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my SMART Life

Deliverable due date: M36 – November 2019

D4.22 Report on retrofitted actions and implemented actions in new buildings including RES and storage

WP4, Task 4.2

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	D4.22 Report on retrofitted actions and implemented actions in new buildings including RES and storage	
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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	

(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
31.6.2019	1.1	Kim Forssén (VTT)	Residential demand response potential in Kalasatama

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28/10/2019	1.2	Suvi Takala (HEN)	Reviewing and updating the contents of HEN.
31/10/2019	1.3	Maria Viitanen (HEL)	Updated sections on citizen engagement in Merihaka.
04/11/2019	1.4	Mikko Virtanen (VTT)	Integration of inputs from different partners (HEL,VTT,HEN) including comments from Siemens
06/11/2019	1.5	Mikko Virtanen (VTT)	Integration of final inputs from partners. Ready for review.
20/11/2019	1.6	Simon Decher (HAW)	Reviewed Version with comments
25/11/2019	1.7	Mikko Virtanen (VTT)	Integration of final inputs
26/11/2019	2.0	Mikko Virtanen Esa Nykänen (VTT)	Finalizing the deliverable, ready for submission

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Table of Content

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

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

Table of Figures

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

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Table of Tables

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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 resident's 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.

A full year's hourly residential electricity consumption sum data of a city block in Kalasatama was analysed and visualized. The analysis provides insight about the electricity consumption habits of Kalasatama residents on a city block level, and illustrates demand peaks and variations in hourly electricity consumption between weekdays, months and seasons. The analysis shows that the hourly electricity consumption of the city block rarely drops below 40 kWh, and during middays is mostly limited to somewhere between 60 and 100 kWh, except on weekends, when the midday consumption is slightly higher. Evenings dominate the top consumption hours on all weekdays.

The third aim of this deliverable is to define the strategies for demand response. The demonstrations of demand response are focused mostly on thermal demand response experiments in buildings connected to district heating. The principles of electricity demand response are introduced, while the details are given in deliverables D4.3, D4.4, and D4.8. Electric demand response potential is studied for a district consisting of smart residential buildings. In regards to demand response, also the viewpoint of the local energy company Helen is discussed.

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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. An electricity demand response potential analysis for residential building district is carried out. 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

1.2 Contributions of partners

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

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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 (UN, 2011). 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.

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 planned to be major changes in urban and traffic planning in the area. Behavioural changes are more

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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 the aim is to make the residents to understand the benefits of district or area level thinking. Residents commitment to planned improvements are crucial for social acceptance and plans to be successful. The engagement has been focusing on two streams: energy advising for the 12 housing associations in the area through studies and workshops; and closer communication and user support for the one housing association adopting the smart thermostat solution.

2.3.1 Surveys and questionnaires

Surveys and questionnaires were employed in the engagement of the building adopting the smart thermostats solution. First, one questionnaire was employed to study the user satisfaction of the smart thermostats one month after the first set of thermostats was installed, in November-December 2017. The questionnaire could be answered in an interview, on paper or via browser. 12 out of 19 households answered. Generally, the people were happy about their apartment's thermal conditions after the installation. The questionnaire was repeated in April-May 2018 after the installations to the whole building were finalized (28/167 answered). People were still generally happy with their thermal conditions but the results prompted to direct more effort into user guidance, especially with the app. As a result, in the fall

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2018, seven sessions were organized in the building to guide the residents in the use. Moreover, some new guidance material was developed.

In addition, Helen, Salusfin, VTT and the City of Helsinki organized a questionnaire for the four voluntary pilot apartments of heat demand response. Feedback was received from the participants of heat demand response during the heating season 2018-2019. The questionnaire was conducted by VTT and done via a QR-code. The results of the survey are presented more in detail in D4.4. The same QR-code feedback was used by the employees in Viikki Environment House.

2.3.2 Trainings

What is more, information was produced about the potential of energy retrofitting actions in the area using the MOBO method (Multi-objective building performance optimization). The method was applied to two buildings in the area and to the area as a whole. The results of the studies were shared in a workshop to the housing associations in the area in November 2018. The results of the areal study suggested that an investment to a sea heat pump would be the most profitable option from a selection of options. The residents were also interested in this option. Further feasibility studies within the city indicated that the infrastructure works in the area mentioned earlier would mean that this plan would need to be put on hold for the next five years.

Furthermore, during February 2019, a heat leakage imaging of the facades of three buildings (Action 44) in the area were conducted. Results and analysis of those images were one topic for a second workshop for the housing associations.

2.3.3 Open data

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

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

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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 9,834 m^2. See also D4.1 for additional baseline description about the demonstration area.

Figure 2: Merihaka district [figure from HEL]

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)

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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).

Deliverable 4.1 gives a description of the area in more detail.

Facades have been imaged with thermal imaging cameras during February 2019 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 due to existing Finnish construction and retrofitting standards. 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 promoting the solution to rest of the district with a commercially viable business model.

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.

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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, such as stone walls, can be used as heat reservoir. All this should 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. The benefits of heat demand response are reached at system level in Helsinki and for a building owner, the driver of participation is not economical savings but contribution to environmental issues and reduction of CO2 emissions in system level.

New technological solutions, such as remote-controlled intelligent thermostats, are a one possible technology for implementing demand response functionality in apartment buildings on apartment level. These new technologies give better control for the customer over personal living conditions and comfort in addition to cost savings and lower environmental impact. Demand response can also be done on building level via the heat distribution centre of the building and this solution is also currently piloted by Helen in the district heating network of Helsinki.

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. Helen has published the demand response commands in a REST API interface and Salusfin requests the commands via the interface, as illustrated in Figure 3. The smart heating management system uses these requests as inputs for heating management algorithms. 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.

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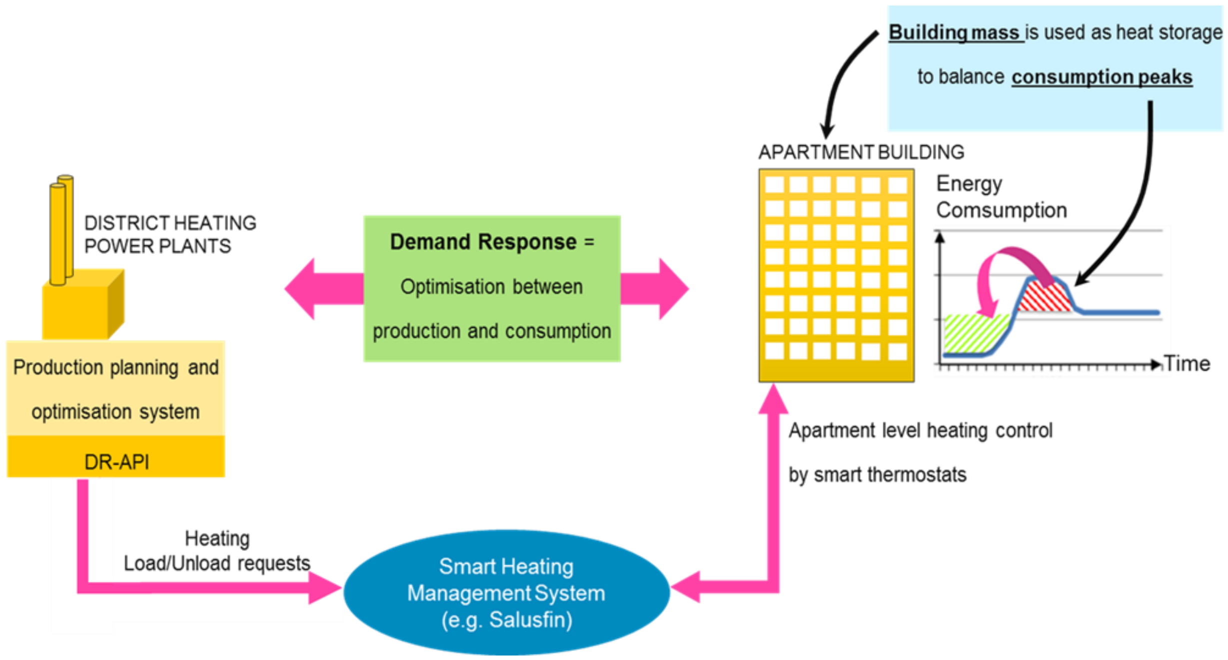

Figure 3: Thermal demand response in district heating system (figure from HELEN)

3.4 Retrofitting potential in Merihaka

To study the areal retrofitting potential in Merihaka, a Multi-objective building performance optimization (MOBO) study was commissioned from a consultant. Using modelling of energy retrofitting alternatives (meaning both improving the energy performance of buildings and investing on new energy sources) from economic and energy consumption point of view, the MOBO method can assist the decision makers to invest on the most cost-effective forms of energy retrofitting. The MOBO method doesn't limit itself to comparing a few alternative solutions but can include several factors representing different features of those solutions in the calculations. In Merihaka, the MOBO focused on three items: on assessing retrofitting alternatives of two individual buildings and assessment of an area energy solution. The optimum was defined as minimal net present value of life-cycle costs during 25 years and yearly specific energy consumption.

The outcome of the study was that the most cost-effective energy retrofitting action for the individual buildings would be to install heat pump systems: for buildings with less than 10 storeys, the best option would be a geothermal pump together with district heat or electric boiler; for taller buildings the best system would be a sea water heat pump system together with district heat. Due to infrastructure works in the area, the heat pump systems can't be installed at the moment. However, these calculations should apply when the conditions are suitable for installations in the future. From the options that can be implemented now, the best would be a centralized adjustment system of the heating radiators.

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3.5 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 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 (inFigure 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

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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.

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

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 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.

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.

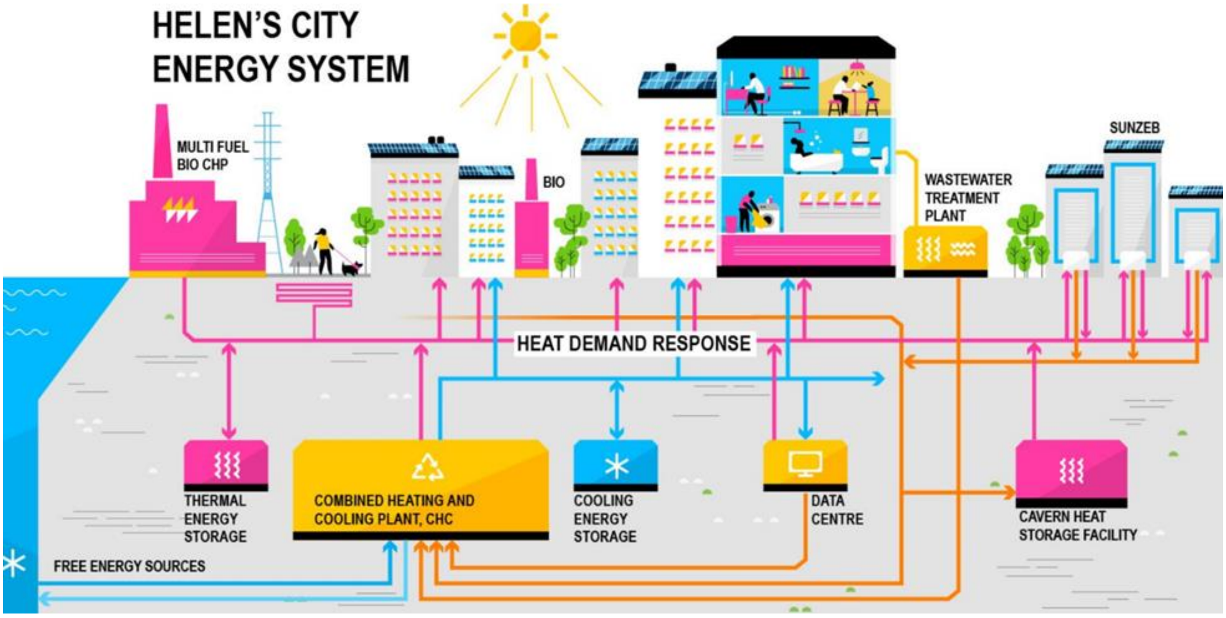

Figure 8: Illustration of the future urban energy system in Helsinki operated by Helen Ltd. SunZEB buildings are integrated with the energy platform and they form an interactive energy community. The heart of the SunZEB is the combined heating and cooling plant (heat pumps) between district heating and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

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

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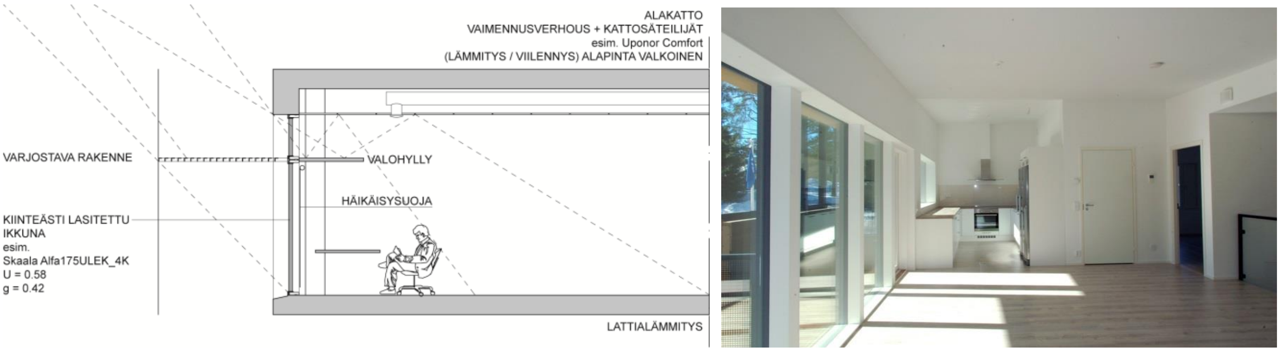

Figure 9: The integrated solar architecture is a key element to maximize the renewable share and the end user comfort (Picture source Jari Kiuru, Architectural office Kimmo Lylykangas)

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 °C*** *(winter) to* ***26 °C*** *(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 construction has started and the first building will be finished in 2020.

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.

The evolving apartment building development program is supporting:

- the diversity of the apartment house types

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

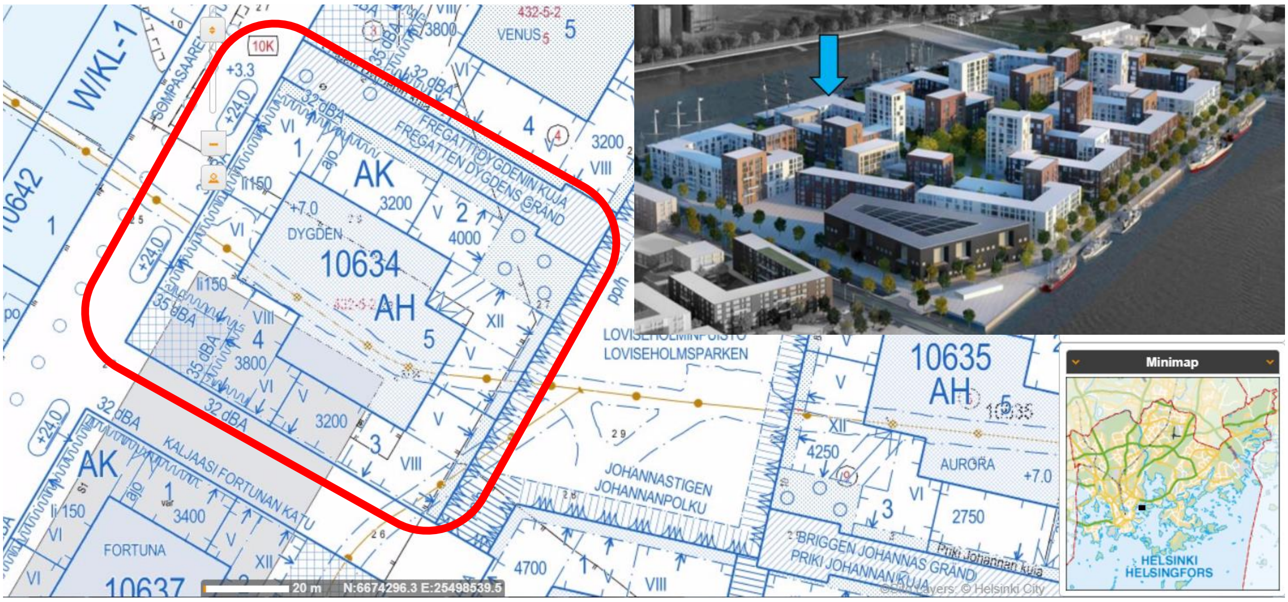

Figure 10: The SunZEB block (inside the red borders and under the blue arrow in the small illustration picture) in the Kalastama in Helsinki. Source: Map service of the City of Helsinki: https://kartta.hel.fi/link/3wZEYQ. The 3D illustration from the detailed plan description, City of Helsinki (https://www.hel.fi/hel2/ksv/liitteet/2014_kaava/ak12200_selostus.pdf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

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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. Kojamo's rental apartment building located in the north-east corner of the SunZEB block under discussion at Fira, ©Jari Shemeikka, VTT

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.

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

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

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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 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.

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)

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The battery energy storage system, BESS, offers also other functionalities regarding the optimization of Environment House's consumption and production. These functionalities include energy 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 could be enabled if revenues in providing such service to distribution grid become 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. However, the main target of the optimization is utilize 100% of the PV production within the building, thus reducing energy costs for the building.

In normal operation, the battery is not utilized by the property owner each hour of the day. Non-utilized hours appear during high PV production days (battery is full), during nighttime (battery is full and waiting for high price hour or battery is empty and waiting for next day PV production) but also during winter time when sun is not shining (electricity price optimization). Within a year, there are over 5 months when the PV optimization is not possible or insignificant. The times not utilized for building optimization could be traded for national transmission system operator's, Fingrid's (Finnish Transmission System Operator) frequency containment reserve (FCR) market by an aggregator as a part of aggregator's other bids. The capacity of the battery alone does not exceed the minimum bid sizes of FCR markets and therefore, it must be bid together with other flexible assets of the aggregator. The trading would happen only during the times that the battery is not used for its main purpose, storing PV production and optimizing the building. The benefits of TSO ancillary markets operation would be divided by the property owner of the Viikki Environment House and the aggregator, Helen (energy company) so that the customer gets a higher share of the revenues. During mySMARTLife, the BESS of Viikki Environment House was connected to the aggregation platform used by Helen (Siemens DEMS), Therefore, readiness in systems exists for the battery to be aggregated to the TSO ancillary markets, but no real FCR market operation has yet been tested. The co-use of electrical energy storage can be seen as an additional value for the customer when purchasing an energy storage system.

Siemens' Distributed Energy Management System, DEMS, is used to control and optimize the Environment House's energy system. Currently, DEMS is also the aggregation platform used by Helen to operate at Fingrid's markets. In addition to controlling the BESS and monitoring 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.

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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 (555 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. 92 m^2 of the panels are located on the roof at a 30 degrees angle and is 463 m^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 which are described in Table 3.

Table 3: Viikki Environment House solar panel models

References of PV panels	Power (Wp)	Square meters installed (m^2)
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 and the sweep area is 0.3 m^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 80 W. In 2016 the turbines output was 0.038 MWh.

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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 the energy from wind turbines can be used to charge cell phone batteries. Originally idea was to use it to illuminate the security lights.

6. Smart Kalasatama area

Kalasatama is a former harbor and industrial area near downtown Helsinki that has been transformed into a smart city district with many new smart grid solutions. Kalasatama features, for instance, one of the largest electricity storage facilities in the Nordic countries (Helen, 2015c), apartment building integrated home automation systems (Helen, 2015b), and a unique ring network solution (Helsinki, 2017), the first closed ring network in a medium voltage grid in Finland where electricity to the grid is continuously supplied from two directions.

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The city of Helsinki is planning to complete the development of the entire district by 2040 (the plan illustrated in Figure 15), by which it is expected to offer housing for 25 000 residents and jobs for 10 000 people. Upon its completion, the district will offer 1 200 000 m2 of residential floor space and 400 000 m^2 of floor space for business premises. (Helsinki, 2018b)

Figure 15: Illustration of the completed smart Kalasatama district in 2030-2040 (Helsinki Business Hub, 2019)

The Kalasatama district had a population of around 3 800 in 2018 (Helsinki, 2018a), 0.6 % of the whole population of Helsinki (643 000 in 2018) (Helsinki, 2018e). In 2030, the population of Kalasatama is expected to have reached around 20 000, 2.8 % of the projected total population of 720 000 of Helsinki.

1 527 apartments in 38 apartment buildings have been built so far (Table **4**) (Helsinki, 2018a), and the average number of residents per household in 2018 was 2.5. Currently over 40 % of the apartments are one-bedroom apartments and 25 % two-bedroom apartments. Studio apartments and larger apartments with three or more bedrooms both form around 17 % of all apartments built in Kalasatama so far. 1 738 apartments in 25 new apartment buildings were under construction in 2018 (Table 5) (Helsinki, 2018a).

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Table 4: Total number and size of apartments and the number of residential buildings already built

		Number of rooms			
	Total	1	2	3	4+
Number of apartments:	1 527	273	629	377	248
Living area (m^2):	97 786	10 643	31 959	28 655	26 529
Number of residential buildings:	38				

Table 5: Total number and size of apartments and the number of residential buildings under construction

		Number of rooms			
	Total	1	2	3	4+
Number of apartments:	1 738	496	660	369	213
Living area (m^2):	94 810	16 169	31 385	26 861	20 396
Number of residential buildings:	25				

This section of the report will first discuss typical residential electrical loads commonly found in modern apartments, and categorize them into different load types based on their flexibility and their feasibility for being utilized as a source of demand response. Technical capabilities and characteristics of typical apartments and apartment buildings in Kalasatama are discussed to form a basis for the analysis.

Next, a full year's hourly residential electricity consumption sum data of a city block in Kalasatama (pictured in Figure 16) will be analyzed. The analysis will provide insight about the electricity consumption habits of Kalasatama residents on a city block level, and will illustrate demand peaks and variations in hourly electricity consumption between weekdays, months and seasons. Examples from individual apartments (the townhouse apartments in the bottom middle in Figure 16, surrounded by the rest of the block) within the city block will also be presented to illustrate non-averaged load profiles from individual Kalasatama apartments.

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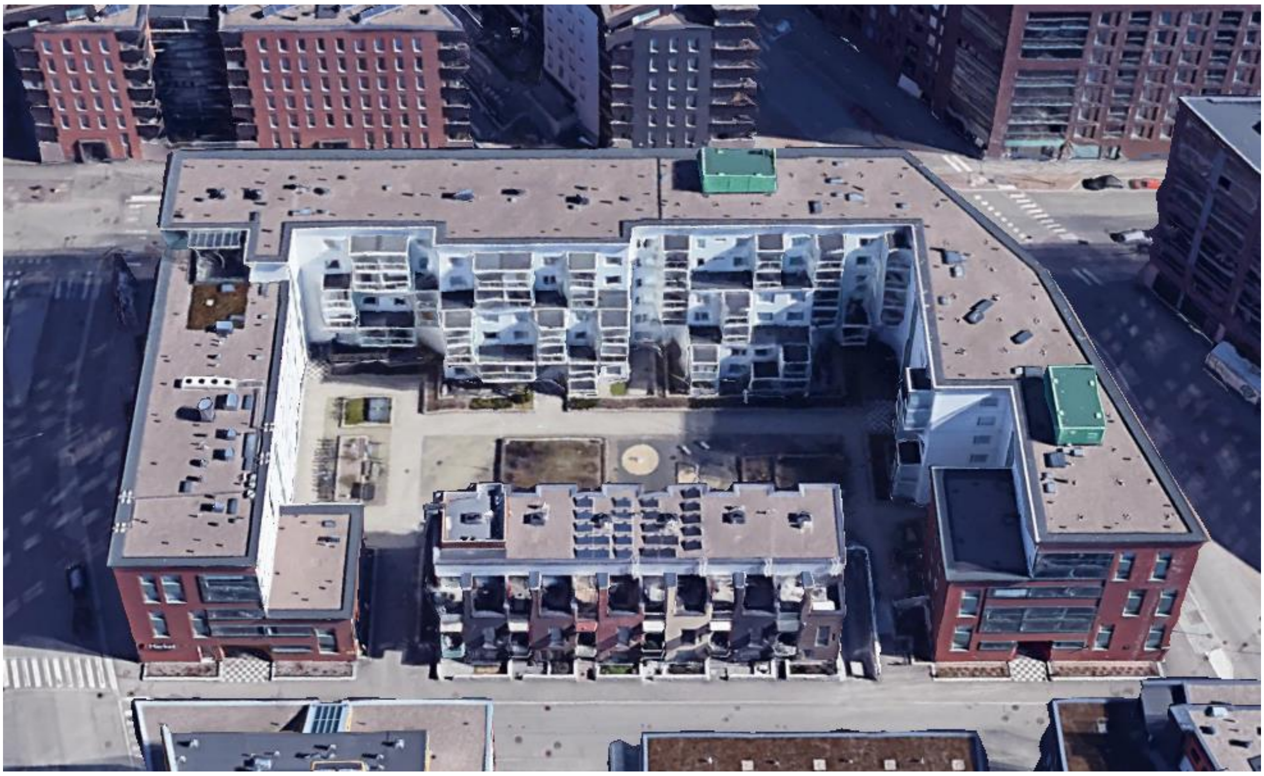

Figure 16: Satellite photo of the Kalasatama city block and the apartments analyzed (Google Maps, 2019)

The dataset from these apartments provides insight into demand peaks and their durations on the apartment-level, but does not show the roles of different loads or load types. While useful for understanding typical characteristics of apartment-level load profiles and demand peaks, it does not reveal the actual demand response potential other than what can be estimated. Thus, a generalized, typical 2-person apartment's electrical loads and electricity use are also analyzed where the loads and their use times on selected days are measured and logged. Different types of example days from different times of a year are analyzed to find out what types of loads are typically causing demand peaks and to find the demand response potential of different load types in a typical apartment.

