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Deliverable due date: M12 – November 2017 (to be updated in M36)

D4.2 Report on retrofitted actions and implemented actions in new buildings including RES and storage

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Project Acronym	mySMARTLife	
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**	
Project Duration	1st December 2016 – 30th November 2021 (60 Months)	
Deliverable	D4.2 Report on retrofitted actions and implemented actions in new buildings including RES and storage	
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Status	■	Working
		Verified by other WPs
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Due date	30/11/2017	
Work Package	WP4 Demonstration in Helsinki	
Lead beneficiary	VTT Technical Research Centre of Finland Ltd	
Contributing beneficiary(ies)	City of Helsinki (HEL), HELEN OY (HEN), Forum Virium Helsinki Oy (FVH), FOURDEG Oy (FOU), SALUSFIN OY (SAL)	
Task description	Task 4.2: Building/District Renovation and Smart Homes Deployment – SMART DISTRICT [HEN] (FVH, VTT, HEL, SAL, FOU) This task focuses on smart retrofitting of existing residential apartment buildings and smart home energy control systems as well as implementing smart demand response in apartments (electricity and heat). In addition, the demonstration of building integrated energy storages and renewable energy sources (PV panels and heat pumps), building integrated energy storages as well as net control strategies for building energy control systems based on thermal comfort models in office buildings. - Subtask 4.2.1: Retrofitted/New high performance district design and deployment; Merihaka and Vilhonvuori: HEN will lead the retrofitting of the residential apartments and the Kalasatama High-Performance residential buildings as well as Viikki Environmental house with the collaboration of HEL, VTT, FVH and SAL. - Subtask 4.2.2: Building integrated energy storage; Implementing Viikki Environment House Electricity Storage (45kWh capacity, peak 90kW). Considering the Smart Meters deployed in all the lighthouse zones and the latest distribution automation technologies and their related information, a data and demand response strategy will be led by HEN and supported by FOU, VTT and FVH. - Subtask 4.2.3: Innovative BEMS and Smart Control Demonstration of heat demand response at apartment level. In Merihaka/Vilhonvuori and Kalasatama High-Performance residential buildings with waste heat recovery and an optimised control system for the district performance and user comfort. The solutions include smart meters and smart building automation systems with demand side management possibilities. The solutions enable demand side management both in heating and electricity use. In addition the automation has interactive and visual user interface. The automation can use both temperature and human comfort set point values	

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	(HTM). The advantage in human comfort set point values is that it takes into account adaptive comfort aspect increasing users' well-being and making possible to save energy. Together with HTM also predictive algorithms are used for optimised energy and peak power use. HEN will lead this task, together with HEL, FVH and VTT - Subtask 4.2.4: RES integrated - specification and deployment. The design and deployment of the concept for building integrated PV panels and heat pumps in new and renovated buildings will be carried out in this subtask, led by HEN. - Subtask 4.2.5: Smart appliances deployment. Smart home solutions in new buildings and smart demand response system in office building with predictive control options and Flexible space management will be designed and deployed by FOU with support from FVH. - Subtask 4.2.6: Monitoring system definition and deployment. VTT and FVH will lead the definition of the Smart monitoring system of building performance in all buildings interventions, included with base line and monitoring the progress in buildings performance.

Date	Version	Author	Comment
14/03/2017	0.1	Mari Hukkalainen (VTT)	Structure of the deliverable and work planning
21/09/2017	0.3	Sara Tuovinen HEL	Viikki
22/09/2017	0.3	Jari Shemeikka VTT	Sunzeb
2/10/2017	0.3	Tapio Toivanen SAL	Salusfin concept
2/10/2017	0.3	Sonja Salo, FOU	Demand response strategy of FOU
11.10.2017	0.4	Mari Hukkalainen, VTT	Integration of partners inputs, contributions to merihaka chapter.
19.10.2017	0.5	Mari Hukkalainen (VTT)	Integration of inputs from Marja Vuorinen (HEL)
19.10.2017	0.6	Kristiina Siilin (HEN)	Added HEN input
19.10.2017	0.7	Timo Ruohomäki (FVH)	Added information on Kalasatama actions
16.11.2017	0.8	Mari Hukkalainen (VTT)	Ready for review
30.11.2017	1.0	Mari Hukkalainen (VTT)	Finalisation after CARTIF's comments

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Abbreviations and Acronyms

Acronym	Description
BEMS	Building energy management system
BESS	Battery Energy Storage System
CHC	Combined Heating and Cooling, heating and cooling of buildings implemented with regional heat pumps, where buildings work as heat sources for the heat pump and the district heating network serves as a distributor of heat collected by district cooling network
DEMS	Distributed Energy Management System
EV	Electrical vehicle
FCR	Frequency containment reserve
HTM	Human thermal model
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy (the project)
nZEB	nearly zero energy building
RES	Renewable Energy Sources
SunZEB	A concept for a energy efficient building that recycles the solar energy from the indoor air to district heating by cooling the building with district heating.

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Executive Summary

This deliverable begins by introducing the energy renaissance strategy in the city of Helsinki. This strategy aims for large scale replication of the demonstration actions in Helsinki. One of the key actors is city's energy advisor, who aims to provide end users, building owners and residents information about possibilities and the potential for replicating actions demonstrated in mySMARTLife.

The main focus of this deliverable is to describe the implemented retrofitting interventions in old buildings as well as energy efficiency actions in new buildings in Helsinki smart city demonstration cases. The following case areas are analysed: 1) Merihaka and Vilhonvuori districts with existing apartment buildings from the 70s; 2) New smart city district of Kalasatama, which is currently under construction; and 3) Viikki Environmental House, which is an excellent example of a very energy efficient office building in Nordic climate. Most of the demonstration actions focus on implementing innovative smart building solutions, such as smart building energy management, rather than traditional retrofitting projects. In addition, Viikki Environmental House includes the integration of electrical storage systems and Renewable energy sources (RES) at a building level. There are also building integrated RES in the Kalasatama district.

The third aim of this deliverable is to define the strategy for demand response is defined. Here, mostly thermal demand response connected to district heating is focused, while the principles of electricity demand response is briefly introduced, and the details are given in later deliverables D4.3, D4.4, and D4.7. Also the viewpoint of the local energy company Helen is discussed.

This is an interim version dated in November 2017, representing the current situation after the first year of the demonstration implementation period. The content will be updated and detailed later in M36, after the actions have been implemented.

The retrofitted and new building actions to be physically implemented in Helsinki demosite areas will not be ready at the current due date established in the original description of the action, this is in month 12.

Considering that an Amendment was requested in September (month 10) and that the process of negotiation and approval can still take several months, it was agreed with the Project Officer to submit an interim report at the original due date, including a first version of Helsinki retrofitted and new building actions including RES and storage solutions.

Therefore, to provide the complete report with the final details of these actions (and not only the initial plans), a new final version will be delivered by month 36.

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1. Introduction

1.1 Purpose and target group

This deliverable reports the retrofitting interventions in existing buildings and implemented actions in new buildings in demonstration cases in Helsinki. Some of the interventions include also the integration of building and district level renewable energy sources (RES) and storage. The three demonstration cases are: 1) Merihaka and Vilhonvuori districts, 2) Kalasatama district, and 3) Viikki Environmental House. In addition, a demand response strategy is defined, including both electrical and thermal demand response. The deliverable is targeted for municipal officials, building owners and facility managers, construction companies and consultants, as well as researchers.

Figure 1. The intervention zones from the district area of Vanhankaupunginlahti in Helsinki.

