM), namely the heat batteries (HBs), are an innovative technology bringing many benefits compared to the state of the art i.e. water-based storage. The innovative elements are: 1) the use of a chemical formulation (organic or inorganic) to store the heat instead of water; 2) the use of a powerful heat exchanger integrated in the storage unit to exchange heat between the PCM and the heat transfer fluid, usually water; 3) the ability to use multiple PCMs optimized to work at different temperatures to maximize the benefit for the final users; 4) the modular and scalable architecture that allows to quickly adapt the storage capacity to the requirements of each size; 5) the smart control of the units allowing to unlock revolutionary services like heat-as-a-service, demand-side-response, etc.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

The building was a large commercial office block in central Paris (Figure 30).

Figure 30 - Location of the pre-pilot in Paris

Technical specifications of the IE as pre-piloted?

The provision of 350kWh of cold (5˚C) storage with the ability to fully discharge the storage in one hour with a charge temperature of 3˚C and discharge temperature of no more than 5.5˚C. the flow rates of the charging and discharging were 13kg/s. Thermal battery charging time six hour maximum in practice the battery can be recharged by the cooling network from fully depleted in just a little over one hour. In addition, the storage had to be installed in an underground carpark / mechanical space within the basement of the building down a steep ramp and with only circa 2.4m headroom.

Technical improvements achieved

There was a huge testing and evaluation regime before the placement of the order which resulted in a technical improvement to the internal lining of the UniQ80 and a greater understanding on the maximum and minimum charging and discharging temperature relative to the flow rates.

Restrictions and problems encountered (regulations, citizen, technical) and mitigation actions?

There was significant technical and engineering curiosity and skepticism that had to be overcome as this is new technology. In essence Sunamp’s technology is facing the chasm in the classic adopter curve for new technology (Figure 31).

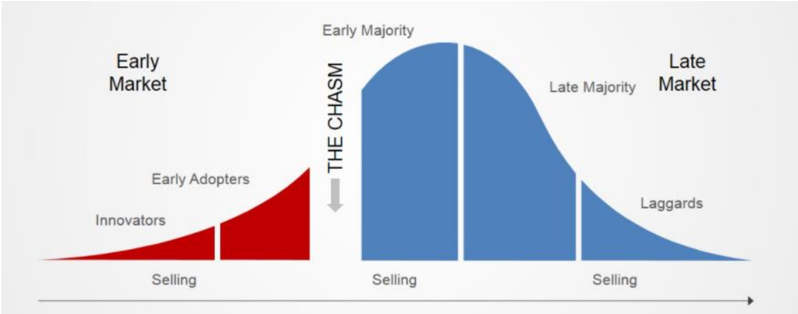

Figure 31 - Classic adopter curve for new technologies

IE 3.2.5 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

The introduction of new technology requires a demonstration and reference site for trades persons to see and touch. The RESPONSE project will provide the reference site within the Nordic and Baltic region of the EU. The challenge between the two heating networks in the Turku PEB has been considerably high return temperature of the local low temperature heating grid. The technological improvements provided by the PCM storage-as-a-service enable lower return temperatures.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

The introduction of large-scale storage for high temperature heating networks is reasonably understood in terms of providing benefits to the heat network operator and system. Currently the value of this storage in the form of Sunamp's phase change material is not known or has been quantified. Particular focus will therefore be on understanding the following:

- Operational savings from reduced pumping and the ability to deliver constant temperature high power heat energy into the network.
- Operational savings associated with peak shaving on water demand especially associated with morning and evening ablutions.
- Amount of carbon emission savings, especially with regards to switch off heat generation equipment and provide constant charging temperature deltas that will prolong the life of heat pumps and other generating equipment.
- Occupancy experience.

Innovation in the proposed IE

The innovation of the IE is the service-nature of the solution. It provides the district heating network operator a carefree buffer between the two different temperature heating networks the PCM storage connects.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

See the product data sheet for the UniQ80(5) in Figure 32. Similar technical information will be provided for the heat batteries that are used in the demonstrator project.