After the analysis on the residential electricity consumption in Kalasatama, the report presents an analysis on the estimated residential demand response potential on a city block level as well as the scaled-up potential on the wider Kalasatama area, and a discussion on the estimations that the analysis is based on.

Lastly, the potential of utilizing solar PV for peak shaving on housing companies' common loads as well as the city block's residential loads will be discussed. The potential of a solar power plant utilizing the maximum roof surface area available will also be analyzed.

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6.1 Load types and flexibility of different residential loads

Demand response is a way to add flexibility to the power system. One way to implement demand response is to shift consumption of electricity from hours with high demand and high prices to hours when the consumption and prices are lower (i.e. load shifting), which does not change the total consumption but lowers demand peaks by temporally distributing consumption (Pöyry, 2018). Another way to implement demand response is to lower the total demand due to the impact of high peak prices instead of shifting consumption to later hours. Advancements in monitoring and controlling systems and new business services are expected to enable wider utilization of distributed demand response potential, such as electrical heating, other residential electricity consumption, service industry and electric vehicles.

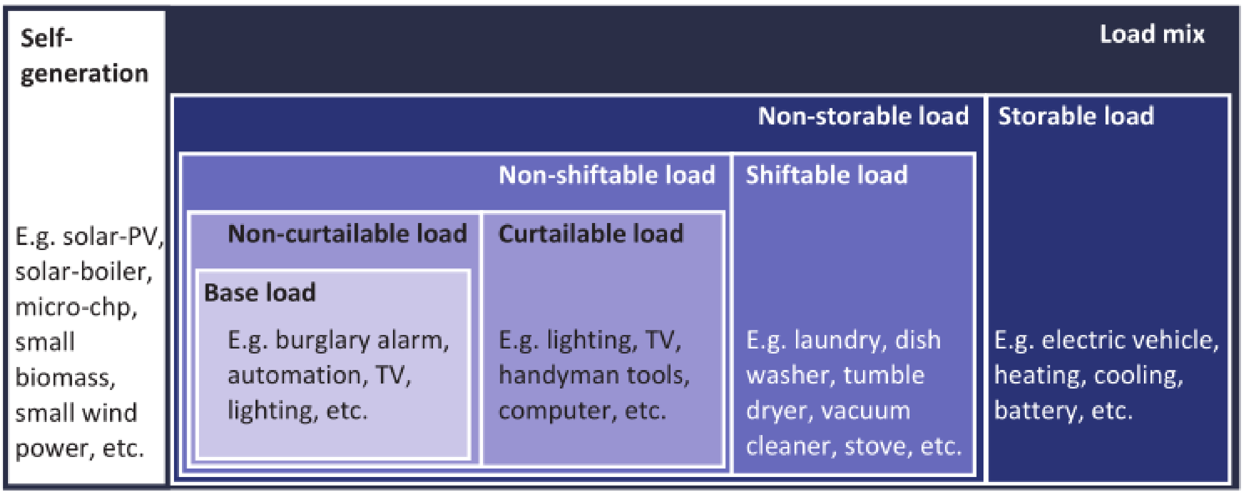

Figure 17: Residential electrical loads categorized based on their characteristics, flexibility and how the appliances behind the loads are used. (THINK project, 2013)

A study by the European University Institute (THINK project, 2013) categorized residential electrical loads into different load types based on how the appliances behind the loads are used (Figure 17). First, according to this framework, the loads can be divided into **storable** and **non-storable loads**, where the study points out that the power consumption and the end-use service are decoupled by storage that can be either batteries or thermal inertia. Storable loads can include refrigerators, freezers or electric vehicles (batteries). Non-storable loads can be categorized into **shiftable** and **non-shiftable loads**, where shiftable loads can be delayed until after peak consumption hours without significantly affecting the end use. Examples of shiftable loads can include washing machines, dishwashers and electric vehicle chargers that can be set on a timer in order to delay the use until electricity demand and price are lower.

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Non-storable, non-shiftable loads can be further categorized into **curtailable** and **non-curtailable loads**. Curtailable load refers to power consumption that cannot be shifted without affecting the end-use, but that can be curtailed or interrupted instantly. Examples of curtailable residential loads could include air source heat pumps or air conditioners, which could be interrupted or curtailed for limited periods without noticeably affecting the end-use. In addition, some lighting could be considered curtailable as part of it could be dimmed or partially turned off to decrease the load.

Loads that are non-shiftable and non-curtailable can be considered base load, which means that the end-use requires instant power and cannot be interrupted, delayed or curtailed. Base load can include for example (most if not all) lighting, cooking appliances and equipment or home electronics such as a TV or a computer. These types of loads typically cannot be utilized for demand response.

Finding the technical potential for residential demand response requires considering the following four factors:

1) Technical abilities of the apartments and the electrical appliances/devices (are there systems that enable remote monitoring and advanced controlling of electrical loads, such as home automation or other smart features?)
2) Typical consumption profiles on both apartment-level and city block-level that show the characteristics of the electricity demand peaks (when do they occur and how high are they compared to the average/expected level?)
3) Percentages of the total load that different specific load types typically account for (in other words: what is, e.g., lighting's role in a typical weekday evening's demand peak?), and which types of loads cause the highest demand peaks?
4) Which of the loads responsible for the notable demand peaks can be considered flexible enough for demand response (i.e. storable/shiftable/curtailable, and thus feasible for demand response purposes)?

6.2 Technical capabilities of Kalasatama's residential buildings in demand response context

The technical potential for demand response depends largely on the characteristics and technical capabilities of the area in question. The smart Kalasatama district is a long-term project that is still in relatively early stages, and not all information is available yet regarding the upcoming building plans, automation projects and system capabilities etc. However, the area already houses thousands of people, and some of the property developers' building plans and the city's construction regulations provide insights into the apartments' current and future technical capabilities.

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To implement demand response functionalities, home automation systems capable of monitoring and controlling the apartments' electrical loads are usually required. New apartment buildings in the Kalasatama district must follow the plot assignment stipulations that require features providing smart grid integration, enabling them to participate in demand response. Apartment-level energy monitoring and smart controls for electricity and heat are required, and at least a third of the residential parking spaces must offer EV charging option. (mySMARTLIfe, 2017)

The city of Helsinki regulates the construction requirements for new residential buildings in Kalasatama and requires new buildings to utilize open standards (Helsinki, 2018c). In some cases also industrial standards are allowed if they are common and widely used (Forum Virium, 2018). The construction regulation and stipulations for the plot assignment are set with the aim of meeting the technical requirements and interoperability of the smart building's integration with smart energy systems. The regulations drive construction of new buildings towards smart homes and smart grid compatible buildings. These requirements and the implementation of open standards form a good basis for development of a smart city district and for the purposes of monitoring and controlling energy consumption.

Kalasatama for the most part utilizes the KNX open standard for building automation, which enables managing lighting, energy consumption, security systems etc. Implementation of the standard enables new building automation and energy management solutions, which should allow residents to participate in demand response in the future. Electricity consumption of apartments will be measured in terms of load and cumulative energy, and the loads are expected to be controllable. More detailed information on the standards, building automation systems and interfaces, as well as the plot assignment stipulations, can be found in D4.3 (mySMARTLIfe, 2017).

The apartments' electrical system designs are expected to group the load types into the following categories:

- Lighting
- Wall outlets
- Stove, oven and kitchen outlets
- Washing machine, drying machine and dishwasher
- Refrigerator and freezer
- Sauna heater
- Direct heating devices
- Storage heating devices
- Water heating
- Air ventilation devices
- Cooling devices
- Electrical vehicle charging

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Two housing companies in Kalasatama have implemented a HIMA home automation system in about 100 apartments (Helen, 2015a). HIMA is a smart home service utilizing the KNX standard, and allows residents to remotely monitor and control their home appliances and devices. A resident can use the system with any internet capable device to see the daily or real-time information on electricity and water consumption, and turn off devices or set timers for them. Figure 18 shows an example of the data recorded by the HIMA system and how it can be visualized. In addition to the HIMA system, other systems are also either planned or already being built (Helsinki, 2018a).

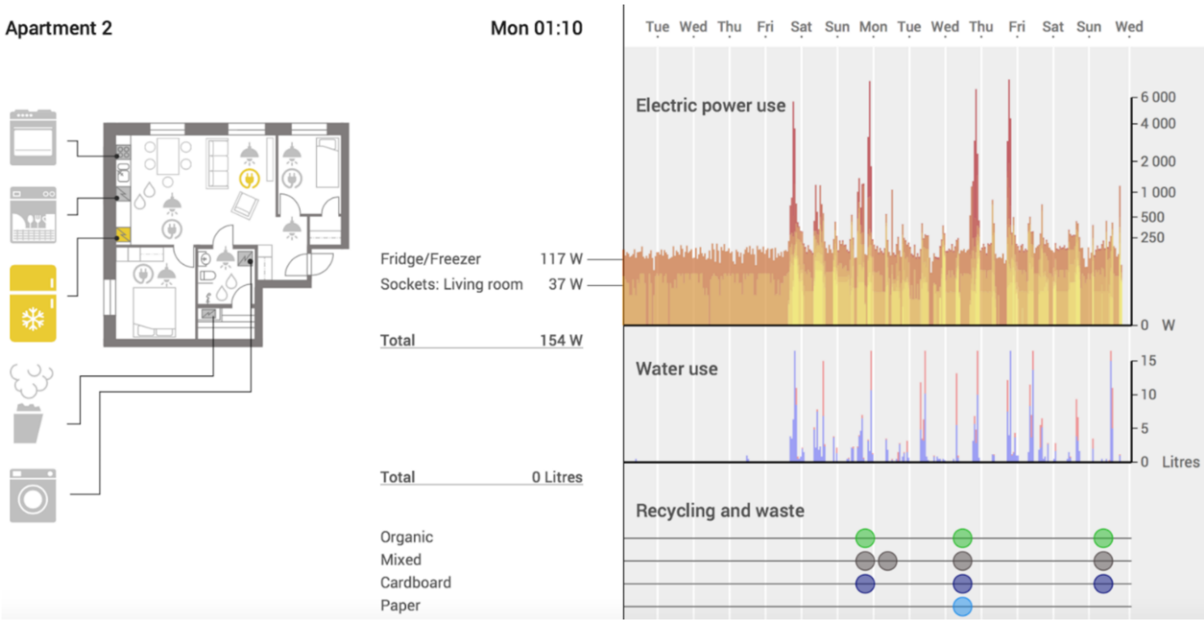

Figure 18: Example of the HIMA system's electricity, water and waste visualizations of an apartment in Kalasatama

Fortum Smartliving is another service directed at the residents in Kalasatama that utilizes the KNX system (Fortum, 2018b). It allows the user to monitor the apartment's energy and water consumption and to remotely control some of the electrical loads. It also shows consumption comparisons to other apartments of the same size, which may help guide residents towards more economic consumption habits.

The building automation systems, the advanced electricity consumption monitoring and the ability to remotely control electrical loads form a good basis for enabling residential demand response. Another factor that significantly influences the demand response potential is of course the average set of residential loads in the apartments, and further, the flexibility of those loads - particularly those with high power draws and high electricity consumption.

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6.3 Typical electrical loads in Kalasatama's apartments

The apartments in Kalasatama are newly built or otherwise modern, and can be assumed to be equipped with modern appliances. For example, one of the housing companies within the city block analyzed in more detail in chapter 6.4.1 has every apartment equipped with home appliances rated for very high energy efficiency (NCC, 2012).

While each apartment building in Kalasatama has unique features, typically all apartments include at least a relatively standard set of basic home appliances, electronics and other electrical appliances or devices. Their average electrical loads and consumptions can be estimated.

Typical home appliances include refrigerator-freezer, stove, oven and dishwasher. Many residents also have a washing machine at their apartment, and some have a tumble dryer as well. Typical small appliances may include for instance a microwave oven, coffee machine, vacuum cleaner or a kettle.

Common electronics include TVs, sound systems and computers. Lighting is naturally also found in every apartment, but for the most part, it nowadays often consists of energy-efficient LED lights with low power draws.

If an apartment has an electric sauna heater, it is often the largest electrical load in the apartment. In cities, housing companies usually have a common sauna available for all residents, but often some part of the apartments also have their own saunas. In the housing company mentioned in the beginning of this subchapter, 35 out of 56 apartments have an apartment-specific sauna (in addition to the housing company's common sauna) (Asunto Oy Helsingin Atsimuutti, 2018a). More generally, the largest contractors in Finland recently estimated saunas to be built in roughly half of all new apartments, but also noted that the demand for saunas is lowest in the Helsinki area because of the apartments' high price per square meter (Yle, 2015). City-specific statistics on saunas are scarce, but based on Kalasatama's active apartment listings on several different occasions, the average share of apartments with their own saunas seems to be around 20 %.

Wattage of a sauna heater is often very high compared to other residential electrical loads (often 6 kW or higher), and it is typically used in the evenings. The relatively fixed timing and duration of the end use make the load quite inflexible, indicating poor potential for demand response purposes (Järventausta *et al.*, 2015). However, Fingrid has insinuated about the possibility of new local electricity markets where residents could participate also with voluntary demand flexibility, for example by avoiding the use of electric sauna heater during periods of very cold freeze (Helsinki, 2018d).

Table 6 lists some examples of the major electrical loads commonly found in residential apartments. Their rated maximum power, typical power draw and average consumption vary significantly depending on the model, size and use habits, but some examples and estimations can be listed. The load type

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classifications may also be flexible. For instance, (THINK project, 2013) suggests that some lighting or even some electronics, such as a TV or a computer, could be considered curtailable. In Table 6, sauna heater is classified as a shiftable load because at least some of the use could be delayed with appropriate incentives.

Table 6: Examples of appliances often found in apartments, and examples or rough estimates of their typical maximum momentary loads and consumption values (Helen, 2018)

Home appliances	Load type	Connected load	Typical max power draw	Estimated average consumption
Refrigerator-freezer	Storable load	250 W	250 W	200-400 kWh / year, 0.5-1 kWh / day
Stove	Base load	3000 W	1000-2000 W	0.4-0.7 kWh per 20 min use
Oven	Base load	2800 W	2000 W	1-2 kWh per 30-60 min use
Dishwasher	Shiftable load	2000 W	2000 W	0.5-1.6 kWh per use cycle
Washing machine	Shiftable load	2000 W	2000 W	0.6-1.7 kWh per use cycle
Tumble dryer	Shiftable load	2000 W	2000 W	1.9-5.5 kWh per use cycle
Small appliances				
Microwave oven	Base load	1200 W	1200 W	0.1 kWh per use (5 min)
Coffee machine	Base load	1000 W	1000 W	0.25 kWh per use (15 min)
Hoover	Base load	2000 W	2000 W	0.7 kWh per use (20 min)
Kettle	Base load	2200 W	2200 W	0.2 kWh per use (5 min)
Electronics				
TV set	Base load	200 W	200 W	0.6 kWh per day (3 hours of use)
Desktop computer	Base load	1000 W	50-250 W	0.05-0.25 kWh per hour of use
Lighting				
10 x LED lights	Base load	10 x 10 W	10 x 10 W	0.1 kWh per hour total (all lamps on)
Sauna				
Sauna heater	Shiftable load	6000 W	6000 W	9 kWh per use (1.5 hours)

Many load type classifications may also depend on the controllability of the devices and appliances themselves. For example, refrigerators and freezers could be aggregated on a city block level and be utilized as a storable load for short-term demand response purposes, but it may require features that are not found in all devices or apartments yet. However, aggregating residential loads for demand response purposes has already been implemented in Finland, for example by utilizing household water heaters from a thousand homes to form a one-megawatt virtual battery by Fortum (Fortum, 2018a).

Electrical heating of space and water is typically a major part of electricity consumption, drawing high electrical loads especially during winters, and as such is considered a good storable load for demand response (Pöyry, 2018). However, virtually all apartments in Kalasatama are heated with district heating, thus electrical heating is not used in significant amounts. District heating can also be utilized for demand

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response, but it does not contribute to residential electricity consumption, and thus is outside the scope of this report.

The apartments in Kalasatama typically feature hydronic radiant floor heating that is connected to the district heating network, so electrical floor heating (which could otherwise be utilized for demand response) is not common. However, some of the apartments do feature electrical comfort floor heating in shower rooms, saunas and toilets in order to keep the floor temperature warm and stable all year, and it is often connected to the apartment's own electricity connection. Electricity consumption of the electric comfort floor heating depends on the size of the heated area and consumption habits of a resident, but a typical comfort floor heating solution can draw around 100 W/m² (Ensto, 2016).

Many apartment buildings that are under construction in Kalasatama will have automated, demand-controlled apartment-specific ventilation systems. According to different property developers' building plans, most of these systems will use the electricity connection of the housing company, but some of them will rely on the electricity connection of the resident. Apartment-specific ventilation systems can typically consume around 1 000 – 2 000 kWh per year depending on the size of the apartment (Helen, 2018).

In conclusion, the residential electrical loads in Kalasatama can be assumed to be modern and energy efficient. Dishwashers and washing machines can be considered shiftable loads, and refrigerator-freezers in larger aggregated entities could potentially be considered storable loads. Electric sauna heaters, while only found in part of the apartments, cause significant power draws when used. They could be considered shiftable loads. Comfort floor heating is also installed in part of the apartments, and could potentially be utilized as storable or curtailable load without affecting the living comfort of the residents too much and with no need for manual input. Apartment-specific ventilation systems installed in some of the apartments are another peculiarity that may increase the residents' electricity consumption. They could be utilized for demand response, but anything else than brief curtailments could negatively affect the air quality.

The next chapter will analyze residential electricity consumption in Kalasatama.

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6.4 Residential electricity consumption in Kalasatama

6.4.1 Hourly electricity consumption on a city block level

The city block analyzed in this chapter (pictured in Figure 16) consists of large, adjoining apartment buildings and six adjoining townhouses. The buildings are built in 2013 and feature modern home appliances. One of the city block's housing companies has electrical comfort floor heating installed in all its 56 apartments (powered by the residents' electricity connections) (Asunto Oy Helsingin Atsimuutti, 2018b). Table 7 presents some key information for this city block for year 2016.

Table 7: Statistics for the city block in Kalasatama in 2016

NUMBER OF CUSTOMERS	130
TOTAL ELECTRICITY CONSUMPTION	699 000 kWh
MAX HOURLY ELECTRICITY CONSUMPTION	179 kWh
HOUR OF MAX ELECTRICITY CONSUMPTION	04.12.2016 20:00
MIN HOURLY ELECTRICITY CONSUMPTION	27 kWh
HOUR OF MIN ELECTRICITY CONSUMPTION	21.07.2016 2:00
AVERAGE HOURLY ELECTRICITY CONSUMPTION	79 kWh

Figure 19 shows the hourly residential electricity consumption of the whole city block in Kalasatama during 2016. The consumption values are the sum from all the 130 apartments within the city block. The average hourly electricity consumption over the year was 79 kWh, the maximum consumption in an hour was 179 kWh (4th of December at 20:00), and the minimum consumption in an hour 27 kWh (21st of July at 2:00).

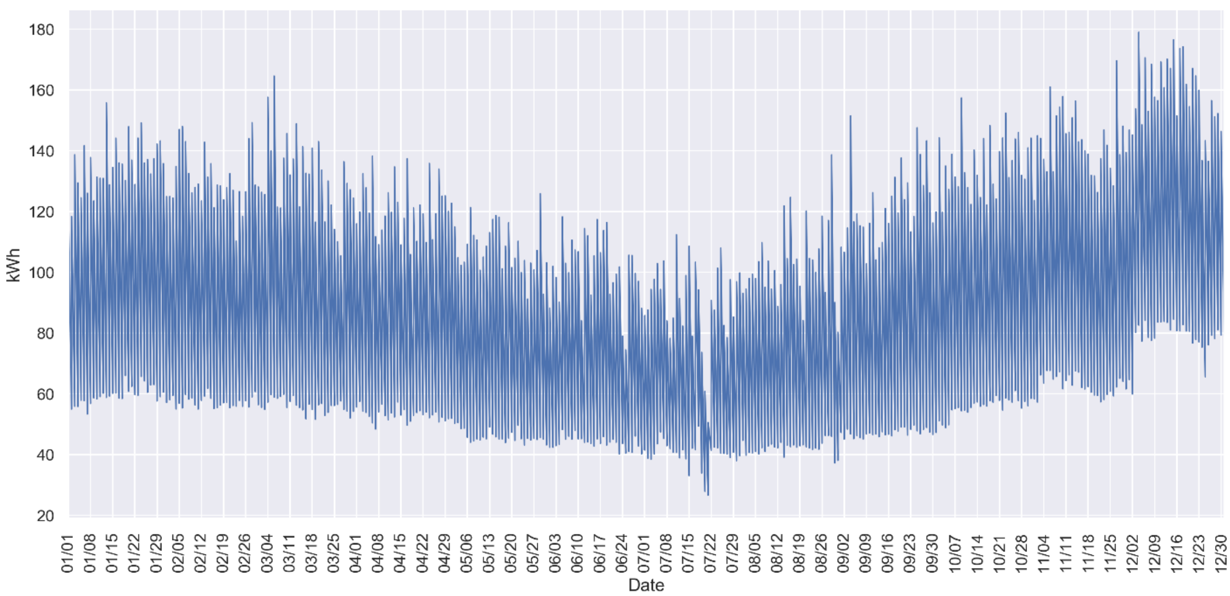

Figure 19: Hourly electricity consumption of a city block in Kalasatama in 2016

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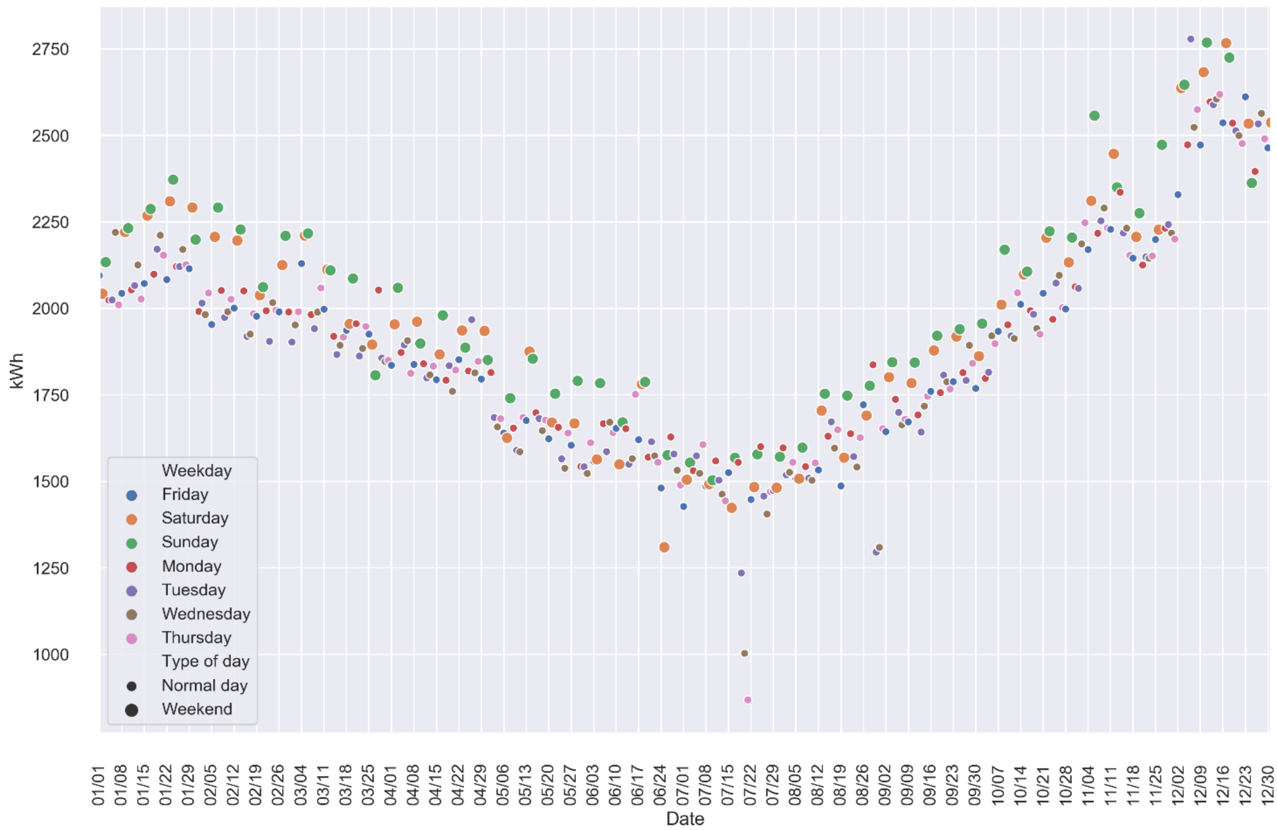

Figure 20: Daily electricity consumption of a city block in Kalasatama in 2016

Whereas Figure 19 illustrates the variance of hourly electricity consumption over the year, Figure 20 presents the total daily consumption within the same city block over the same year. In the figure, weekdays are marked with different colors for easier identification of consumption patterns, and weekends (Saturdays and Sundays) are highlighted with a larger marker than the other days of the week. Figure 19 and Figure 20 both show that the electricity consumption is significantly higher in the winter than in the summer. Weekends (large green and orange markers) show higher total daily consumption at almost all times of the year, as seen in Figure 20.

