Results of Finnish demonstration

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1. PUBLISHABLE EXECUTIVE SUMMARY

The **Objective** for this report is to describe Finnish demonstration site in Helsinki. The objectives were met working together with city officials, constructor, board of housing company and the dwelling inhabitants.

Overall aim for the demonstration was to compare the neighbourhood area before and after implementation of EEPOS software, including usability tests to the system. As a practical result reduction of CO_2 emission was expected as well as key numbers and findings. All this work was carried out by gathering relevant information from the areal level information given by the measuring equipment.

During the data collection privacy issue was come up. Thus part of collected data was anonymised and generalised to ensure privacy.

The work performed has resulted the following major achievements:

- Defining the needed hardware
- Defining the needed software as well as need for software improvements
- Software improvements
- EEPOS system concept installation on areal, building and dwelling level
- Simulation software for fault detection
- Simulation software for engineers to easily discover and access problematic areas
- User interface for examining own energy usage
- Interfaces and data transfer for the control room to monitor and surveillance data gathered from the area

The **Intentions for use and impact** for the work done is to gather data on living environment in order to have equipment setup changes aiming for energy positivity as well as user behaviour impacts. The work done for this deliverable is the basis for advanced system and setup changes within companies own research & development & innovation activities.

Dissemination of this deliverable will be taken place as described in D7.3 Dissemination and exploitation task of EEPOS-project.

2. INTRODUCTION

2.1 Purpose and target group

The purpose of this document is to describe the results of the Finnish demonstration. The report is the outcome of Task 5.1 under Work package 5 (WP5) in the EEPOS project. The report provides all relevant information, which needs to be taken into account for those who want to implement a similar pilot to demonstrate energy management activities in energy efficient neighbourhoods. The report includes technical definitions of the solution which was be implemented in the demonstrator buildings and prescribe existing frame conditions as well as the main results of the demonstration.

2.2 Contributions of partners

The report was written with contribution of the EEPOS partners: Caverion, VTT, Fatman.

2.3 Baseline

The Finnish demonstration site was changed from the preliminary plan from city of Espoo to the current place in the city of Helsinki as described in EEPOS DoW. The activities was somewhat changed due to the reason the new demonstration site is having District Heating system (CHP) instead of renewable energy option planned to build at the originally planned demonstration site. According to local regulations all buildings must be connected to the District Heating System in areas the District Heating exists.

Despite of the switch of the Finnish demonstration site the planned activities (stated in DoW) of the EEPOS project are to be met utilizing the Merenkulkijanranta area as the demonstration site for EEPOS system.

2.4 Relations to other activities

The input of Task 5.1 is mainly based on the works and results of the work packages 1, 2, 3 and 4, where the EEPOS specific tools and platforms are developed and tested in prototypes. The Deliverable D4.1 – “Integrated systems ready for demonstration” is a very important input, because it describes all the relevant technical aspects to implement the developed technology in real world scenarios, like the Finnish demonstrator. Furthermore the Deliverable D1.1 – “Validation strategy and application scenarios – revised version” includes the following important information:

- Which number of scenarios will be put when into practice and evaluated at which demonstration site
- How the status of the demonstration sites is defined
- How potential problems arising from the small number of energy sources at demonstration sites, the weak integration of renewable energy sources at demonstration sites and the lack of price fluctuation for end users will be tackled or circumvented.
- What is planned to balance the fact that end-users have no possibilities to change the energy supplier.

Chapters 1, 2, 3, 4, 5 and 9 in this report are updated version of the report D5.1 “Baseline report on Finnish demonstration”. Chapters 6, 7 and 8 include the results conducted during the project months 25-36.

3. PRE-CONDITIONS OF THE DEMONSTRATOR

3.1 Location and scope

The location of demonstration – apartments above water is presented in figure 1.

Merenkulkijanranta is the very first residential area in Finland built partly above sea. The area is located in Helsinki in one of the most respective residential areas. Building at occasionally stormy and windy property at times freezing weather was both difficult yet innovative solutions demanding from both designers and engineers. The ten building modern high class residential area was selected as Construction Site of the Year in 2011.

Figure 1 *Location of the Finnish Replicator site*

Scope of construction was to build high class living environment in an ecologically sustainable manner as well as to provide user friendly and easy to use interface for adjusting heating, cooling and HVAC systems. New possibilities utilizing modern automation techniques was considered and implemented. At summer time the cooling of apartments is using sea water energy.

Users habits of using energy and adjusting living conditions are guided to energy friendly using information gathered from automation systems the users are able to follow. Apartments are provided with YIT Niagara equipment that follows and centrally steers HVAC, heating, cooling, sea water and water measurement systems. Included in the system was built a user interface where habitants may with extensive precise adjust individually each rooms with settings of users own choice.

The apartments are connected to Caverion's 24/7 control room where conditions are followed on apartment, house and areal level. Measurement information of the system is stored and analysed by control room personnel as well as by technicians maintaining the area conditions.

Architectonically the construction area represents ambitious designing together with latest techniques. The buildings are forming a comb arrangement that outlines a terrace overview against shore. The two layer apartments closest and over the sea provides a feeling of living close with the sea environment. The area consists of 225 apartments providing total floor area of 25.000 m².

3.2 Neighbourhood characteristics

The area Lauttasaari, which is presented in figure 2 is one of the most expensive residential areas of Finland located only couple miles from the heart of Helsinki. The apartments are placed at sea shore, partly above sea. All dwellings are provided with the eTalo network service where inhabitants are able to follow key figures of usage for example temperature individually room by room. eTalo also supplies information on housing company's news, tips to ease living e.g. food markets, and laundry service. Inhabitants may book common sauna and club facilities right from their own apartment. The residential are also offers indoor and outdoor activities like gym and kayaks. Almost 300 car parking facility for cars is located under the spacious courtyard.

The heating for the housing companies is provided by district heating. There for in the EEPOS system heating was not considered as part of the energy positive neighbourhood characteristics.

3.2.1 Neighbouhood area as a whole

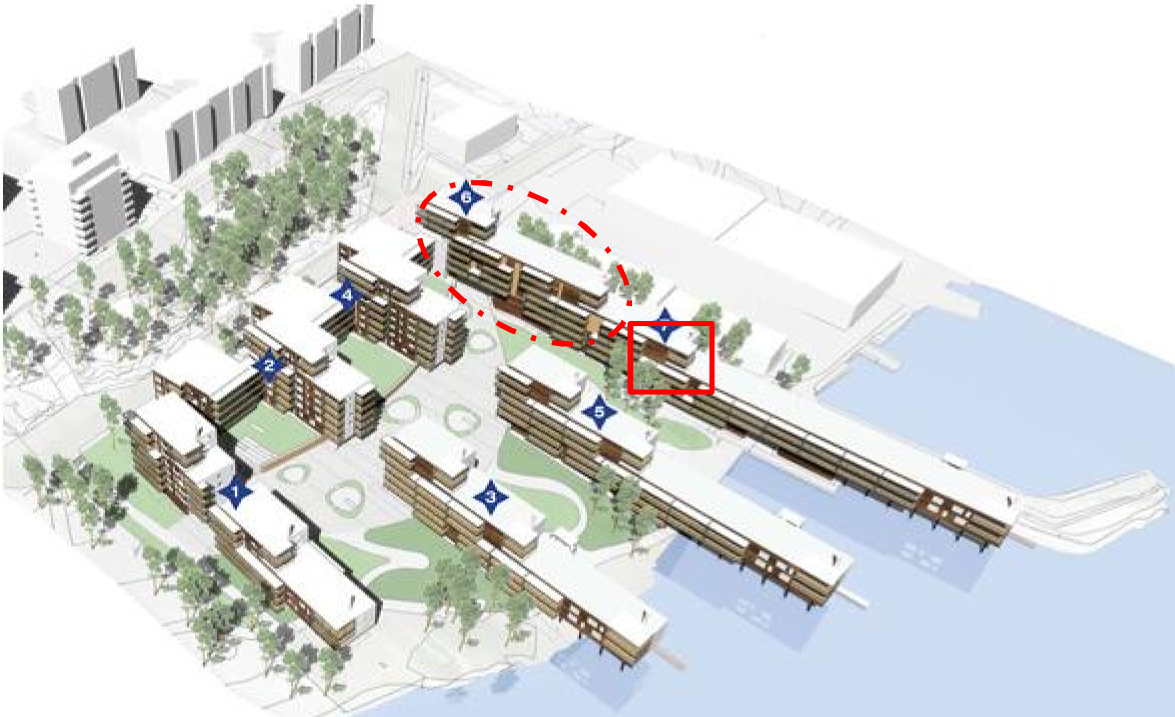


Figure 2 *Areal figure of Merenkulkijanranta, demonstration building circled*

Merenkulkijanranta was the first construction site of YIT where areal level sea water cooling system was placed. The sea provides energy witch is lead to cooling exchanger from deeper of the gulf. From this exchanger the piping leads to building exchanger.

The housing companies are provided with:

- Sea water cooling (-heating)
- YIT Niagara automation system
- Caverion control room

- Electrical housing handbook (http://www.yitextra.fi)
- YIT RAMI (Reporting And Monitoring Instrument)

3.2.2 Phase I – 1st demonstration building

Real Estate information of the building is presented in table 1:

Table 1 *Characteristics of housing company*

Information	Data
Apartments	32
Elevator	Yes
Car parks for sale	33
Energy class	A2007
Heating	District heating
Additional Service	Access control, Building systems control, Building company extranet
Property	Own

The building is shown at Figure 2 as house number 6 (circled red). Sketch drawing of pilot software and EEPOS connections is presented in figure 3.

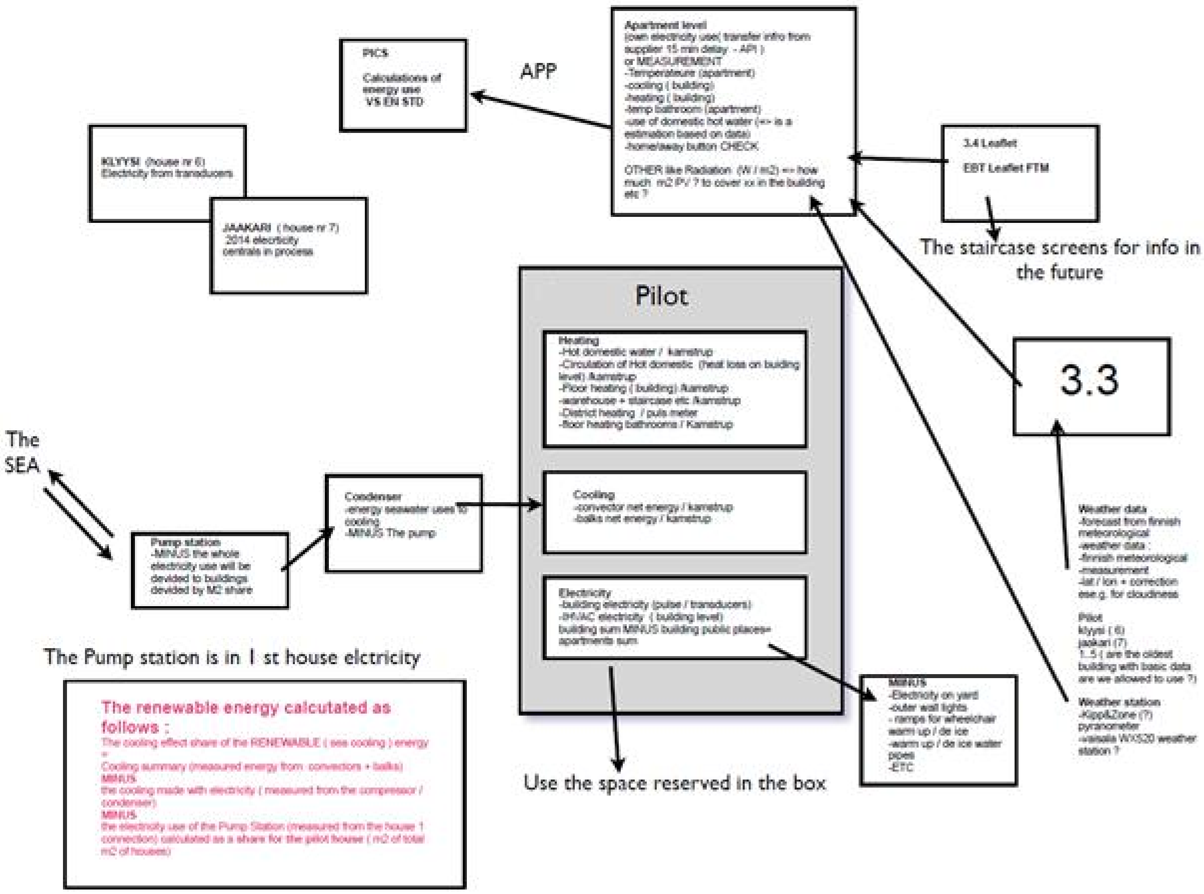


Figure 3 *Pilot software and EEPOS connections*

3.2.1 Phase II – 2nd demonstration building

Real Estate information of 2nd building is presented in table2:

***Table 2** Characteristics of housing company*

Information	Data
Apartments	51
Elevator	Yes
Car parks for sale	60
Energy class	A2007
Heating	District heating
Additional Service	Access control, Building systems control, Building company extranet
Property	Own

The 2nd demonstration building is shown at Figure 2 as house number 7 rectangled.

3.2.1 Decision making system for housing company

As Merenkulkijanranta area is a high class area most inhabitants are technology driven. Tenants have been attracted from the very beginning of EEPOS team first contacts to participate EEPOS project as end users. First contacts to housing company and tenants took place in 2012 as EEPOS team members visited housing company management meeting with the constructor to advice what the energy positive neighbourhood is about and what are the characteristics.

City officials are giving some guidelines as building construction methods. These methods are being considered by constructor, building systems company (Caverion) and EEPOS team. According to these guidelines EEPOS team has developed a plan on what to measure, show to tenants, the ability for tenants to adjust settings and how this interacts with the objectives of EEPOS project. These plans and changes to the plans have to be accepted by the housing company management. The management consists of tenants voted to the management group. The management group grants permissions on measuring, adjusting and equipment installation. In addition to this the each apartment inhabitants need to be asked permission also. As EEPOS represents new technology it has been relative easy after the housing company acceptance to find tenants interested in taking part of EEPOS as end users. The decision making model of Merenkulkijanranta as whole is presented in figure 4.

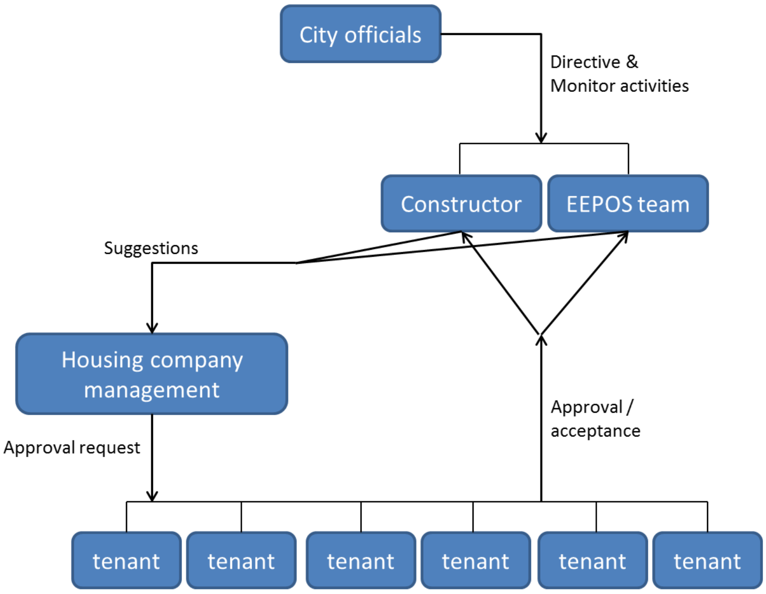


Figure 4 *Decision making model for Merenkulkijanranta*

Users are able to adjust manually climate conditions and energy usage according to the statistics they follow. The project has raised the awareness of tenants and is a self-educating process where EEPOS team has estimated a 15% saving may be made for each housing company. However awareness about build technical system has proved to be low. The modern building automation system and interdependences between all installed equipment are challenging to understand by an expert as well.

3.3 Building technical system characterization

Speciality: in the area exists Sea water cooling – heating for all housing companies. The Sea water cooling – heating chart is presented in figure 5.