5. Technical Specification (Tables 1 & 2)

Table 1: Technical specification		
Model reference		UniQ 80_SU05_P0xxx
PCM		SU05
Weight of unit: Empty / Installed	[kg]	568 / 1,155
Overall dimensions: Width x Depth x Height	[mm]	1,200 x 1,000 x 1,470
Water content: LPC / HPC / Total	[Litres]	30 / 40 / 70
Maximum working pressure: LPC & HPC	[MPa / bar]	1.6 / 16
Nominal storage capacity between 3°C – 15°C	[kWh]	30 – 36
• Working temperature range – Charging & discharging fluids • Maximum charging fluid inlet temperature • Minimum discharging fluid inlet temperature • Design discharging fluid outlet temperature	[°C] [°C] [°C] [°C]	2 – 17 3.5 6.0 4 – 6
Heat loss/gain rate @ 45K Temperature difference	[kWh/24h] [W]	3.0 127
Pressure loss characteristics (See also Figure 3) High power circuit: 1 – 3 Low power circuit: 2 – 4 Both circuits in parallel	Kv-Value M³/h at 1bar DP	 13.0 8.0 21.0
Pipe connection 1. Top manifold – High power circuit (HPC) 2. Top manifold – Low power circuit (LPC) 3. Bottom manifold – High power circuit (HPC) 4. Bottom manifold – Low power circuit (LPC)	 1¼" BSP Parallel Female (DN32) 1¼" BSP Parallel Female (DN32) 1¼" BSP Parallel Female (DN32) 1¼" BSP Parallel Female (DN32)	

Figure 32 - Product data sheet for the UniQ80

Area of implementation and positioning of the IE in the PEB/use case?

Originally the PCM heat storage-as-a-service was planned to be installed in the retrofitted building block in the PEB. However, the energy efficiency of the retrofitted buildings increases due to the RESPONSE project implementations to the extent that the PCM storage would have been idle most of the year. An alternative location for the storage was therefore planned. An old heat exchanger site near the Tyyssija new construction building proved to be a viable alternative for the PCM storage location.

The PCM heat storage-as-a-service will be installed between the high temperature citywide district heating network and the low temperature local heating network. The planned installation of the IE 3.2.5 District heating PCM heat storage-as-a-service is marked with a red circle in Figure 33.

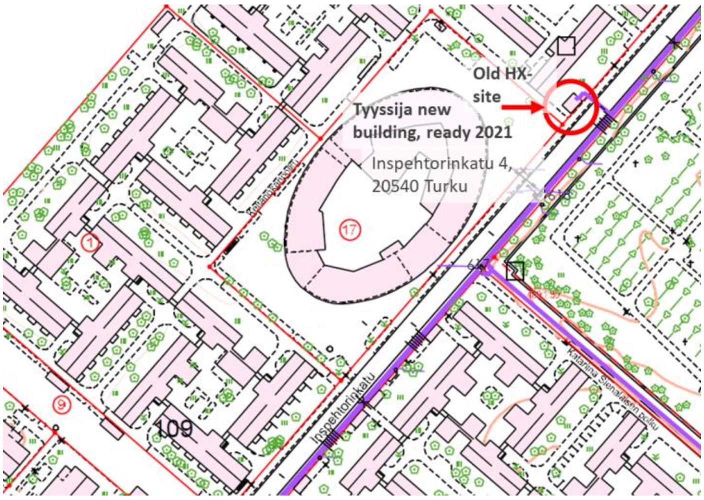

Figure 33 - Location for IE 3.2.5 near the Tyyssija building

Important stakeholders to be involved in the process of deployment of the IE.