Figure 21 is a visualization of all the year's hours divided into their respective weekdays so that the color illustrates the time of the day. The vertical axis shows the hours' respective electricity consumption, and the range of values on the vertical axis indicates how widely the hourly consumption values are distributed on a given weekday over the year. The visualization shows that the hourly electricity consumption of the city block rarely drops below 40 kWh, and during middays is mostly limited to somewhere between 60 and 100 kWh, except on weekends, when the midday consumption is slightly higher. Evenings dominate the top consumption hours on all weekdays.

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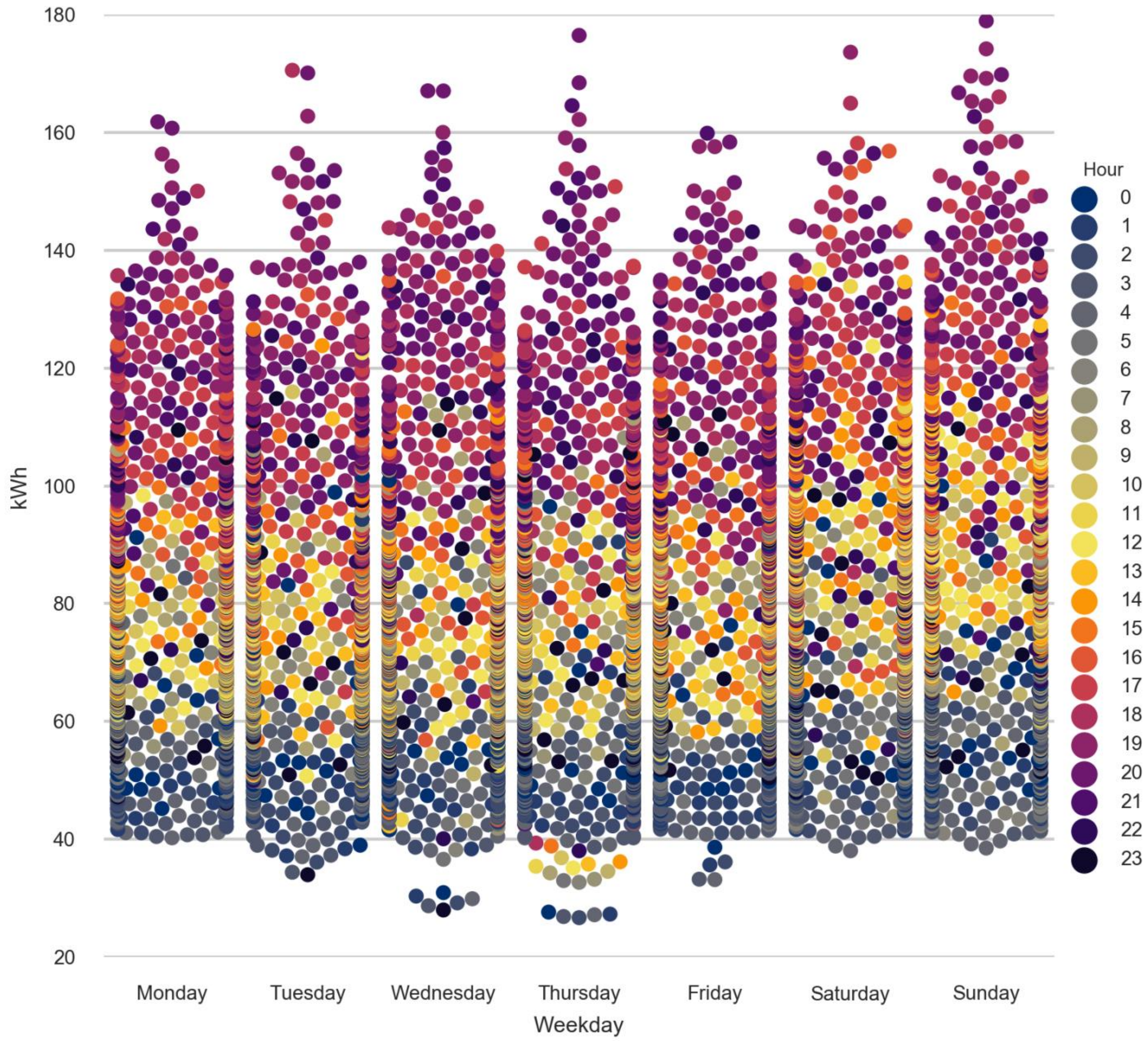

Figure 21: All hours of the year divided into their respective weekdays. The color of the marker visualizes the hour of the day, and the vertical axis denotes the electricity consumption of the hour in kWh

Figure 22 lists the thirty hours of the year during which the city block had the **highest total electricity consumption** (orange table on the left) as well as the hours with the **lowest total electricity consumption** (green table). It also lists the thirty hours that saw the **highest increases** (purple table) and **decreases** (blue table on the right) when compared to the preceding hour, illustrating the moments where the hour-to-hour consumption differences were largest during the year. The data may help identify the times when demand response would be most useful, and on the other hand, whether the demand at those times is flexible or not.

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Day	Max kWh hour	kWh
Sunday	04.12.2016 20:00:00	178.99
Thursday	15.12.2016 20:00:00	176.52
Sunday	18.12.2016 19:00:00	174.23
Saturday	17.12.2016 19:00:00	173.66
Tuesday	06.12.2016 18:00:00	170.59
Tuesday	13.12.2016 20:00:00	170.13
Sunday	18.12.2016 20:00:00	169.85
Sunday	27.11.2016 19:00:00	169.62
Sunday	11.12.2016 19:00:00	169.22
Thursday	08.12.2016 20:00:00	168.48
Wednesday	21.12.2016 20:00:00	167.10
Wednesday	14.12.2016 20:00:00	167.08
Sunday	11.12.2016 20:00:00	166.79
Sunday	11.12.2016 18:00:00	166.08
Sunday	04.12.2016 19:00:00	165.33
Saturday	17.12.2016 18:00:00	165.00
Thursday	22.12.2016 21:00:00	164.59
Sunday	06.03.2016 19:00:00	164.57
Tuesday	06.12.2016 19:00:00	162.80
Sunday	18.12.2016 21:00:00	162.73
Thursday	08.12.2016 19:00:00	162.24
Monday	19.12.2016 20:00:00	161.84
Sunday	06.11.2016 18:00:00	161.02
Monday	12.12.2016 20:00:00	160.76
Wednesday	21.12.2016 19:00:00	160.04
Friday	23.12.2016 21:00:00	159.90
Thursday	15.12.2016 19:00:00	159.11
Sunday	06.11.2016 19:00:00	158.50
Sunday	27.11.2016 18:00:00	158.47
Friday	23.12.2016 20:00:00	158.40

Day	Min kWh hours	kWh
Thursday	21.07.2016 2:00:00	26.67
Thursday	21.07.2016 3:00:00	26.86
Thursday	21.07.2016 4:00:00	27.16
Thursday	21.07.2016 1:00:00	27.27
Thursday	21.07.2016 0:00:00	27.61
Wednesday	20.07.2016 23:00:00	27.97
Wednesday	20.07.2016 3:00:00	28.69
Wednesday	20.07.2016 2:00:00	29.18
Wednesday	20.07.2016 4:00:00	29.88
Wednesday	20.07.2016 1:00:00	30.33
Wednesday	20.07.2016 0:00:00	30.92
Thursday	21.07.2016 6:00:00	32.67
Thursday	21.07.2016 5:00:00	32.97
Friday	15.07.2016 4:00:00	33.13
Thursday	21.07.2016 7:00:00	33.19
Friday	15.07.2016 3:00:00	33.20
Tuesday	19.07.2016 23:00:00	33.96
Thursday	21.07.2016 8:00:00	34.27
Tuesday	19.07.2016 3:00:00	34.38
Thursday	21.07.2016 9:00:00	34.53
Thursday	21.07.2016 12:00:00	35.11
Thursday	21.07.2016 11:00:00	35.39
Friday	15.07.2016 1:00:00	35.63
Thursday	21.07.2016 13:00:00	35.76
Tuesday	19.07.2016 2:00:00	36.10
Friday	15.07.2016 2:00:00	36.14
Thursday	21.07.2016 14:00:00	36.16
Wednesday	20.07.2016 5:00:00	36.58
Thursday	21.07.2016 10:00:00	36.84
Tuesday	19.07.2016 4:00:00	37.02

Day	Max ΔkWh hours	kWh
Thursday	03.03.2016 17:00:00	40.16
Tuesday	18.10.2016 18:00:00	37.78
Sunday	02.10.2016 18:00:00	37.30
Sunday	14.08.2016 18:00:00	35.23
Monday	26.12.2016 16:00:00	35.22
Monday	08.02.2016 17:00:00	34.78
Monday	05.12.2016 16:00:00	34.13
Saturday	17.12.2016 16:00:00	34.07
Friday	05.02.2016 19:00:00	33.57
Saturday	10.12.2016 16:00:00	33.46
Thursday	10.03.2016 17:00:00	33.16
Thursday	07.01.2016 16:00:00	32.67
Sunday	24.04.2016 18:00:00	32.47
Sunday	21.08.2016 17:00:00	32.39
Thursday	28.01.2016 17:00:00	32.17
Thursday	03.11.2016 17:00:00	32.12
Thursday	16.06.2016 16:00:00	31.43
Monday	19.12.2016 16:00:00	31.31
Thursday	17.03.2016 17:00:00	30.94
Wednesday	09.03.2016 19:00:00	30.65
Thursday	13.10.2016 17:00:00	29.83
Saturday	07.05.2016 20:00:00	29.72
Wednesday	27.04.2016 18:00:00	29.66
Monday	26.09.2016 18:00:00	29.63
Wednesday	30.03.2016 18:00:00	29.57
Thursday	08.12.2016 17:00:00	29.37
Sunday	09.10.2016 17:00:00	29.17
Friday	21.10.2016 17:00:00	29.14
Saturday	06.08.2016 20:00:00	28.68
Thursday	25.02.2016 17:00:00	28.62

Day	Min ΔkWh hours	kWh
Thursday	22.12.2016 23:00:00	-38.86
Sunday	08.05.2016 22:00:00	-38.74
Monday	10.10.2016 21:00:00	-38.66
Wednesday	28.09.2016 21:00:00	-38.42
Wednesday	17.02.2016 23:00:00	-37.78
Sunday	30.10.2016 22:00:00	-37.47
Monday	26.09.2016 21:00:00	-37.19
Wednesday	23.11.2016 23:00:00	-35.78
Wednesday	13.01.2016 23:00:00	-35.68
Wednesday	10.08.2016 22:00:00	-35.53
Saturday	27.02.2016 22:00:00	-35.49
Saturday	15.10.2016 22:00:00	-35.27
Sunday	04.09.2016 20:00:00	-35.14
Sunday	31.01.2016 23:00:00	-34.49
Sunday	17.01.2016 23:00:00	-34.15
Monday	29.08.2016 23:00:00	-33.94
Tuesday	06.09.2016 22:00:00	-33.75
Wednesday	21.12.2016 22:00:00	-33.69
Wednesday	06.04.2016 22:00:00	-33.50
Wednesday	16.11.2016 23:00:00	-33.26
Thursday	26.05.2016 22:00:00	-33.26
Wednesday	28.09.2016 22:00:00	-33.24
Thursday	10.11.2016 23:00:00	-33.14
Thursday	19.05.2016 21:00:00	-32.93
Saturday	07.05.2016 22:00:00	-32.76
Sunday	21.08.2016 22:00:00	-32.75
Sunday	04.12.2016 21:00:00	-32.49
Thursday	25.02.2016 23:00:00	-32.47
Sunday	07.08.2016 22:00:00	-32.21
Thursday	07.04.2016 22:00:00	-31.88

Figure 22: Hours of the year with maximum and minimum electricity consumption, and hours with the biggest consumption increase or decrease compared to previous hour

Of the 30 hours with the highest total electricity consumption, 25 occurred during December, four during November and one in March. 13 of these hours occurred on a Sunday. 25 of these hours occurred between 19:00 and 21:00, and the other five at 18:00.

All 30 hours with the lowest total electricity consumption of the year occurred during July. 15 of them occurred on the same day, and none of the hours on a weekend. 20 of the hours with the lowest total electricity consumption occurred between midnight and 07:00.

The hours with the largest consumption increases compared to previous hour did not feature the same kind of consistency regarding the month of the year, but at least one hour in every month except for July was represented on the list of 30 hours. Most of these hours occurred on weekdays. However, every hour on this list occurred between 17:00 and 21:00.

Lastly, the hours with the largest consumption decrease from the previous hour were quite well distributed between different months and days, indicating no clear trends. Clearer was the time at which these demand decreases occur, as every hour on the list of the largest demand decrease from the previous hour occurred between 21:00 and midnight.

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In conclusion, the absolute highest demand hours occurred mostly in December and often on a weekend. The absolute lowest demand hours all occurred in July and mostly during nighttime. The largest electricity demand increases from the preceding hour all occurred in the evenings during 16:00 and 20:00, and the largest electricity demand decreases all happened during late evenings.

Winter				
Max kWh hour	kWh	Δ to season avg	Δ in next hour	Day
04.12. 20:00:00	178.99	30%	-18%	Sunday
15.12. 20:00:00	176.52	29%	-16%	Thursday
18.12. 19:00:00	174.23	29%	-3%	Sunday
17.12. 19:00:00	173.66	29%	-10%	Saturday
06.12. 18:00:00	170.59	34%	-5%	Tuesday
13.12. 20:00:00	170.13	24%	-18%	Tuesday
18.12. 20:00:00	169.85	24%	-4%	Sunday
11.12. 19:00:00	169.22	26%	-1%	Sunday
08.12. 20:00:00	168.48	23%	-11%	Thursday
21.12. 20:00:00	167.10	22%	-6%	Wednesday

Spring				
Max kWh hour	kWh	Δ to season avg	Δ in next hour	Day
06.03. 19:00:00	164.57	42%	-17%	Sunday
04.03. 19:00:00	157.62	36%	-10%	Friday
13.03. 19:00:00	148.87	29%	-10%	Sunday
10.03. 20:00:00	145.65	28%	-14%	Thursday
20.03. 20:00:00	143.01	26%	-12%	Sunday
04.03. 20:00:00	142.27	25%	-10%	Friday
15.03. 19:00:00	141.33	22%	-13%	Tuesday
18.03. 20:00:00	140.86	24%	-17%	Friday
05.03. 19:00:00	139.95	21%	-4%	Saturday
06.03. 18:00:00	138.71	30%	19%	Sunday

Summer				
Max kWh hour	kWh	Δ to season avg	Δ in next hour	Day
29.08. 18:00:00	138.65	56%	-5%	Monday
29.08. 19:00:00	131.99	43%	-9%	Monday
16.08. 19:00:00	124.64	35%	-12%	Tuesday
14.08. 19:00:00	121.86	32%	-1%	Sunday
14.08. 18:00:00	120.74	36%	1%	Sunday
14.08. 20:00:00	120.45	30%	2%	Sunday
21.08. 20:00:00	120.15	30%	-18%	Sunday
29.08. 20:00:00	120.12	30%	-23%	Monday
21.08. 18:00:00	120.02	35%	-2%	Sunday
26.08. 20:00:00	118.48	28%	-18%	Friday

Fall				
Max kWh hour	kWh	Δ to season avg	Δ in next hour	Day
27.11. 19:00:00	169.62	31%	-13%	Sunday
06.11. 18:00:00	161.02	31%	-2%	Sunday
06.11. 19:00:00	158.50	23%	-1%	Sunday
27.11. 18:00:00	158.47	29%	7%	Sunday
10.11. 20:00:00	157.82	30%	-12%	Thursday
06.11. 20:00:00	157.61	29%	-13%	Sunday
09.10. 19:00:00	157.38	22%	-19%	Sunday
14.11. 19:00:00	156.36	21%	-6%	Monday
09.11. 19:00:00	154.36	20%	-10%	Wednesday
23.10. 17:00:00	152.41	35%	-4%	Sunday

Figure 23: Ten hours from each season that had the highest hourly consumption, and the consumption difference to the season's average consumption on that same hour

Figure 23 shows ten hours from each season during which the hourly consumption was the highest, and the difference to the respective hour's seasonal average. It also shows the change in consumption in the *following* hour, which is important to take into account when considering load-shifting strategies in order to minimize the rebound effect. For instance, if the hour following a certain peak demand hour were to have a much lower consumption, load shifting the flexible consumption from the peak hour to the following hour would pose no issues related to the rebound effect. On the other hand, if consumption did not change much in the next hour (i.e. if the peak consumption remained high), load shifting would need to be done over a longer period of time in order to distribute the delayed consumption evenly to avoid creating another (only delayed) demand peak.

In this case, the differences to the seasonal hourly averages were in range of 20-56 %, and the differences in the following hours' consumption in range of -23…+1 %.

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Figure 24 illustrates the city block's average electricity consumption of each hour over the year. The black color graph represents the average hourly consumption over the whole year. In addition, different seasons are shown for comparison. The difference in electricity consumption between the seasons is clear, as the average electricity demand during winter months is the highest and during summer the lowest on every hour, with spring and fall ranking in the middle not far from the whole year's average.

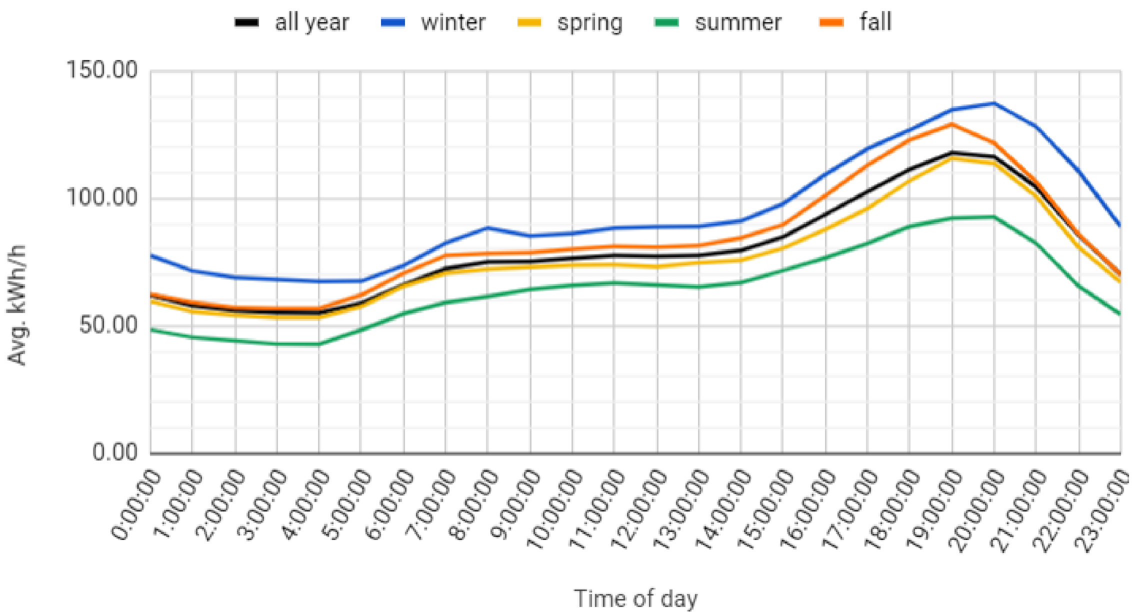

Figure 24: Average electricity consumption for each hour of the day, comparing different seasons of the year (winter: December to February, spring: March to May, summer: June to August and fall: September to November)

While the total electricity demand differs significantly between different seasons, the daily electricity consumption profile still looks very similar for all seasons in that the demand is lowest at the early morning hours, then a slight peak in demand occurs during the morning hours, and then a more significant demand peak in the evening.

Figure 25 shows another visualization of the variations in consumption, where the average hourly consumption is compared between different months of the year by plotting them on a heat map. July seems to have the lowest electricity consumption at all hours, while December's consumption is the highest. The consumption is highest between 16:00 and 22:00, and the highest peak in demand occurs every month at 19:00 – 21:00.

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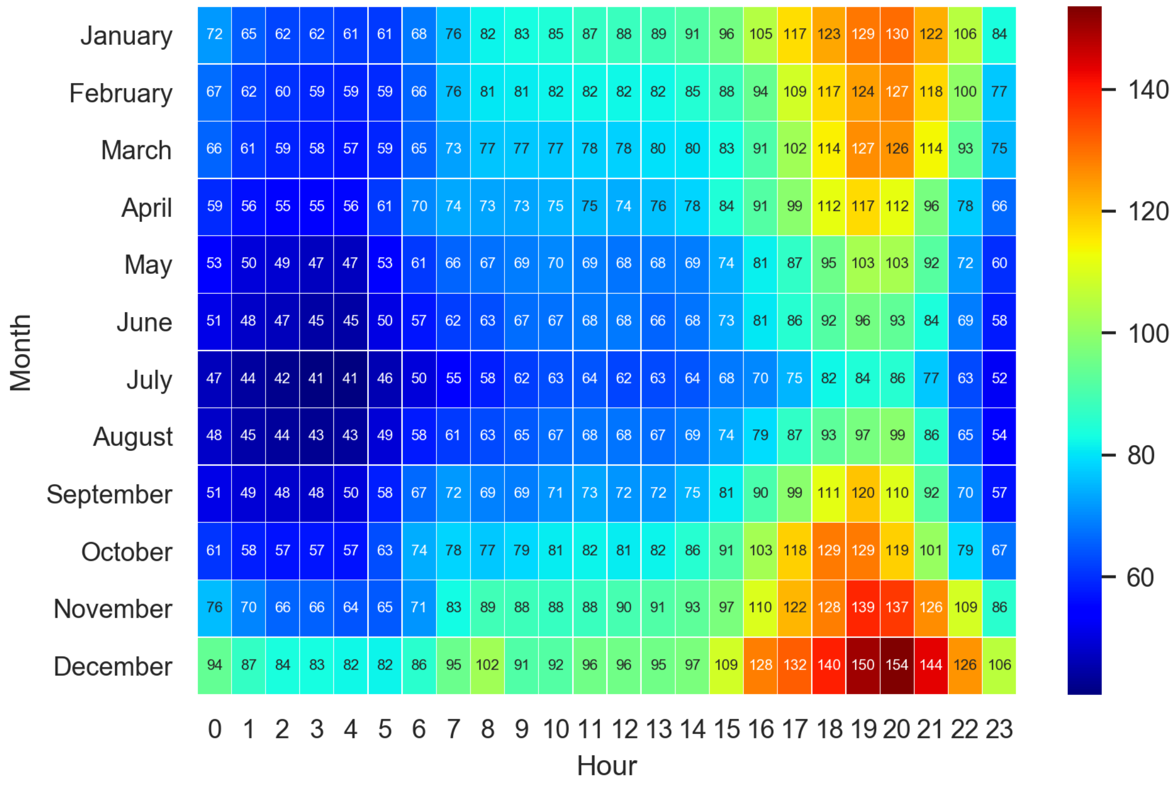

Figure 25: Monthly variations of the average hourly electricity consumption over the year

Figure 26 illustrates the average hourly electricity consumption variations between different days of a week. Based on this, it can be concluded that the average consumption in this Kalasatama city block is very low during the early night hours regardless of the weekday, but while the low consumption hours continued a bit later into the weekend mornings, the late morning and afternoon hours on the weekends were clearly more active than on normal days. The average consumption on the evening hours was clearly higher on Sundays compared to other days of the week.