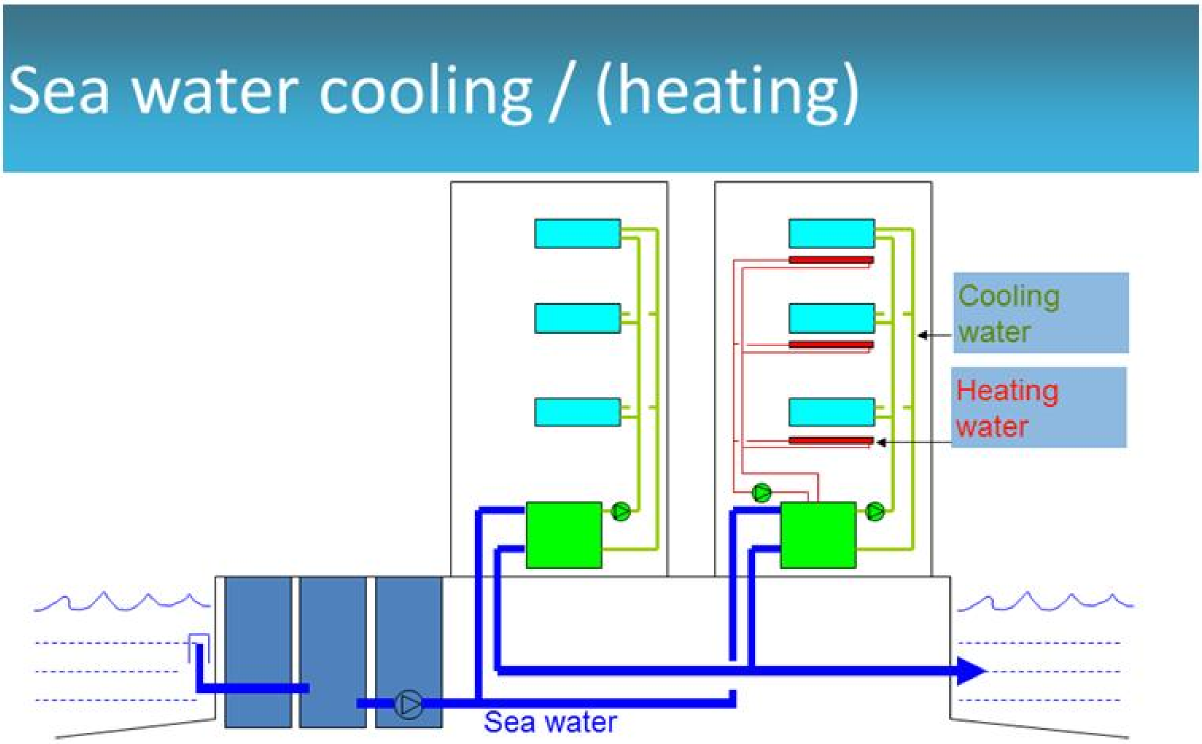


Figure 5 *Sea water cooling – (heating) chart*

In the buildings the following characteristics exist:

- Real time remote monitoring
  - Web based user interface
  - Extensive data collection
  - Ease process adjusting
  - Analysing fault
- Dwelling level water consumption measuring
  - Ultra sound technics, buss interface
  - Enabling consumption based invoicing
- Condition control using room adjustments
  - HVAC
  - Chilled beam
  - underfloor heating
  - Fan Convector
  - temperature measuring, condensation guard

Energy saving using home – out switch

In figure 6 is presented water consumption measuring. In figure 7 is presented monitoring and reporting information screens.

Figure 6 *Water consumption measuring*

Reporting & monitoring information

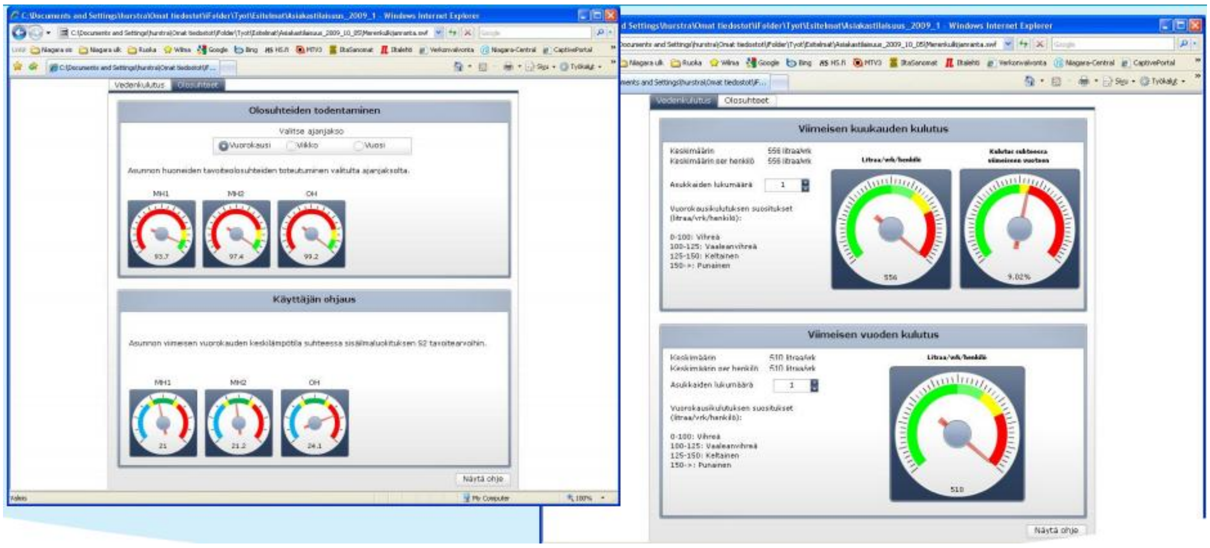


***Figure 7** Monitoring and reporting information screens*

Niagara

The Niagara Framework is a helpful tool for buildings towards more energy efficient, reducing energy usage and driving down costs. Niagara Framework also enables to reschedule operations in buildings which helps cutting down peak loads. Today, there are over 235,000 instances of Niagara operating in 45 countries worldwide in office buildings, manufacturing plants, mission-critical facilities, hospitals, educational and government campuses, military bases, hotels, retail stores, airports as well as dwellings. In figure 8 is presented Monitoring interface top on Niagara framework.

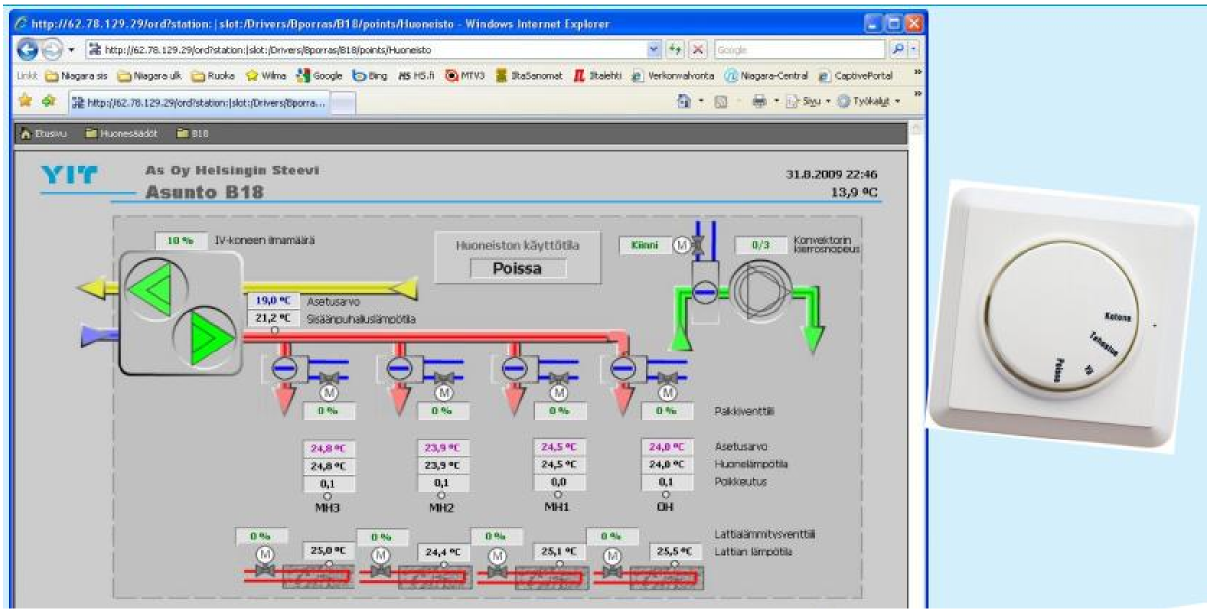


***Figure 8** Monitoring interface top on Niagara framework*

Built on an open architecture, the Niagara Framework merges multi-vendor automation systems and real-time integration into a single, extensible platform that monitors, manages and controls the power consumption of all building systems and drives energy efficiency and reduces energy costs. Niagara takes into account all critical areas that form the subsystems that make a building function including lighting, heating, ventilation and air-conditioning (HVAC), security, and energy management. It allows devices to share information with each other and streamlines them into a common system where management can control and monitor the buildings' operations.

Niagara has removed the barriers to assess the proprietary and legacy data from different systems in a facility. It is the bridge between systems and devices and simplifies the process of connectivity and integration that makes building and facility management easier.

Niagara is a scalable platform that delivers measurable ROI enabling users to capture the benefits of integration, automation and energy control of their buildings and maximize the value of information in real-time contained within them.

In addition to integrating energy consuming devices and systems within a building and getting them to work together to be managed, controlled and operate at optimum levels, Niagara also includes energy measurement and verification tools options that allow users to implement the most efficient and sustained energy strategies in a building today.

As a real-time integration platform and automation infrastructure, Niagara allows users to deploy optimal energy and environmental management strategies that notifies about events before they occur and provides users with the tools to execute control such as schedule and temperature adjustments or activation of on-site generation. Niagara interacts in real-time, with the systems that control the energy consuming and generating equipment in a facility.

The technology also enables users to collect information and benchmark buildings to expose operational inefficiencies. From a green building perspective, Niagara allows users to capitalize on accurate and concise intelligence relating to the energy performance of a building in order to achieve lower energy consumption and enhanced efficiencies.

4. TECHNICAL ASPECTS OF EEPOS IMPLEMENTATION

4.1 Architecture of ICT systems

Finnish demonstration utilizes the architecture specified in T3.1. Caverion Jace devices are used as data source using oBIX interface. In the T5.1 were added Active Poller component to the ICT platform to enable also passive data sources. Trend within the automation systems are to offer passive rest API's to enable access to the data. To be able to utilize this we needed active component to do the actual data reading from the source and storing it to our OpenJEVIS database through implemented proxy service. Currently it is possible to have active data source like Ogema storing the data directly to the database through proxy or to have passive data source and utilize the Active Poller component. Currently only oBIX interface has been implemented but the principles are the same for any REST based interface and it is relatively fast to implement similar solutions. In figure 9 is presented the system architecture.

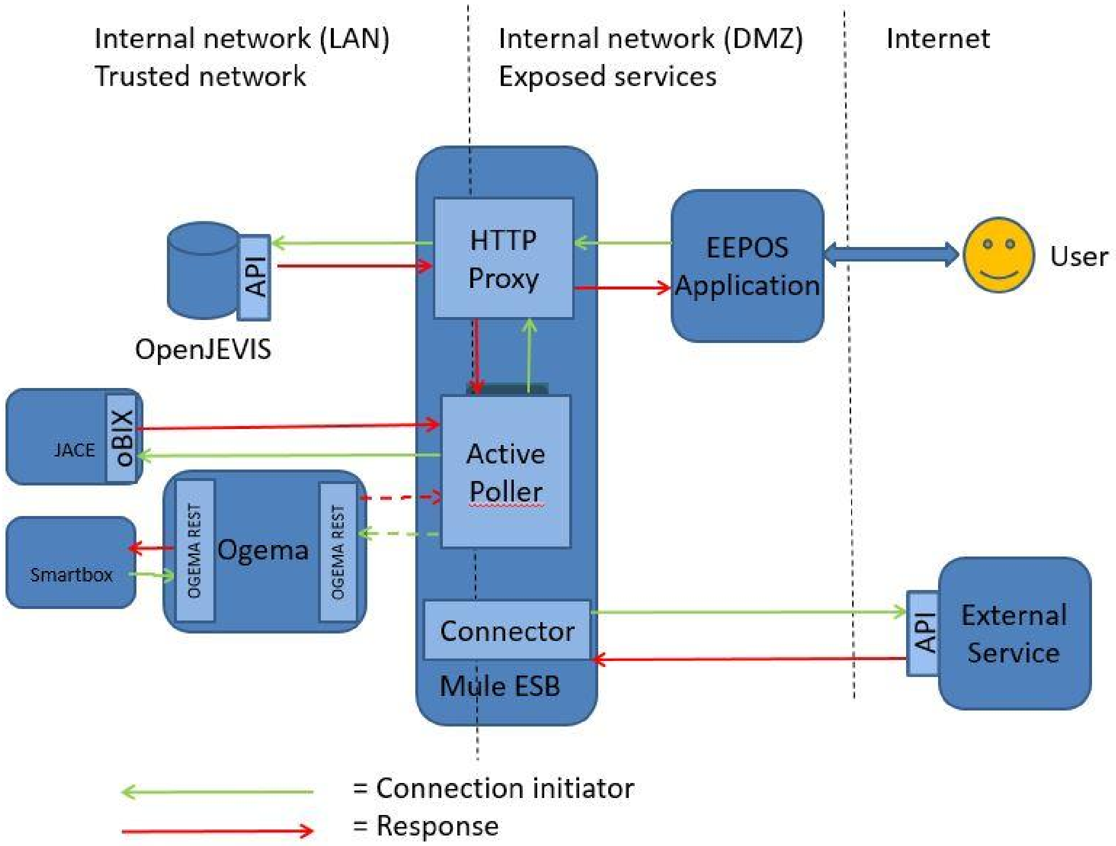


Figure 9 *System architecture from D3.1 (updated in T5.1)*

For EEPOS application we are using the Energy Brokering Tool (T3.2) and End-User Collaboration Tool (T3.4). EBT is able to utilize data directly from the OpenJEVIS database.

Jace devices locates in the building and all of the other components are used from the cloud. For this demonstration it is suitable solution, for production use in real case there is lots of redundancy and security issues that would need more advanced solutions.

4.1.1 Concept of hardware system

In Neighbourhood

Heating (one for each condominium)

Merenkulkijanranta area is connected to district heating and has its own heat exchangers for domestic hot water and heating networks. Heat is being extracted to apartments via floor heating. Staircases and other rooms in shared use are heated by radiators. In addition, 1st demonstration building condominium has a separate heating network for floor heating in bathrooms. In figure 10 is presented district heating process view for remote controlling.