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1.2 Contributions of partners

The following Table 1 depicts the main contributions from participating partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
VTT	Main responsibility of the deliverable.
HEL	Viikki environmental house inputs and action descriptions; inputs to the description of Merihaka. end-users' involvement; energy advisor and energy renaissance .
HEN	Energy storage in Viikki; Merihaka heat demand response actions in sections: 3.3
FVH	Kalasatama actions
SAL	Demand response strategy development in Merihaka and Vilhonvuori.
FOU	Demand response strategy development in Viikki.

1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the mySMARTLife project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D4.1	Baseline report describes the starting situation of the actions.
D4.3	Contains smart demand control system description.
D4.4	Innovative smart system appliances and control algorithms, BEMS and smart control.
D4.5	District heating and cooling improvements: e.g. SunZEB concept.
D4.8	Electrical demand response concepts in detail
D4.13	City 3D model in detail

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2. Energy renaissance strategy in Helsinki (action 32, non-technical)

2.1 Introduction to Helsinki's climate goals

Cities contribute up to 70 % of all global greenhouse gas emissions. The City of Helsinki has a long history in taking major steps together with the residents and local business towards the target to be carbon neutral.

Helsinki's new strategy seeks to make Helsinki the world's most functional city, to ensure sustainable growth, and to provide good everyday life for all residents. New strategy includes the goal to render Helsinki carbon neutral by 2035. Helsinki aims to reduce emissions by 60 per cent by 2030. Measures to implement these goals include increasing renewable energy production and energy efficiency. The energy efficiency of buildings will be improved both in the construction of new buildings and the renovation of old ones. Helsinki strives to combine renewable energy sources with energy efficiency in an optimal way, both in individual buildings and at districts.

2.2 Energy renaissance model

Helsinki's new strategy and the goal to be carbon neutral by 2035 are on the background when talking about the importance and the potential for improving energy efficiency of existing building stock. Therefore, Helsinki will adopt a model for district-level energy renovation for Helsinki. The aim is to improve residents' possibilities to influence in decision making by involving them in every phase of the process.

2.2.1 Formulating the model for district level energy renovation

Planned actions for the model are as follows (and they are explained more thoroughly below):

1. Building the network of housing associations and relevant stakeholders
2. Conducting surveys and questionnaires
3. Planning and proposing actions
4. Arranging events and work shops
5. Formulating the model based on the experiences of actions in Merihaka

First step of the model formulation process is to identify areas or building blocks, which have the potential and possibilities for energy saving. In this project, it is Merihaka area (overview of the area can be found in D4.1). Merihaka is an ideal area to examine not only because of the project actions, but because there is

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planned to be major changes in urban and traffic planning in the area. Behavioural changes are more likely to occur in conjunction with other changes when there is discontinuity with previous practices. New plans include e.g. following: nearby bridge Hakaniemensilta will have a new alignment, as there will be a new tram line and bridge connection to Laajasalo (The Crown Bridges), and the urban structure will be more dense with new building construction.

The intention is to build a network of housing associations and board members to plan together and clarify the most cost and energy effective ways to improve energy efficiency of the buildings. The network will find out the present state of the buildings and residents' current behaviour and willingness to make improvements. Network can be expanded to include e.g. experts from the urban planning sector of the city or companies which have expertise in areal strategy planning.

One objective of the model is to find out suitable solutions for financing of energy renovations and developing incentives for residents in order for them to be more willing to implement energy renovations. On the other hand, one objective is to find barriers for that willingness. Furthermore, the aim is to improve business potential of actors in the field of energy renovation.

Based on the experiences and results of this project and actions in Merihaka, Helsinki will formulate a model for district-level energy renovations.

2.3 Methods for citizen engagement

Residents of Merihaka will be actively informed and engaged through different information channels throughout the project. Together with the above mentioned network of housing associations we need to make the residents to understand the benefits of district or area level thinking. Social acceptance and making residents to commit to planned improvements are crucial for plans to be successful. Incentives, rewards or acknowledgments will be examined and developed during the project as an engagement tool.

2.3.1 Surveys and questionnaires

The residents of Merihaka are involved by making an interview and/or questionnaire study about the current needs and requirements of the residents. Based on the feedback and analysis of the results of the surveys, energy advisor supports and promotes also other residential building owners and residents in the Merihaka area to replicate the potential energy performance improvements and measures. These will be closely discussed with the network of housing associations.

Surveys for the residents will contain topics such as current situation and occupant behaviour, attitudes towards domestic energy saving and willingness to implement domestic energy saving measures.

2.3.2 Trainings

Based on the results of the surveys and requests of the network there will be different kinds of support and guidance for the residents. E.g. information events and co-creative workshops will be held about

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systematic and planned maintenance of the property, possibilities and best practises for energy savings and how to make an areal strategy for building maintenance and procurements.

Furthermore, there will be implemented a heat leakage imaging in the facade of a building (Haapaniemenkatu 12, Action 44). Results and analysis of those images will be one topic for an information event. Also, the use and benefits of smart thermostats (Action 4) that have been installed in Haapaniemenkatu 12 is going to be discussed as an example of energy saving possibilities.

2.3.3 Open data

Open data and City 3D model will be used as a visual and digital tool in energy advising. Open energy data and map services will be further developed and deployed during the project. Action 44 is described more thoroughly in the D4.13.

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3. Retrofitting interventions in Merihaka and Vilhonvuori

3.1 Description of residential buildings in Merihaka and Vilhonvuori

Zone 1 of the lighthouse district consists in a residential construction area from the 1970s-1980s (Merihaka, Vilhonvuori blocks), which borders the district towards the old city center and Kallio (built in 1800s and early 1900s). The Merihaka and Vilhonvuori buildings are the project retrofitting targets and, as typical buildings of their era, they also represent the vast amount of building stock in Helsinki still waiting for energy refurbishment: there are total of 10,262 residential high-rise buildings in Helsinki (22.28M sqm) with 4,427 of them being built in the 1960-1980s (9M sqm).

Merihaka and Vilhonvuori area consists of 34 buildings, with each building having a residential area between 2,876 m^2 and 9,834m^2. See also D4.1 for additional baseline description about the demonstration area.

Figure 2. Merihaka district [figure from HEL]

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The buildings in the Merihaka area are mainly residential buildings, and in addition there are: one large office building, a sports center, few shops and large underground parking with two visible parking places. The buildings' age is quite same, as they are element construction built in the 70's. In the residential buildings, many of such renovations are already done, which could affect the energy performance. For instance, in the pilot building (Haapaniemenkatu 12) there has been renovations affecting to the energy efficiency of the building as follows: retrotiffing of rooftops (1997), new heat exchanger for the district heating system (1999), elevator's renovation (2000), facades have been renovated (2001) with extra insulation in the first floor (2012), building automation system renovation the renovation of water pressure pumps (2009) and renovation of general lighting (2011-2012). The area is described in more detail in D4.1.

Facades will be imaged with thermal leakage cameras during winter 2017-2018 and further possibilities for insulation improvements may be found. In some of the Merihaka buildings, there is also studied a heat recovery possibilities of waste water and preliminary studies suggest this to be a cost efficient way of energy improvements (source: Wasenco, Jouni Helppolainen).

The city planning in the area is ongoing and also a wide complementary construction is studied, which may effect in future also the parking halls next to the major street.

The pilot building is connected to the district heating. The baseline for the building energy consumption is presented in Deliverable D4.1.