For the Paris cooling project the important stakeholders were the other organizations within the project. As Sunamp's product is not an intrusive item that creates noise or has toxic materials or requires maintenance if it meets the standard electrical and water regulations for the country or municipality then it really is the other project partners that are crucial to the success of the project:

- Sunamp: Responsible partner/project manager, providing the PCM units
- TYS: Building owner
- HögforsGST: Integrating control systems
- Turku Energia: District heating network owner
- VTT and TUAS: Research partners

Appendix B. Additional Information about the Dijon PEB, IS and IE

In order to keep this deliverable clear and concise, not all the collected information was included in its main part. The additional information collected is presented in the following annexes.

a. IE 3.1.1 - Zn-Air Battery

The Zn-Air battery solution will not be implemented in RESPONSE. The information collected is therefore removed from this deliverable.

b. IE 3.1.2 - 2nd life Battery Storage System (BESS)

The general information about this IE as well as the prepilots is the same as detailed in Appendix A for Turku.

IE 3.1.2 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

PEB2 is composed of a wide variety of constructions: social housing, schools, recreation centers and car parks. It has the particularity to produce more energy (2,103 MWh/year) than it consumes (1,805 MWh/year), thanks to solar panels, a nearby biomass plant, waste heat recovery and biogas through Green Certificate Contracts. A unique collective experimentation will be deployed to maximize self-consumption at the scale of PEB2. Because the production and consumption needs cannot not match at any time, energy storage is required in this experimentation. The IE is trying to solve the challenge of getting the best out of battery storage (grid flexibility) without its disadvantages related to environmental issues.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

By reusing electric car batteries for stationary storage, the IE will solve both grid flexibility and environmental challenges of PEB2. The IE will be controlled at the scale of PEB2 by taking into account the overall production and consumption needs to maximize collective self-consumption. Circular economy within this IE enables to get grid flexibility without environmental issues related to lithium-ion batteries.

Innovation in the proposed IE?

The IE is designed and developed specifically to integrate electric vehicle batteries for them to be used in an environment (stationary storage) which is technically very different from the original usage (within a vehicle). The IE is a 2nd life battery storage system for stationary applications. The system is composed of 1) batteries designed for and previously used in electric vehicles, 2) a tailored power conversion unit connectable to any power grid and 3) a programmable logic controller which manages charging and discharging of the batteries.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

The IE consists in a 2nd life battery storage system of 60kWh. Integrated batteries are recycled batteries from electrical vehicule, based on Lithium-Ion. The battery is mounted on racks with a dedicated part for the BMS directly on racks as well . Batteries are connected to a power conversion unit of 60kW. The system also integrates a programmable logic controller, which can be operated in Modbus TCP/IP by a third-party Energy Management System (EMS).

At the time of this deliverable, the supplier of the batteries is still to be confirmed.

Area of implementation and positioning of the IE in the PEB/use case?

The 2nd life battery storage system will be installed in the Buffon School in Dijon (Figure 34). It will be connected electrically behind the school power meter. The integration to PEB2 will be performed through the EDF GeneSys onsite box, to which it will be connected with a wire and Modbus TCP/IP communication protocol. Installation details will be arranged with the building owner CDD (Commune de Dijon) and EDF as follows:

- The battery pack will be positioned on a dedicated foundation provided by CDD to support a 6 feet container with the weight of 1 000 kg
- The connection cable to the Buffon School, will be installed trough and underground buried connection by the electrical renovation company. The internal wiring and connection will be performed by Bouygues Construction and the commissioning with the support of the battery supplier.
- The delivery and installation will be planned between July and October 2022 (To be confirmed by planning renovation works)

Figure 34 - Location for the battery container on the Buffon school site

Important stakeholders to be involved in the process of deployment of the IE.