Bill of material of real-estate automation for heating:

- Web server; Tridium JACE 660
- Controller; Caverion UIO032
- District heating control valves / actuators; Belimo R..D, HRYD24-SR
- Temperature sensors, heating network; Produal TEAT NTC10
- Temperature sensor, domestic hot water; Produal TENA NTC10
- Heating network pressure sensors; Produal VPL 16
- Energy meters, water; Kamstrup Multical 402, 602
- Energy meters, electricity; Carlo Gavazzi EM21, EM24

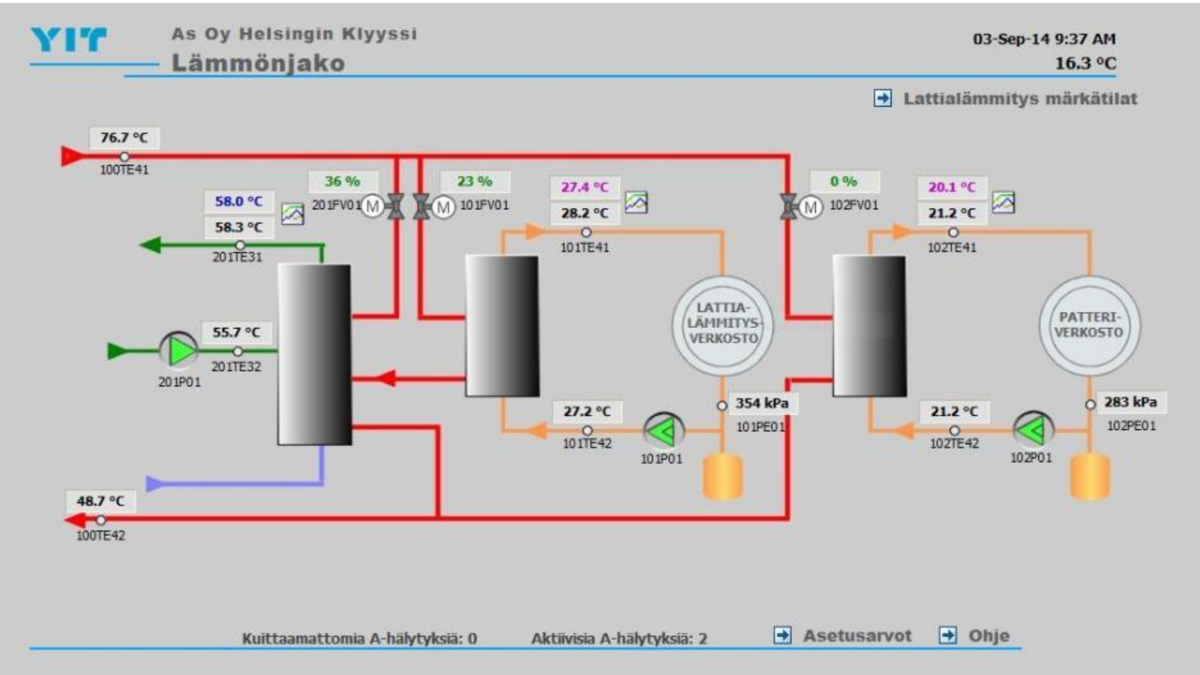


***Figure 10** District heating process view for remote controlling*

Cooling (one for each condominium)

Merenkulkijanranta condominiums are equipped with water chillers that use sea water in their condensing circuits. Cooling water is then shared for fan coil unit network and chilled beam network. Fan coil units are equipped with drains but chilled beams are not, so chilled beam network has its water temperature controlled by dew point of the outdoor air to prevent condensing. Pressure differential over each cooling network is kept constant by circulation pumps controlled by pressure differential sensors. In figure 11 is presented cooling network process view for remote controlling.

Bill of material of real-estate automation for cooling:

- Controller; Caverion UIO032
- Temperature sensors; Produal TEAT NTC10
- Cooling network pressure sensor; Produal VPL16
- Cooling network pressure differential sensors; Produal VPEL 4.0/6.0
- Control valve / actuator; Belimo H540B / NVC24A
- Energy meters, water; Kamstrup Multical 602
- Energy meters, electricity; Carlo Gavazzi EM21, EM24

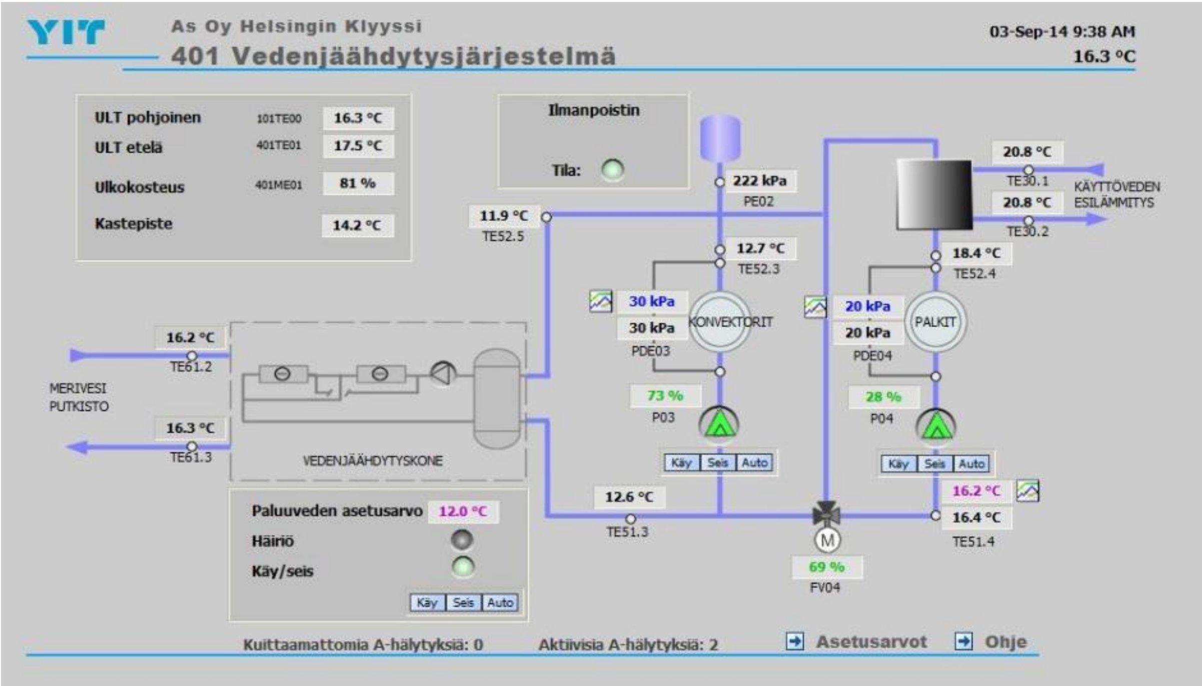


Figure 11 *Cooling network process view for remote controlling*

Seawater pumping station

Merenkulkijanranta condominiums are connected to circulating sea water network that is used for water chiller condensing circuits. Pressure in the network is maintained by a pumping station equipped with two sea water pumps controlled by a pressure sensor.

Bill of material of real-estate automation for seawater pumping station:

- Web server; Tridium JACE 230
- Controller; Caverion UIO 032
- Temperature sensors; Produal TEAT NTC10
- Seawater network pressure sensors; Produal VPL 16
- Seawater level sensors; Labko DMU 08S
- Frequency converters for pump drive; Danfoss FC100

Other devices in common

- Weather station; Vaisala WXT-520
- Pyranometer; Kipp & Zonen CMP6

In Dwellings

Dwellings are equipped with room controllers controlling heating, cooling and ventilation. Each apartment has one or two fan coil unit and each bedroom or living room has one or multiple chilled beams. Heating is executed by floor heating which has different circuits for each bedroom and living room. Bathroom has its own floor heating connected to a separate network. When temperature rises, floor heating is first deactivated, then chilled beams are activated and at the same time ventilation is increased by controlling the air handling unit. If temperature keeps rising, fan coil unit is then activated. Room temperature can be set by a set point knob installed into each bedroom and living room affecting to all heating and cooling equipment at the same time.

Chilled beams are equipped with condensation detectors that are activated if excessive humidity is causing the chilled beams to condensate despite chilled beam network temperature being controlled by outdoor dew point. When activated, condensation detectors close the valve in that particular chilled beam and turn the fan coil unit on to dry out room air.

Apartment is equipped with room operating panel that includes four different modes:

1. "At home" Heating and cooling follow room temperature set point devices. Air volume is controlled by cooling.
2. "Away" Heating set points are lowered and cooling is turned off to save energy. Ventilation is reduced.
3. "Night" Ventilation is not increased by cooling and fan coil unit is limited to run only at slowest speed to minimize noise.
4. "Intensified" Heating and cooling follow room temperature set point devices. Air volume is increased to maximum.

These basic settings for inhabitants are the first step for users to be involved and participate energy consumption savings and towards the aim of achieving neighbourhood level energy positivity. This also serves as a first step towards requirement based indoor conditions which means for instance that inhabitants may in practise adjust level of ventilation according to their personal preference.

Each apartment has two water meters; one for cold and one for hot tap water. Water meter readings are read remotely by JACE servers.

Room temperature and water consumption data is read from JACE servers to external YITextra server. An internet portal is created for dwellers to observe their apartments' room temperatures and water consumption. In figure 12 is presented apartment process view for remote controlling. In figure 13 is presented outdoor and indoor temperatures. In figure 14 is presented domestic hot & cold water consumption.

Bill of material of real-estate automation for dwelling:

- Room controller; Caverion UIO032
- Air handling unit; Enervent Piccolo Eco ECE
- Fan coil unit; Chiller BOX
- Chilled beams; Halton, active type
- Chilled beam valves / actuators; Danfoss RA-C 15 / TWA-A
- Condensation detectors; Thermokon WK01
- Floor heating valves / actuators; Uponor
- Room temperature sensors; Produal TEHR NTC10
- Floor temperature sensors; Produal TEL NTC10
- Bathroom extraction air temperature sensor; Produal TEK NTC10
- Apartment operation room operating panel; Thermokon WRF06S
- Water meters; Kamstrup Multical 62

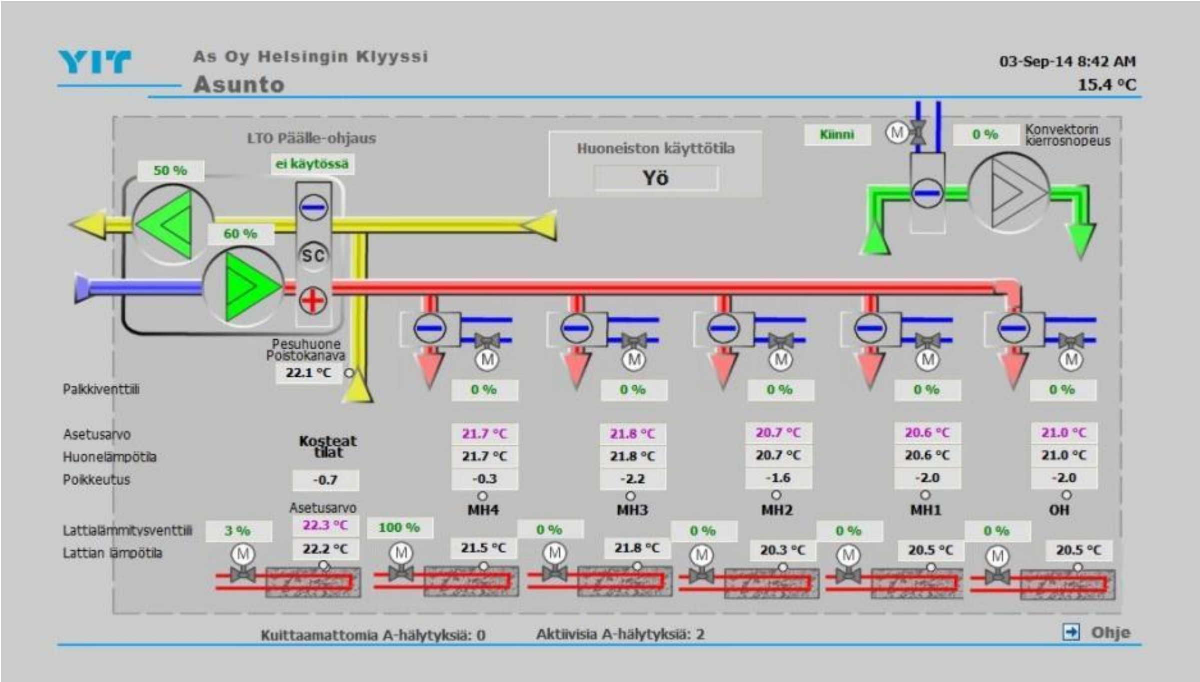


Figure 12 *Apartment process view for remote controlling*

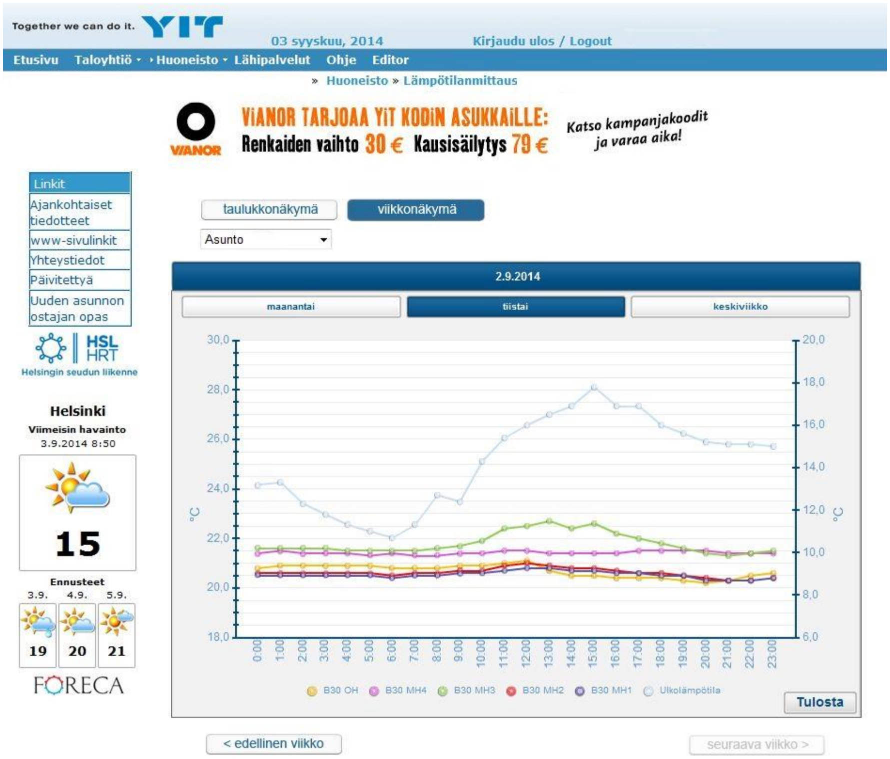


Figure 13 *Temperature view for resident. Highest line present outdoor temperature. Lower lines present room specific temperatures in household.*

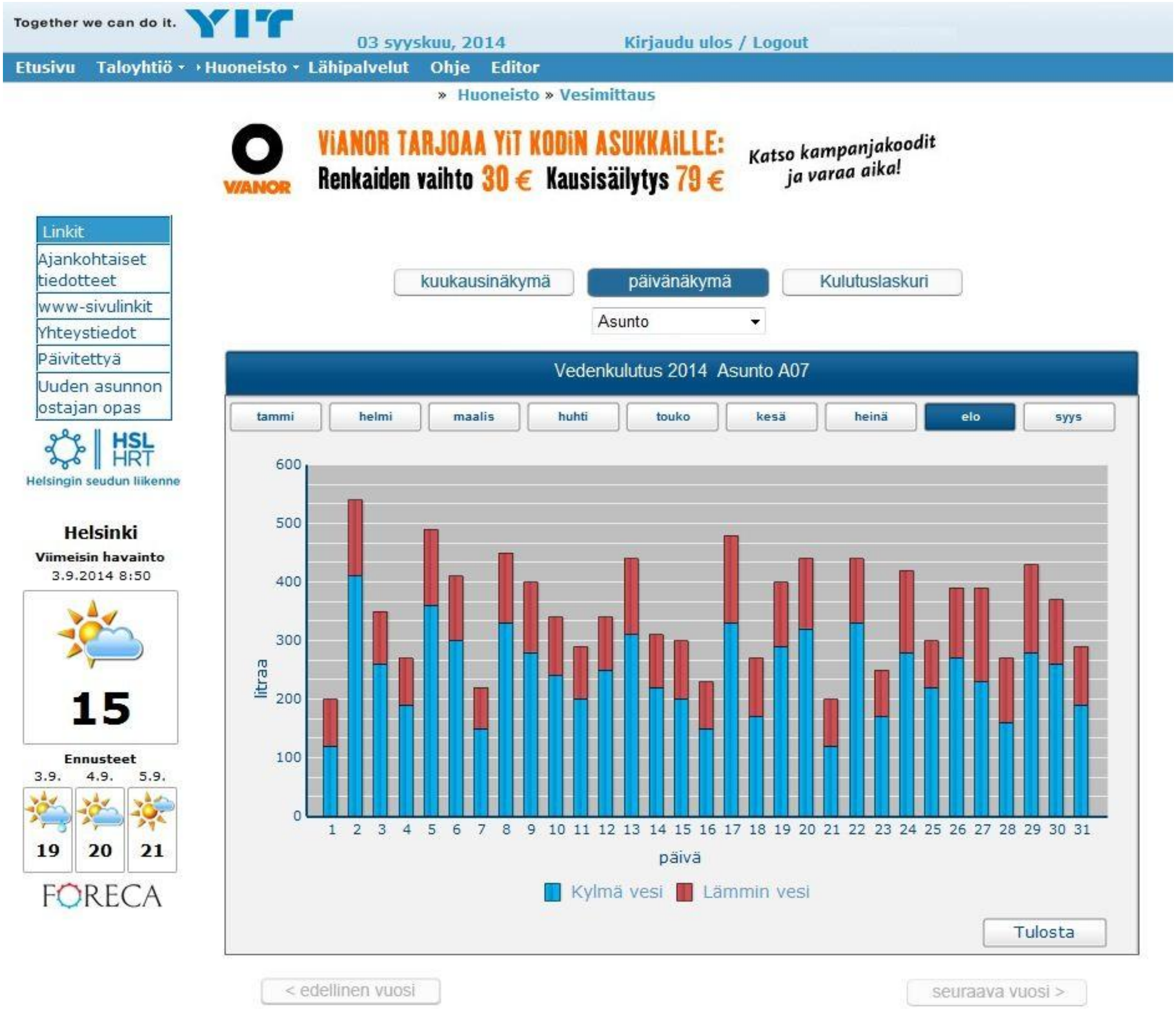


Figure 14 *Domestic tap water consumption view for inhabitants in eHouse*
Cold water by blue, hot water by red colour

4.2 EEPOS Applications

4.2.1 Applications in FIN demo

In the Finnish demonstration JACE web servers monitoring pumping station's and 1st demonstration building condominium's HVAC processes and storing data are connected to internet. Data was collected to external systems via oBIX interface. In figure 15 is presented seawater pumping station process.