3.2 Retrofitting interventions focusing on active energy management

Within mySMARTLife activities, the project aims to develop a model for further retrofitting, at further impact 200:1 to project scale (see also Policy actions in WP1). The U-values of this residential building stock is however already relatively good when compared to European building averages. For example, more than two-layer windows have been the standard since 1970s. Also, substantial amount of the Helsinki residential buildings from the suburban growth era have recently been through either facade and/or pipeline renovations. Thus, to produce replicability and impact, the interventions are focused more on the managing the energy performance than on the building fabric (passive solutions, e.g. insulation of the envelope or glazing). Installation of smart controls for management of apartment level heat demand is key intervention in the retrofitting (see also actions related to Domotics). For the retrofitting and domotics up-take, the project executes pilot-in-a-pilot approach with first planning the action and demonstrating the solution at a pilot building (167 flats), and then further uptaking the solution to rest of the district with a commercially viable business model.

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After installation of first smart control systems (in Haapaniemenkatu 12) it is possible to demonstrate the effects of the system to the stakeholders of neighbouring buildings and get them to do similar actions. This is linked to Action 40, Implementing Energy Advisor and Action 32 Smart District-level Energy Renaissance Strategy, which were explained more deeply in the chapter 2. Furthermore, this uptake gets also support from the city's 3D model, in which energy related data will be added during the mySMARTLife project.

Action 1 focuses on developing a model, how municipality can support and promote energy efficient building retrofitting and improving the energy performance of the residential construction. This model will be tested in the Action 40) Implementing Energy Advisor Activity for the residential building owners (co-operatives) and small businesses in the Zones 1 and 2. The common goal for both of these actions 1 and 40 is to demonstrate, how municipality could boost interventions for improving the energy performance of the residential construction. The residents will be involved to the model development and Energy Advisor Activities by making an interview and/or questionnaire study about the current needs and requirements of the residents, and based on the feedback, the potential energy performance improvements will be promoted in the area, targeting to boost energy efficient retrofitting activities in at least 12 buildings.

3.3 Thermal demand response in an apartment building

Most urban heating in bigger cities in Finland is done by district heating. District heating network is a thermal grid wherein a centrally heated fluid is circulated through a network of pipes and heat exchangers to meet the heating needs of residential and commercial buildings.

Housing and real estate are major energy users. Traditional energy efficiency measures, such as improving the insulation or increasing heat recovery in ventilation, are essential ways to reduce building stock energy consumption and emissions. In addition to these, an important factor for reducing the emissions and costs of the energy system is increasing demand response.

A main task of demand response is to reduce power demand in the energy system during consumption peaks. Momentary consumption can be reduced or the consumption can be shifted to a different time. In this shift the building mass can be used as heat reservoir. All this should naturally happen without compromising living comfort.

Optimizing the district heating energy system with demand response can lead to lowering energy production costs and lower emissions, which come from better flexibility in production planning and control. For the customer, the participating into demand response mechanism ultimately can lead to decrease in the heating costs of the property.

New technological solutions, such as remote-controlled intelligent thermostats are a possible technology for implementing demand response functionality in apartment buildings on apartment level. Demand response can also be done on building level with heat exchangers. However, these new technologies give

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better control for the customer over personal living conditions and comfort in addition to cost savings and lower environmental impact.

Haapaniemenkatu 12 is a retrofit building, where a smart heating management system is built to control apartment room thermostats. The heating management system manages room level temperatures. Demand response requests from district heating system are given to the smart heating management system as input. See also Figure 3. The apartment level heating is increased or decreased within the resources (i.e. heat storage capacity) that the apartment building can provide, which functionality creates the demand response activity. More detailed description of the functionality can be found from deliverable D4.3 New predictive and adaptive control algorithms and monitoring of performance, smart demand control system.

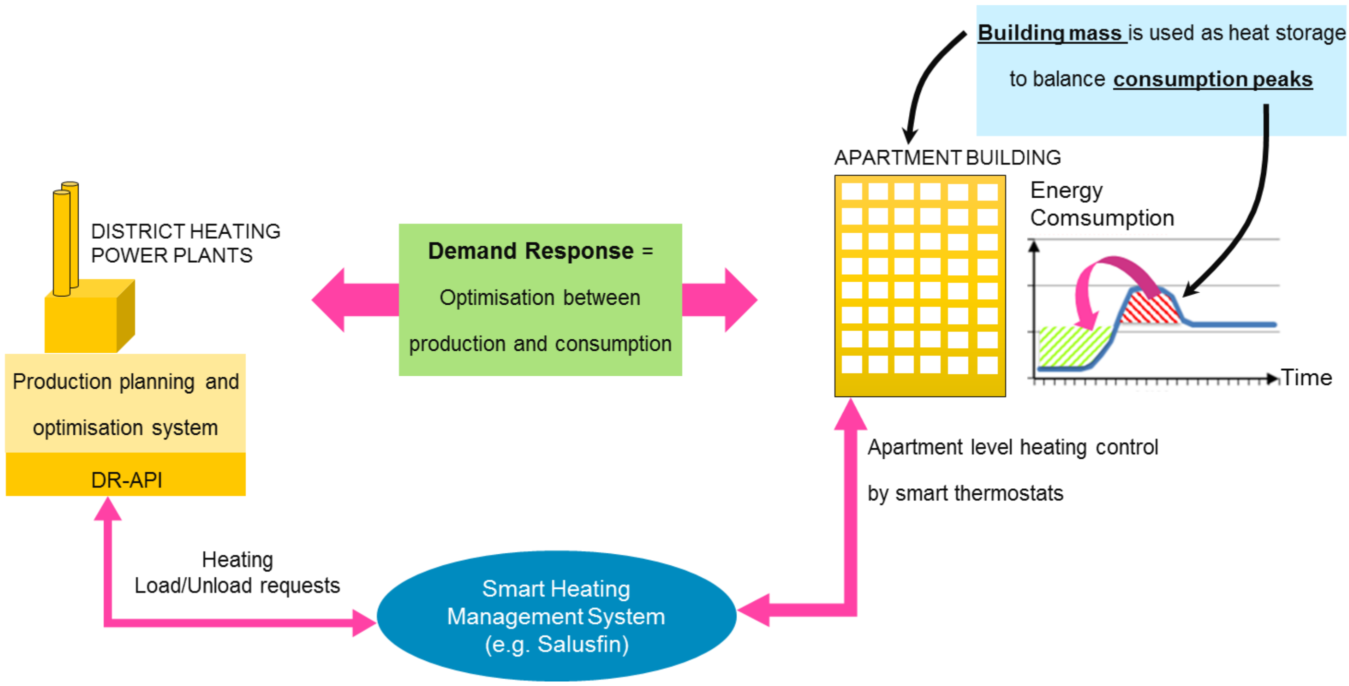

Figure 3. Thermal demand response in district heating system (figure from HELEN)

3.4 Action 44: urban platform energy data, energy leakage

As part of the project, the Helsinki Urban Platform will be extended to better support real-time sensor data and building data. The data is collected from specific sensors or data gateway products, that can e.g. forward BACnet or KNX messages over IP to the platform. Once received to the platform, it can forward the data streams into visualization or analytical services, following the MyData principles and in accordance of the General Data Protection Regulation. Being able to associate services with the sensors and other sources of data streams is seen as an important step to provide a platform and ecosystem to

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developers. This approach will make it easier in the future for the new companies to start providing energy related services, since the platform provides key mechanisms to manage the user consent.

The following illustration (in **Figure 4**) describes the urban platform concept in a high level.

Figure 4. The urban platform concept in Helsinki on a high level [figure from FVH].