- Building owner: Commune de Dijon (CDD) determines the exact location and date of the installation, as well as manages the installation of the IE
- IT integration: EDF deploys the IT architecture and controls IE of PEB2 to maximize collective self-consumption
- 2nd life battery system provider: To be selected by Bouygues through a call for tender
- Other technology provider (same location and same controller): Zinium
- Installer: To be selected by CDD through a call for tender
- Dijon Metropole (DM).

c. IE 3.2.1 - Phase Change Material (PCM) Tanks

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

In large housing complexes, hot sanitary water is produced in a central heating station and distributed through hot water loops continuously circulating and reheated in the whole building. This design is implemented to reduce the time for hot water to reach individual taps, and to minimize the dead water volumes where hot water is stagnating and thus cooling down. This cooling down has 2 main consequences: increasing the time for hot water to be available at the tap and increasing dramatically the bacteriological risk, that rises with a stagnation temperature between 35 and 45°C. On the other hand, this recycling of hot water is a huge energy sink: the water loop usually features great heat losses and pressure drops. A great share of the energy used for hot sanitary water production is lost in this recycling loop, heating up the building itself and using pumping energy all around the clock. This energy loss can range from 20 to 60% of the total energy use for hot water production.

The technical solution to solve this problem and reduce significantly this energy loss consists in a hybrid design with centralized and decentralized production and storage. Basically, it includes decentralized latent heat storage units, that can be sized for one or a few housing units (flats) and that will be charged by the central heating loop only a few hours in a day. This heat shall be then sufficient to produce instantly the hot sanitary water consumed. This design has many advantages: (i) it cuts down the heating process for at least 2/3 of the day, (ii) it also stops the pumping for the same period of time, (iii) it doesn't increase the waiting time for hot water nor the bacteriological risk, and (iv) it even increases comfort and reliability of the hot water system with a local storage capacity with stable temperature (because latent) and constant pressure (because direct heating from cold water).

This solution is based on 3 innovative approaches. (i) The heat storage is a latent heat system using a phase change material (PCM). The temperature of the freezing/melting material is thus always the same, ensuring a very stable hot water temperature. At the same time there is no warm water stagnating at biologically dangerous temperatures, because the tank volume is filled with PCM, not with water. The distance between the tank and the taps is low by design, ensuring low dead water volumes. (ii) The heating process shall be seen as a “charging” process, while the small decentralized PCM tanks will charged, hence molten, with existing heat sources. In the present project, existing hot sanitary water loop will be used as the heat source for the charging process, thus needing limited piping works to modify the existing system. One could also use existing heating loop, this would make the full hot water loop useless, including hot water production plant, but it would make it necessary to run the heating plant during summer. This has to be decided for each individual project. (iii) The 2-stage hot water production process increases the storage capacity of the full system and thus makes it much more flexible. Hot water production (charging) and consumption (discharging) are disconnected, which makes it possible to integrate better energy management system to reduce energy costs, reduce consumption peaks and reduce environmental impact.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

A pre-pilot plant has been installed in the FAFCO factory to test the solution with real user’s consumption cases. A specific software was developed to simulate the user cases and pilots the charge and discharge modes.

The loops were equipped with temperature transmitters, flowmeters and servo 3 way valves (Figure 35).

Figure 35 - PCM storage units , temperature transmitters, flowmeters and servo 3-way valves

Technical specifications of the IE as pre-piloted?

The pre-pilot includes a square-shaped insulated plastic tank with 2 heat exchangers, one for charging and one for discharging. The tank is filled with the FAFCO PCP50 phase change material, that has a phase change temperature between 50 and 54°C. 4 fittings have been installed on top to connect charging and discharging heat exchangers and PCP50 has been filled in through an extra hole on the top of the tank. PCP50 is bio-based and produced as a powder. It is introduced as a solid and has to be molten during filling to reach full capacity. The charging loop has been connected to a standard electrical hot water tank.

The PCP50 tank prototype has a capacity of 300 L. The main goal of the pre-pilot is to prove the replicability and stability of the charging and discharging processes. It is a long term trial to show in real conditions: (i) the life time of the system, having set an objective of 10 years, and (ii) the storage capacity and the heat instantaneous production capacity (heating power) of the system, which are of course linked to the cold and hot water temperature levels.