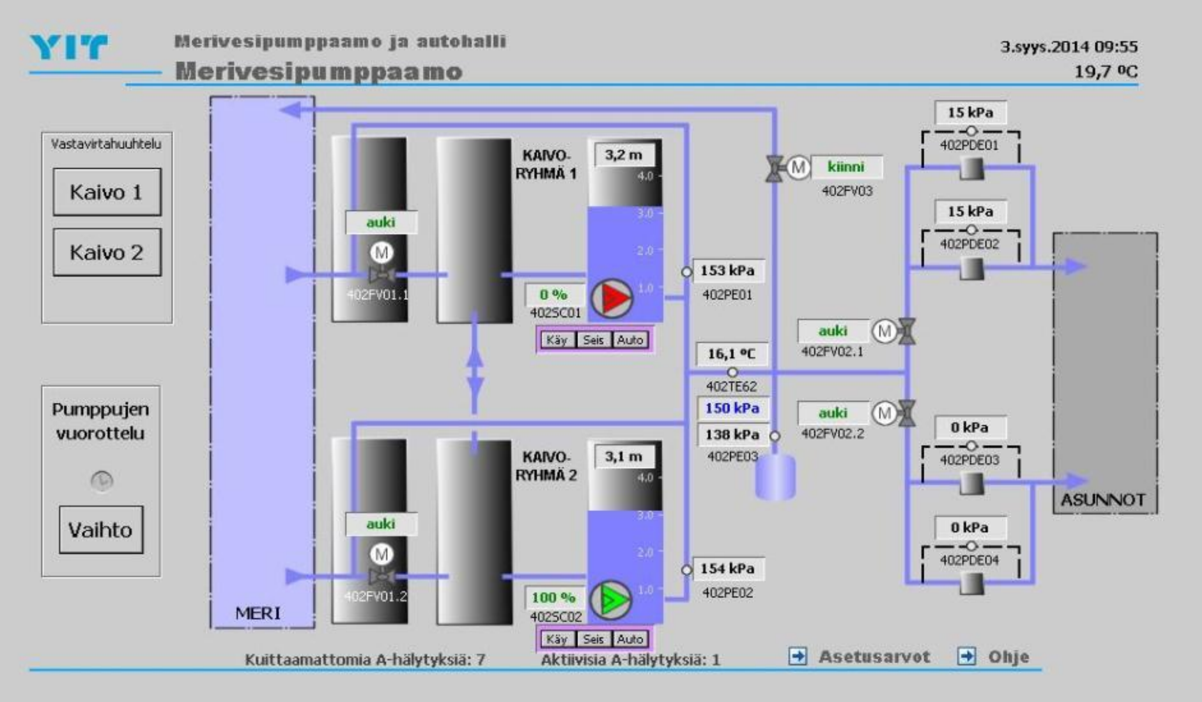


Figure 15 *Seawater pumping station process view for remote controlling*

To integrate diverse systems a physical connection to a device's network is required. The Java Application Control Engine (JACE) is the mechanism that provides this connectivity to systems within a building. By connecting common network protocols such as LonWorks, BACnet, and Modbus, along with many proprietary networks a unified system without seams emerges. Scalability and reliability concerns are avoided with the unique distributed architecture that a network of JACE's creates.

The Finnish Demonstration Team made guidelines for automatic software adjustments to achieve results on correct improved settings. Before applying automatic changes the adjustments must be closely manually verified. This is because the conditions in dwellings must not be compromised in case of incorrect automatic adjustments because no malfunctions are allowed in real living environment.

4.2.1 Utilisation in neighbourhood

Merenkulkijanranta HVAC processes are monitored and controlled by a remote control room. JACE web servers are being used for controlling processes, displaying graphical process views, collecting data and sending alarms when some measured value goes out of normal range.

4.2.1 Utilisation in dwellings

Finnish demonstration dwellings are equipped with multiple temperature sensors. Data from those sensors are collected by JACE. And the data can be monitored by a remote control room. All apartments have an easy interface for end user to control their indoor conditions. The controller enables end user to make effect their apartment by four preset programs that makes effect on heating, cooling and ventilation. Programs are call “At home”, “Intensified”, “night” and “Away”. The status of controller can be monitored from the control room which is presented in figure 16.

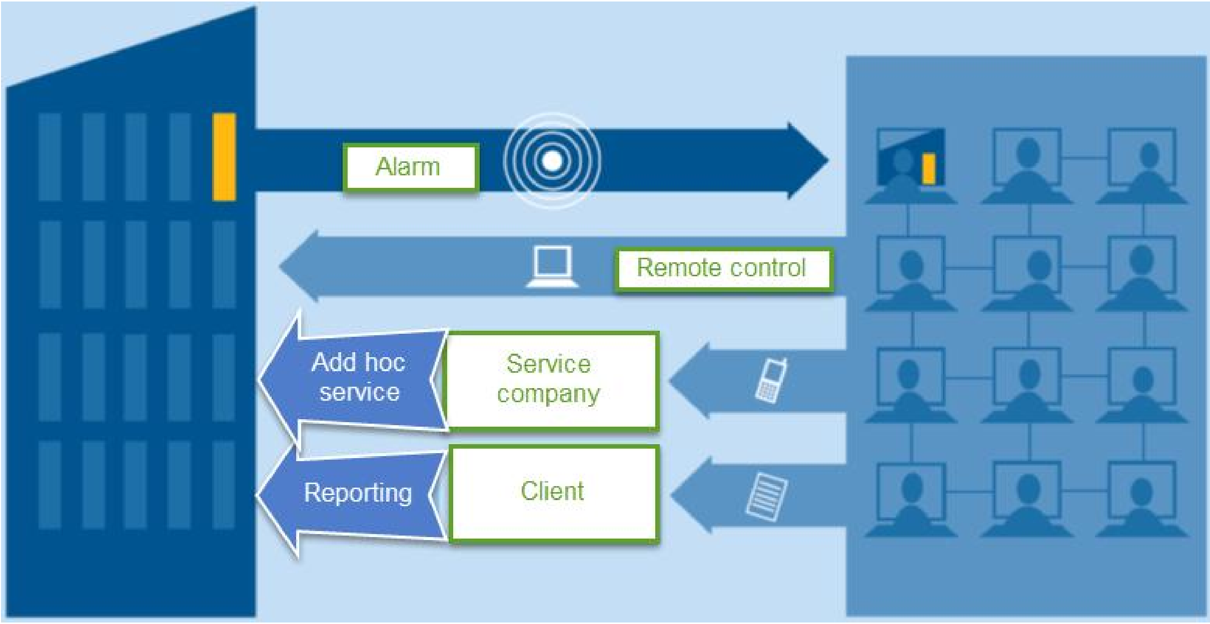


***Figure 16** Control room*

The 24/7 control room monitors data coming from EEPOS system and assists the engineers on fault situation handling as well as have the possibility to make adjustments of their own.

All inhabitants are personally invited to involve in EEPOS demonstration. In the case accepting the invitation, their dwellings are equipped with electricity meter as well.

4.3 Final versions of ICT applications and services for Finnish demonstrator

This chapter describes shortly final versions of implemented EEPOS ICT applications and services for Finnish demonstrator.

4.3.1 EEPOS softwares based on VTT's external services

Three VTT's external SOAP based web service has been integrated, utilized and demonstrated in Finnish demonstrator. The first one is for forecasting building and neighbourhood energy consumption, the second one is building energy simulation service and the third one is for detecting energy consumption related faults.

4.3.1.1 Energy consumption forecast service

Forecasting of building and neighbourhood energy consumption is based on open weather data and related weather forecast for next 48 hours. In Finnish demonstration Finnish Meteorological Institute's (FMI) open weather data on-line service is used.

EEPOS forecasting module use external space heating calculation model through web service API. The space heating calculation model is implemented before EEPOS and the model based on EN ISO 13790:2008 (*Energy performance of buildings: Calculation of energy use for space heating and cooling*) and EN 15241:2007 (*Ventilation for buildings: Calculation methods for energy losses due to ventilation and infiltration in buildings*) standards as well as the models for estimating solar radiation. The model includes methods for a dynamic hourly-based calculation of building energy and thermal performance, including the periods of heating and cooling, and airflow-related energy losses.

An example of forecasting 1st demonstration building energy consumption in Finnish demonstrator is shown in Figure 17.

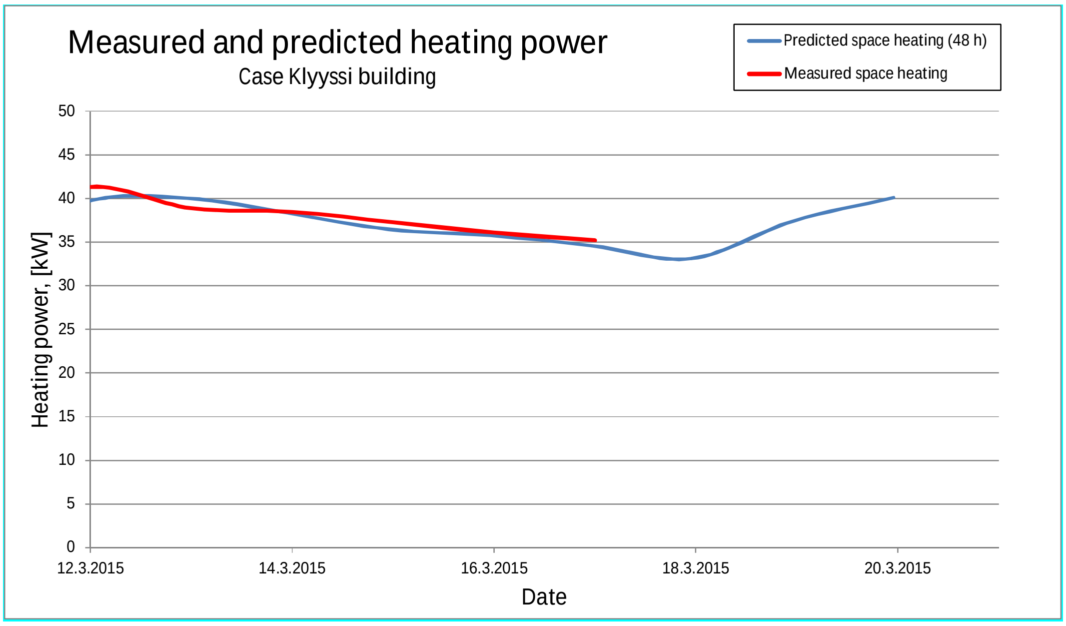


Figure 17 Space heating related energy consumption forecast – case Finnish demonstrator.

4.3.1.2 Building energy simulation service

EEPOS energy simulation service (SOAP based web service) is based on the same standard as the building energy consumption forecast service but there are a lot of different simulation outputs like energy, average power, peak power, CO_2 emissions and costs for e.g. demand and delivered building hot water, household electricity, space heating and space cooling etc. This service utilizes also open weather data as input.

An example of utilizing this EEPOS integrated external building simulation service for comparing estimated and measured 1st demonstration building energy consumption in Finnish demonstrator is shown in Figure 18.

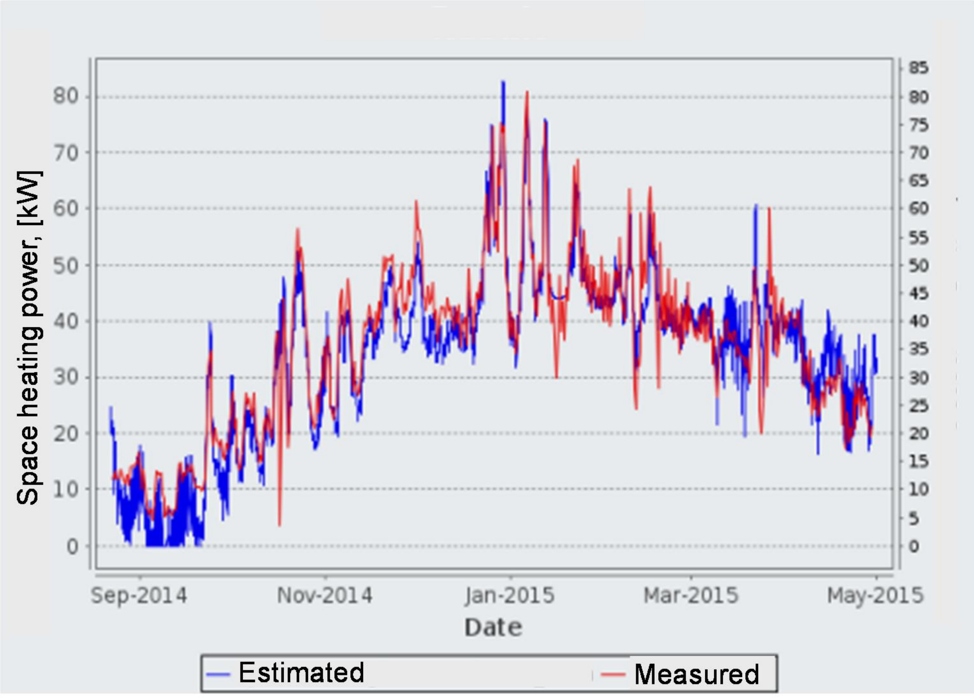


Figure 18 *Measured and estimated optimal space heating energy consumption – case Finnish demonstrator.*

4.3.1.3 Service for energy consumption related fault detection

EEPOS energy consumption related fault detection module use external fault detection engine through web service API. Fault detection engine use e.g. "energy signature method" described in Annex B of the standard EN 15603:2008 Energy performance of buildings.

An example of the space heating related fault detection (Finnish demonstrator) is shown in Figure 19.

Figure 19 *Space heating related fault detection – case Finnish demonstrator*

4.3.2 Software tools

4.3.2.1 BimZone for BIM based visualising and analysing building performance

VTT's existing client-server based BimZone tool has been further developed, integrated and demonstrated in Finnish demonstrator. It utilises internally e.g. open source BIM model server (BIMserver) and some VTT's existing databases. The tool can visualize and analyse building level data by means of 3D BIM. It support both near real time and historical data.

The tool is powerful for detecting, locating, analysing and visualising energy related problems in buildings. It makes it possible to visualize which spaces and in which date and time (e.g. now/day/month/year) e.g. the indoor temperature value is lower or higher than the selected value (see figure 20).