The diagram illustrates the data sources on lower part or the picture, some of which containing data elements that fall into the category of personal data in GDPR. Such data streams go through MyData consent management which means, that only the owner of the sensor or apartment can decide to which services the data is allowed to be forwarded. These data streams can be used together with public data sets, such as those stored in the Helsinki Region Infoshare, a CKAN service supporting the Helsinki region. The selection of services available for data processing is dynamic, new services can be introduced with minimum effort. The interfaces for both sensors and the services are based on open standards such as SensorThings and Common Information Model (CIM) for Smart Grids.

The realtime energy consumption information is also provided to the platform by a specific, CIM-compliant FacilityAPI. The use of the API will be mandatory in some districts, such as the Kalasatama area. The FacilityAPI created as part of the mySMARTLife –project will be included in the CitySDK family of urban platform related APIs (http://www.citysdk.eu).

4. New high performance residential buildings in Kalasatama

4.1 Design and deployment of a new high performance Kalasatama district

The Kalasatama district is a new construction area where construction started in 2012 and will continue until 2032 when the area is expected to be completed, providing housing and services for 20.000 residents. The Kalasatama port area in 1999 is shown in **Figure 5**, and the current state of the Kalasatama construction site in 2017 is shown in **Figure 6**, and the whole construction schedule for the Kalasatama district is shown in Figure 7. The construction requirements for new residential buildings in this zone are regulated by the city and the regulations drive the construction towards smart homes and smart grid compatible buildings.

Figure 5. Kalasatama port area in 1999 (figure from HEL)

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Figure 6. Kalasatama construction site in 2017 (figure from HEL)

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Figure 7. Kalasatama district construction 16.10.2017 (figure from HEL)

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In the Kalasatama district, the apartment buildings are expected to connect to underground vacuum waste pipelines, connect and integrate with smart grids, have electric car charging for 1/3 of the residential parking spaces and have apartment-level energy measurement and smart controls for electricity and heat. The integration with smart grids means capability of being controlled as a demand response load.

As part of the project, 20 living lab workshops shall be held to support project activities. While there are no specific activities going on in the Kalasatama district for the mySMARTLife project, the living labs will follow the ongoing co-creation activities that Forum Virium (FVH) has started as part of the Smart Kalasatama project. Since 2015, near 100 events has been held in the co-creation space dedicated to the living lab activities. The sessions have attracted over 2.500 participants from the district and from other areas. The Kalasatama area and the co-creation methods have also been demonstrated to visitors from various countries: so far over 1.500 people have visited the living lab.

The Kalasatama district is not part of the technology demonstrations of the project, meaning that the project will not do install there any technical appliances. Instead, the project has been involved with the updating process of the construction regulation in the stipulations for the plot assignment, in order to better meet the technical requirements and interoperability of the smart buildings integration with smart energy systems. The assumption is that the updated Kalasatama plot assignment stipulations would in the future make it possible to get dwelling-level temperature information from any new building, therefore making it unnecessary to set up an additional sensor network for new energy-related services. To support the regulation work, a living lab workshop was arranged in August with the participants currently planning to build a co-op apartment building with geothermal heating and solar panels as addition to advanced smart home systems. The 14 attendees were introduced to the regulations and latest developments in the automation technology, especially KNX. As part of the living lab session, a workshop was held where the attendees had the chance to come up

By the end of November 2017, the following living lab co-creation sessions have been organized in Kalasatama:

- 7.9.2017 “Smart Home Meets Smart Grid” – co-creation workshop for the co-op apartment building group
- “Helsinki Loves Developers – Open Energy Data from Buildings” – service demonstrations and co-creation workshop for software developers interested in energy data
- 17.10.2017 “Gadget Workshop – Build Your Own AQ Sensor” – co-creation workshop to build air quality sensors to crowd-source sensor data on urban platform.

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4.2 Design and deployment of new SunZEB building block

The SunZEB is a district level integrated Nearly Zero Energy solution for buildings to maximize the renewables in the district heating using district cooling recycling in the dense city area. SunZEB buildings are integrated with the urban energy platform and they form an interactive energy community (Figure 8). The urban energy platform acts as an enabler for the resource efficiency to harvest, convert, store and distribute the heating, cooling and electricity in the city of Helsinki. This platform has evolved during decades and enables diverse energy supply for City of Helsinki. The SunZEB is the latest addition to this platform. The SunZEB solution is mainly focusing on the thermal energy (district heating and district cooling).

This implementation of the SunZEB is the first in kind realization in Finland and is now piloting the new opportunities of the integrated district heating and cooling systems.

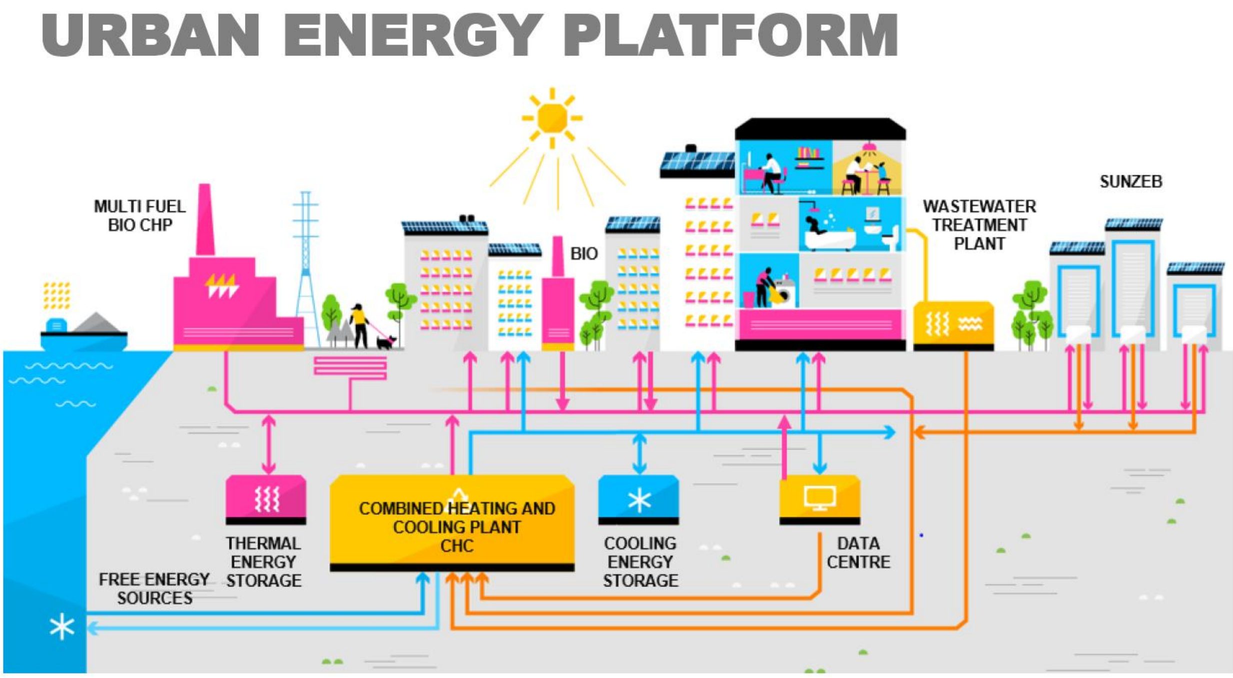

Figure 8: The urban energy platform in Helsinki operated by Helen ltd. SunZEB buildings are integrated with the energy platform and they form an interactive energy community. The heart of the SunZEB is the combined heating and cooling plant (heat pumps) between district heating and district cooling networks converting the renewable sun from the cooling to the heating. (Picture source Helen, Jouni Kivirinne).