Technical improvements achieved

Practical learnings: the way to install and fill it up has been tested and improved. The phase change at more than 50°C makes the filling of the tank critical, and potentially hazardous. Also, the volume expansion of the material makes it tricky.

Main parameters of capacity and heating levels of the PCP50 have been validated but need long term experiments to confirm and measure precisely. Durability can only be confirmed after a few years of operation.

Energy savings, increase of overall efficiency, performance data, power generation etc ?

First results confirm expected latent heat and heating capacities. Because the main interest of the system is the very important amount of energy being stored at a high and stable temperature, the main application for the PCP50 is the hot water recirculation loops, like in the RESPONSE project. There is no such loop at the factory so that no energy savings can be measured in this application. The main interest of this pre-pilot is to developed a quick discharge heat exchanger able to produce in few seconds hot water from a cool water loop (at 12°C).

Socioeconomic benefits reached (citizens acceptance of solution, improved experience, and standard of living; both qualitative and quantitative info can be provided if available)?

The main social advantage reaches at this stage for the PCP50 tank is comfort: hot water temperature is stable, and the tank volume will be able to produce a larger hot water volume. This should brings comfort to the end user.

Restrictions and problems encountered (regulations, citizen, technical) and mitigation actions?

Implementation has been a real issue, which means that specific training and user guides shall be developed. The other main issue is the charging level measurement: a cheap and reliable system is still to be developed in order to better manage and control charging and discharging phases and use the PCP50 tank as a real energy storage equipment.

IE 3.2.1 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

The building where the PCP50 solution will be implemented features 4 stores above ground level. The whole hot water and heating system is designed as a vertical distribution from a main horizontal piping system located in the basement. Each single radiator is connected to such a vertical pipe connected vertically to the same radiator on each level and to the main line in the basement. Similarly, hot sanitary water is distributed vertically to the same consumption point on each level. This design makes the losses of the hot water loops very high: each single hot water consumption point is directly connected to a circulating loop. Noise reduction rules also make it impossible to have direct hydraulic connections between two neighboring flats. In addition, all walls and casings of the building contain asbestos making all modifications of the hydraulics very heavy in terms of administrative paper works.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

Considering these specific constraints, it has been decided that the PCP50 tanks would be charged using the hot sanitary water loops themselves, and not the heating system. Also, the produced hot water will be distributed only in one “wet module” (bathroom neighboring a kitchen) of one flat on each level. This avoids creating a horizontal distribution across one flat and from one flat to another. So that only one hot sanitary water loop will be running for only around 8 hours a day, instead of 2 loops running 24/7. This should divide the heat losses by 6, thus possibly reducing the losses from around 50% to 8%.Yet, this estimate can only be validated through real conditions experiments to take into account actual hot water consumption, vacation periods, relative use of hot water in kitchen and bathroom, etc…

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

8 tanks of 200 L of PCP50, (tank volume will be around 500 L, PCP50 and heat exchangers volumes) connected with motorized valves to one vertical hot water distribution line. These tanks are equipped with 2 internal heat exchangers, one for charging, connected to the hot sanitary water line, one for discharging, connected to the freshwater line and the hot water consumption points. The tanks will be installed in each flat on each level, thus using around 1 m^2 of the flat area.

The connection of the vertical hot sanitary water line to the main horizontal line in the basement will also be controlled with a motorized valve to let it run only for 8 hours a day and close it the rest of the time.

All tanks and lines should be monitored and measured to assess energy use, energy savings, to better understand the main advantages and forces of the system, and to improve its design for future projects. Main sensors should monitor: temperatures on in and out lines of the 2 heat exchangers of each tank, energy measurement on the vertical distribution line, hot water consumption out of each tank.