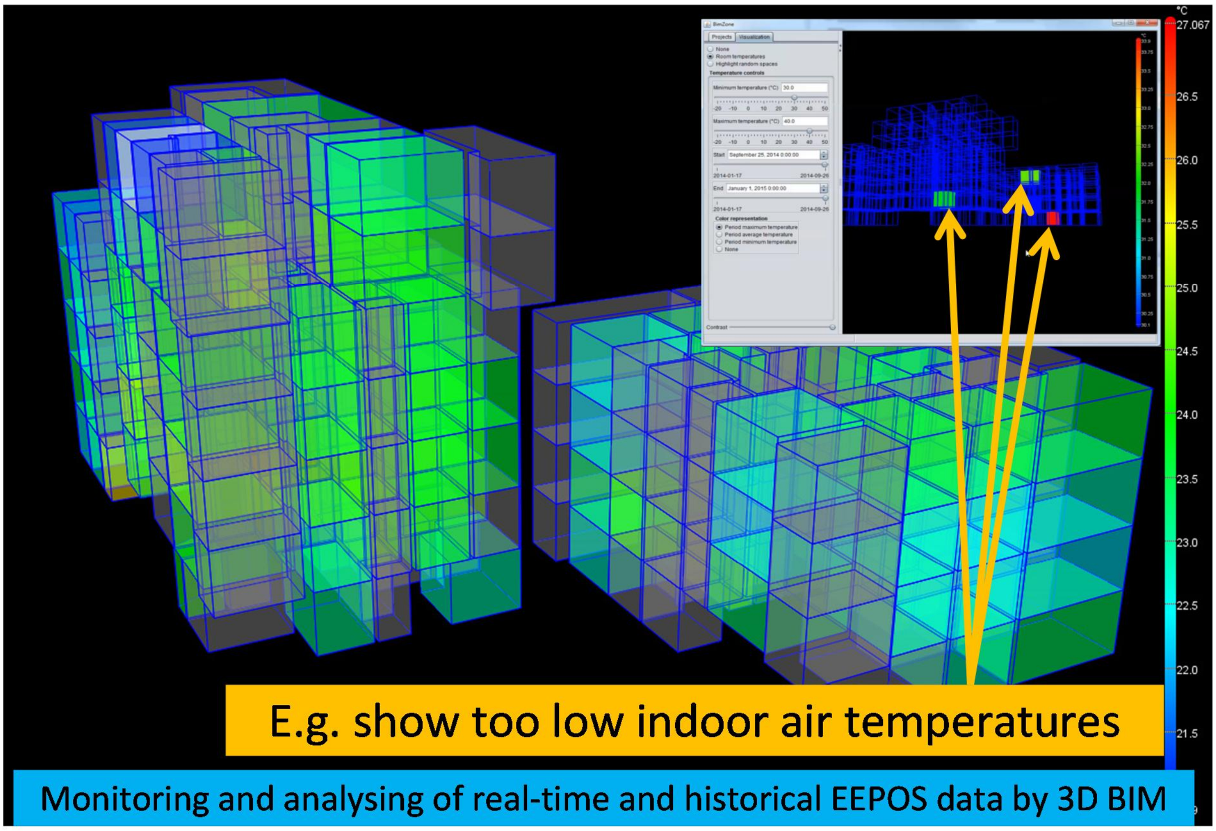


Figure 20 *Example of VTT's BimZone tool's BIM based visualizing and analysing: which spaces has too low indoor temperatures on selected time period – case Finnish demonstrator*

4.3.2.2 Unity game engine based visualising building and neighbourhood level energy performance

Finnish demonstration area is also modelled for Unity game engine. This virtual model based EEPOS Unity application acts as a user interface for the demonstration area energy data including several menus for different types of KPI or service request as follows.

- Monitoring neighbourhood and building level measurements and KPI values.
- Monitoring forecasted and actual consumption.
- Detecting possible building energy consumption related faults.
- Benchmarking buildings energy consumption
- Verifying measured energy consumption to on-line simulated energy consumption.

Example of a menu started by clicking the building in Unity game engine based 3D model is shown in Figure 21.

Figure 21 *Example of menu started by clicking the building in Unity game engine based 3D model.*

Examples of different kind of views started from Unity game engine based 3D model of the Finnish demonstrator is shown in Figure 22.

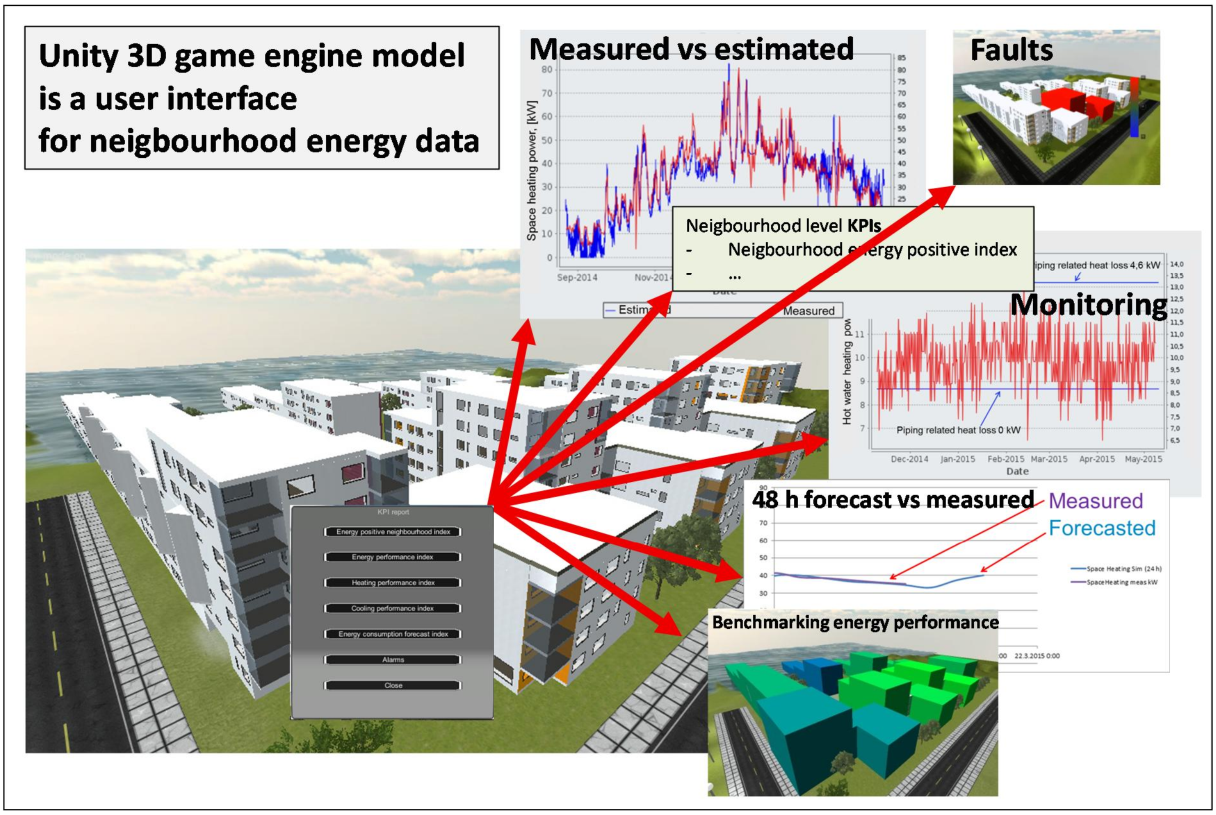


Figure 22 *Examples of different kind of views started from Unity game engine based 3D model of the Finnish demonstrator.*

Most of this Unity game engine based EEPOS application features works also in Android devices (Figure 23).

Figure 23 *Testing of Unity Game Engine based EEPOS application in Android tablet.*

5. ENERGY BASELINES

The energy consumption baseline in the case of 1st demonstration building does not exist because the house is new. However the previous buildings in the neighbourhood can be used to the energy baseline as far as the technology is the same. The housing companies are a lot alike but not identical. Some of the developments have been taking place during the years e.g. the floor heating is now all water while it was electricity heating in bathrooms in first housing companies.

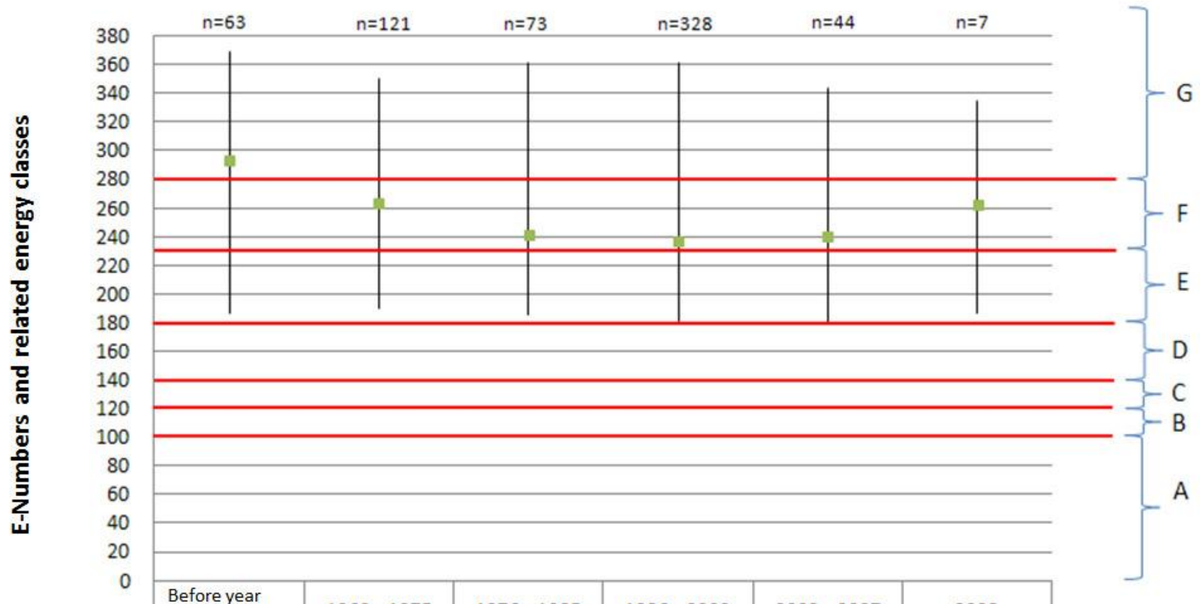
Other energy baseline is the Finnish energy classification system. More precise in Finland new apartment buildings are classified (energy certificate) in energy classes from A to G using E-number. Class A is the most energy efficient and class G is the most energy consuming one. The energy classes are presented in table 3.

The E-number (building total annual energy consumption per building gross area) includes building heating, ventilation, cooling, lighting and consumer electronics related energy consumption. The E-number does not include car heating, outdoor lighting and other building outdoor area related energy consumption and only bought energy is included in the calculation. In addition the calculation of E – number takes into account different forms of energy, having different coefficients as follows: electricity 1.7, district heating 0.7, district cooling 0.4, fossil fuels 1.0 and renewable fuels 0.5.

Table 3 *Energy classes and related limit values for apartment buildings in Finland*

Building energy class	Building total annual energy consumption per building gross area [kWh/m^{2}a]
A	0 ... 75
B	76 ... 100
C	101 ... 130
D	131 ... 160
E	161 ... 190
F	191 ... 240
G	241 ...

Third energy baseline is statistical data of 727 apartment building related energy consumption in different parts of Finland. The statistical data of apartment building is presented in figure 24.



	Before year 1960	1960 - 1975	1976 - 1985	1986 - 2002	2003 - 2007	2008
Highest	369	350	361	361	344	335
Lowest	186	190	185	181	180	187
Average	294	263	241	237	240	263

Construction year of the apartment building

Figure 24: *Statistical data of apartment building (located in different part of Finland) related energy consumption and related E-numbers [1]*

These energy baselines was utilized in benchmarking and energy saving calculations.

6. EEPOS DATA COLLECTED FORM TECHNICAL SYSTEMS

In Finnish demonstration case Merenkulkijanranta there were collected data from various kinds of systems. Totally close to 1200 sensors and other measuring equipment were collecting the data during the testing period. The primary period were carried out between 26.6.2014 and 5.3.2015. Some supplemental data were collected outside of that period as well. The period between 26.6.2014 and 31.8.2014 was named as summer season and the period between 1.12.2014 and 28.2.2015 were names as winter season. Totally over 30 000 000 rows of data were collected and stored into database. The collected data in general was categorized into *real estate regulation element functions*, *energy and electricity consumption*, *water consumption*, *resident behavioural mechanisms*, and *ambient conditions*. Any data that may cause a privacy issue were aggregated to the upper level, where no sensitive information can be seen any more.

Selected data points of analyses in detail are presented in figure 25.

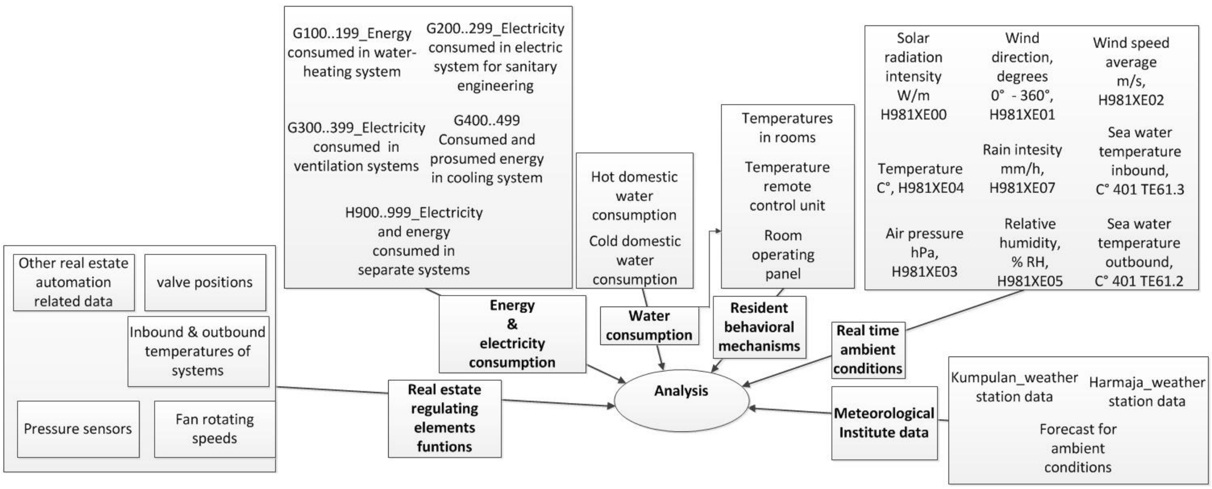


***Figure 25** Data collected during the EEPOS project at main categorical level*

The electricity was metered by number of meters which delivered data of electricity consumption on intermediate level before the main distribution electricity meter. Each of the electricity meters were coded individually. The code key of electricity meters is presented in table 4.

***Table 4** Electricity meters code key*

H901EM03_7	**H901EM03_7**	**H901EM03_7**	**Drawing numbers**
H901= Electric system	**EM03=G300..399_Energy consumed in ventilation systems**	**_7=** Consecutive numbering of electric meters	
	EM01=G100..199_Energy consumed in water-heating system **EM02=G200..299**_Electricity consumed in electric system for sanitary engineering **EM04=G400..499**_Consumed and prosumed energy in cooling system **EM02=H900..999**_Electricity and energy consumed in separate systems		**EM01=6101** **EM02=6201** **EM03=6300** **EM04=6400** **EM02=6900**

All measured resources such as cold and hot water, distributed heat and electricity have hierarchical structure and some of the meters provide subtotals of consumption. The consumption meter hierarchies are presented in figures 26 and 27.