The SunZEB building solution relying on the urban energy platform is based on the highly energy efficient building design (low energy demand in the first place) and the integrated solar architecture, which is enhanced with the connections to the regional heating and cooling networks enabling the recycling and collecting of the solar thermal energy that otherwise would be wasted. The optimized solar architecture (Figure 9) in building design is the key to optimize the renewables (=cooling energy) to be recycled to the

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urban energy system and to guarantee the comfortable indoor climate with lots of ambient light and spacious feeling at the same time.

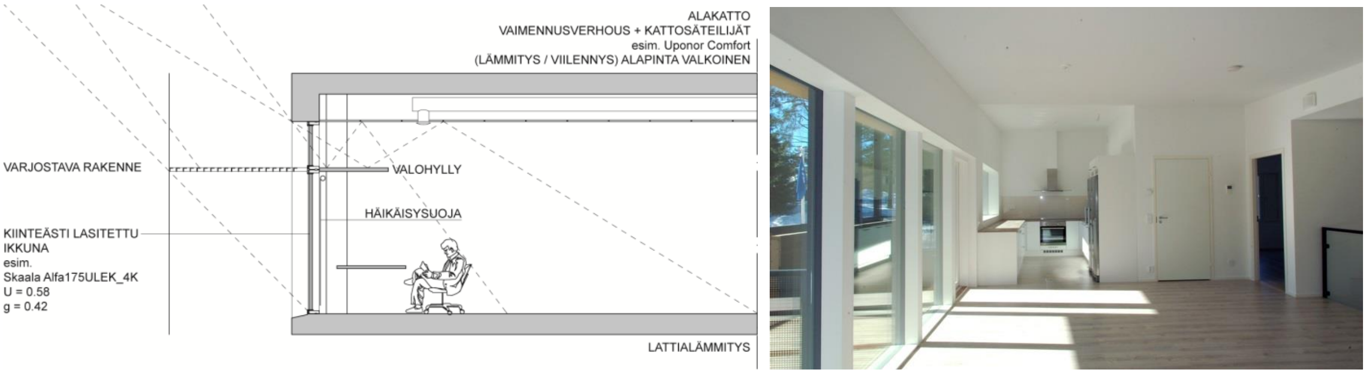

Figure 9: The integrated solar architecture is a key element to maximize the renewable share and the end user comfort (Picture source Jari Kiuru, Architectural office Kimmo Lylykangas).

The target values of the SunZEB building in measurable numbers are:

- *District heating demand* ***< 60 kWh/m²,a***
- *District cooling* ***< 20 kWh/m²,a***
- *Electricity* ***< 40 kWh/m²,a***
- *Primary energy (national E-value)* ***100 - 105 kWh$_E$/m²,a***
- *Indoor temperature between* ***21 ºC*** *(winter) to* ***26 ºC*** *(summer)*

Definitions

- *SunZEB= nearlyZero Energy Building, where solar architecture, wide outside views, advanced building technology and CHC*-technology, combines heating and cooling energy flows and connects the building to a regional entity*
- *CHC = Combined Heating and Cooling, heating and cooling of buildings implemented with regional heat pumps, where buildings work as heat sources for the heat pump and the district heating network serves as a distributor of heat collected by district cooling network*

The SunZEB block (Figure 10) is located south from the district of Kalasatama center in the Sompasaari area in Helsinki, Finland. The block is a residential apartment building block totaling 14 200 m² for 350 residents. The SunZEB block is implemented by the builder companies Fira, Kojamo and Asuntosäätiö, which are developing both rental and private owned housing.

The new SunZEB building block is part of the “Kehittyvä kerrostalo” -program - *“The evolving apartment building” program*, which is an initiative of the city of Helsinki to increase the attractiveness, flexibility and individual solutions of apartment buildings in the city area. The city of Helsinki has been committed to develop apartment buildings in order to offer individual housing solutions and to enable a competitive option to live in the capital area. The program targets are realized by granting city owned lots to builders, whose construction projects support the common development targets.

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The evolving apartment building development program is supporting:

- the diversity of the apartment house types
- flexibility of housing
- quality of the yard areas
- affordable housing
- end user orientated approach in living
- energy efficiency

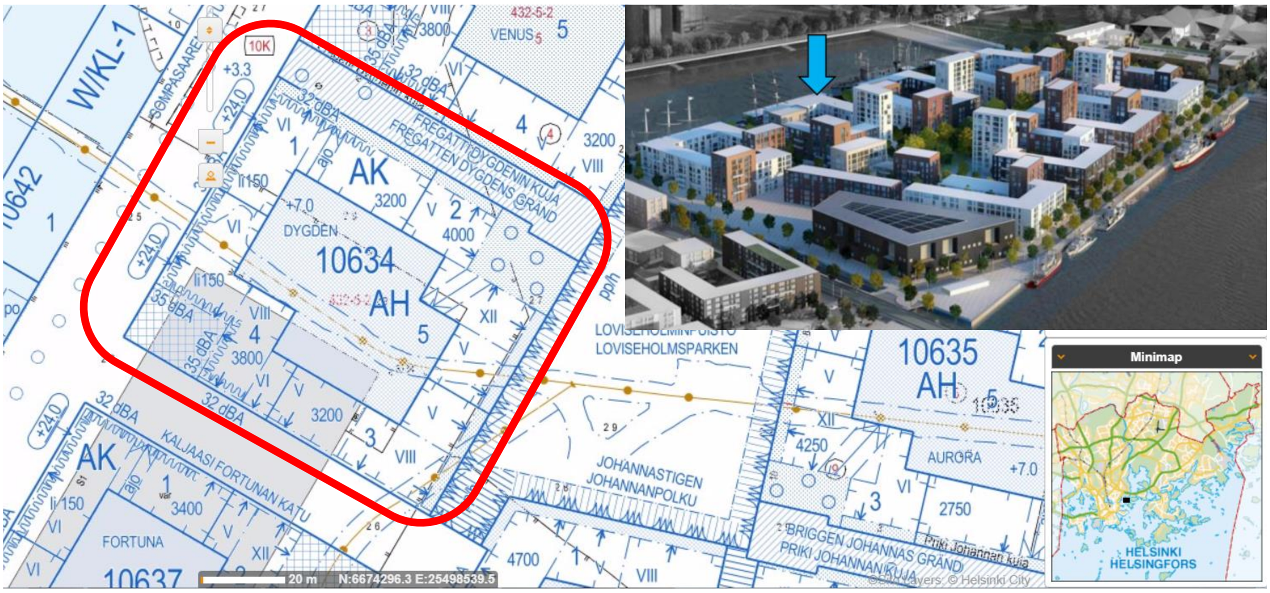

Figure 10: The SunZEB block (inside the red borders and under the blue arrow in the small illustration picture) in the Kalastama in Helsinki. Source: Map service of the City of Helsinki: https://kartta.hel.fi/link/3wZEYQ. The 3D illustration from the detailed plan description, City of Helsinki (https://www.hel.fi/hel2/ksv/liitteet/2014_kaava/ak12200_selostus.pdf)

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The SunZEB concept represents a new highly energy efficient building design and it differs from the traditional design and needs a performance based design approach to reach the targets. The complexity of joining the high-class indoor environment, energy efficiency, renewables and district integration leads to a need for an enhanced working method for the designers and other stakeholders. The energy targets are set by measurable numbers, which can be checked during follow-up period. The energy targets guide the design process with the help of the energy simulations.