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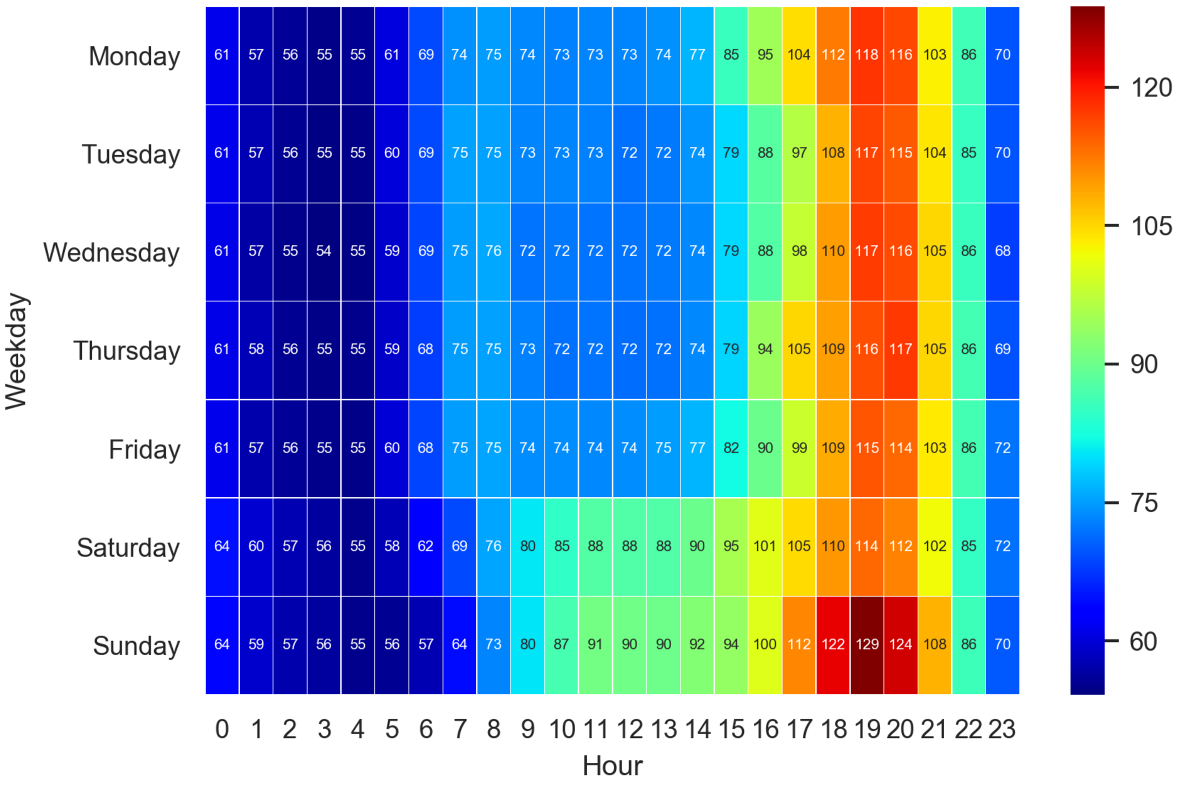

Figure 26: Weekdays' variations of the average hourly electricity consumption over the year

6.4.2 Power draws in individual apartments

The data analyzed in chapter 6.4.1 was the city block's average consumption data measured in one-hour intervals. This subchapter will show two different load profiles from selected example days for every season. The load profiles shown here are average power draws measured in one-minute intervals from individual apartments located in the same city block. This will give more insight to the actual power load variations and load peaks in individual apartments in Kalasatama.

The following load profile figures will show the apartment's load profile for the selected day (in watts) in blue and for comparison also the season's average hourly consumption for an average resident in the city block (in kWh) in red.

In Figure 27 (summer), the apartment's load profile shows a base load of around 200-600 watts, a few short peaks of around 2 700 watts during the day, and a very high load (typical to an electric sauna heater) of over 6 kilowatts (peaking at 7.7 kilowatts for five minutes near the end) starting right after 20:30 and lasting for exactly 90 minutes. The load peak takes the apartment's hourly consumption (or the average power load over an hour) from 0.355 kWh/h at 19:00-20:00 to 2.73 kWh at 20:00-21:00 and 6.04

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kWh at 21:00-22:00, while the city block's seasonal averages per customer were 0.71 kWh/h, 0.71 kWh/h and 0.63 kWh/h, respectively.

Figure 28 (summer) shows another day's load profile for a different apartment in Kalasatama. The baseload in this apartment was low at around 120 watts for the most part of the day. The major demand for the day occurred between 6:00 and 7:00, when the apartment had loads that exceeded 2 kW for a total of 21 minutes and briefly peaked at 5.3 kW.

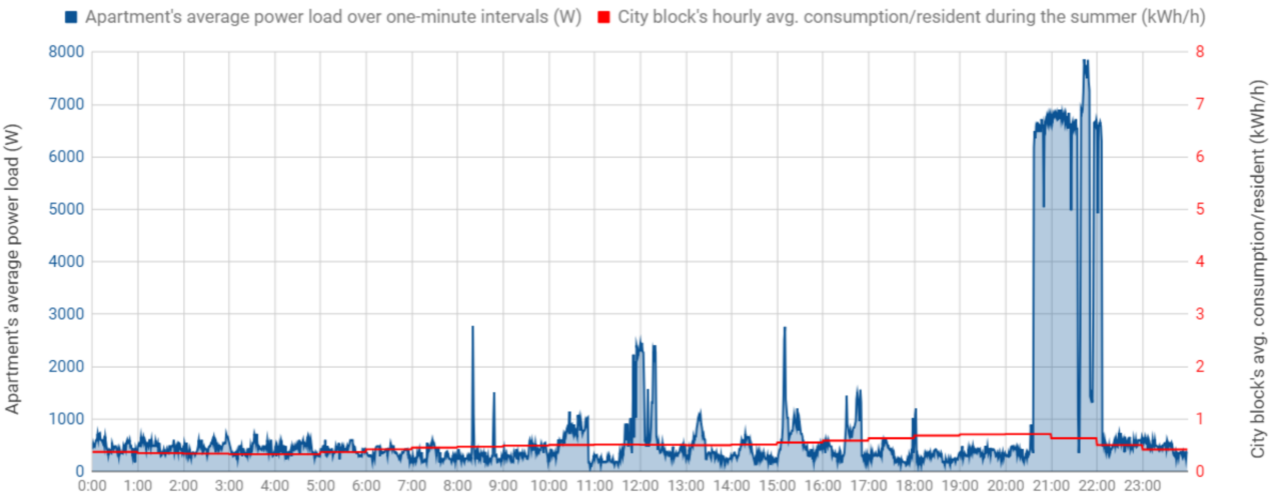

Figure 27: Example day from summer: Apartment's average power load (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the summer (kWh/h) in red

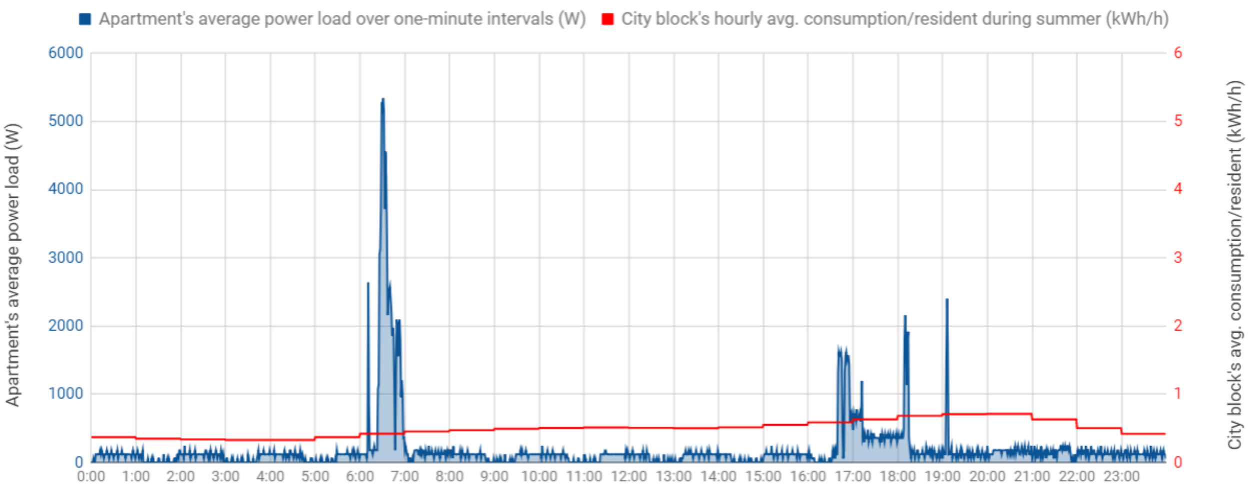

Figure 28: Another example day from summer: Apartment's average power loads (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the summer (kWh/h) in red

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Figure 29 and Figure 30 show similar presentations for fall days. In Figure 29, the base load hovers at around 500 watts, and during the day the load profile shows several short load peaks of 1-5 minutes in duration. The highest short peaks may be explained by an apartment-specific elevator, which is a rare special feature of this apartment. The other peaks of at least a few minutes in duration are likely caused by typical home appliances.

In Figure 30, the baseload and the day's consumption as a whole are very low except for some 2-3 kW loads in the morning and some light, short loads in the evening. The loads in the morning are likely mostly caused by cooking appliances, dishwasher or washing machine, or a combination of them.

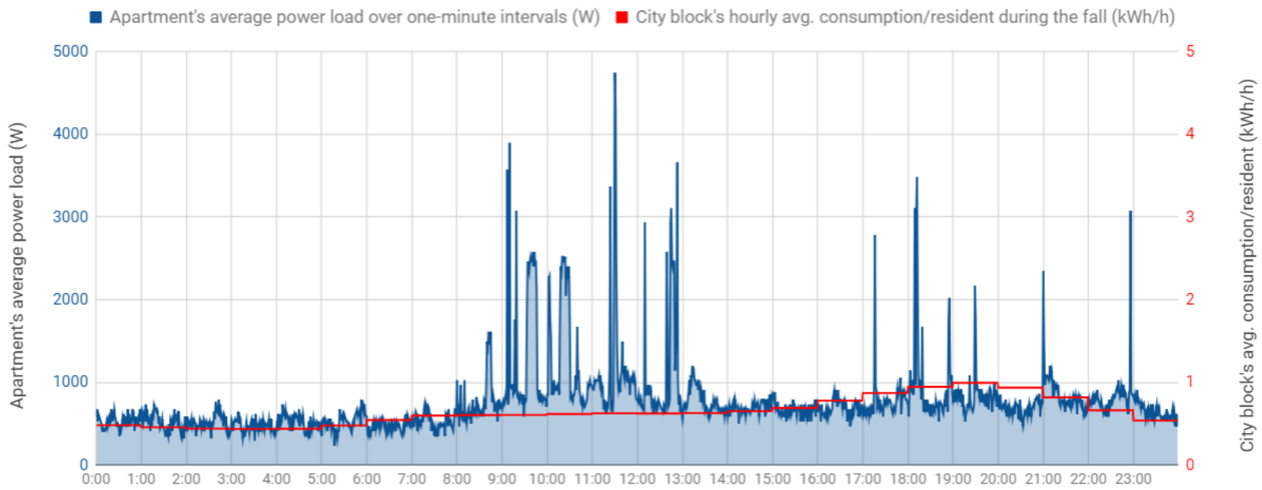

Figure 29: Example day from the fall: Apartment's average power load (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the fall (kWh/h) in red

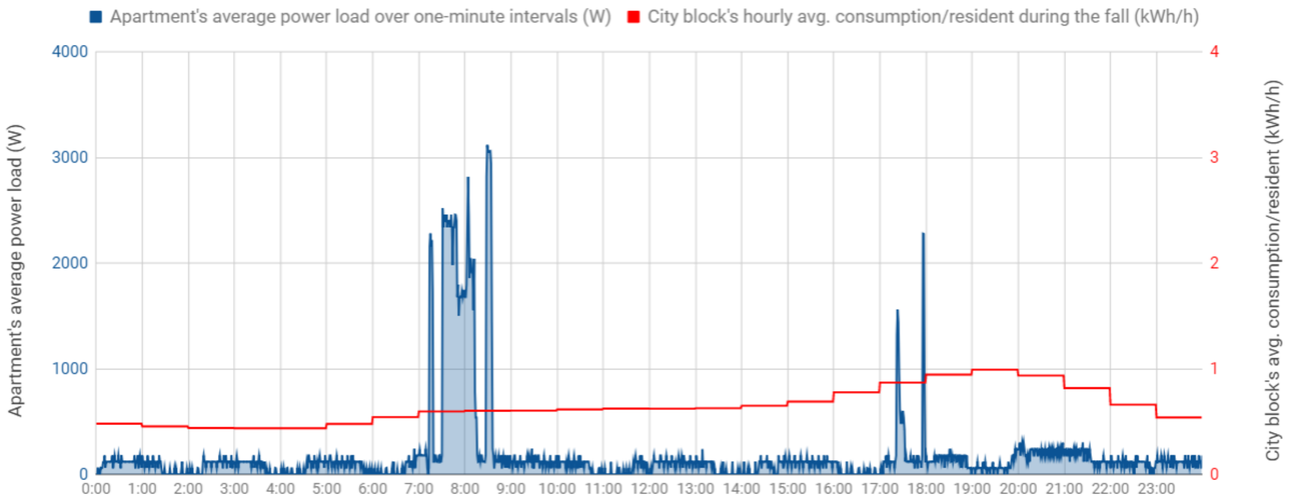

Figure 30: Another example day from the fall: Apartment's average power load (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the fall (kWh/h) in red

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Figure 31 and Figure 32 show similar load profiles for winter days. In Figure 31, the apartment's total consumption for the day was 18.8 kWh. Interestingly, the apartment's *hourly* consumption would show almost identical consumption (1.25 kWh/h) at 16:00-17:00 and 20:00-21:00, but the load profile with one-minute measuring intervals shows that the power draws during these hours are in fact very different. At 16:47, the apartment's total load goes from 938 W to 3 135 W and stays above 3 kW for 14 minutes. The load peaks at 3 340 W, and reaches 3 kW again twice right after 17:00. In comparison, during 20:00-21:00, the apartment's total load only peaks at 1 641 W, and reaches that maximum gradually, in stark contrast to the earlier sudden increase to over 3 kW.

The four other peaks of 2.5 kW or higher that are visible in the figure are short, lasting 1-4 minutes. They are likely explained by the apartment's elevator.

Figure 32 shows a load profile with the base load varying between 60 W and 1 000 W, likely caused by an air heat pump. After 01:00 at night, the total load starts increasing, and then stays above 2 kW for 14 minutes, peaking at 4438 W. During the evening hours of 16:00-19:00, loads peak at 3-4 kW.

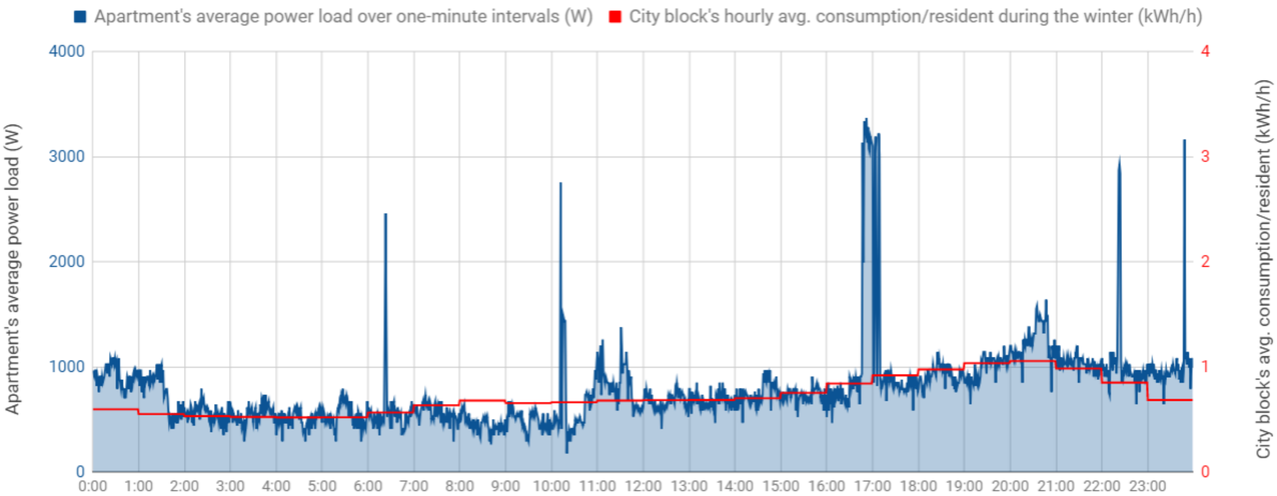

Figure 31: Example day from the winter: Apartment's average power loads (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the winter (kWh/h) in red

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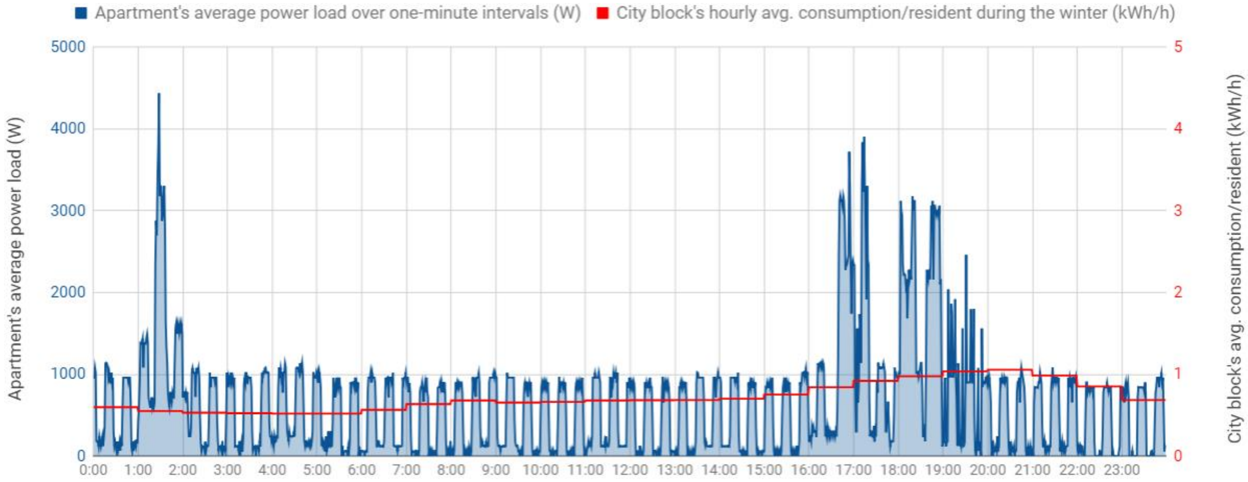

Figure 32: Another example day from the winter: Apartment's average power loads (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during the winter (kWh/h) in red

Finally, Figure 33 and Figure 34 show load profiles for spring days. Figure 33 again shows fairly high base load, some short peaks likely caused by the elevator, and several instances at various times that the load increases by roughly 700-900 watts for 40 minutes and then returns back to the baseload. Figure 34 shows a very low base load mostly from the refrigerator-freezer, averaging at 75 watts. The morning and evening hours see loads increase above 1 kW and peaking at 2.2-2.4 kW.

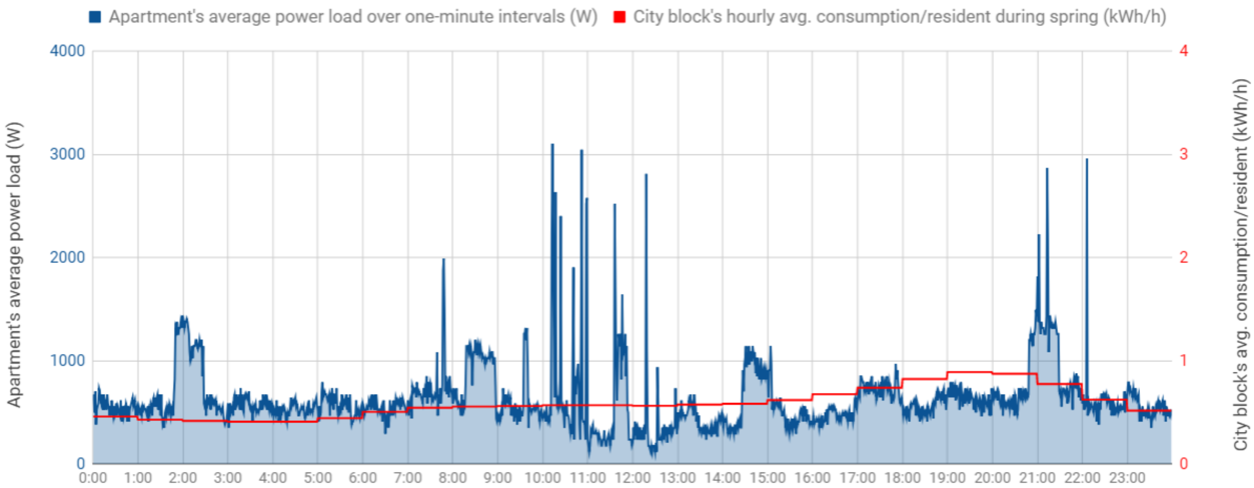

Figure 33: Example day from spring: Apartment's average power loads (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during spring (kWh/h) in red

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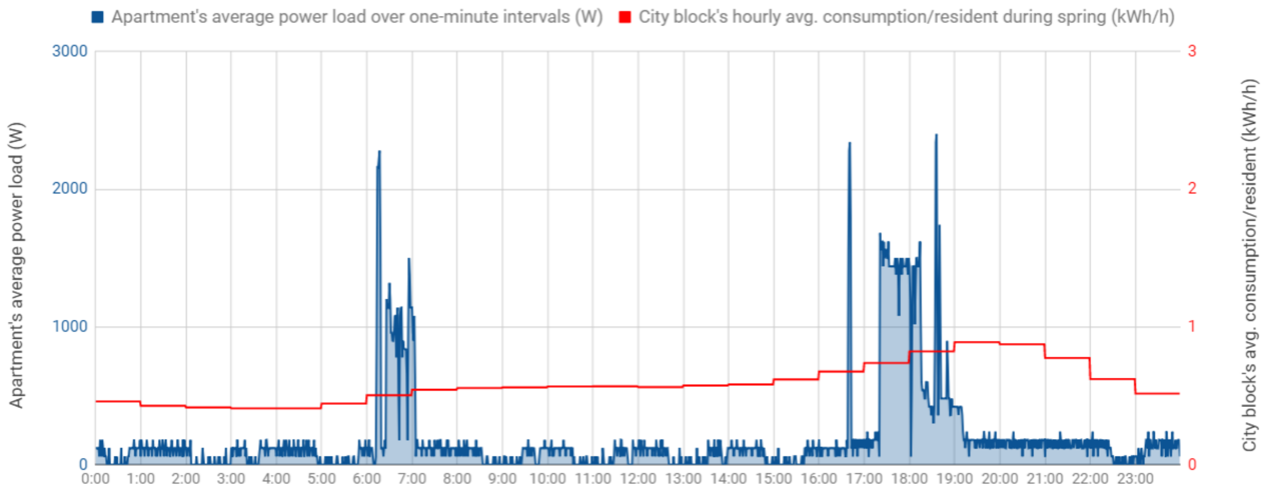

Figure 34: Another example day from spring: Apartment's average power loads (W) in one-minute intervals in blue, and the city block's average resident's average hourly electricity consumption during spring (kWh/h) in red

These load profiles from the selected example days provide insight to the magnitude, duration and frequency of the load peaks that occur in typical Kalasatama apartments. However, as the dataset does not include details on the individual loads or load types, it is difficult to reliably attribute the peaks to specific loads or load types. The next subchapter will study residential loads in more detail in order to identify the actual role of different load types in typical demand peaks in individual apartments, and on the other hand to analyze their flexibility in order to find their practical potential for demand response.

6.5 Loads and load types behind demand peaks in a typical urban apartment

To form an understanding of the range of loads in typical urban residential apartments and to identify the roles of these load types in a daily electricity consumption, the hourly consumption of a typical modern apartment with two residents is analyzed next. All the apartment's electrical loads were listed and then categorized into lighting, home appliances, small appliances and electronics. While every apartment is unique in their range of electrical loads, consumer habits, apartment and family size etc., urban residential apartments in Finland still mostly feature the same major load types.

Lighting in this generalized example apartment includes all types of lighting, consisting mostly of energy-efficient LED lights but also a few incandescent and fluorescent lights. **Home appliances** consist of a convection oven, stove with exhaust hood, fridge-freezer, chest freezer, dishwasher and washing machine. **Small appliances** consist of a microwave oven, food processor, coffee machine, toaster, blender, rice cooker, vacuum cleaner and a kettle. **Electronics** consist of a TV set (including the sound system) and a desktop computer. Smallest consumer electronics loads such as mobile phone and laptop

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chargers were disregarded as the loads they draw are minuscule in this scale and would not be suitable for demand response purposes anyway.