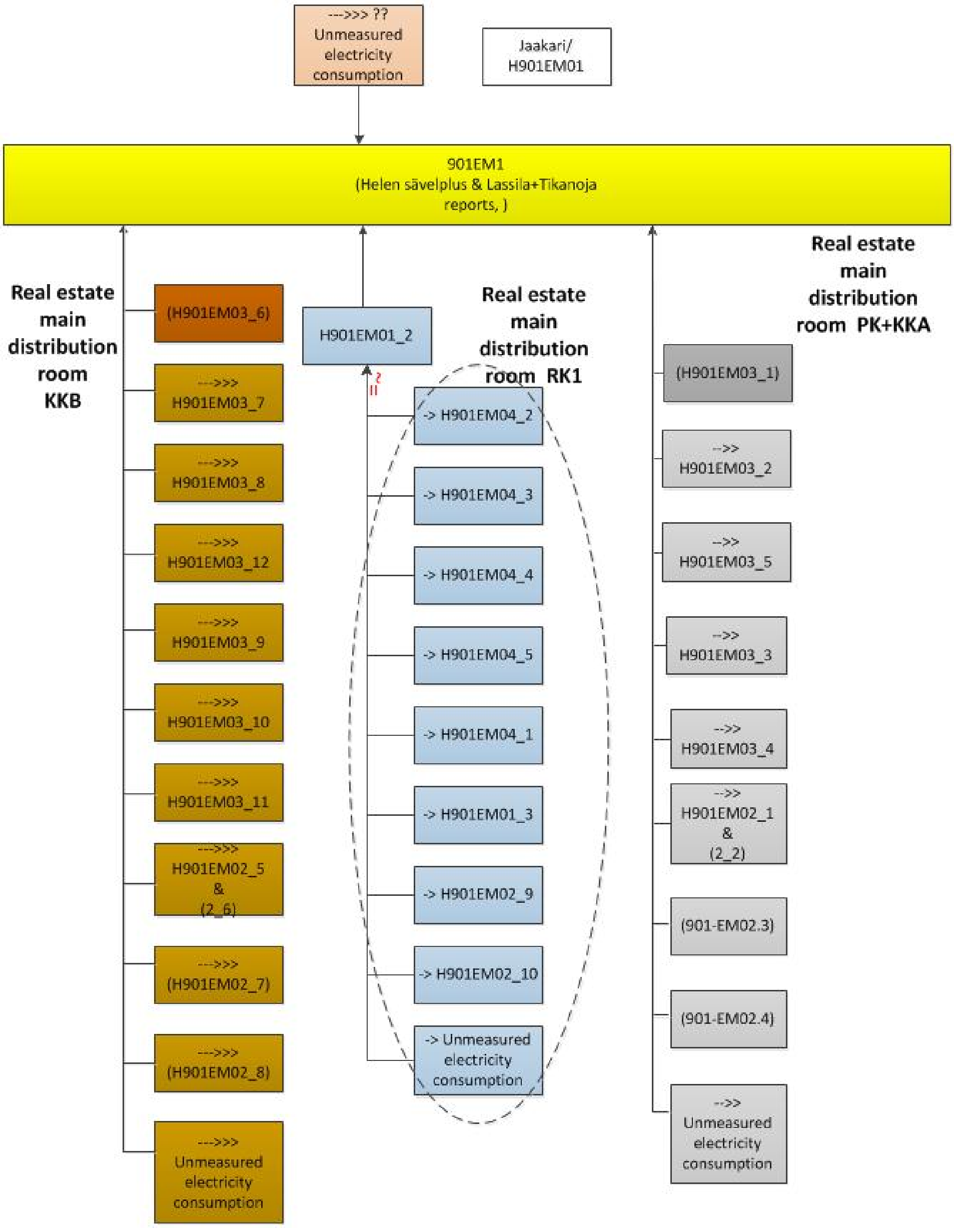


Figure 26 *Hierarchical structure of electricity meters*

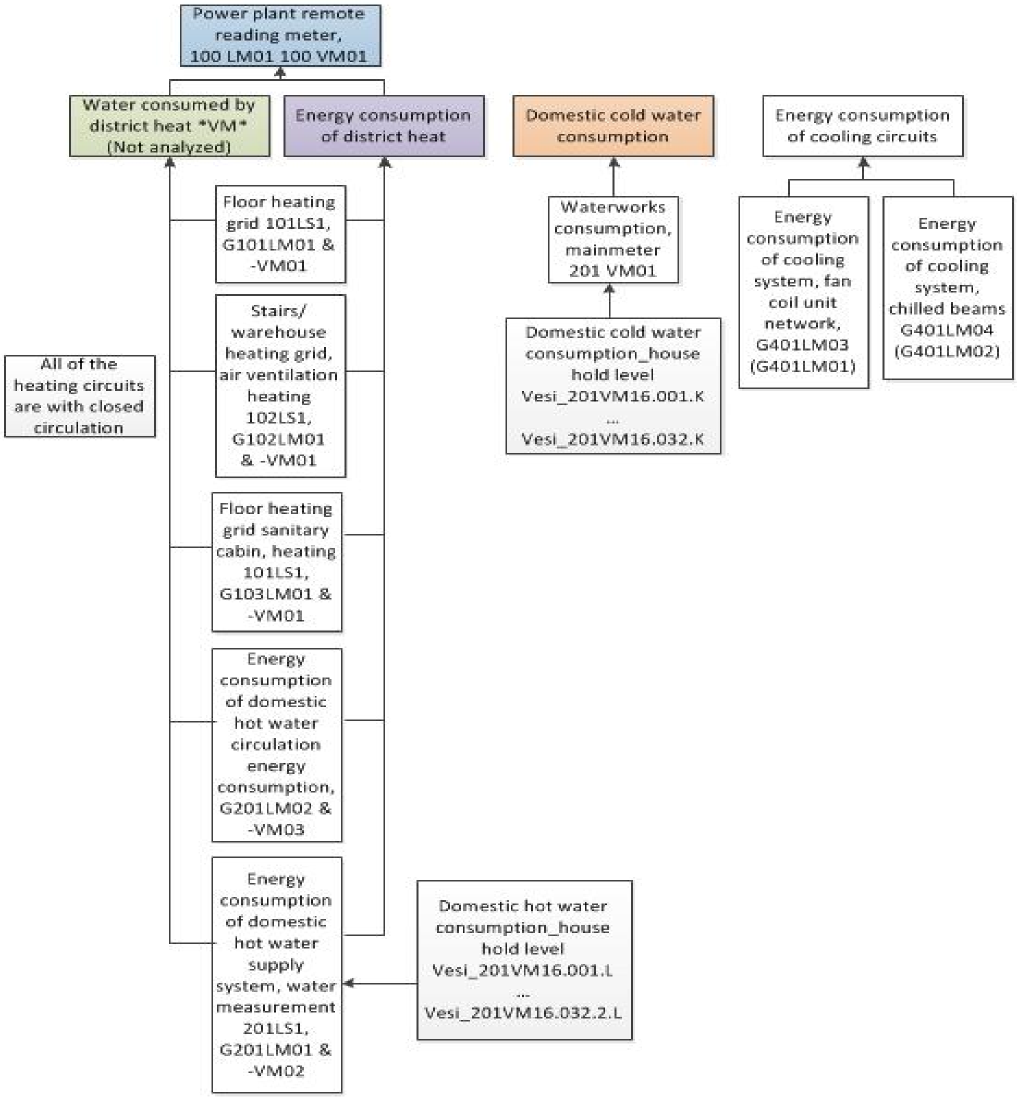


***Figure 27** Distributed heat, cool and hot water and cooling meters hierarchical structure*

Each of the produced analyses category had own point of view regarding energy positive neighbourhood. In real estate regulation element analyses where analysed which way instruments function in the real estate. In energy, electricity and water consumption analysis was analysed how much energy is consumed in each automation system measurement point and which sort of consumption profile the consumption forms. In residential behavioural mechanisms was analysed residential behaviour and scale of apartment specific water resources usage. In ambient conditions category the main focus was to analyse how much on-site resources such as electricity, heat and water can be harvested on site.

Initially was analysed how much electricity is consumed in the real estate. Each electricity meter was placed into real-estate automation system category and analysed on category level. The sum of categorical consumption was compared into electric bill by the power company. Conclusion was that the consumption values are concurrent, although not identical.

The consumption analysis was taken from two time samples which were: 26.6.2014 - 31.8.2014 and 1.12.2014 – 28.2.2015. The time samples presented cooling and heating period. The time samplings were restricted by implementation time of the measurements meters, therefore the measurements were not ideal representatives.

In figure 28 is presented electricity consumption during the cooling period. From the figure can be seen that the primary electricity consumer is the ventilation system and as secondary electricity consumer is the cooling system.

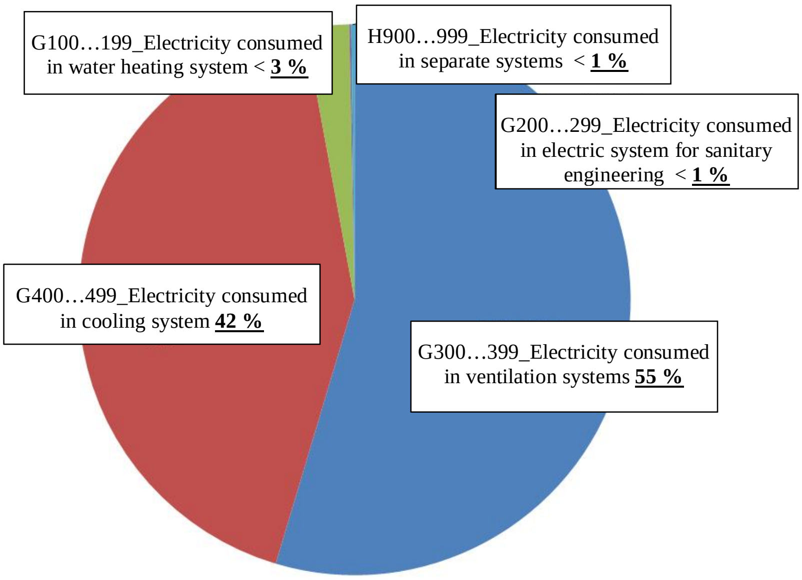


Figure 28 *Electricity consumption, sampling width 26.6.2014 - 31.8.2014*

The electricity consumption during the heating period is presented in figure 29. From the figure can be seen that the ventilation is the primarily electricity consumer. As a conclusion of from the analyses was that the system level electricity metering is extremely useful tool to scale electricity consumption between the real-estate automation systems and duo to its scale of magnitude the ventilation system is category in which electricity consumption should be analysed more thoroughly.

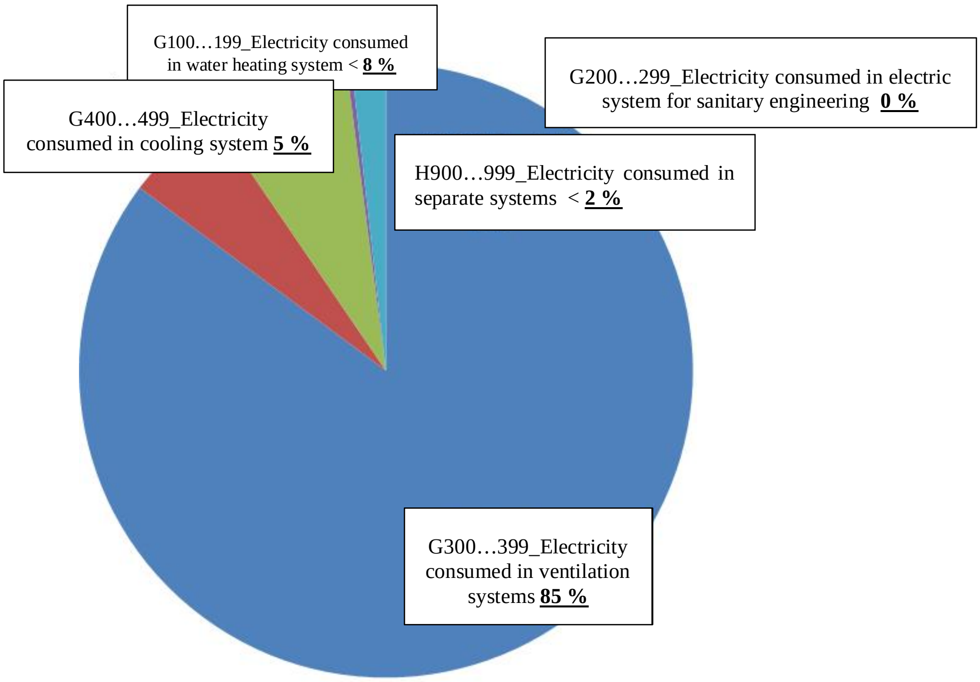


Figure 29 *Electricity consumption, sampling width: 1.12.2014 – 28.2.2015*

6.1 Heating system data

In appendixes 1-5 are presented apartment temperatures which can be affected by real-estate automation heating and cooling system, which consume energy. Both heating and cooling system energy consumption were measured in detail.

Initially the heating system energy consumption were compared into the billing of the power company. The comparison is presented in the figure 30. In figure 31 is presented the energy consumption distribution during the sampling width.

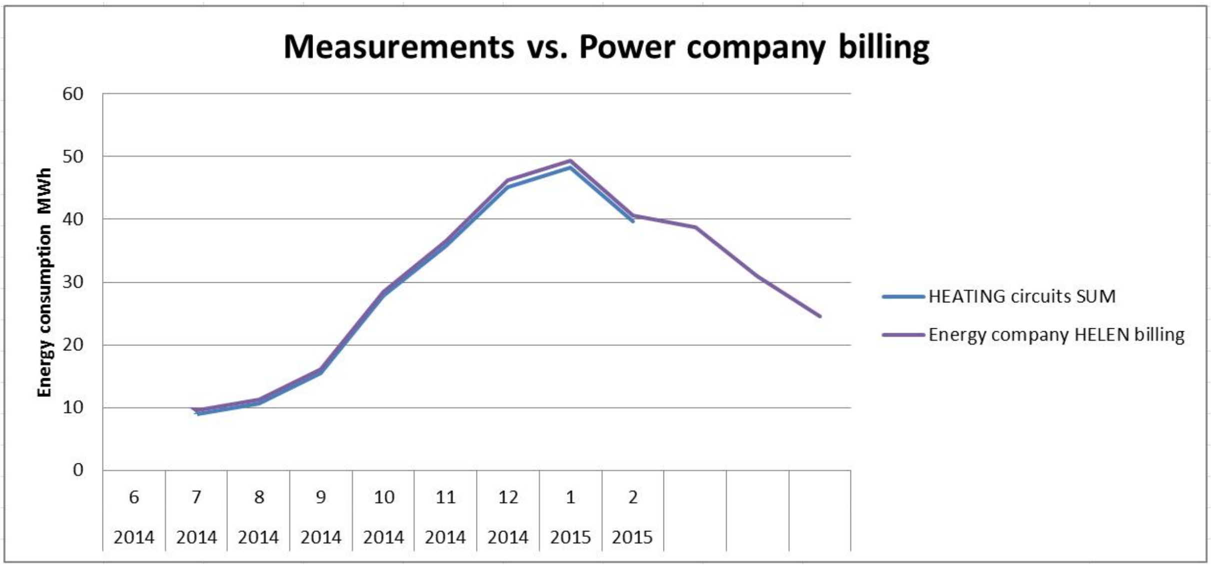


Figure 30 *Electricity consumption comparison, sampling width: 1.12.2014 – 28.2.2015*

From the comparison can be seen that sum of heating circuits is almost the value as the power company has billed. As conclusion from the comparison can be made that the measurements are valid and further analyses from the measurements can be made reliably.

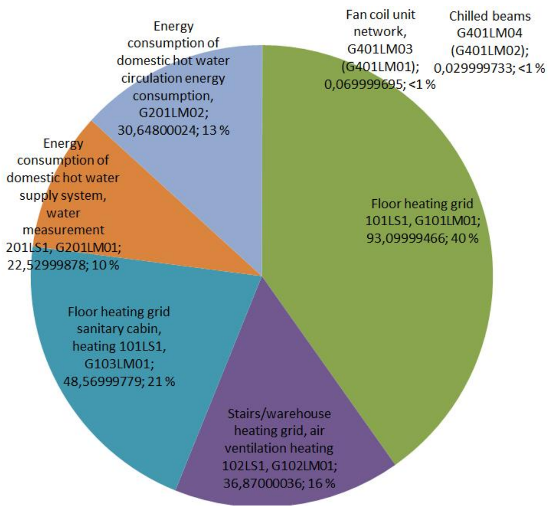


Figure 31 *Energy consumption distribution, sampling width: 1.7.2014 – 1.2.2015*

After the validation of data the heating system analyse consumption pie graph was formed from time period which include both cooling and heating period, however in this sample width the cooling metering systems where not yet implemented. As from the figure can be seen at the sampling period primary energy consumer is floor heating grid. As a secondary energy consumer is sanitary cabin heating, tertiary is heating of common spaces and as a quaternary is hot water circulation energy. The circulation energy represents measured heat losses which could be mitigated by increasing insulation, therefore it was taken into closer examination in energy analyse section.

6.2 Cooling system data

In figure 32 is presented the cooling magnitude evaluation. In cooling system analyses was evaluated the scale of magnitude of cooling compared to heating. In this analysis the domestic hot water and the circulation data extend only till 1.2.2014. As from the figure can be seen the magnitude of floor heating is in class of its own, unfortunately the ICT data assissting for deeper analysis & evaluating energy savings is lacking, therefor the effect of increasing insulation cannot be evaluated by measured values.