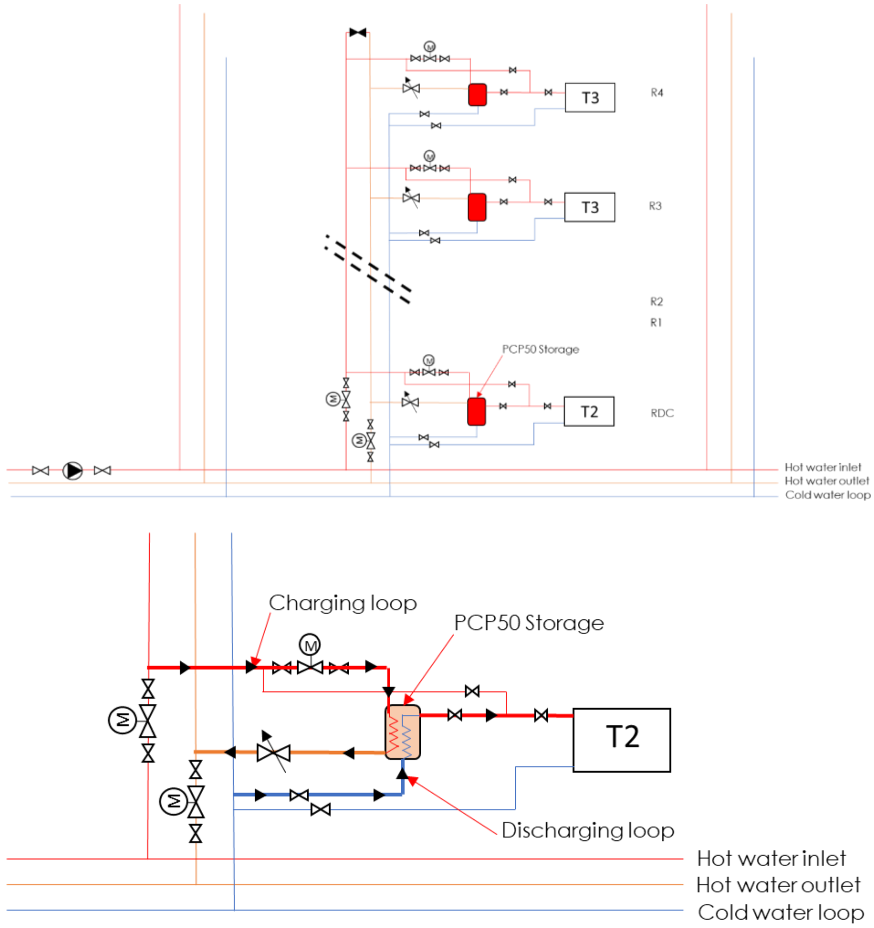

Figure 36 - Project P&ID of water loop integration

Area of implementation and positioning of the IE in the PEB/use case?

The positioning and location of the tanks is part of the solution and critical for the energy savings. More precise details on these issues will be defined during the detailed feasibility study

Important stakeholders to be involved in the process of deployment of the IE.

Most important stakeholders for this implementation are:

- Grand Dijon Habitat (GDH), including communication department to introduce the system to the inhabitants, GDH operation and maintenance department for the technical feasibility and input data, the inhabitants themselves as end users of the system for the final feedback, GDH financial department to assess return on investment
- The tank manufacturer to optimize shape and size of the PCP50 tanks.

d. IE 3.2.2 - Industrial Hot Water Buffer Tank

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

The heating needs of buildings vary throughout the day. This has the effect of degrading the efficiency of heat production installations. To mitigate this effect, thermal storage makes it possible to smooth the pattern of heat demand and to optimize the operation of the boiler rooms.

Optimization of combustion efficiency by operating the boilers at constant speed.

Optimization of boiler sizing; Increase in equipment life.

Better energy management

The innovation lies in the thermal storage of heat, enabling the use of continuous production biomass power instead of gas burners.