In order to identify the roles of different loads and load types of the total demand and to provide real examples, the hourly electricity consumption on selected individual days is analyzed. On the selected days, the time and duration of use for each individual load was logged, and the power draws and cumulative energy consumption of those loads with varying power draws were also measured with an energy meter, thus providing an estimate of the role that each load had in the daily consumption profiles. Some loads were slightly altered in order to generalize the apartment and the consumer habits, and to more accurately depict a typical average apartment's consumption profile. Each example day's total consumption as well as the consumption profile were validated by comparing the data to the hourly electricity consumption data provided by the distribution system operator for the same day.

In this analysis, **base load** (i.e. load not suitable for demand response purposes) was considered to consist of all lighting, electronics, small appliances and home appliances *other* than refrigerator, freezer, dishwasher or washing machine. Shifting or curtailing these loads would likely have a negative or hindering effect on the end-use. No loads were considered practically curtailable in this type of urban apartment. In this case, **shiftable loads** were considered to consist of the washing machine and the dishwasher as the use of those appliances could be delayed until later hours without significantly affecting normal life. **Storable loads** were considered to consist of a fridge-freezer and a chest freezer.

In the following examples, two figures for each day are presented:

1) The first figure on each example day shows the day's hourly electricity consumption where the four different load types (lighting, home appliances, small appliances, and electronics) are separated and stacked, showing the amount of electricity consumption that each load type caused hourly during the day. The hourly electricity consumption is shown in kilowatt hours, and below the profile are shown the percentages that different load categories formed of the day's *total* electricity consumption.
2) The second figure on each example day shows the same hourly electricity consumption of the day but focuses on the amount of flexibility available on each hour (and in total). The available flexibility is based on the classification of load types made in chapter 6.1, and it should be noted that with a different classification, the flexibility would look different (if, e.g., lighting or some electronics were considered curtailable loads). The hourly electricity consumption is shown in kilowatt hours, and below the profile are shown the percentages that different load types formed of the day's total electricity consumption.

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6.5.1 Example day 1

Figure 35 shows an example of a typical summer Sunday's consumption profile for the apartment with two residents spending the day at home. During the night, only a very low load from refrigerator and freezers (home appliances, red color) and always-on small electronics is visible. In the morning hours, lighting is increased (yellow color), and at 10:00 demand is increased by small appliances (coffee machine and toaster, green color). At 11:00, the washing machine causes another peak. At noon, vacuum cleaner is being used. At 14:00, food processor causes a slightly lower peak, and at 15:00 convection oven is turned on. At 19:00 – 20:00, desktop computer with its monitor and peripherals is being used. The highest peak of the day happens after 20:00, when oven and stove are being used to cook dinner. At 21:00, dishwasher causes another peak in consumption. The last two hours' electronic loads are mostly caused by the TV set.

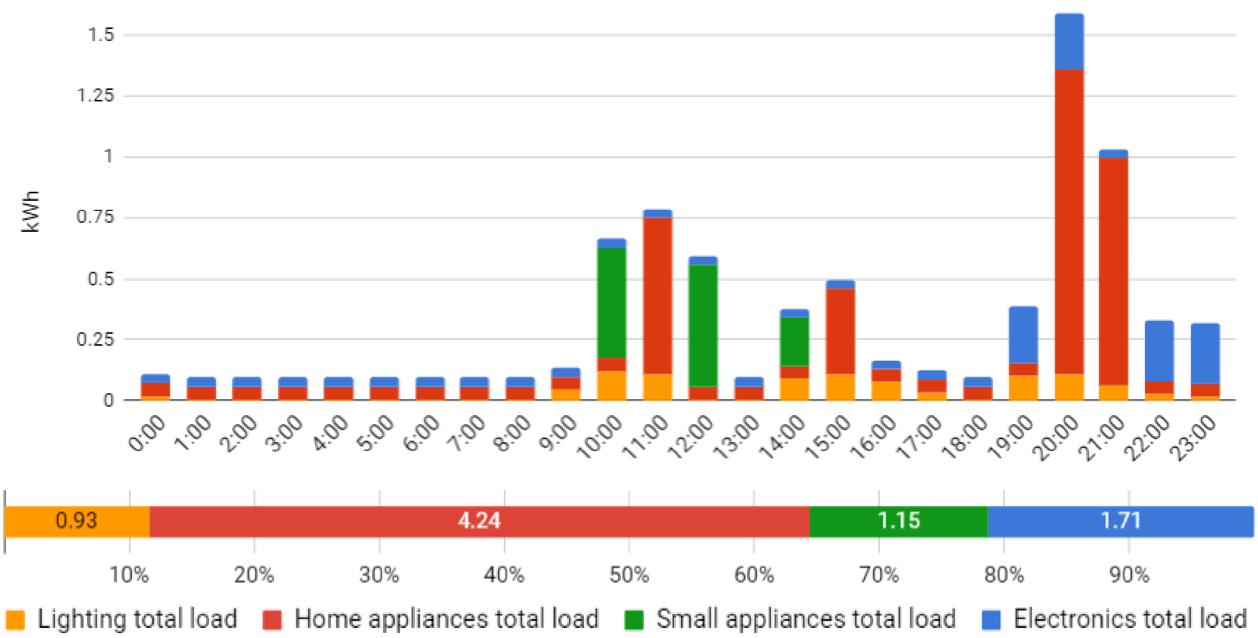

Figure 35: Hourly load profile for a typical Sunday in August on top, and below that the kilowatt hours and percentages that different load categories formed of the day's total electricity consumption

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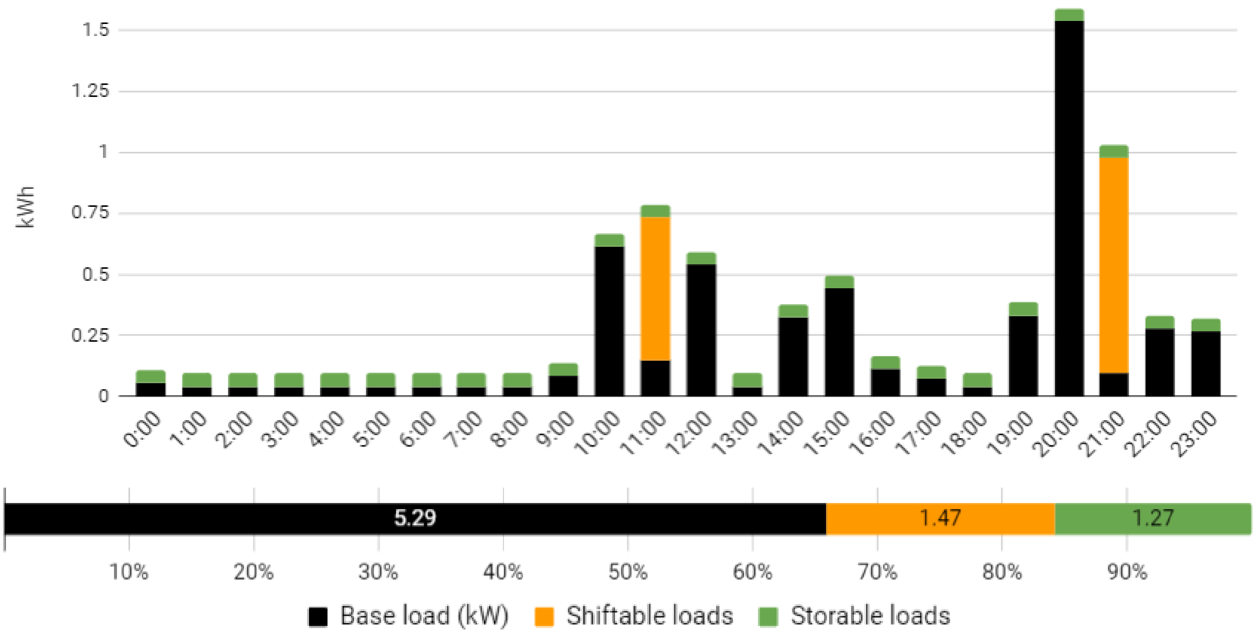

Figure 36: Hourly demand response potential for different load types on top, and below the kilowatt hours and percentages that different load types formed of the day's total electricity consumption

In Figure 36, all loads have been categorized into the above-discussed demand response types. Even though refrigerator and freezer function practically in an on/off manner (consuming almost no electricity part of the time, and at times causing typically a 50-200 W load), their load is spread relatively evenly throughout the whole day. In case of potentially aggregated refrigerator-freezer loads, the variations would even out even further. Washing machine and dishwasher on the other hand have a very dissimilar use pattern as they consume no electricity until they are turned on, after which they cause a very distinctive although variable load, typically in range of for example 100-2000 W for 30-90 minutes (depending on the model, washing program etc.).

Total electricity consumption for the day was 8.03 kWh. 5.29 kWh (65.9 %) of the total power consumption was formed by base load, which is considered unsuitable for demand response. 1.47 kWh (18.3 %) of the total consumption was formed by loads considered shiftable, and 1.27 kWh (15.8 %) by storable loads, bringing the total consumption of the residential loads considered at least theoretically applicable for demand response to 34.1 % for this specific day.

In conclusion, during this example Sunday, an average of 53 watt load from the refrigerator-freezer and the chest freezer could be considered available for residential demand response purposes at any hour of the day. Between 11:00 and noon, 0.59 kWh of energy used by a washing machine can be considered shiftable, assuming that the residents would be willing to delay the use. Between 21:00 and 22:00, 0.88 kWh used by a dishwasher could be considered shiftable as well.

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6.5.2 Example day 2

Figure 37 shows the hourly consumption and the proportions of different load types on a typical January Wednesday, where both residents are away at work at daytime but home for the evening.

At 06:00-07:00, lighting is turned on and small appliances (coffee maker and kettle) are being used. During the working hours, as well as the night hours, only a very light load of around 0.1 kWh/h on average is consumed by the always-on devices (refrigerator, freezer, night lamp). Around 16:00 onwards, the residents return home and lighting is increased, and at 16:00-17:00, a two-kilowatt vacuum cleaner is used for around 18 minutes, consuming around 0.6 kWh.

At 18:00, convection oven is turned on for 15 minutes at around 1700 watt power load, consuming approximately 0.45 kWh. Around the same time the washing machine is also turned on, this time on a wash program with high temperature (95 °C) and fast spinning (1400 rounds per minute) that takes a little over two hours to complete. The washing machine consumes 2.3 kWh in total, with its peak load reaching a maximum of around 2200 watts.

The day's total consumption was measured at 7.47 kWh. As illustrated in Figure 38, 3.89 kWh (52 %) of the consumption was base loads, 2.31 kWh (31 %) was shiftable loads and 1.27 kWh (17 %) was storable loads.

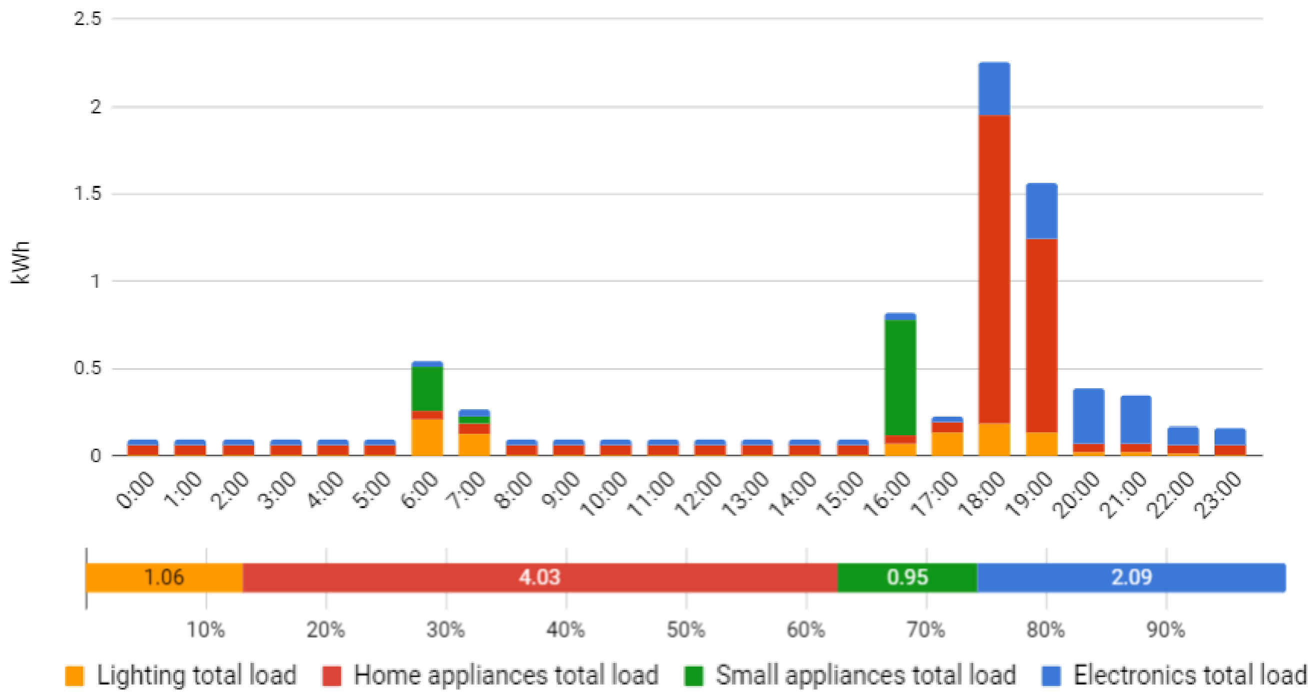

Figure 37: Hourly load profile for a weekday in January on the top, and below that the kilowatt hours and percentages that different load categories formed of the day's total electricity consumption

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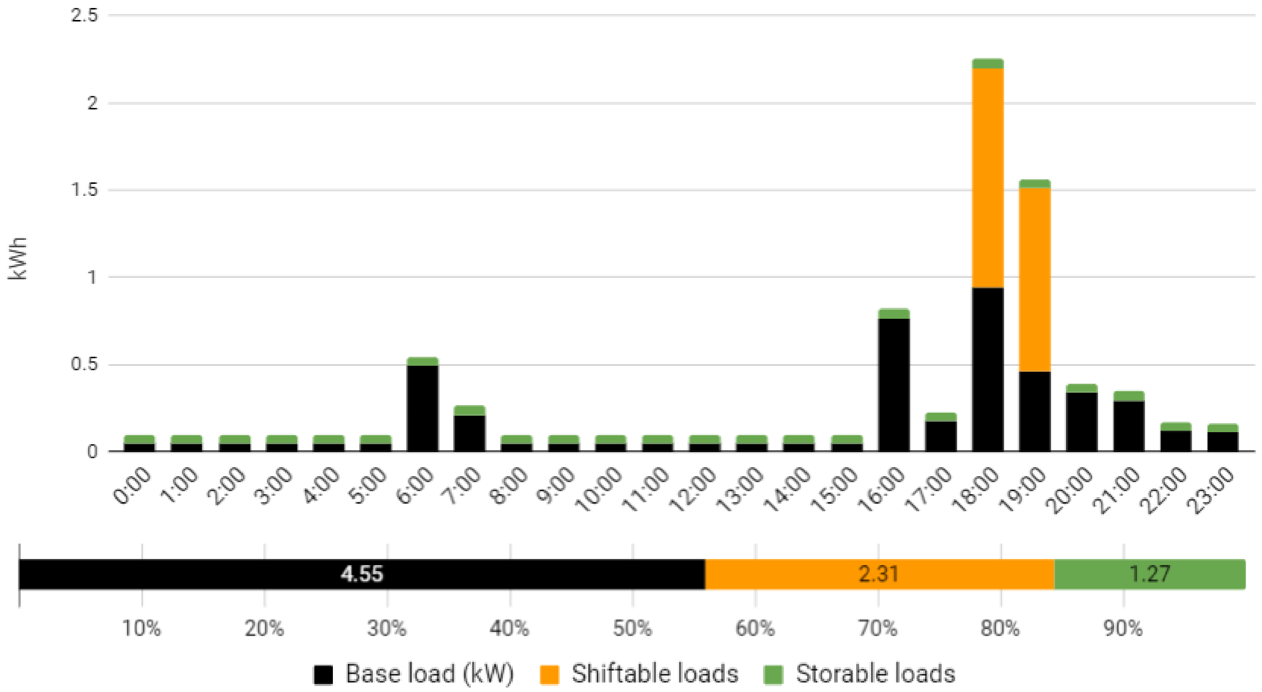

Figure 38: Hourly demand response potential for different load types on top, and below the kilowatt hours and percentages that different load types formed of the day's total electricity consumption

6.5.3 Example day 3

In this example day from November, only one resident is home during the day, and both residents are home in the evening. As shown in Figure 39, electricity consumption during the morning and daytime is quite low, consisting of lighting, occasional small kitchen appliances and computer use. At 19:00-20:00, oven and stove are used for cooking food, causing the only major load peak for the day. Consumption on evening hours consists mostly of small electronics (TV, sound system).

Figure 40 illustrates that on this particular day, the electricity consumption had very little flexibility. While total consumption was moderately high at 9.5 kWh, almost all of it (8.2 kWh, or 86 %) was by base loads, namely essential lighting, computer use, cooking and TV use. 1.27 kWh (13%) was consumed by refrigerator and freezers, distributed evenly to each hour of the day.

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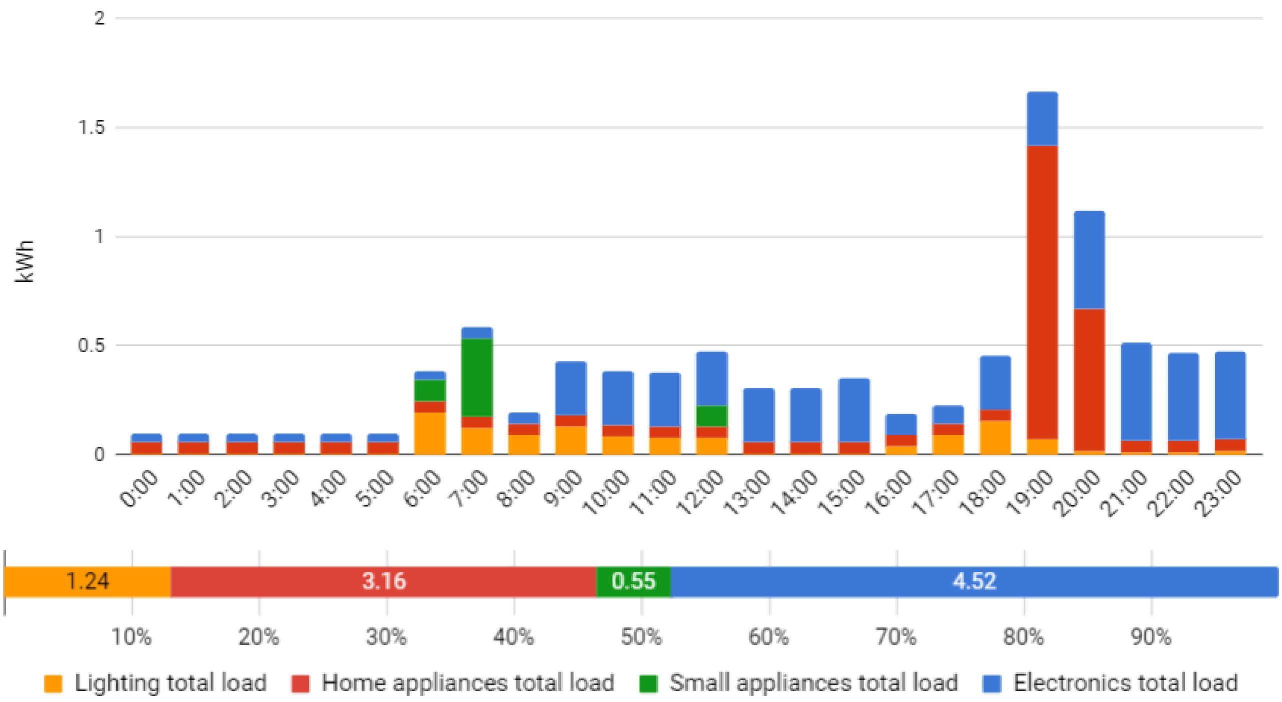

Figure 39: Hourly load profile for a weekday in January on the top, and below that the kilowatt hours and percentages that different load categories formed of the day's total electricity consumption

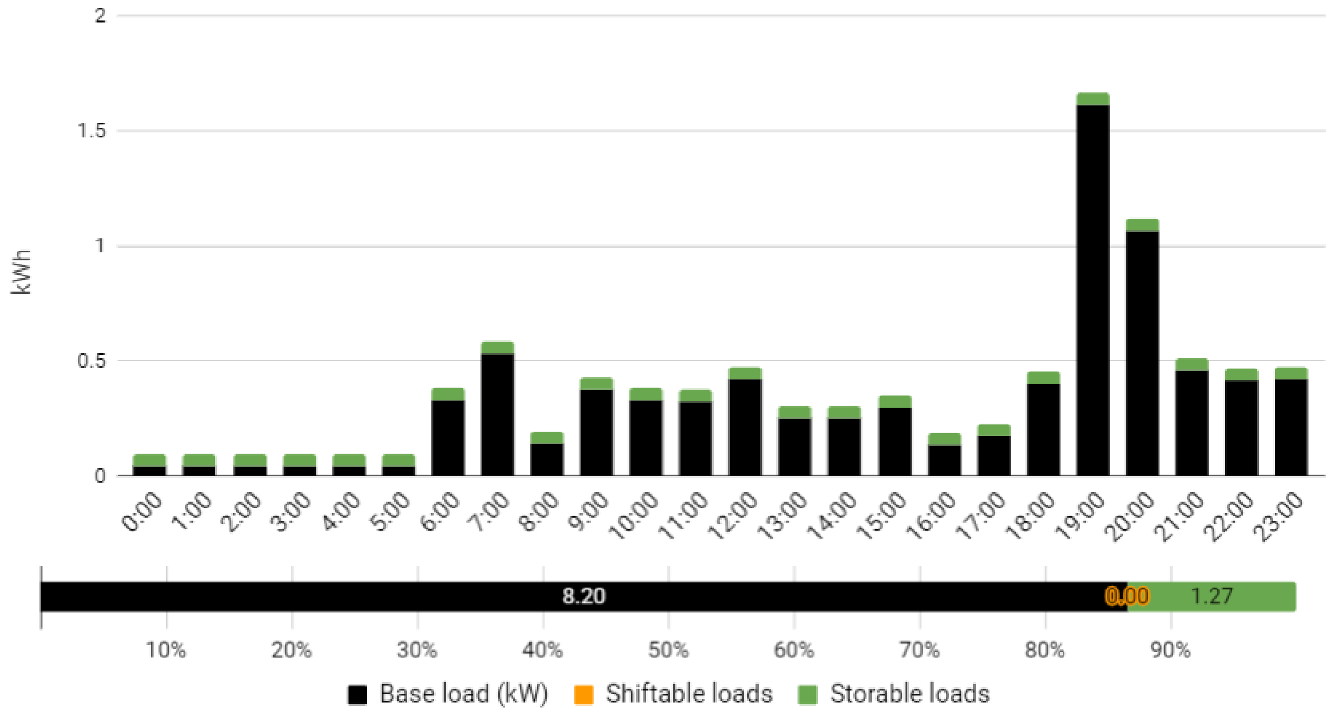

Figure 40: Hourly demand response potential for different load types on top, and below the kilowatt hours and percentages that different load types formed of the day's total electricity consumption

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6.5.4 Example day 4

The earlier examples have mostly shown days that have illustrated many different appliances (whether flexible or not) being used. However, often the electricity consumption on busy working days may be very light. Figure 41 and Figure 42 show an example of a day in April where total consumption is only 3.2 kWh, which is well below the average for this apartment but not uncommon. On this day, the maximum demand occurred at 17:00-18:00 with just over 0.3 kWh per hour.

Morning hours at 05:00-06:00 show the residents leaving for work, and evening hours show a small increase in lighting and some increased electronics usage (TV, computer). Other than that, the only loads drawing power are the refrigerator-freezer and other small always-on electronics.