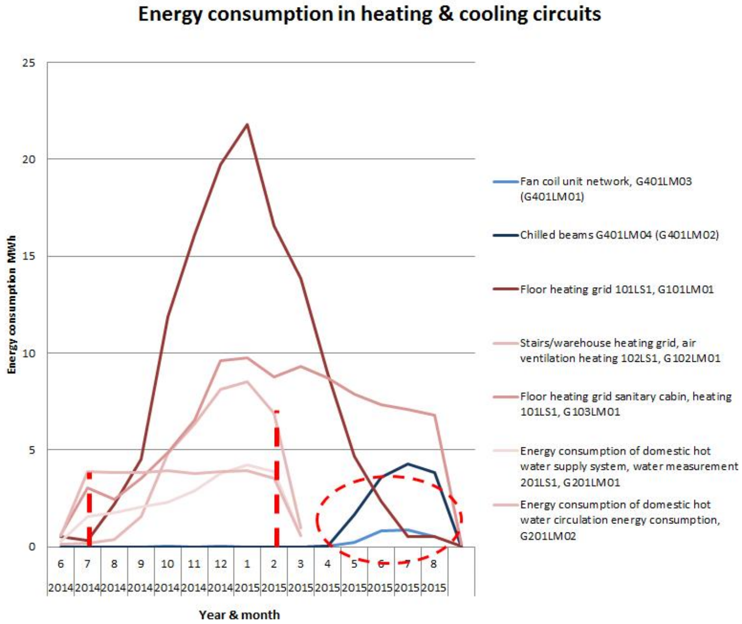


Figure 32 *Cooling magnitude evaluation, sampling width: 1.7.2014 – (1.2.2015), 1.8.2015*

As a other interesting detail from the figure is that the both heating and cooling circuits are operating parallel on cooling period. For example in June there has been used 2,5 MWh of cooling and 2,5 MWh heating. Parallel operating was not studied in more detail due to time pressures in the project. It is however interesting detail which should be studied in more detail level in future.

The sea water pump's electricity consumption is metered in two points. The sea water pump has individual electricity meter and the actual billing of the consumption is done by garage & seawater electricity meter.

Annually the share of seawater electricity consumption of pump station is approximately 8,5% of the garage electricity consumption. The annual consumptions of both of the meters are presented in table 5. Electricity consumption of the sea water pump station is ~ 8,5 %

Table 5 Annual energy consumption of sea water pump station and garage

	Annual energy consumption
J/H901EM01 (Sea water pump station meter)	21 800 kWh
Garage & Sea water pump station meter	258 500 kWh

6.3 Ventilation system data

As was already mentioned in chapter six the ventilation system was identified as potential energy saving point and it was studied in more detail level. In figure 33 is presented Electricity consumption profile of stairwell A ventilation machines.

In the detail study was identified that most of the electricity consumption in ventilation category was formed by H901EM03_1 measurement point which indicate electricity consumption of household specific ventilation machines in stairwell A. In this phase was also learned that similar electricity meter H901EM03_6 for stairwell B was not collecting data. As a solution to the problem was introduced data from stairwell A as representative for stairwell B electricity consumption.

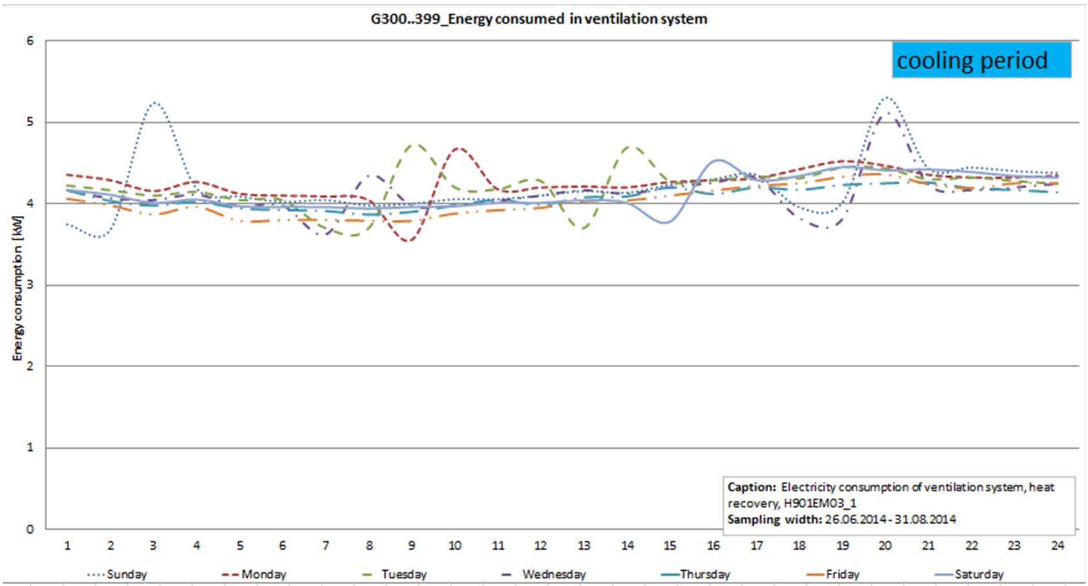


Figure 33 *Electricity consumption profile of ventilation system stairwell A, sampling width: 26.6.2014 –31.8.2015*

As can be seen from the consumption profile presented in figure 33 the consumption is stable and is on hour level approximately 4,3 kWh. On monthly level the consumption builds up to approximately 3100 kWh.

In last phase of analyses was evaluated how well the findings from the consumption profile are in alignment with the measured electricity consumption and the known electricity consumption data from the ventilation machines. The evaluation is presented in figure 34.

As a conclusion in the evaluation was made that 400W heating resistors are the primary electricity consumer and the resistors in ventilation would be ideal study target for theoretical evaluation of reducing emissions. Emission cuts can be made when electricity is replaced by district heating.

					Staircase A ventilation machines [pcs]	Number of days in month	Number of hours in day
					12	31	24
Staircase A & B ventilation machines resistor share of electricity consumption	Staircase A ventilation machines resistor share of electricity consumption	Metered electricity consumption - Overall, Supply fan- & Exhaust fan electricity consumption [kWh] /kk	Number of month	Metered electricity consumption, staircase A [kWh]	Electricity consumption per ventilation machine [kWh]	Electricity consumption per day and ventilation machine [kWh]	Per hour & ventilation machine [W]
		483,8	**6**				
5 087,5	2 543,8	2 543,8	**7**	3 027,6	252,3	8,1	0,3
5 506,1	2 753,1	2 753,1	**8**	3 236,9	269,7	8,7	362,6
4 255,7	2 127,9	2 127,9	**9**	2 611,7	217,6	7,0	292,5
4 871,1	2 435,6	2 435,6	**10**	2 919,4	243,3	7,8	327,0
4 399,7	2 199,9	2 199,9	**11**	2 683,7	223,6	7,2	300,6
4 604,3	2 302,2	2 302,2	**12**	2 786,0	232,2	7,5	312,1
4 222,3	2 111,2	2 111,2	**1**	2 595,0	216,2	7,0	290,7
3 873,3	1 936,7	1 936,7	**2**	2 420,5	201,7	6,5	271,1

Figure 34 *Ventilation electricity consumption analysis*

6.4 Domestic water system data

In water consumption data analysis was compared the water consumption differences between hot and cold water, differences in day week and month data extracted from the server, compare sum-up of household consumption of hold and hot water.

In addition consumption report data from a service company, billed quantity of cold water and the potential quantity of harvesting rain fall were added to the graph. The domestic hot and cold water consumption & rain water harvesting potential are presented in figure 35.

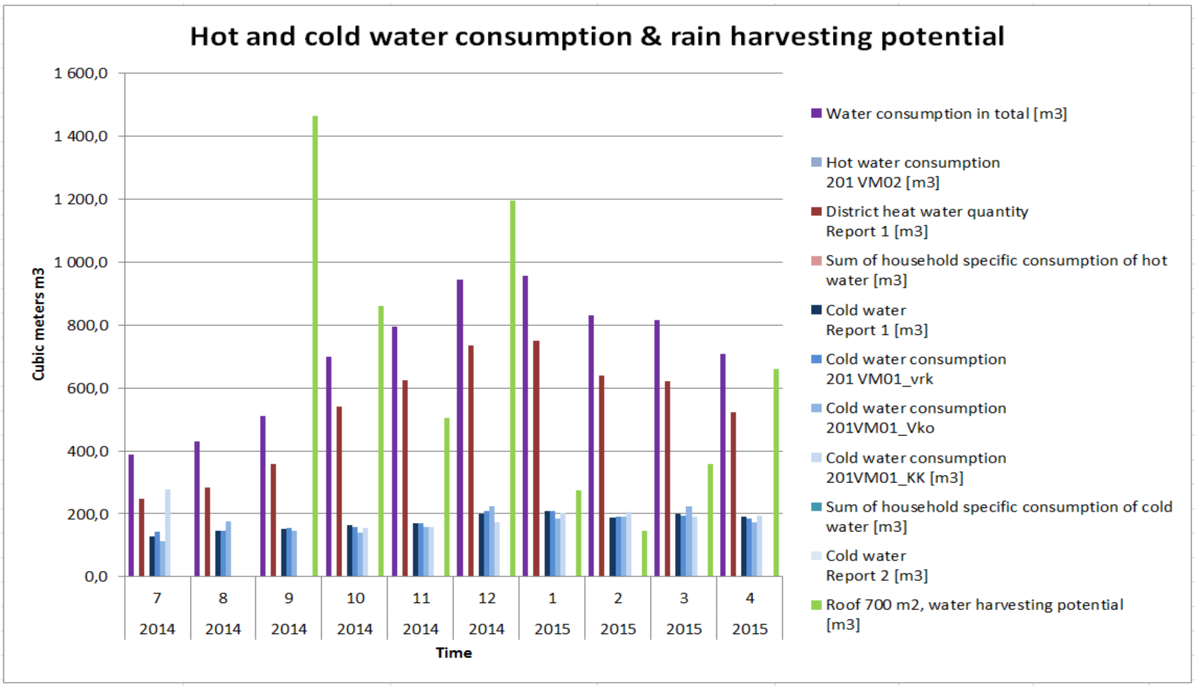


Figure 35 *Domestic hot and cold water consumption & rain water harvesting potential*

As a conclusion from the domestic analysis is that the consumption of hot water of district heat is almost in every month multifold compared to the cold water consumption.

6.5 Other technical systems data

The other automation systems which were evaluated were electricity consumed for sanitary and electricity consumed in separate systems. The sanitary category covers electricity consumption of staple water- and sewerage pumps. In sampling width of 26.6.2014 – 31.8.2015 the electricity consumption was altogether 136,4 kWh which means that that the value was insignificant when compared to other measured consumptions. Electricity consumption profiles of sanitary engineering are presented in appendixes 6-11.

Other minor real estate system that was analysed less thoroughly was electricity consumed in separate systems. Electricity consumption profiles of separate systems are presented in appendixes 12-13.

The electricity metering covers two consumption points of outdoor illumination from stairwell A and two consumption points from stairwell B. The measurement point were initially supposed to cover more consumption points, which were drop out due to their insignificancy. The overall consumption of separate systems in sampling width of 26.6.2014 - 5.3.2015 was in total 691,3 kWh.

Although the sanitary systems (G200) and other systems (H900) are insignificant when compared to other systems electricity consumptions it is highly recommendable to implement less energy consuming solutions such as frequency controlled motor and pumps and LED lamps in outdoor lighting.

6.6 Weather data data

As presented in chapter 6 in figure 25. there exist number of weather data which is collected by onsite weather station (Vaisala WXT520). Some of the Merenkulkijanranta weather data was also compared into data gathered from meteorological Institute. The Merenkulkijanranta weather station was implemented at the end of september 2014. Therefore in solar radiation case which was seen an important analysis the meteorological Institute data was the only full year datasource for data analysis. In wind analysis was used onsite data since the behaviour of wind is very onsite case specific. Meteorological institute three day weather forecast and weather station positions are presented in figure 36.

The initial weather data related analysis was to create temperature graph from three day temperature forecast.

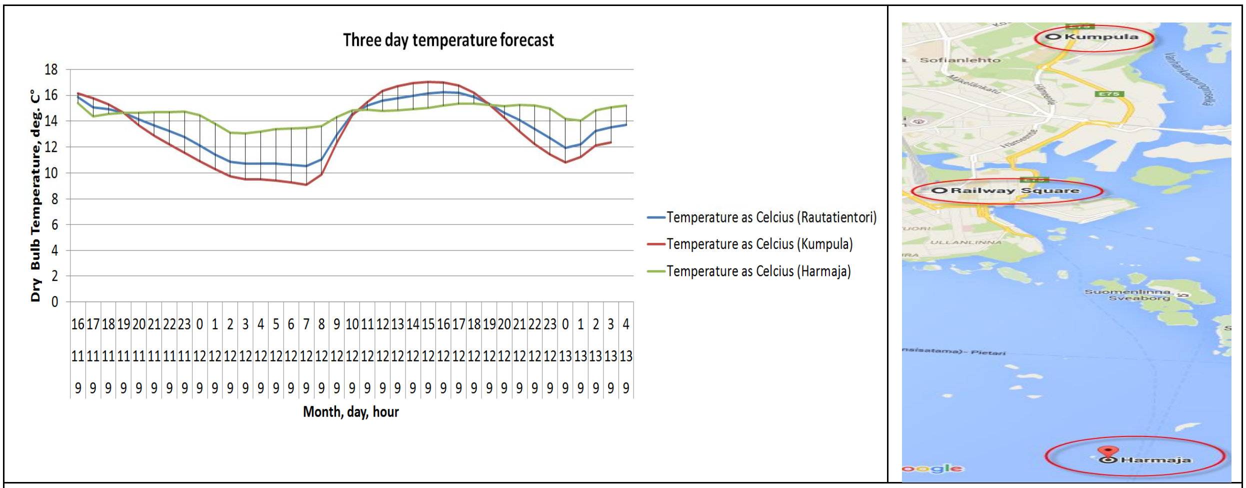


Figure 36. Weather forecast data from meteorological institute

As an conclusion from the graph is that altough the distance from Kumpula weather station to Harmaja only 13 km the temperature forecast for each site varies by number of degrees. A second conclusion is that since the Merenkulkijanranta is onshore Harmaja weather station data should be more close to the weather data collected by WXT520. In this point was also noticed that most of Harmaja weather data is missing and that the demonstartion building do not have collection of full year data.

After studying the weather station data differencies was studied air pressure data collected by Merenkulkijanranta weather station. In the airpressure data main principle is to identify if the value rising or declining. As a rule of thumb declining value indicated increasing wind, rain and worsening weather conditions. When the airpressure is increasing it indicates tranquil and dry weather. Airpressure data from Merenkulkijanranta weather station is presented in figure 37.

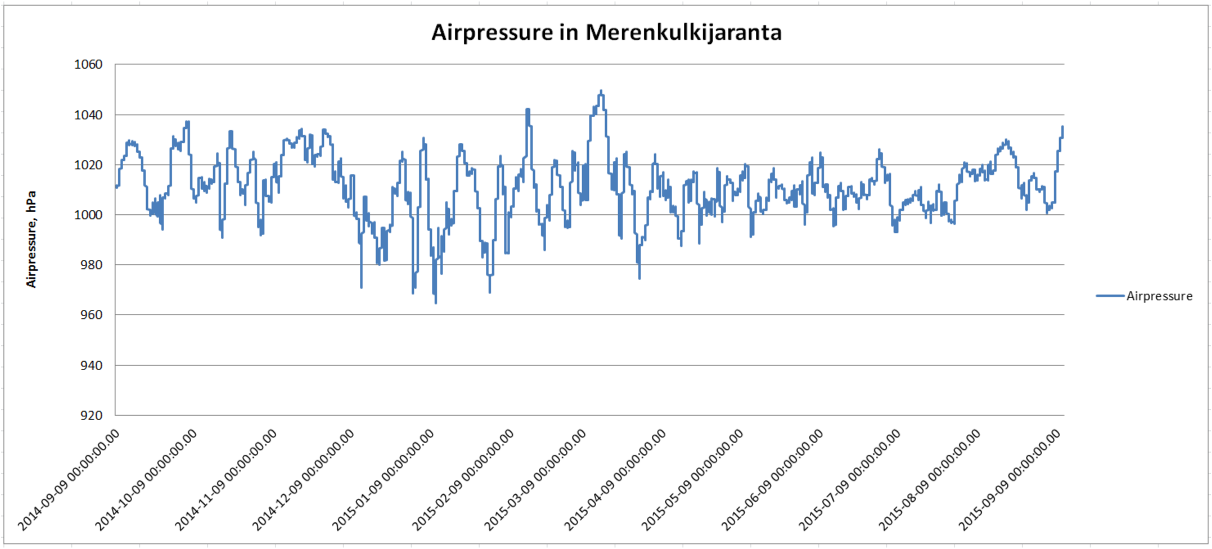


***Figure 37** Air pressure data from Merenkulkijanranta weather station, sampling width: 09.09.2014 –09.09.2015*

Next weather analysis was to create temperature-humidity graph. The temperature humidity data can be used to on optimise the real estate ventilation both in desing and operating of the building. In Merenkulkijanranta case where each appartment have own ventilation system the data could be used to scale the humidity of the home. Temperature and humidity data from Merenkulkijanranta is presented in figure 38.