The complexity of the SunZEB block design is tackled by the collaborative “Big room” design concept, which is part of the “Verstas”® project development concept owned by Fira (https://www.fira.fi/en/palvelut/verstas/). In addition, the block level design gives benefits from the scale and learning point of view - same designers are involved in the block design process. Traditionally four different design groups would have designed this kind of block, because the block in question contains four lots meaning four separate projects. Construction projects have traditionally not been discussing and sharing the knowledge between each other leading to a loss of information and knowledge.

> *“Our task is to understand the targets of the customer and help him to reach them, develop the project in a transparent manner with people participating, assist the customer in making good decisions and generate essential information for user in a format they can use.”*
>
> *- Fira Verstas®*

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Figure 11: The “FIRA Verstas” process contains a collaborative “Big room” design working method, which brings the stakeholders of the planned building into the same space to share their views and discuss about the solution under planning and to insure that the planning process is on track according to the targets set by the builder. Picture (below): Kojamo’s rental apartment building located in the north-east corner of the SunZEB block under discussion at Fira, ©Jari Shemeikka, VTT

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5. Implemented actions in Viikki Environmental House

5.1 Introduction to Viikki Environmental House

Completed in September 2011, the energy-efficient office building is used by the City of Helsinki Environment Centre and the University of Helsinki. It is currently the most energy-efficient office building in Finland. It has an energy efficiency goal of 70kWh/m^2 year. This rate is half of what the 2012 Finnish regulations for new buildings require. A typical office building's energy efficiency rate is approximately 150kWh/m^2. The Environment House improves its efficiency by combining several different energy saving solutions. Low energy consumption is implemented mainly by means of commonly-used technical solutions. For example: The structures are energy-efficient; Bedrock-based cooling is used to cool the premises; The south façade has been designed for the efficient utilisation of solar panels (see Figure 12), which also shade the façade to prevent an excessive heat load in the summer: Natural daylight is utilised by means of, for example, light shafts.

Figure 12. Viikki environmental house, an office building with solar panel façade (figure from HEL)

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Environment House building shows the best energy performance of an office building ever built in Finland. Measured total primary energy use of 85 kWh/m^2 year including small power loads is expected to comply with future nearly zero energy building (nZEB) requirements. The energy efficiency objectives of the new buildings are ambitious and the starting point of the planning is to define solutions that are environmental friendly, sustainable and cost efficient. The main objective of Environment House building demonstrations is to find out the cost efficient solutions for the New building's energy production system, define the right technical dimension as well ensure the system integration of the technical administration and maintenance. The automation can use both temperature and human comfort set point values (HTM). The advantage in human comfort set point values is that it takes into account adaptive comfort aspect increasing users wellbeing and making possible to save energy. Together with HTM also predictive algorithms are used for optimised energy and peak power use. Environment House will be a regional "showcase", complementing existing solutions with the new mySMARTLife Actions, and project experiences will be exploited for the planning of new buildings in Helsinki. The first of these is the City's Technical Departments new headquarters building at Zone 2 that will be completed 2020. Also, the Environment House already serves annually thousands of people with professional excursions. The main outcome of the demonstrations will be technical solutions with verified performance and cost data for all important nZEB technology areas such as HVAC, passive solutions and renewable energy production, and methods and tools needed in the decision making, design and performance verification of nZEB buildings. The smart energy system and demand response related actions are described in detail in deliverables D4.3 and D4.4.

5.2 Action 9: Building integrated energy storage

In 2015 Viikki Environment House contracted Siemens with leasing-contract of first customer scale electrical energy storage in Finland shown in **Figure 13**. Viikki's lithium ion battery utilizes LG's chemistry, which provides 45 kWh energy capacity for the building's optimization purposes. The nominal power capacity of the battery is 90 kW. The battery is used to improve the photovoltaic panels' production utilization: the Environment House has 60 kWp installed PV capacity. During office hours the self-produced electricity is completely consumed but the storage is needed e.g. in weekends when the building's base load is lower, approximately 20 kW.

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Figure 13. The battery energy storage at Viikki Environment House used to optimize the building's own energy production and consumption (Helen, 2017, photo by Niklas Sandström).

The battery energy storage system, BESS, offers also other functionalities regarding the optimization of Environment House's consumption and production. These functionalities include cost optimization, peak shaving of electric vehicles' charging, and a new feature of cutting the peak of elevators. The BESS is also capable to produce or consume reactive power which should be enabled if revenues in providing such service to distribution grid becomes available. The local optimization can be controlled by controlling the energy costs or by keeping the net power to the grid in zero, P = 0 kW.

The reality is that the battery is not utilized by the property owner each hour of the day. Non-utilized hours appear during night time but also during winter time when sun is not shining. In one year time there is over 5 months when the PV optimization is not possible. Viikki Environment House and Helen, the energy utility company, demonstrate how the best value of efficient operation of the BESS can be achieved by benefit stacking. It is agreed and contracted between property owner and Helen that the times not utilized for building optimization are traded for national transmission system operator's, Fingrid's (Finnish Transmission System Operator) frequency containment reserve (FCR) market. The value from market driven operation is shared between property owner and Helen. Such co-use of electrical energy storage is seen by Helen as additional value for the customer when purchasing energy storage.

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Siemens' Distributed Energy Management System, DEMS, is used to control and optimize the Environment House's energy system. DEMS is also the aggregation platform used by Helen to operate at Fingrid's markets. In addition to controlling the BESS, PV panels, electric vehicle charging and elevators, DEMS can control the air condition and ventilation of Environment House and offer electrical demand response to FCR market similarly as the BESS via DEMS. Smart control of each asset in smart buildings is needed to result in overall efficient and profitable combined operation of such solutions. The benefits of the BESS as one asset in total optimization are shown by Viikki case and the control strategy and the different solutions should be taken into account when planning new future office buildings.

5.3 Building integrated RES in Viikki

There are several renewable energy systems in Viikki Environment House. Building is cooled by the borehole system and there are also solar and wind systems in the building. The BEMS for Viikki building are described in detail in Deliverable 4.3.

All the cooling need of the Environment House is covered with free cooling from borehole water and there is no mechanical cooling systems at all. The borehole system consists of 25 boreholes each 250 meters deep. A simple borehole cooling system with a circulation pump and a water tank serves both the central air handling units and chilled beam units installed in offices and other spaces. Boreholes are sized to provide 15 °C supply design temperature (return 20 °C) to the water tank. Air handling units' cooling coils and chilled beams network are sized to 16/20 °C design flow temperatures from the water tank. The cooling capacity of boreholes was calculated at the construction phase at 68 MWh per year with electricity consumption of about 2 MWh per year. In 2016 the capacity of the borehole system was 58.4 MWh. South facade of the building is a double facade with vertical solar panels and some panels are also installed on the roof. The total installed solar power is 60 kW (570 m^2) that provides about 17% of electricity use of the building. In 2016 the capacity of the solar power plant was 28.9 MWh. 92m^2 of the panels are located on the roof at a 30 degrees angle and is 463m^2 is installed at the south façade. Solar panels, inverters and other necessary parts are delivered by Naps Solar Systems Oy. There is three panel models:

References of PV panels	Power (Wp)	Square meters installed (m2)
NP130GG – S1414,	130	312.36
NP230GG – S1409,	230	151.11
NP205GG	200	91.35

There are also four small city wind turbines installed on the roof of Viikki Environment House (see Figure 14). Turbines are designed by Oy Windside Production Ltd. They are designed to operate as autonomous units with low maintenance. Turbines model is WS-0.30B. The weight of one WS-0.30B turbine is 43 kilos

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and the sweep area is 0.3m^2. They can constant wind of 40 m/s. Wind turbine's wings are made by glass fiber, fasteners are aluminum, generator and end flanges are made by steel and aluminum and all the bolts are made of stainless steel or galvanized steel. All the four WS-0.3B turbines have a total power of approximately 80W. In 2016 the turbines output was 0.038 MW.