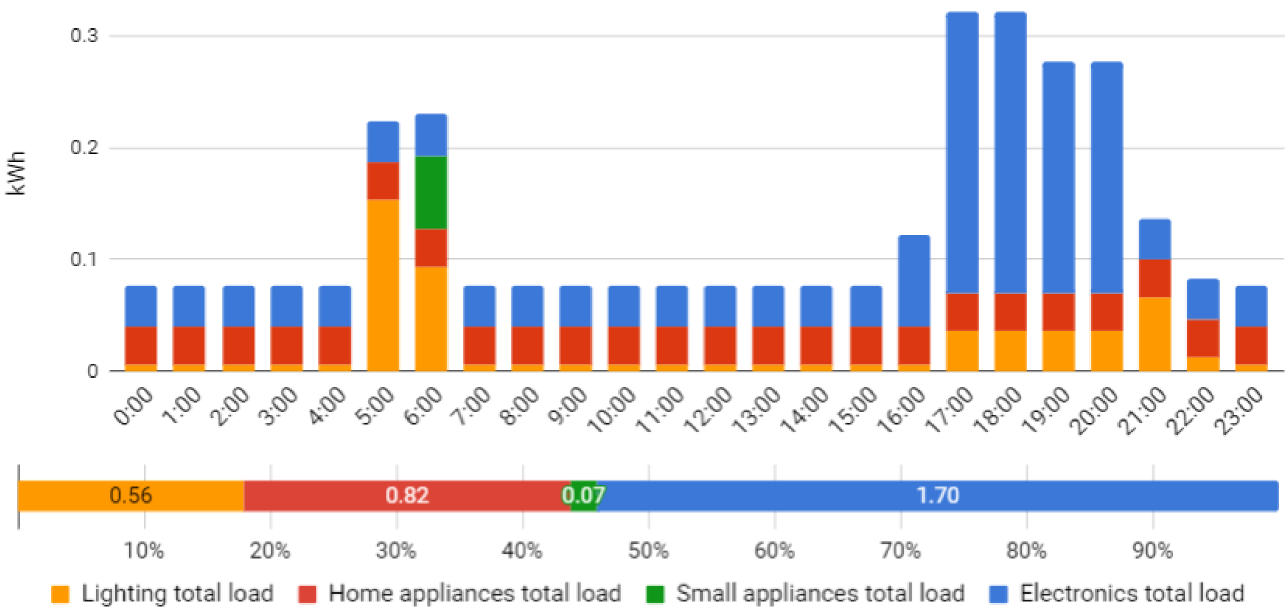

Figure 41: Hourly load profile for a weekday in April on the top, and below that the kilowatt hours and percentages that different load categories formed of the day's total electricity consumption

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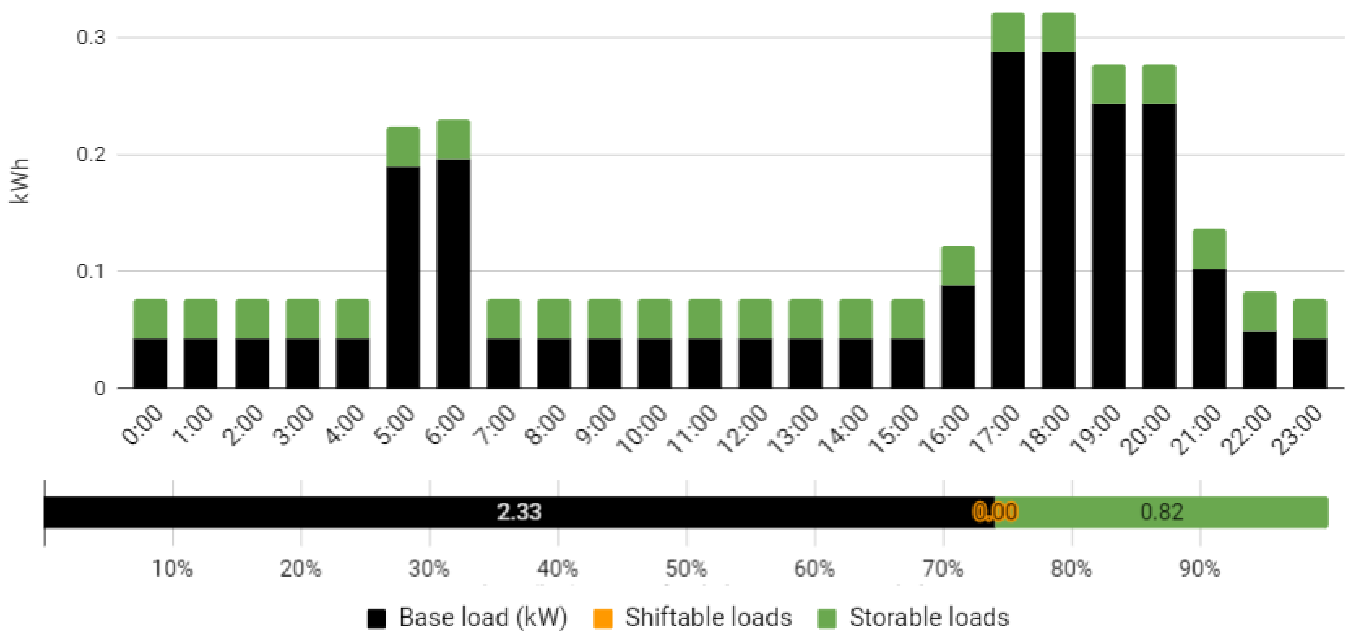

Figure 42: Hourly demand response potential for different load types on top, and below the kilowatt hours and percentages that different load types formed of the day's total electricity consumption

6.5.5 Example day 5

As discussed in chapter 6.2, some apartments also feature saunas with electric sauna heaters, which are often the appliances with the largest power draw in the apartment. Figure 43 shows two example days' hourly electricity consumption from a different apartment (a modern, urban apartment with two bedrooms and one resident) with an electric 8 kW sauna heater. In this example, the other electrical loads were not separated from the total, but instead the figure only illustrates the typical effect that sauna use may have on the electricity consumption.

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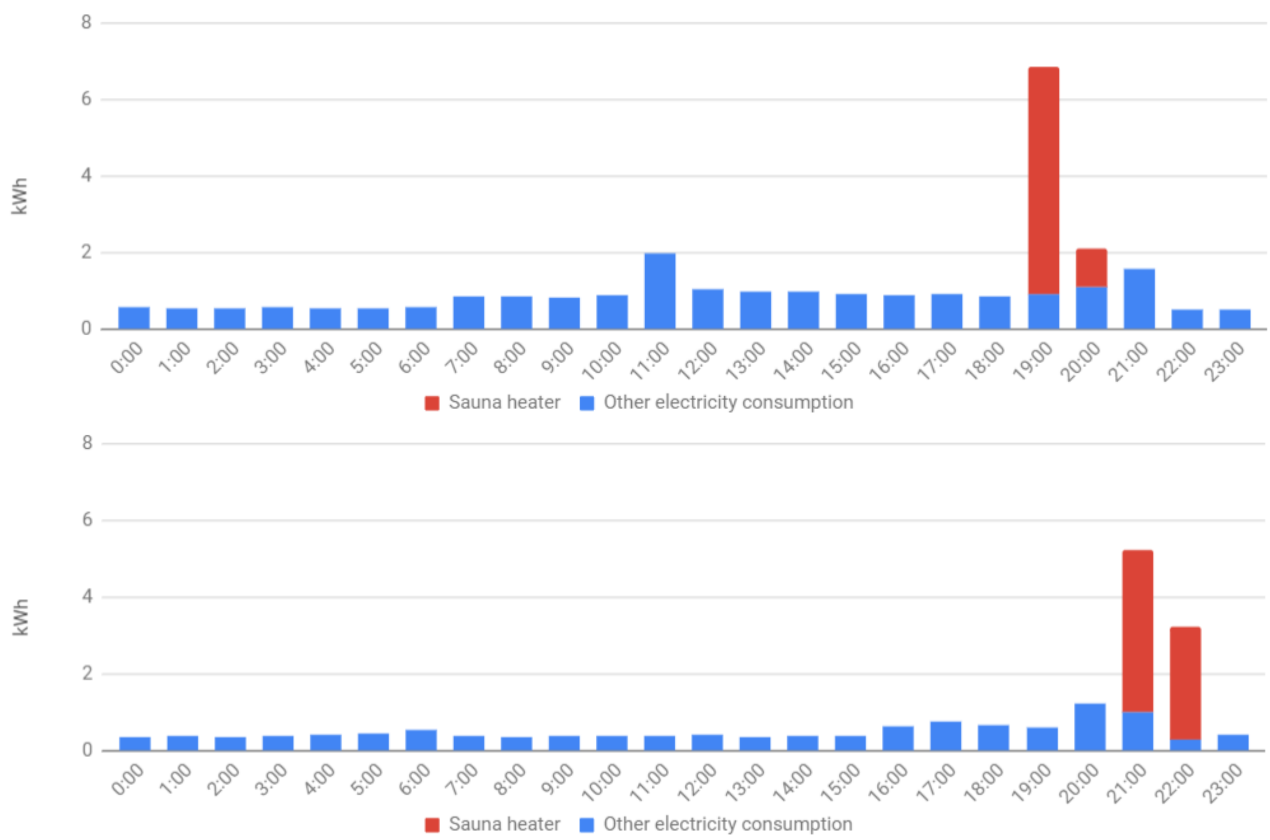

Figure 43: Two example days showing the effects of an electric 8 kW sauna heater in an apartment's hourly electricity consumption

It should be noted that as with every other example, individual consumer habits may vary greatly, which would also result in differing electricity consumption profiles. However, electric sauna heaters typically take around 45 minutes to pre-heat the sauna for the actual use, suggesting that the heaters are typically on for an hour at the minimum, and potentially longer depending on the user's preferences.

The sauna heater was used at 19:00-20:00 on the first example day and at 21:00-22:00 on the second example day. On the first day, a Saturday in October, the sauna heater consumed a total of 7 kWh. The second day, a Monday in October, had 7.2 kWh of consumption from the sauna heater. While sauna use/habits are typically not considered very flexible, the resident in question noted that the use of the sauna heater could often be delayed up to one or two hours within the evening hours if necessary. For example, if there was a request and some incentive to follow it, turning on the sauna heater could in some cases be delayed from 19 until 20 – 21 with no significant disturbance to normal life.

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6.6 Residential demand response potential in Kalasatama

6.6.1 Demand response potential from residential loads

The highest hourly consumption values in the city block of the 130 customers were in range of 150-180 kWh (analyzed in chapter 6.4.1). Figure 44 shows the temporal distribution of all the city block's hourly consumption values that exceeded 150 kWh during the analyzed year, and it shows that all of them occurred during the evening hours between 16:00 and 22:00. Figure 23 and Figure 24 in chapter 6.4.1 show that on average, the consumption within the city block peaked within this time period during all seasons and all days of the week. Therefore, examination of flexibility and demand response potential of different residential appliances during demand peaks can be limited to those six evening hours.

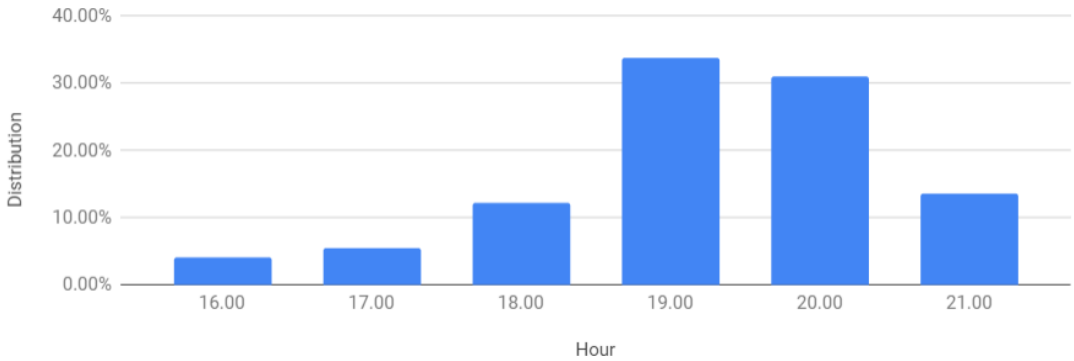

Figure 44: Temporal distribution of the city block's hourly consumption values exceeding 150 kWh

In order to estimate the potential for residential demand response, the following assumptions are made for the typical high-demand evening hours based on technical specifications of modern appliances, findings in chapters 6.4 and 6.5, apartment and building information on the area's active apartment listings as well as some estimates:

- Every apartment has a refrigerator-freezer that continuously draws 40-60 W of power on average (consumption of around 1.2 kWh/day), and that can have 100 % of its power load reduced for a maximum duration of 30 minutes.
- 90 % of the apartments are equipped with a dishwasher that consumes 0.7-1.05 kWh over a 2.5-hour wash program on average. An average dishwasher is assumed to be used 5 times during the peak hours of a typical week, and its use can be delayed into later hours.
- 80 % of the apartments are equipped with a washing machine that consumes 0.8-1.2 kWh over a 2.5-hour wash program on average. An average washing machine is assumed to be used 4 times during the peak hours of a typical week. Their use can be delayed into later hours.

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- 20 % of the apartments are equipped with a tumble dryer that consumes 1.3-1.95 kWh over a 2.5-hour program on average. An average tumble dryer is assumed to be used 3 times during the peak hours of a typical week. Their use can be shifted into later hours.
- 20 % of the apartments are equipped with an electric sauna heater that consumes 9.6-14.4 kWh over a two-hour session on average. An average sauna heater is assumed to be used once during a typical week's peak hours, and it can technically be used for load shifting as well.
- 10% of the apartments are equipped with electric comfort floor heating that draws 200-300 W of power on average when in use. 50 % of its power load can be curtailed.
- 10% of the apartments are equipped with apartment-specific HVAC that continuously draws 40-60 W of power on average. 50 % of the power load can be curtailed for a duration of 15 minutes without noticeably reducing the air quality.

Figure 45 shows the theoretical potential (based on these assumptions) for temporary peak load reduction and the potential for consumption reduction (via load shifting) during 3 kWh/h and 7 kWh/h peak consumption hours in an individual apartment that has all the above-mentioned appliances. Sauna heater has by far the highest potential for peak load reduction, followed by tumble dryer and washing machine.

	Refrigerator-freezer	Dish-washer	Washing machine	Tumble dryer	Sauna heater	Comfort floor heating	Apartment-specific HVAC
Days per week in use during peak hours (days, max 7)	7	5	4	3	1	7	7
Hours per day drawing power if used (h, max 24h)	24	2.5	2.5	2.5	2	12	24
Average load over an hour when in use (W, or consumption of Wh/h)	40 - 60	280 - 420	320 - 480	520 - 780	4800 - 7200	200 - 300	40 - 60
Consumption per day if used (kWh)	0.96 - 1.44	0.7 - 1.05	0.8 - 1.2	1.3 - 1.95	9.6 - 14.4	2.4 - 3.6	0.96 - 1.44
INDIVIDUAL APARTMENT: Theoretical potential with all appliances							
Theoretical average peak load reduction in individual apartment (kW)	0.04 - 0.06	0.28 - 0.42	0.32 - 0.48	0.52 - 0.78	4.8 - 7.2	0.1 - 0.15	0.02 - 0.03
Consumption reduction potential during a 3 kWh/h hour in apartment (%) *	0.7 - 1%	9 - 14.%	11 - 16%	17 - 26%	160 - 240%	3.3 - 5%	0.2 - 0.3%
Consumption reduction potential during a 7 kWh/h hour in apartment (%) *	0.3 - 0.4%	4 - 6%	5 - 7%	7 - 11%	69 - 103%	1.4 - 2.1%	0.1 - 0.1%
Total maximum theoretical peak load reduction (kW):	6.1 - 9.1						

*) Limitation in duration taken into account, 0.5h maximum in refrigerator-freezers and 15 minutes in apartment-specific HVAC

Figure 45: Theoretical flexibility of the most suitable home appliances and devices during peak hours

Figure 46 shows theoretical and practical peak load reduction and load shifting potential for the same city block of 130 residents that was analyzed in chapter 6.4.1. The theoretical peak load reduction potential is calculated by considering the average power load of the appliance over an hour (when in use), ubiquity of the appliance within the city block, flexibility of the appliance (the percentage of the load that may be shifted or curtailed), and the probability of the appliance being in use during any given peak demand hour (16:00-22:00) of an average week. It is the amount of load that could be avoided when demand peaks are expected or starting if the use of the shiftable loads was delayed beforehand and the curtailable loads were curtailed. For the consumption reduction (load shifting) potential, also taken into account is the

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maximum duration that the appliance can be curtailed without noticeably affecting the end-use. For theoretical potential, it is assumed that all the city block's appliances that were otherwise going to be used could be utilized for peak load reduction and load shifting purposes during demand peaks if it was necessary.

The practical potential in the same figure examines the same potentials but with lower and more realistic participation percentages. Load shifting that requires manual decisions and delays the desired outcome is unlikely to interest all residents and may be unfeasible for many households at least part of the time. Each appliance is given a high and a low estimate regarding average participation probability in demand response activities, which then affect the peak load reduction and load shifting potentials. For instance, a range of 10-25 % was estimated for dishwashers, meaning that an average dishwasher would be available for demand response activities only 10-25 % of the times that it is used during the evening peak hours.

	Refrigerator-freezer	Dish-washer	Washing machine	Tumble dryer	Sauna heater	Comfort floor heating	Apartment-specific HVAC
Days per week in use during peak hours (days, max 7)	7	5	4	3	1	7	7
Hours per day drawing power if used (h, max 24h)	24	2.5	2.5	2.5	2	12	24
Average probability of being in use during any peak hour of a week (%)	100%	30%	24%	18%	5%	100%	100%
Ubiquity in apartments (%)	100%	90%	80%	20%	20%	10%	10%
Average load over an hour when in use (W, or consumption of Wh/h)	40 - 60	280 - 420	320 - 480	520 - 780	4800 - 7200	200 - 300	40 - 60
Consumption per day if used (kWh)	0.96 - 1.44	0.7 - 1.05	0.8 - 1.2	1.3 - 1.95	9.6 - 14.4	2.4 - 3.6	0.96 - 1.44
Flexibility amount (%)	100%	100%	100%	100%	100%	50%	50%
Flexibility duration (h)	0.5	2+	2+	2+	1+	1.0	0.25
Estimated participation in demand response activities, low (%)	20%	10%	10%	10%	5%	10%	10%
Estimated participation in demand response activities, high (%)	100%	25%	50%	50%	20%	30%	30%
CITY BLOCK: Theoretical potential with 100% of appliances participating in demand response activities							
Theoretical peak load reduction in city block of 130 apartments (kW)	5.2 - 7.8	9.8 - 14.6	7.9 - 11.9	2.4 - 3.6	5.9 - 8.9	1.3 - 2	0.3 - 0.4
Load shifting potential during city block's 125 kWh/h peak (%) *	2.1 - 3.1%	7.8 - 11.7%	6.3 - 9.5%	1.9 - 2.9%	4.8 - 7.1%	1 - 1.6%	0.1 - 0.1%
Load shifting potential during city block's 175 kWh/h peak (%) *	1.5 - 2.2%	5.6 - 8.4%	4.5 - 6.8%	1.4 - 2.1%	3.4 - 5.1%	0.7 - 1.1%	0 - 0.1%
Total theoretical peak load reduction in city block (kW):	33 - 49						
Total load shifting potential during city block's 125 kWh/h peak (%):	24 - 36%						
Total load shifting potential during city block's 175 kWh/h peak (%):	17 - 26%						
CITY BLOCK: Practical potential with estimated participation in demand response activities taken into account							
Practical peak load reduction potential in city block of 130 apartments (kW)	1 - 7.8	1 - 3.7	0.8 - 5.9	0.2 - 1.8	0.3 - 1.8	0.1 - 0.6	0 - 0.1
Load shifting potential during city block's 125 kWh/h peak (%) *	0.4 - 3.1%	0.8 - 2.9%	0.6 - 4.8%	0.2 - 1.4%	0.2 - 1.4%	0.1 - 0.5%	0 - 0%
Load shifting potential during city block's 175 kWh/h peak (%) *	0.3 - 2.2%	0.6 - 2.1%	0.5 - 3.4%	0.1 - 1%	0.2 - 1%	0.1 - 0.3%	0 - 0%
Total practical peak load reduction in city block (kW):	4 - 22						
Total load shifting potential during city block's 125 kWh/h peak (%):	2 - 14.%						
Total load shifting potential during city block's 175 kWh/h peak (%):	2 - 10%						

*) Limitation in duration taken into account, 0.5h maximum in refrigerator-freezers and six minutes in apartment-specific HVAC

Figure 46: Theoretical and practical potential of residential appliances in a city block of 130 apartments

With the earlier assumptions, the total theoretical peak load reduction potential of the city block is 33 - 49 kW during the peak hours. Again, that is if all the appliances within the city block that were otherwise going to be used could be utilized for demand response when necessary. Total load shifting potential during the city block's 125 kWh/h consumption peak hour would be 24 – 36 %, and during a 175 kWh/h

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consumption peak 17 – 26 %. 125 kWh and 175 kWh are typical consumption values for winter's and summer's peak demand hours in the analyzed city block, and are used here as examples for scale.

Taking into account the estimates on the average participation in demand response activities, the practical peak load reduction potential of the city block is just 4 - 22 kW. Total load shifting potential during the city block's 125 kWh/h consumption peak hour would be 2 - 14 %, and during a 175 kWh/h consumption peak hour 2 - 10 %.

Figure 47 shows similar analysis for the whole Kalasatama area with the assumption that all the apartments were equipped with systems that enable residents to participate in demand response activities (currently not the case yet). First is shown the current situation scaled up with 1 527 apartments (2018), and under that the situation projected for 2030 with estimated 13 000 apartments.

	Refrigerator-freezer	Dish-washer	Washing machine	Tumble dryer	Sauna heater	Comfort floor heating	Apartment-specific HVAC
Days per week in use during peak hours (days, max 7)	7	5	4	3	1	7	7
Hours per day drawing power if used (h, max 24h)	24	2.5	2.5	2.5	2	12	24
Average probability of being in use during any peak hour of a week (%)	100%	30%	24%	18%	5%	100%	100%
Ubiquity in apartments (%)	100%	90%	80%	20%	20%	10%	10%
Average load over an hour when in use (W, or consumption of Wh/h)	40 - 60	280 - 420	320 - 480	520 - 780	4800 - 7200	200 - 300	40 - 60
Consumption per day if used (kWh)	0.96 - 1.44	0.7 - 1.05	0.8 - 1.2	1.3 - 1.95	9.6 - 14.4	2.4 - 3.6	0.96 - 1.44
Flexibility amount (%)	100%	100%	100%	100%	100%	50%	50%
Flexibility duration (h)	0.5	2+	2+	2+	1+	1.0	0.25
Estimated participation in demand response activities, low (%)	20%	10%	10%	10%	5%	10%	10%
Estimated participation in demand response activities, high (%)	100%	25%	50%	50%	20%	30%	30%

KALASATAMA 2018	Amount of apartments:	1 527					
Theoretical peak load reduction in Kalasatama's 1 527 apartments (kW)	61 - 92	115 - 172	93 - 140	28 - 43	70 - 105	15 - 23	3 - 5
Practical peak load reduction in Kalasatama's 1 527 apartments (kW)	12 - 92	11 - 43	9 - 70	3 - 21	3 - 21	2 - 7	0 - 1
Total theoretical peak load reduction in Kalasatama in 2018 (kW):	385 - 578						
Total practical peak load reduction in Kalasatama in 2018 (kW):	41 - 255						

KALASATAMA 2030	Amount of apartments:	13 000					
Theoretical peak load reduction in Kalasatama's 13 000 apartments (kW)	520 - 780	975 - 1463	792 - 1189	241 - 362	594 - 891	130 - 195	26 - 39
Practical peak load reduction in Kalasatama's 13 000 apartments (kW)	104 - 780	98 - 366	79 - 594	24 - 181	30 - 178	13 - 59	3 - 12
Total theoretical peak load reduction in Kalasatama in 2018 (kW):	3279 - 4919						
Total practical peak load reduction in Kalasatama in 2018 (kW):	350 - 2169						

Figure 47: Theoretical and practical potential of residential appliances in Kalasatama's current 1 527 apartments, and the estimated 13 000 apartments in 2030

With the earlier assumptions regarding Kalasatama's residents' consumption habits, electrical loads and their ubiquity, and the assumption that every apartment was able to participate in demand response, the currently completed 1 527 apartments could in theory be able to provide a momentary peak load reduction of 385 – 578 kW. More realistically, the practical peak load reduction could be in range of 41 - 255 kW when lower participation estimates are considered. Other things equal, the 13 000 apartments projected for 2030 could theoretically provide a momentary peak load reduction of 3.3 - 4.9 MW, and with more realistic participation estimates, 350 – 2 169 kW.

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In conclusion, many apartments feature loads that draw relatively high loads on average and that could, if properly incentivized or motivated, be load shifted for later hours in order to reduce demand peaks. When all the variables are factored in, the practical potential for momentary peak load reduction and load shifting seems relatively low. For instance, the high end of the city block's peak load reduction range is 22 kW, which is equal roughly to just three electric sauna heaters or ten stoves, which may not seem significant in scale of 130 apartments. However, the analysis on residential consumption profiles in chapter 6.4 shows that in order to flatten the consumption profile during the evening hours on a city block level (as opposed to the level of individual apartments), relatively low amounts of load shifting may often be enough.

As an example, Figure 48 shows the hourly consumption profile of the day with the highest consumption hour of the inspected year. At 19:00 - 20:00 the hourly consumption was 165.33 kWh, and at 20:00 - 21:00 it peaked at 178.99 kWh (both hours marked with red color). In order to stabilize the hourly consumption of the evening at 150 kWh/h (as before and after these two high-consumption hours), the 19:00 - 20:00 consumption of 165.33 kWh would need to be reduced by 15.33 kWh (9 %), and the 20:00 - 21:00 consumption of 178.99 kWh by 28.99 kWh (16 %).