Pre-pilot

Pre-pilot area including geographical overview and types/problematics of the building(s) involved in the pre-pilot.

The Pimlico tower in London stores 2 500 m^3 of hot water (Figure 37).

Figure 37 - Pimlico tower (London)

Technical specifications of the IE as pre-piloted?

The Pimlico tower in London which stores 2 500 m^3 of hot water (see RCT45 AMORCE):

Benefits:

- Simple design
- Possibility of rapid discharge
- Low maintenance

Disadvantages:

- Storage temperature limited to 100°C
- Need auxiliary equipment to adapt to network pressure
- Risk of poor stratification, and therefore of inconsistent discharge temperature.

Socioeconomic benefits reached (citizens acceptance of solution, improved experience, and standard of living; both qualitative and quantitative info can be provided if available)?

Energy storage has two objectives:

- Smooth the load curve of the boilers in order to improve the efficiency of the installations
- Maximize the rate of renewable energy on the grid

These two requirements will make it possible to strengthen the economic balance of the network and to offer subscribers energy that is competitive both from an environmental and economic point of view.

Restrictions and problems encountered (regulations, citizen, technical) and mitigation actions?

As the investments related to the installation of a water storage tank are significant, a technical and economic study must be carried out in order to ensure the economic balance of the heating network.

IE 3.2.2 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

The heating needs of buildings vary throughout the day. This has the effect of degrading the efficiency of heat production installations. To mitigate this effect, thermal storage makes it possible to smooth the pattern of heat demand and to optimize the operation of the boiler rooms.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

The hot water storage tanks will both improve the efficiency of heat production units and the rate of renewable energy on the network. This installation will generate significant energy savings and a reduction in CO_2 emissions. Optimization of combustion efficiency by operating the boilers at constant speed; Optimization of boiler sizing; Increase in equipment life; Better energy management.

Innovation in the proposed IE?

The innovation lies in the thermal storage of heat, enabling the use of continuous production biomass power instead of gas burners.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

Characteristics of the Valendon storage tank (geographical location: 22, rue des Valendons, Dijon):

- Volume : 1 200 m3
- Height : 10 m
- Outer diameter : 12.4 m
- Thickness : 20 cm

In the main pipes of the storage tank, 1 isolation valve and 1 motorized valve will be fitted.

Expected deployment ending on july-november 2022 (to be confirmed).

A second tank located in Fontaine d'Ouche was under study (location: chemin de la Rente de la Cras, Dijon). The water storage tank installed at the Fontaine d'Ouche boiler room would have a capacity of 1 800 m3, which represents stored energy of around 230 MWh. The results of the feasibility studies show however that this storage is not needed in that location. It will therefore not be implemented during the project.

Area of implementation and positioning of the IE in the PEB/use case?

Valendon storage tank will be located 22, rue des Valendons, Dijon

The hot water storage tank will be installed in the Fontaine d'Ouche boiler room. The objective is to rehabilitate the tank formerly used to store fuel oil.

Important stakeholders to be involved in the process of deployment of the IE.

SODIEN, a subsidiary of the Coriance group, is dedicated to the operation of the district heating network of the metropolis of Dijon. The company is responsible for ensuring an economic balance throughout the contract. The main player in this project is therefore Coriance, which is the investor. SODIEN is then responsible for operating the network and ensuring optimal operation of the storage tank.

e. IE 3.2.3 - Collective hot water tank with a dedicated BEMS

General Introduction

General problem and challenges that this IE aims at addressing. How the IE solves these challenges. The innovation behind the IE?

Increasing solar electricity self-consumption ratio demands that some produced energy may be consumed away from production time. The offsetting of consumption in regards with production can be achieved through energy storage.

Collective hot water tank with a dedicated BEMS (connected with GENESYS, IS 4.1), on a building level in order to optimize the self-consumption ratio. It will store energy produce by PV as hot water during overproduction

Storage of PV power is spontaneously envisioned on batteries, which might be expensive, while degradation to heat for hot water may be cheaper but less effective (from an energetic perspective). Hence, the choice of hot water storage over batteries to be integrated in a collective autoconsumption program is the challenge, and the performance of such system must be tested.