Figure 14. Small vertical axis wind turbines at Viikki office building (figure from HEL)

Wind turbines could not be too big because they were designed to be installed on the Environment House's roof. The structures of building needed to withstand their weight and they should not have noise disturbance to the inhabitants of the area. The idea of turbines was more of a demonstration of the potential of wind power than the energy production for the building. Currently you can use energy form wind turbines to charge cell phone batteries. Originally idea was to use it to illuminate the security lights.

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6. Definition of a demand response strategy

6.1 Thermal demand response strategies

In mySMARTLife, two thermal demand response implementations are demonstrated by Finnish SMEs Fourdeg and Salusfin. Both of these solutions are described shortly below.

6.1.1 Fourdeg's system

Subtask 4.2.5: Smart appliances deployment. Smart home solutions in new buildings and smart demand response system in office building with predictive control options and Flexible space management will be designed and deployed by FOU with support from FVH.

Introduction

Fourdeg is deploying smart heating devices to the Viikki Environmental House together with HEN, HEL, VTT, and FVH. During the upcoming heating season, Fourdeg's predictive heating and energy optimization algorithms increase indoor comfort while making the Environmental House even more energy efficient.

In addition, heat response algorithms are tested. These signals come from HEN, and the API between the partners is created. Furthermore, VTT tests their Human Thermal Model in selected rooms in the Environmental House. These actions would not be possible without the Wi-Fi connected digital thermostats, as described later.

Currently, the Wi-Fi connections of the building are extended so that the IoT devices can be connected to the Internet. The building was not applicable for so many IoT devices which are connected directly to the Wi-Fi network of the building. The embedded solution lead by FVH is comprehensive to support more IoT devices also in the future.

About Fourdeg's Service

Fourdeg is a company for optimizing heating of buildings. The system operates electronic wireless radiator thermostats (see Figure 15) in district or central heated buildings of all type. The Service improves indoor comfort with individual and stable heating, and saves on heating costs by 15-35% due to lower heating energy consumption and heating Demand Response. The savings are achieved by heating or cooling each room individually at the right time, with the appropriate heating energy, and based on the room's intended use. The Service works fully automatically at room-level accuracy in any size of old and new buildings, including both commercial and residential premises. The company's core competence is a cloud-based Service utilizing patented predictive algorithms.

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Figure 15. Smart thermostat at Viikki office building (figure by HEL)

Technical Details on Viikki Environmental House

Fourdeg's IoT thermostats learn the individual heat resistance of the room. Fourdeg's smart heating system enables heating Demand Response. However, Demand Response can be a useful tool in local cross-commodity intersections when heating power production depends on local weather factors. When the demand for heating peaks, the smart automation system directs heat energy in rooms where it is mostly demanded.

In this Deliverable, new insights on user behaviour are implemented in the system to maximize user comfort at the time of occupancy and minimize heat consumption at other times. The smart heating system adopts occupancy patterns with smart sensors and schedule shearing. The target is to raise and decrease indoor temperature without that the employees feel discomfort. At first, the indoor temperature will shift within ±1°C according to HEN's Demand Response signals. When deploying demand response, the indoor temperature does not immediately drop but has a shift in time depending on the time constant of the radiator, the indoor air, and the surrounding surfaces. Whenever an employee feels that the room temperature is too warm or cold, the employee could be instructed to provide feedback. Depending on the received feedback, the Demand Response shift can be changed.

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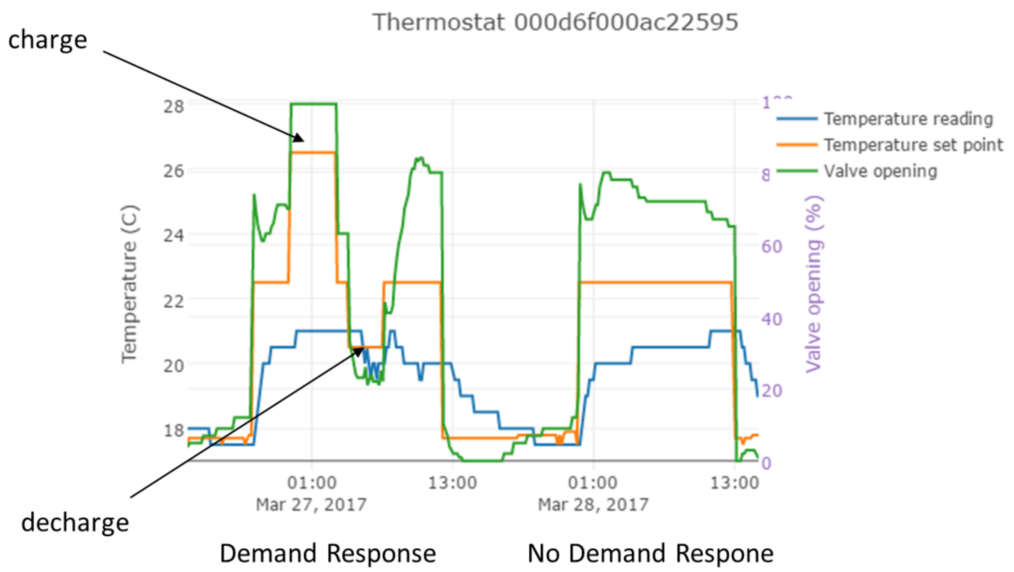

Figure 16: Schematic representation of a day with heating Demand Response and a day without Demand Response. Charge refers to heating the rooms before the peak load time, and then during the high peak load times the room temperature is lowered to decharge the thermal energy used.

VTT will mount external sensors to selected locations. With these, further data of indoor temperature shifting is gained. The air temperature near the radiator is typically higher than air temperature in the centre of the room. Additionally, the effect of environmental factors, such as solar radiation, may not be visible to the sensor, as radiators and thermostats are usually under the window, without direct exposure to the radiation. A simple approach to overcome these issues would be to measure the temperature offset of thermostat's measurement, i.e. the difference between thermostat's measurement and an external sensor, "true temperature", located at a point in which the residents are assumed to be most of the time, and subsequently use the corrected temperature measurement in control.

Heating consumption and other data are extracted from the technical room in the Environmental House. In addition, the digital thermostats send information on the air temperature near to the radiator, the send target temperature, valve position, battery state, and RSSI signal strength to Fourdeg's cloud server from which it can be shared to other servers as well. Currently, an API to VTT is created. By analysing the data, estimations on indoor comfort and the relation to energy consumption lead to further knowledge of smart Demand Response in office buildings.

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6.1.2 Salusfin's system

Salusfin Demand-response strategy is based on technical, behavioral and contractual approaches. Objective is to bring savings to the residents, add comfort level, increase energy usage efficiency and lower CO_2 emissions. Technically Salusfin solution is based on three layer architecture, where Layer 1 consists of wireless components (gateway, thermostats and temperature sensors), Tier 2 is the cloud and Tier 3 the UI layer with web and mobile clients (iOS/Android platforms). Connected home with controlling capability and utility company backend integration are the building blocks for thermal demand-response solution.