According to the results in the analysis presented in Figure 46 (and assuming that the apartments within the city block had the technical capability required), residential demand response could provide a notable contribution towards leveling out the highest consumption hours between 19:00 and 21:00. With the higher end of the participation estimates, residential load shifting could be able to flatten out the consumption at least for the most part. Of course, most consumption would need to be delayed until at least 22:00 or 23:00 to avoid the rebound effect.

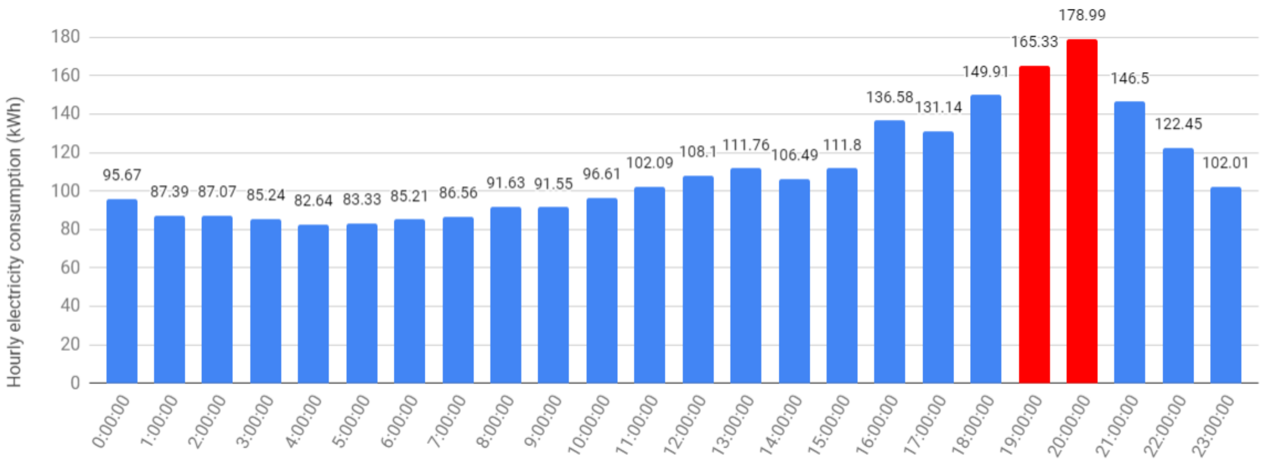

Figure 48: Hourly consumption profile of a Saturday in December with the year's highest consumption hour at 20:00

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6.6.2 Solar power peak shaving potential

Residential solar power could potentially also contribute to peak shaving by covering part of the consumption during demand peaks with solar power generation. However, due to the current electricity market regulation model in Finland, electricity produced by a housing company's solar panels cannot feasibly be shared inside the property grid to be used amongst the housing company's residents to cover their individual, apartment-specific loads (Motiva, 2018). For this reason, solar power installations are usually sized based on only the housing company's electricity consumption, which includes *common loads of the apartment buildings* such as lighting (hallways, yards, etc.), elevators, laundry rooms, common saunas and car heating poles.

Figure 49 illustrates an average day's hourly consumption profile of one of the housing companies located in the city block that was analyzed in chapter 6.4. The housing company consists of an apartment building with 56 apartments. The apartment building was built in 2013 and has district heating and centralized heat recovery ventilation. Although housing companies have their own dedicated electricity connections and the loads are mostly quite different from residential loads, the consumption profile of the housing company's common loads still resembles Figure 24 in shape (an average day's consumption profile for the city block's residential loads) in that the hours with the highest electricity consumption are between 17:00 and 20:00. A slight increase in demand in the morning hours can be seen here as well.

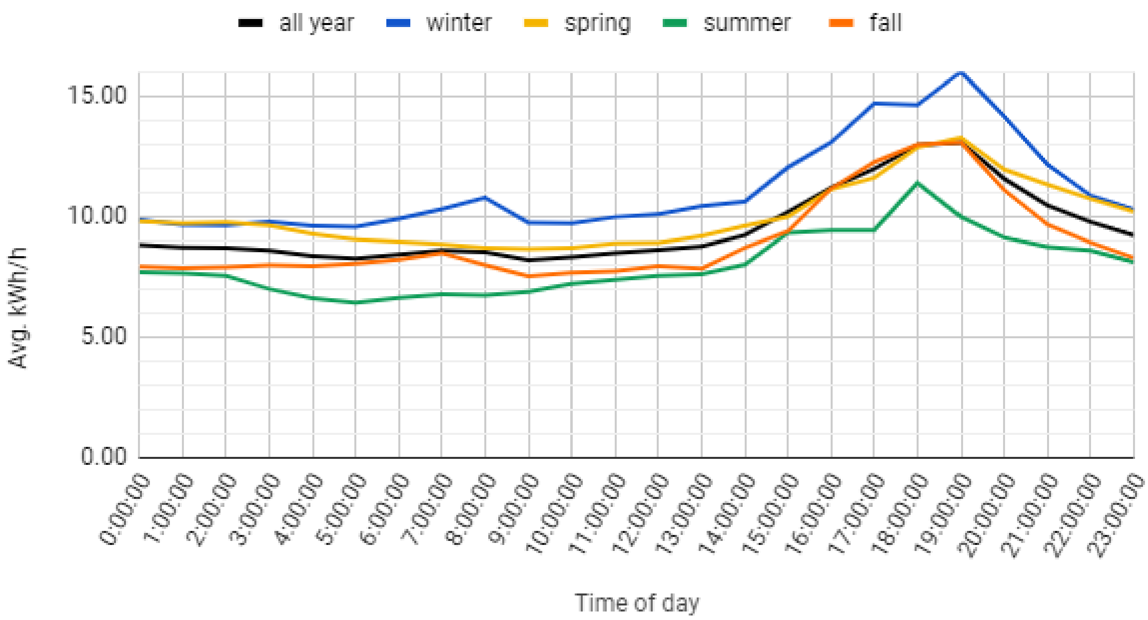

Figure 49: Average electricity consumption of a housing company's common loads for each hour of the day, comparing different seasons of the year (winter: December to February, spring: March to May, summer: June to August and fall: September to November)

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Assume the housing company had a solar power system on the roof of the apartment building for generating part of the electricity consumed by the common loads. Figure 50 shows the housing company's daily electricity consumption over a year with the daily electricity production from a 17.5 kWp solar power plant. It also shows the percentage of the daily electricity consumption that could be covered by this solar power plant.

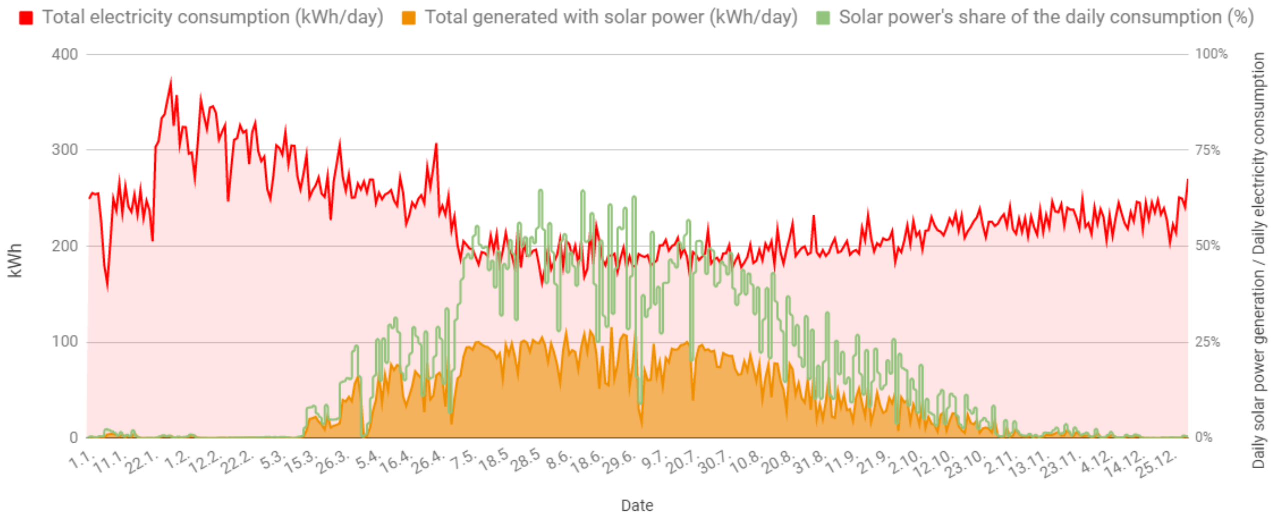

Figure 50: Daily electricity consumption of a housing company over a year in red, and daily solar power generation of a 17.5 kWp solar power plant in orange. Solar power's potential share of the daily electricity consumption in green

The solar production data visualized here is collected from another nearby housing company's solar power plant in Helsinki, and has been slightly scaled up to represent a 17.5 kWp solar PV installation to better match the consumption of the housing company here. The panels are installed in a 15-degree tilt, and half of them have been installed facing east while the other half face west. The surface area of the scaled-up installation is 108 square meters. For reference, the total surface area of the housing company's roof is roughly 1150 square meters. The total amount of electricity generated over the year by the solar power plant in Figure 50 is 13 349 kWh, and the total consumption of the housing company is 83 790 kWh.

Figure 51 shows as an example the week from June that had the largest deviation in the housing company's hourly consumption compared to the average (consumption on Saturday at 15:00 was 95 % higher than the summer's average hourly consumption at 15:00). Consumption increase from the previous hour was also one of the highest (85 % increase). In red, the figure shows the housing company's hourly electricity consumption, and in orange the solar PV generation. In blue, the figure shows the hourly consumption's deviation from the summer's hourly average. Lastly, in green is shown the share of the housing company's hourly consumption that could be covered by the 17.5 kWp solar power plant.

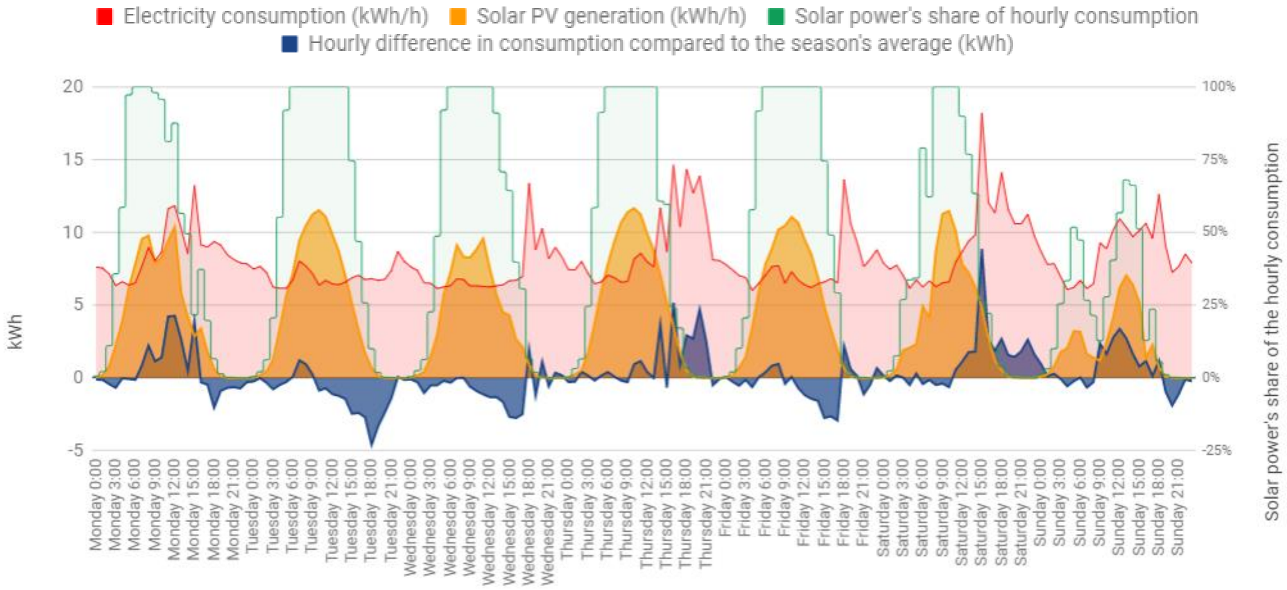

Figure 51: Hourly electricity consumption and solar PV generation from an example week in summer (June)

On most summer days, the electricity generated by solar power covers a significant part of the housing company's electricity consumption. However, within the typical evening peak demand hours (from 16:00 to 22:00, as in the analysis in chapter 6.6.1), only 6-15 % of consumption per day was covered by solar power. The share of each day's maximum consumption hour that was covered by solar power varied a lot depending on whether the demand peaked during the evening hours or earlier in the day. On Monday and Saturday of this week, demand peaked earlier in the day, and 22 % and 26 % of the consumption during those hours was covered by solar power. On the other days the demand peaked during the evening hours, and 0-24 % of the peak consumption hours was covered.

Figure 52 and Figure 53 show similar comparisons for spring and fall. They are similar as the summer profile in that the main solar power generation occurs from the early hours to the afternoon, but is already quite low when the demand for electricity peaks. During the spring week's 16:00 - 22:00 peak demand periods on each day, solar power covered only 1-4 % of the consumption. From the demand peaks that occurred earlier in the day, solar power covered 17-18 %. Most of the peaks that occurred between 16:00 and 22:00 had no simultaneous solar power generation.

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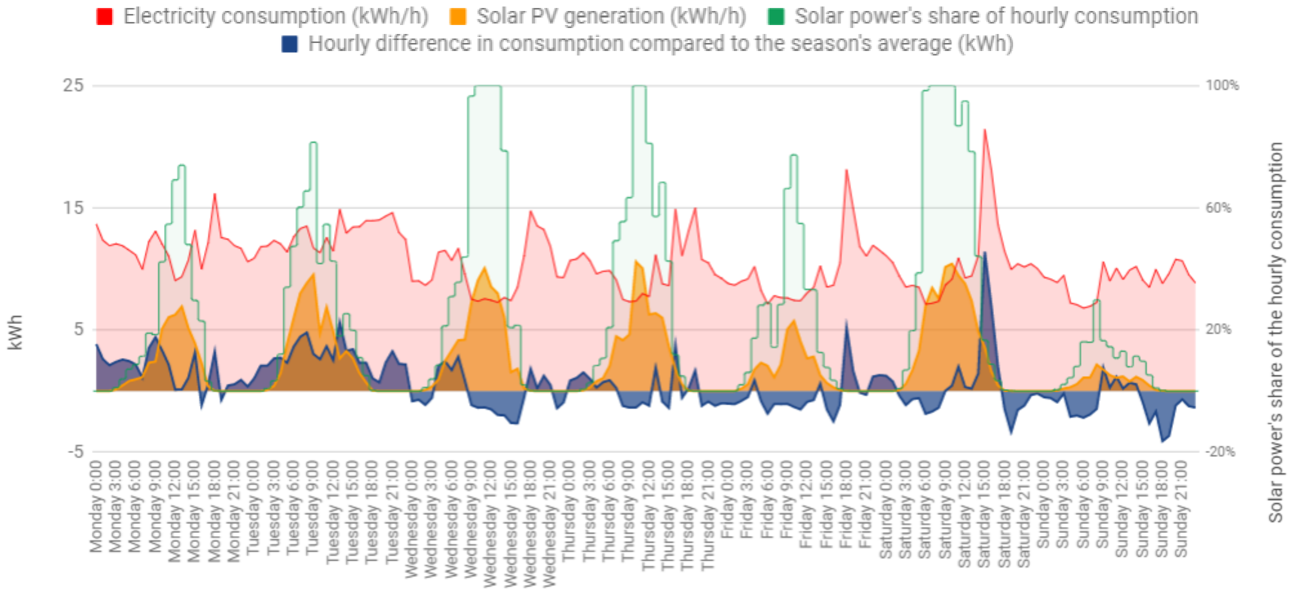

Figure 52: Hourly electricity consumption and solar PV generation from an example week in spring (April)

During the fall week's peak demand hours (Figure 53), 0 % of the consumption was covered by solar power generation. The panels still generated electricity during the days, but would have had no effect on the demand peaks that all occurred between 16:00 and 22:00.

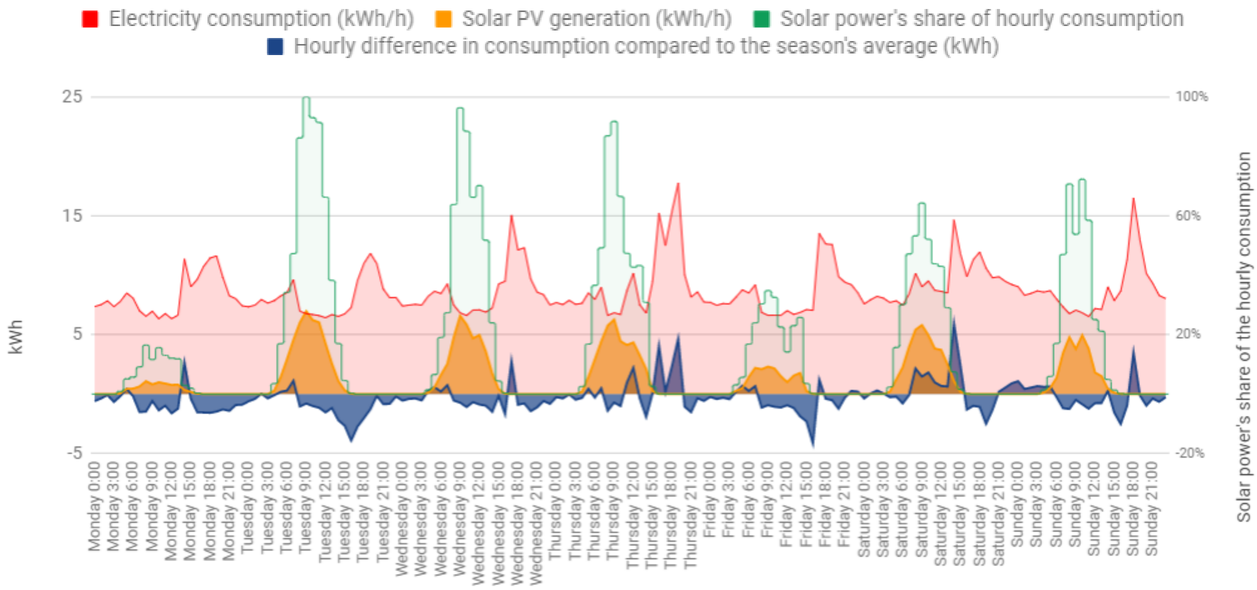

Figure 53: Hourly electricity consumption and solar PV generation from an example week in fall (September)

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This analysis indicates that while solar power could help in leveling out part of the demand peaks that occur in the housing company's electricity consumption during the summer, it may not provide much help during the other seasons of the year when the conditions for solar power are not optimal and the electricity consumption is also higher. Example week from the winter is not visualized here because solar power generation during the winter months was virtually non-existent, especially so during the evenings.

While not optimal for maximizing power generation, if all the panels were installed facing the west instead of east and west, the installation could be better suited for peak shaving purposes as it would generate more electricity during the evening hours when consumption is higher.

Another way to better utilize solar power for peak shaving purposes would be coupling it with a battery energy storage system (BESS), i.e. to store the electricity generated by the solar panels during the day in batteries, and then discharge them during the evening hours when the electricity demand peaks and the solar power generation is lower.

Theoretical maximum potential considering the available roof surface area

A larger solar power installation could of course cover a larger share of the peak consumption. As mentioned earlier, the 17.5 kWp installation analyzed here would require a 108 square meter surface area, roughly 10 % of the housing company's roof surface area. The maximum share of an apartment building's roof's total surface area typically available for solar power installations is estimated to be a little over 40 % (Pöyry, 2015). While it might not be economically feasible or optimal due to cost and the current regulation, according to this estimate, the housing company in question could install a solar power plant covering 460 square meters, over four times larger than the one in the earlier example. This size could scale up to roughly 74 kWp in terms of maximum installed solar PV capacity.

Figure 54 illustrates the daily electricity consumption of the housing company with the daily generation from a 74 kWp solar power plant. Also shown is the daily percentage of the consumption that could be covered by the plant. Total power generation of the solar power plant over the year would be 56 467 kWh, while the total consumption of the housing company was 83 790 kWh.

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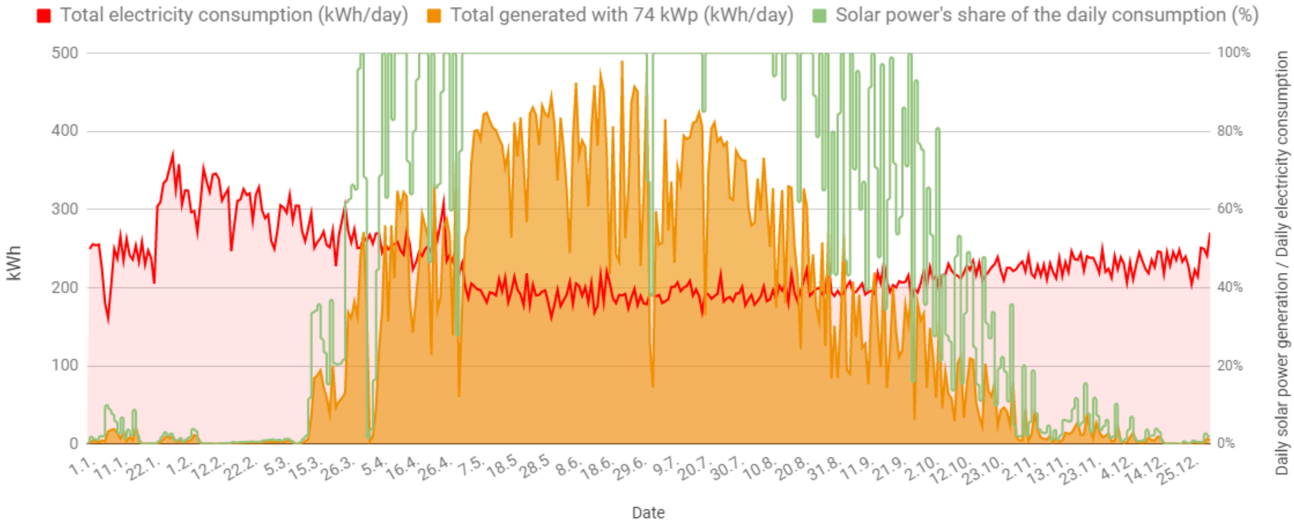

Figure 54: Daily electricity consumption of the housing company and power generation from a 74 kWp solar power plant.

Figure 55, Figure 56 and Figure 57 show the same example weeks as earlier but with a larger 74 kWp solar power plant that utilizes the maximum space available for installation, covering approximately 40 % of the roof's total surface area. During daytime, power generation from the solar power plant exceeds the housing company's consumption by a large margin, except on some seemingly cloudy days in the spring and the fall.

During the summer week (Figure 55), the solar power generation is able to fully cover the Saturday afternoon demand peak, but the peaks that occurred later in the evenings are covered only partly. During this example week's daily peak demand hours (16:00-22:00), the 74 kWp solar power plant was able to cover 27-61 % of the consumption depending on the day. Any hour's consumption before 19:00 had at least 20 % simultaneous generation (and often more), but from 19:00 onwards the solar power generation dropped to just 5 % or less of the hourly consumption.

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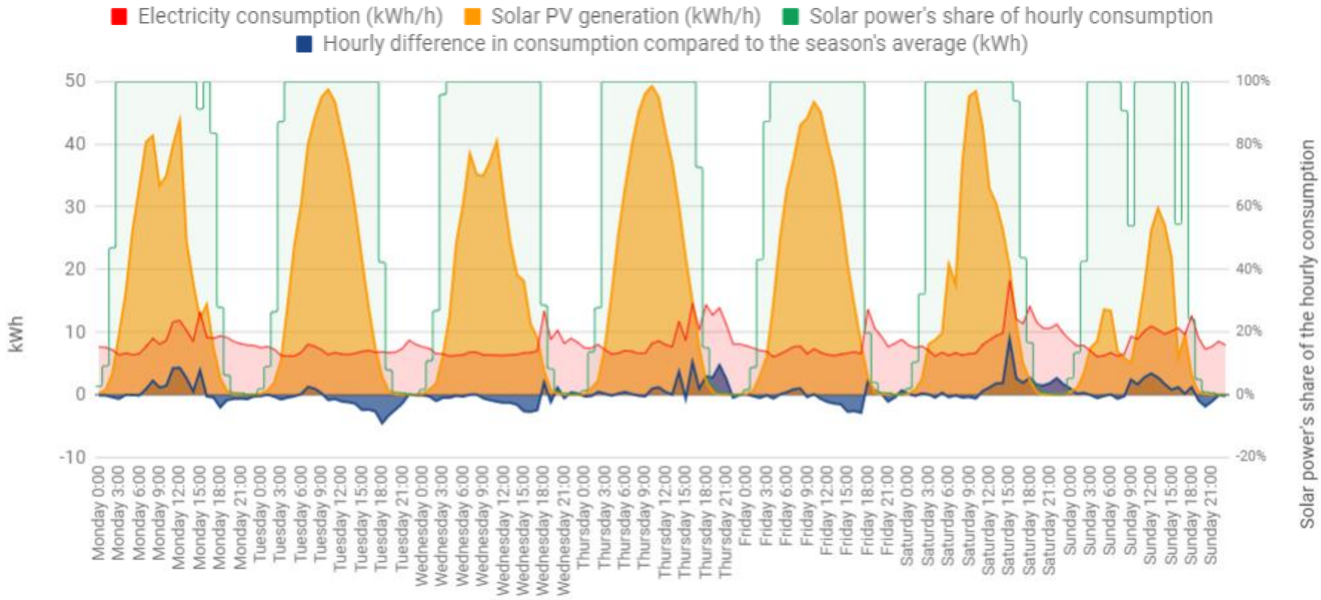

Figure 55: The housing company's hourly electricity consumption and the hourly power generation from a 74 kWp solar power plant, example week from summer

Figure 56 shows another example week from spring. While a significant share of the electricity generated by solar power exceeds consumption during the days, its coverage of the consumption during the peak demand hours of 16:00-22:00 is lower and more fluctuating at 2-15 % depending on the day. Any consumption peak that occurred after 18:00 got virtually no coverage from solar.