IE 3.2.2 In RESPONSE

Specific challenges and needs of this particular PEB/Area/Building that the IE is trying to solve?

Collective hot water tank with a dedicated BEMS, on a building level in order to optimize the self-consumption ratio. Residential buildings have the capacity to consume (relatively) low temperature hot water, which enables to use fatal electricity for hot water.

How the IE solves these challenges for this PEB/Building/Area towards RESPONSE Objectives

Collective hot water will store energy produce by PV as hot water during overproduction to feed domestic hot water network.

Innovation in the proposed IE?

The innovative part is the integration of such heat storage in a complex collective electricity self-consumption program. The goal is to prove that low-cost heat storage will be efficient to consume photovoltaic fatal power instead of reselling this unused power to the grid. The degradation of high-quality electricity to heat must remain financially effective.

Technical specifications of the IE: Type of technology, power/capacity, arrangement, specific components etc including dimensions and other technical data

EDF has been working on the global scheme of collective self-consumption and on the dimensioning of the hot water tank.

First results show that the Grand Dijon Habitat building doesn't need a hot water tank, as the PV panels won't produce much unused power.

Area of implementation and positioning of the IE in the PEB/use case?

Two hot water storage systems were supposed to be implemented:

- one in Orvitis building (Ile-De-France PEB1 B3), the exact location in the building has been identified;
- one in Grand Dijon Habitat building (Franche-Comté, PEB2 B2), the exact location has been identified.

The first study results show that the Grand Dijon Habitat building won't need a hot water tank, as the PV panels production on the building is not expected to generate much unused power.

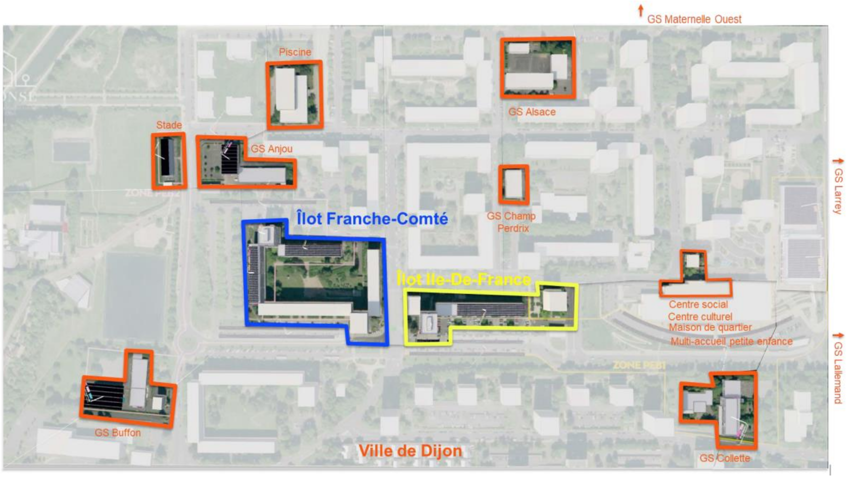

Figure 38 - The tank will be located in the yellow zone Ile-De-France.

Figure 39 - The PV on Ile-De-France roofs is expected to cover 5% of the domestic hot water needs

Important stakeholders to be involved in the process of deployment of the IE.

- EDF as pilot of IS 4.1 (GENESYS)
- GDH and Orvitis are building owners (funders). For Orvitis, Leon Grosse will take care of the installation. The supplier for the tanks is not identified.
- Coriance is district heat supplier for both GDH and Orvitis. Coriance will be involved, due to the fact that the heat storage solution will interfere with future heat demand, hence modifying billing.

RESPONSE

Integrated Solutions for Positive Energy and Resilient Cities

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