Energy savings are coming from technical solution implementation and user behavior. Smart thermostats measure and adjust the temperature quicker and with better precision than conventional thermostats. Thermostats contain machine learning capabilities and ventilation/window open features. Energy savings can range from 10% to 25% depending on user activity and motivation. In the pilot building the savings converted to CO_2 emissions can be up to 80 tons of CO_2 per year.

Effects of end user behavior on savings are related to the utilization of the solution. Do the users configure dynamic heating patterns, use the weekend/vacation temperature drops and are the users affected by energy usage information and increased cost awareness.

Contractually, thermal heating demand-response has four parties: Utility company as concept owner, housing association as contractual party towards utility company, residents as end user and operator, operating the solution and having contracts with utility company and end user. This is visualized in **Figure 17** below.

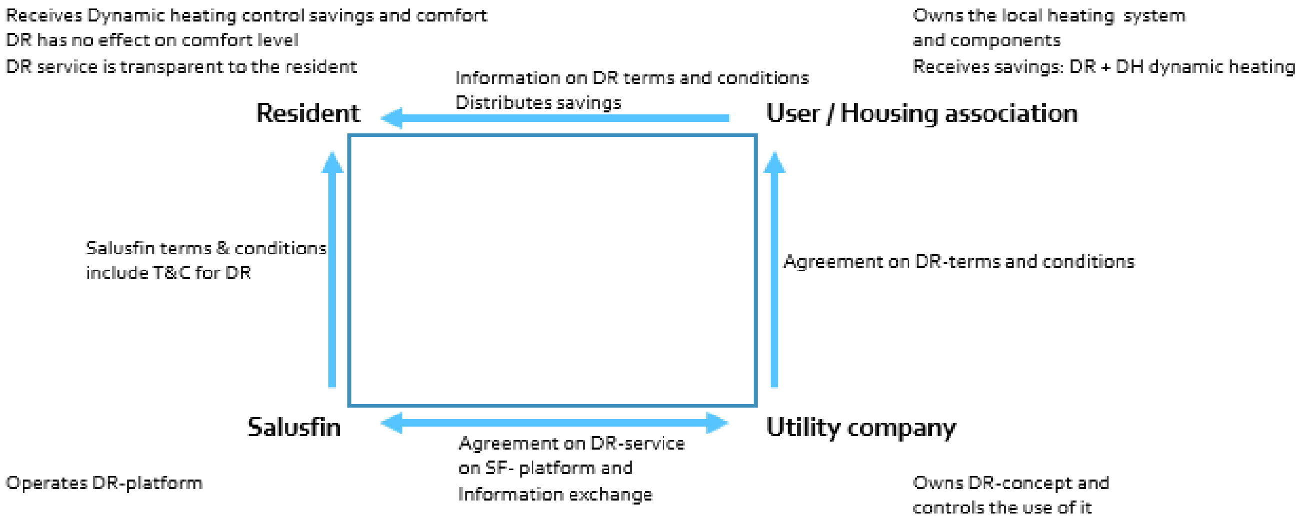

Figure 17. Contracts required between the four parties participating to the thermal demand response [figure by Tapio Toivanen, Salusfin].

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The district heating price information is retrieved from utility company interface, which is offering three alternatives: high (+1), average (0) or low (-1) and this price information is reflected to apartment heating.

6.2 Electrical demand response strategies

Electrical demand response is studied in several mySMARTLife Helsinki actions (in Kalasatama area in Action 10 and EVs in Actions 11 and 27). In Kalasatama region, the demand response potential of residential buildings is estimated based on smart meter data obtained from the distribution system operator and general information on the buildings (number and size of flats, assumed appliances in flats such as sauna stove or electrical underfloor heating, building common loads such as elevators etc.). Some Kalasatama buildings also have PV production and/or EV charging points. When defining the potential and strategy for demand response also these resources need to be taken into account. The results of this action are used to evaluate the amount of controllable loads in a new residential area and to draw conclusions on which types of loads could be utilized for demand response in these types of area. This action is described in detail in D4.7 Report on monitoring and control concepts and improvements and the results are not repeated here.

EVs are a very promising resource for demand response and are studied from different viewpoints in mySMARTLife Helsinki actions. Data on EV charging in 54 public charging stations in Helsinki is analysed to determine charging patterns and evaluate possibilities to utilize the EVs as controllable resources. Also control strategies for combined operation of EV, PV and storage are developed and their operation in the demonstration sites of mySMARTLife is evaluated. These actions are described in detail in D4.8 Report on grid to vehicles strategies and performance and the results are not repeated here.

6.3 Demand response from the viewpoint of local energy company

The electricity system needs flexibility and it is the transmission system operator's (TSO) responsibility to make sure that the power system is stable and operative. For this reason, Fingrid, the Finnish TSO, operates several market places from where it gathers flexible resources in reserve. These resources can be either disconnected from the grid in case of fault or they can provide continuous services to adjust the grid's frequency in order to avoid fault situations. The services are compensated based on the capacity that has been accepted in the reserve.

The heat network and its operation on the other hand is totally controlled and operated by same company who produces and plans the heat production of the local energy system. Hence, there is not market driven incentive for customers to reduce heat consumption but the motive is more to reduce emissions and total energy consumption. The heat demand response is also motivated by the energy company in case it optimizes the system level operation and reduces operation costs and emissions.

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The energy company, Helen in Helsinki, participates in electricity demand response with its own heat pumps at Katri Vala heat pump plant. Helen also operates as an aggregator when offering a service for its customers with flexible resources in terms of electrical loads. The heat demand response is also seen as part of the developing system where customers participate to the energy system for example producing the energy or reducing their consumption as anticipated. The heat demand response is piloted in one extent in mySMARTLife project with the smart thermostats in Merihaka and Viikki, since there is no market for heat demand response. With the pilot it is aimed at recognizing the value of the heat demand response.

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7. Conclusions

This deliverable describes the retrofitting interventions in old buildings and implemented energy efficiency actions in new buildings in Helsinki smart city demonstration cases. At first, the energy renaissance strategy in the city of Helsinki is described. This strategy aims for large scale replication of the demonstration actions in Helsinki. It also describes the planned activities for the city's energy advisor, which aims to provide end users, building owners and residents, information about possibilities and the potential for replicating the actions demonstrated in mySMARTLife and to roll out energy efficiency improvements in existing buildings in collaboration with the private housing organisations.

Next, the building related demonstration actions implemented in the care areas are presented, including 1) Merihaka and Vilhonvuori districts with existing apartment buildings; 2) New smart city district called Kalasatama; and 3) Viikki environmental building. These action descriptions include also the integration of energy storage systems and RES in buildings and districts, where applicable. The demonstration actions include piloting smart thermostats to provide residents and end-users better indoor temperature conditions, increasing the energy efficiency by reducing unnecessary overheating and thereby decreasing the heating costs. These actions also contribute to studying, what would be the value of thermal demand response as a part of city's district heating network operation. Furthermore, activities include paving the road for easy integration of smart home solutions in new buildings in Kalasatama district and beyond in the whole city of Helsinki through urban planning and related mandatory terms for the plot assignment.

In addition, the strategy for demand response is defined. This consists both for Salusfin's and Fourdeg's solutions for smart thermostats, which enable the thermal demand response. The main principles for electrical demand response are shortly introduced. Also the viewpoint of the local energy company Helen is presented.

This deliverable will be updated and detailed later in M36, when the actions have been implemented. This version describes the overall situation as known before the implementation of the demonstration actions.

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