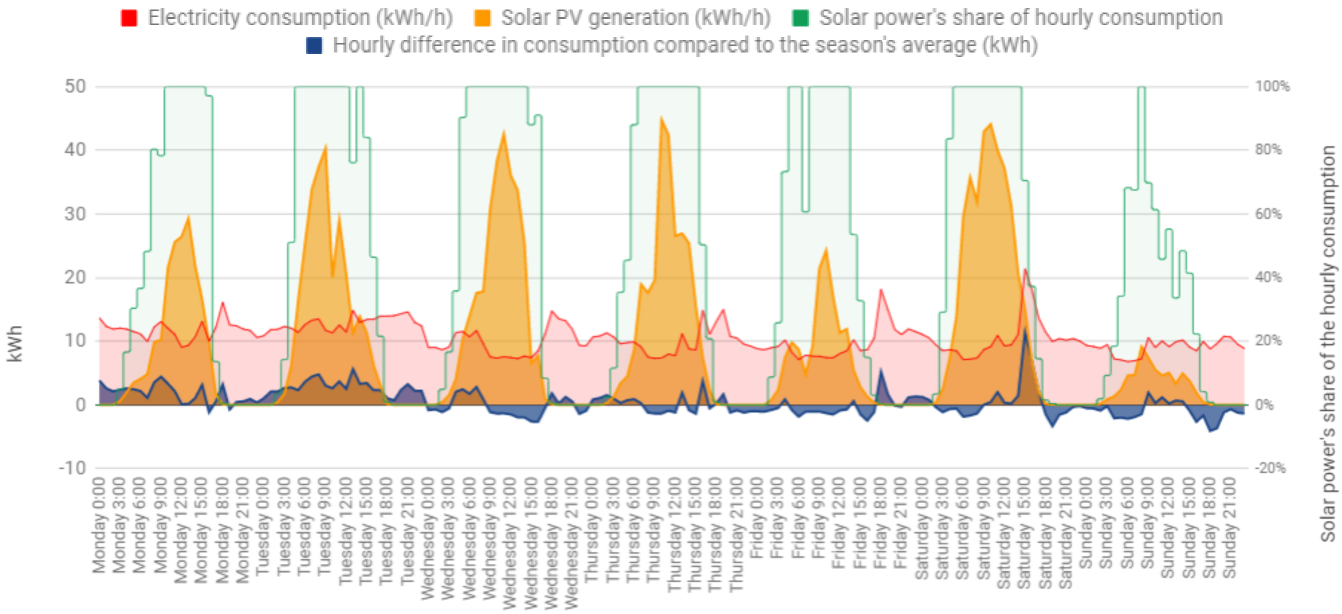

Figure 56: The housing company's hourly electricity consumption and the hourly power generation from a 74 kWp solar power plant, example week from spring

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Figure 57 shows an example week from the fall. While the hourly solar power production still exceeds consumption on most mornings and days, during the peak demand hours in the evenings it is already almost non-existent, providing no contribution towards peak shaving.

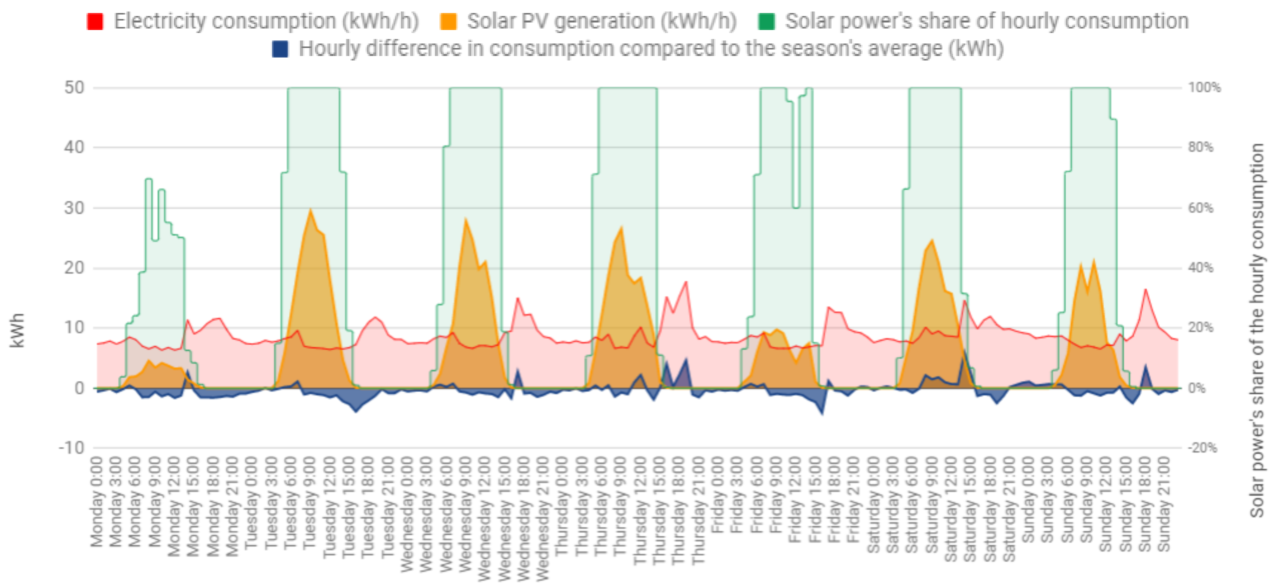

Figure 57: The housing company's hourly electricity consumption and the hourly power generation from a 74 kWp solar power plant, example week from fall

Maximum installed solar PV capacity compared to the residential consumption

Lastly, the regulation may change in the future so that the residents in a housing company might start to utilize the solar power installed on the roof of the apartment building for their own electricity consumption. The last part of this section here will look at a brief comparison of the residential electricity consumption of the whole city block against the estimated maximum solar power generation when considering the maximum installation surface area.

The total surface area of the city block's roof is roughly 2 800 square meters. Based on the previous assumptions, the city block could potentially fit up to 180 kWp solar PV capacity regarding the available roof space.

Figure 58 shows the entire city block's residential electricity consumption on the same example summer week compared to the estimated solar power production of a 180 kWp solar power plant. The green graph illustrates the percentage of the hourly consumption that could be covered with solar power during the week. The results seem similar to the previous comparison between the housing company's common loads and the solar power plant in that the generation from the solar panels often exceeds consumption

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from early mornings until afternoons, but is low when the demand for electricity peaks. Of an average day's consumption during the evening peak hours (16:00-22:00), solar power could cover roughly 10 %. The highest peak demand hours occurred so late in the evenings that the percentage of them that could be covered with solar power is just 0 - 6 %.

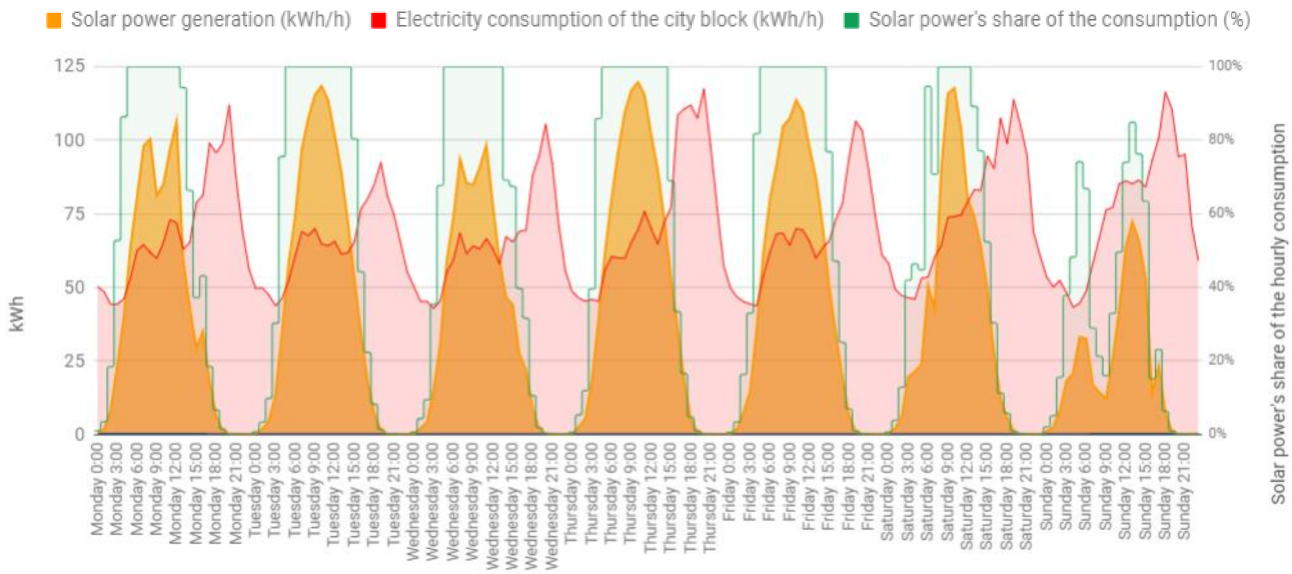

Figure 58: Electricity consumption of the city block and solar power generation of a 180 kWp solar power plant, example week from summer

Figure 59 (for a week in spring) and Figure 60 (for a week in fall) show that even the large 180 kWp solar power plant would provide little help during the demand peaks in the evenings unless coupled with a battery storage system.

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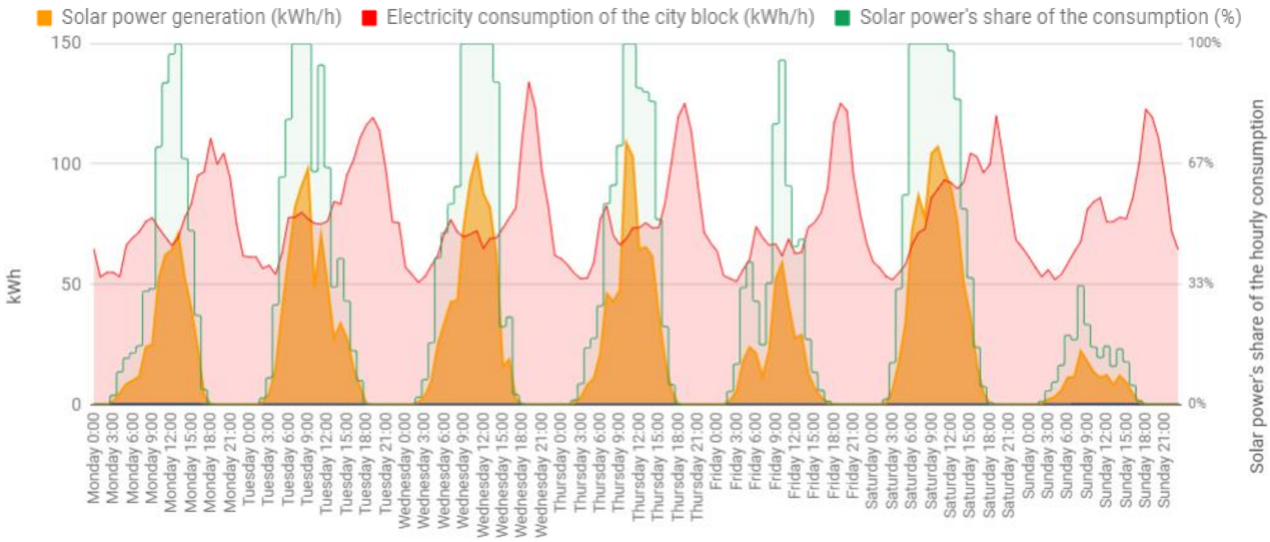

Figure 59: Electricity consumption of the city block and solar power generation of a 180 kWp solar power plant, example week from spring

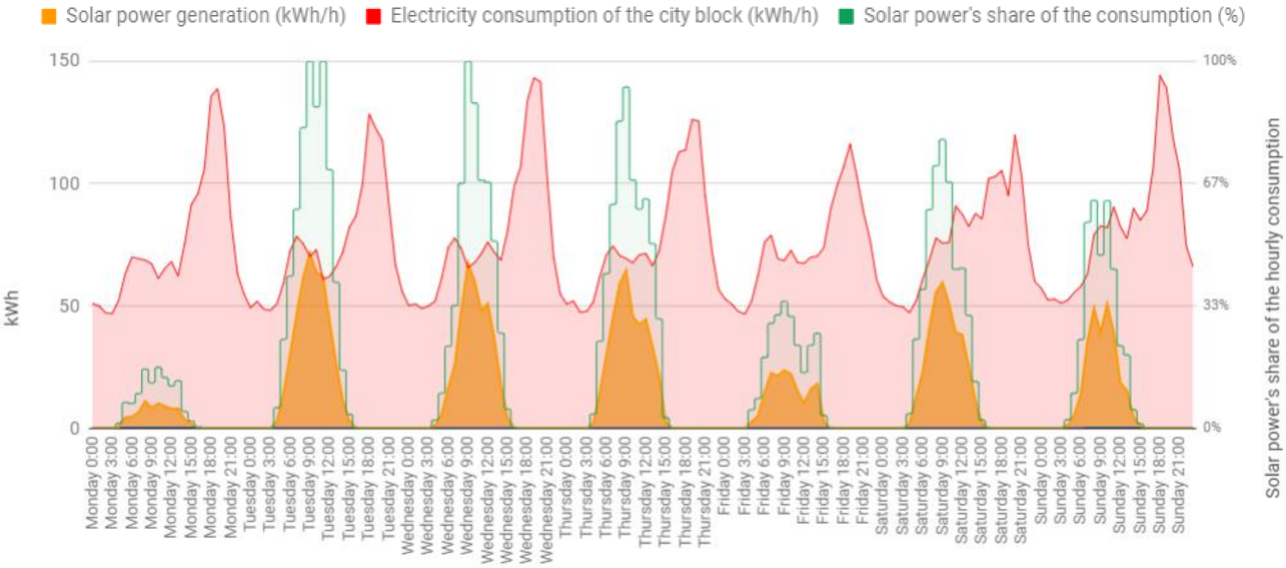

Figure 60: Electricity consumption of the city block and solar power generation of a 180 kWp solar power plant, example week from fall

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6.7 Conclusions on residential demand response and solar power peak shaving potential

Residential electricity consumption is not always considered the most practical source for demand response because individual electrical loads are low and consumption is relatively inflexible. However, it could be beneficial to decrease some of the demand peaks that typically occur during the fairly fixed and predictable high-demand evening hours in order to flatten out the fluctuating consumption. Engaging residential loads in demand response could also add stability to the power system that needs solutions in order to adapt to the growing share of renewables.

Home automation systems are becoming more common in Kalasatama, and with smart appliances, they could enable Kalasatama's residents to monitor and control their consumption more actively and to participate in demand response. Likely a vast majority of residents would be uninterested in *actively* participating, which highlights the importance of automated processes and adequate incentives. A recent survey in Finland showed that 49 % of residents would consent to a third party remotely controlling their electrical loads if it happened without the residents noticing it and if it benefited the residents in some way (Energiatalous, 2019). Many also wanted to get information about their home's demand peaks, and 65 % were willing to adjust their consumption by avoiding simultaneous use of high-consumption appliances.

Some loads, such as refrigerator-freezers or floor heating, could potentially be aggregated, and when necessary, be remotely controlled by the aggregator without needing manual action from the residents. Shiftable loads such as dishwashers, washing machines and tumble dryers could be used for load shifting in order to delay their electricity consumption during the high-consumption hours. This could require residents to manually set timers and/or adjust their consumption habits to an extent. Again, any participation that requires residents to take active action should be assumed relatively low by default, which further signifies the importance of incentivizing the residents. However, even with the estimates on the lower participation in this section's analysis, based on the assumptions made, it would seem that residential demand response could contribute towards mitigating at least some of the residential demand peaks in Kalasatama.

Research has shown that the monetary savings for individual residents participating in demand response are typically low, which is why alternative incentives could be considered as well in order to engage a meaningful number of residents. For example, before or during a demand peak, residents could be notified with a request to limit heavy consumption for a few hours, and as a compensation, they could be offered a free wash on a dishwasher during nighttime or a certain number of free kilometers for their electric vehicle (with timers set to start after midnight). Developing functional and intuitive interfaces for participating is likely also essential.

The potential of utilizing solar power for peak shaving in Kalasatama during demand peaks was also considered. However, because of the temporal mismatch between solar power generation and high residential electricity consumption, solar power seemed to effectively contribute towards peak shaving only during summertime when the conditions for solar power are optimal. In order to get the full benefits of solar power during demand peaks, battery energy storage systems would likely be required.

7. Definition of a demand response strategy

7.1 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.

7.1.1 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.

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About Fourdeg's Service

Fourdeg is a company for optimizing heating of buildings. The system operates electronic wireless radiator thermostats (see) 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.

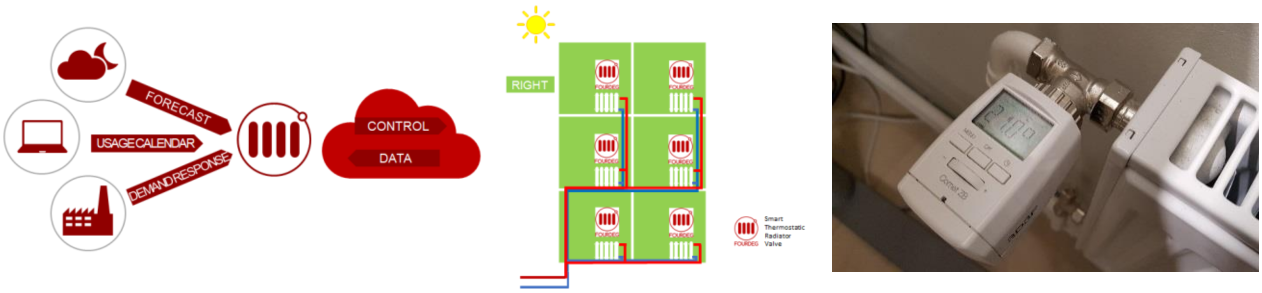

Figure 61: Fourdeg Srart Heating(R) & Smart thermostat at Viikki office building (figure by HEL)

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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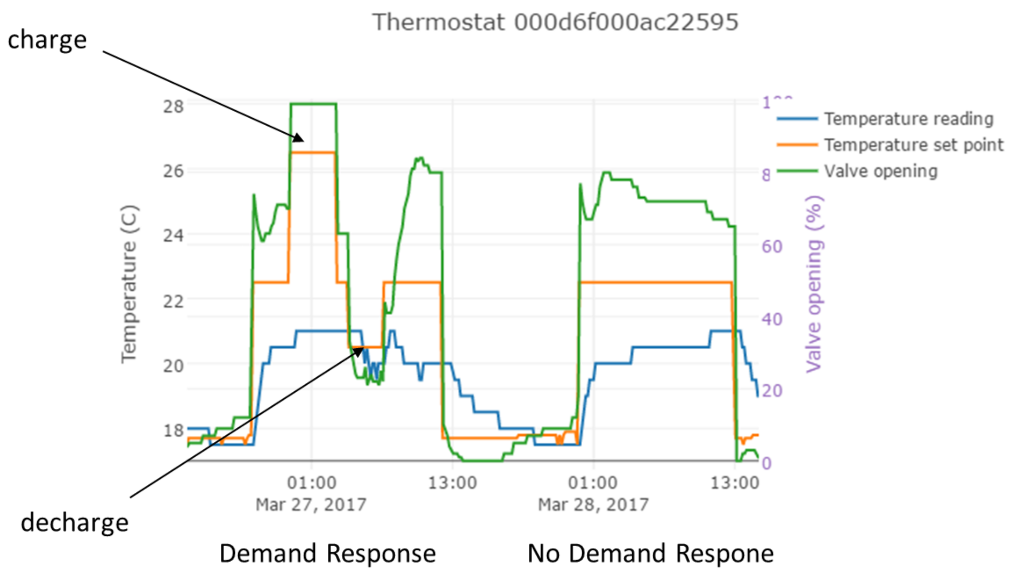

Figure 62: Schematic representation of a day with heating Demand Response and a day without Demand Response. Charge refers to heating the rooms before the peak load time, and then during the high peak load times the room temperature is lowered to decharge the thermal energy used.

VTT has mounted 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.

7.1.2 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

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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, in commercial operation phase, 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 63 below.

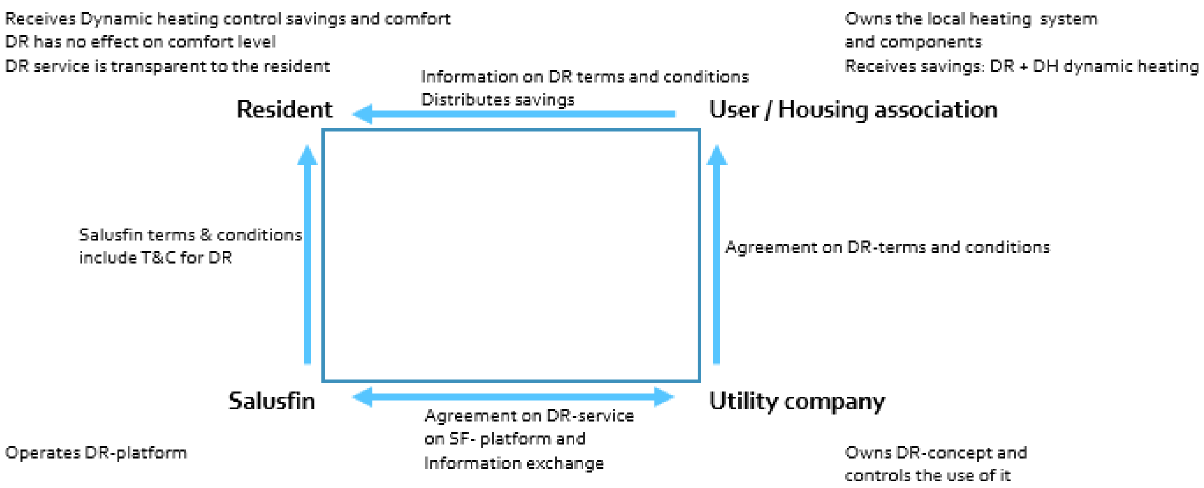

Figure 63: Contracts required between the four parties participating to the thermal demand response [figure by Tapio Toivanen, Salusfin]

The district heating information is retrieved from utility company interface, which is offering three alternatives: -1, 0, +1 degrees and this information is reflected to apartment heating.

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7.2 Electrical demand response strategies

Electrical demand response was 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 was 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 were 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. The vertical axis in Figure 21 in chapter 6.4.1 shows the hours' respective electricity consumption, and the range of values on the vertical axis indicates how widely the hourly consumption values are distributed on a given weekday over the year. The demand response potential has been calculated from the data as for example the visualization shows that the hourly electricity consumption of the city block rarely drops below 40 kWh, and during middays is mostly limited to somewhere between 60 and 100 kWh, except on weekends, when the midday consumption is slightly higher.

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.

7.3 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.

In Helsinki, 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. Helen is currently evaluating the potential of heat demand response in Helsinki with a preliminary

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evaluation project contributing to mySMARTLife district heating & cooling actions. More information about the preliminary evaluation project is given in deliverable D4.5.

The energy company, Helen in Helsinki, participates in electricity demand response with its own assets Helen also operates as an aggregator offering a service for its customers with flexible resources in terms of electrical loads. The heat demand response is also seen as a 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 pilots and evaluation projects, recognizing the value of the heat demand response in Helsinki is aimed.

8. 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.

This deliverable also defines the strategies for demand response. 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 and a comprehensive demand response potential analysis for residential buildings carried out. In the context of demand response, also the viewpoint of the local energy company Helen is presented.

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