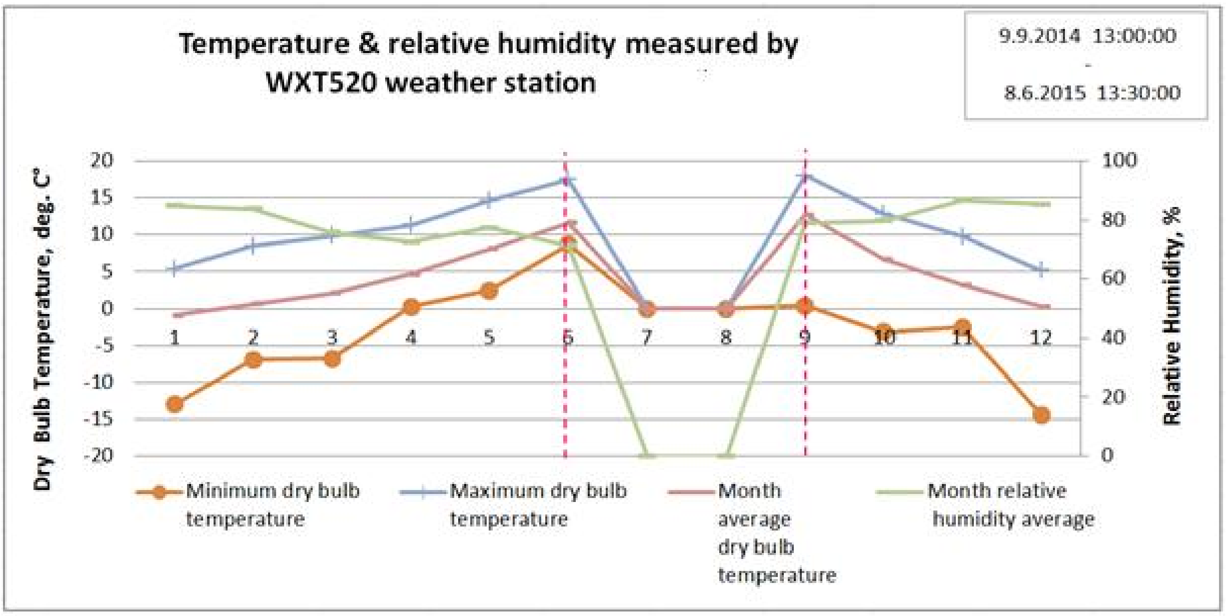


Figure 38 Temperature and humidity data from Merenkulkijanranta, sampling width: 9.9.2014 –8.6.2015

As can be seen from the chart the weather station in Merenkulkija ranta was implemented in september and the sampling width is still june. Alotough the samping is less than year from the results can be seen that there exist clear seasonal changes in both humidity and temperature values.

First analyse from natural force which is used in some parts of the world as resource for real-estate was the rain fall. As is commonly known Finald is land of thousand lakes and is should stand out in the railfall analysis. The Merenkulkijanranta results of analysis are in alignment with the world bank statistics of the annual average precipitation. While comparing global statistics it turned out bit suprisingly that it rains more in Sweden and Denmark and that rainfall of United kingdom is double compared to Finland. Temperature and rainfall data from Merenkulkijanranta weather station is presented in figure 39.

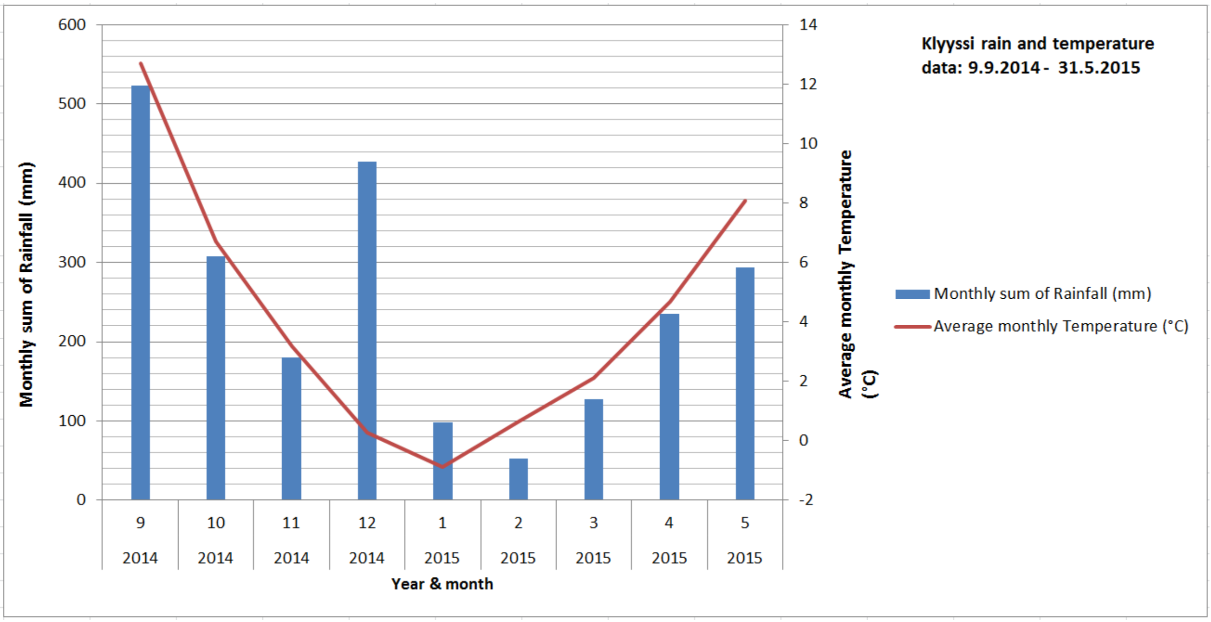


Figure 39 Temperature and rainfall data from Merenkulkijanranta, sampling width: 9.9.2014 –31.5.2015

Next in turn of potential resource for real estate was to study the wind speeds and solarirradiance in Merenkulkijanranta. In figure 40 is shown the comparison of wind speed sum and solar irradiance sum.

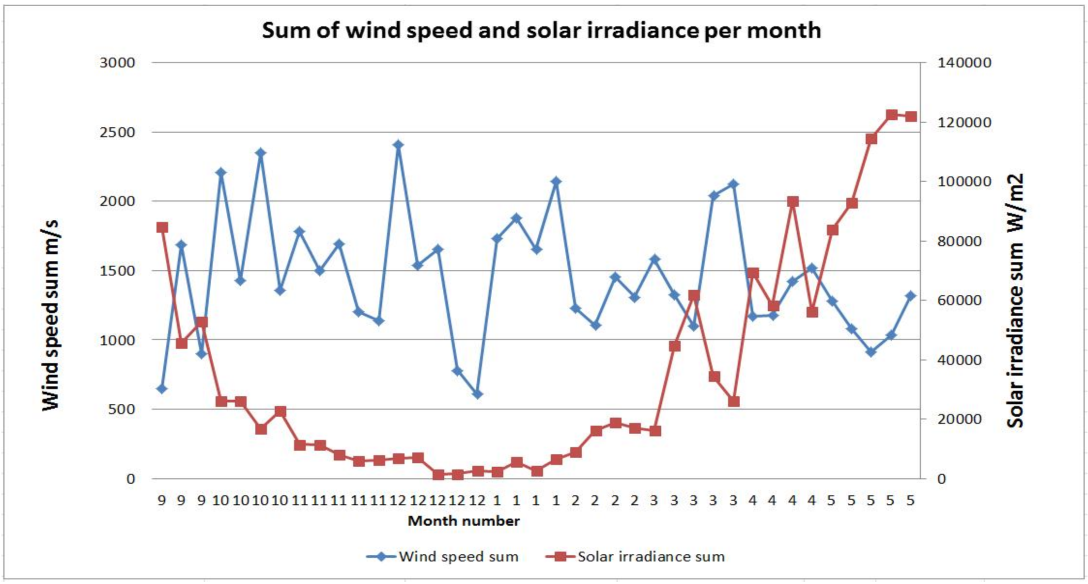
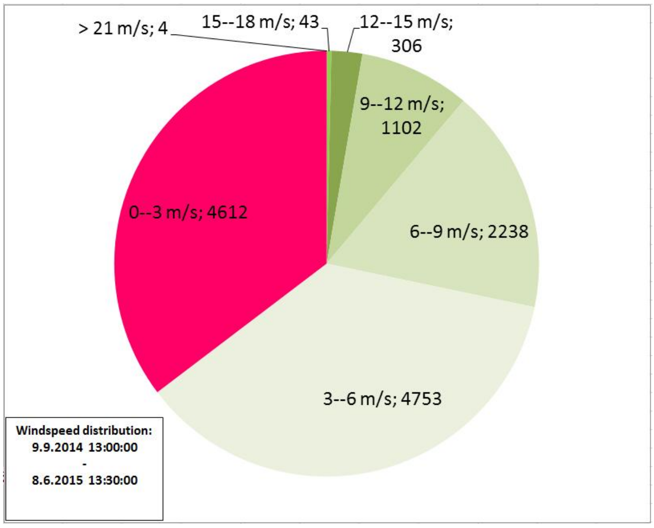


Figure 40 *Sum of wind speed and solar irradiance per month, sampling width: 9.9.2014 –31.5.2015*

From figure 41 can be seen that the solarpower and windpower complement eachother. However in order to make conclusions from the urban windpower potential more detail analysis was needed. In the next stage of the analysis the wind speeds were classidied by windspeed and windspeed per month which are presented in figure 43.



			Months											
			1	2	3	4	5	6	7	8	9	10	11	12
Windspeed m/s	0	3	475	586	536	611	793	0	0	0	567	499	446	530
	3	6	428	541	472	585	475	0	0	0	343	450	585	485
	6	9	319	156	260	194	171	0	0	0	75	331	328	252
	9	12	199	53	163	47	41	0	0	0	35	174	69	164
	12	15	60	6	55	3	8	0	0	0	9	31	12	47
	15	18	6	2	0	0	0	0	0	0	1	5	0	9
	18	25	1	0	0	0	0	0	0	0	0	0	0	1

Figure 41 *Wind speed distribution by wind speed (top) and wind speed distribution by wind speed and month*

From the figure 41 can be seen that there exist wind that is above small wind turbine cut in speed (3m/s) more than half of the time.

Next was analysed the nature of the wind, which directions the wind is blowing and by which speeds. The data can be analysed by graph called wind rose. Wind rose grapg is required in order to select correct type of urban wind turbine it is required to know is the wind type prevailing or uniform. Windrose patter is presented in figure 42.

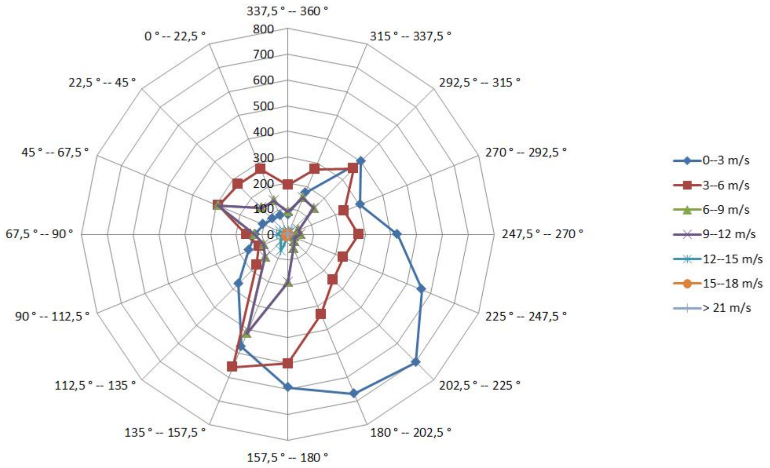
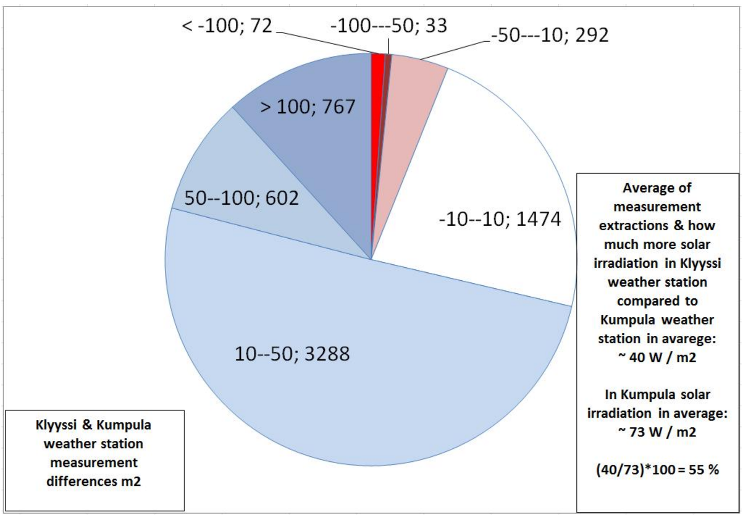


Figure 42 *Windrose pattern created from Merenkulkijanranta collected data*

From the figure 42 can be seen than most of the wind blow is distributed in 180 degree between angles of 135° and 292,5° and the wind distribution is more like uniform distribution type. The turbintypes which are recommended for uniform wind are Vertical Axis Windturbine (VAT) and Spiral Axis Windturbine (SAT), which are also have low noise level, due to their operational behaviour less risk for icicles and low cut in speed.

After wind analysis was conducted solar irradiation analyses. On the top of figure 43 is presented the cross check results of Merenkulkija and Kumpula weather station data. As a result of the check was that Merenkulkijanranta weather station has higher irradiation values than Kumpula weather station and while comparing Finnish environment solar irradiation satistics Kumpula was closes to the statistics. In addition the sample width of Merenkulkijanranta was less than a year. Since there existed three strong arguments to use Kumpula solar irradiation data Kumpula data used for PV simulation presented in chapter 8.1.2.



Solar irradiance sum per month Kumpula weather station											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2,50	4,74	19,55	33,83	45,68	44,30	28,53	20,32	13,44	4,12	0,97	0,69
Solar irradiance sum per month Klyyssi weather station											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1,99	5,26	14,30	23,66	38,09				17,51	9,54	3,55	2,25

Figure 43 *Solar irradiance differences between Merenkulkijanranta and Kumpula weather station (top) and solar irradiance sum per month in the weather stations*

In figure 44. Is presented the solar irradiation data from Kumpula weather stations. The data was used in chapter 8.1.2 PV simulation.

Number of day	1	2	3	4	5	6	7	8	9	10	11	12
01	0,03	0,21	1,54	3,13	2,96	5,17	1,81	6,68	1,80	2,92	1,24	0,20
02	0,04	0,40	0,52	3,64	5,14	2,88	3,62	6,16	3,40	2,05	0,06	0,11
03	0,04	0,20	0,23	2,28	4,64	1,02	6,42	6,16	3,73	1,50	0,11	0,36
04	0,03	0,22	0,53	4,43	5,45	7,02	6,61	6,40	4,09	0,52	0,24	0,26
05	0,10	0,52	0,95	4,96	3,62	6,11	7,94	6,57	4,69	0,86	0,50	0,06
06	0,03	1,03	1,61	0,68	5,34	5,41	8,18	6,45	4,13	0,35	0,10	0,03
07	0,03	0,22	0,76	1,13	6,87	5,12	7,57	5,36	4,41	1,61	0,11	0,10
08	0,06	0,10	2,14	4,07	0,69	5,35	7,77	6,10	4,22	0,25	0,35	0,03
09	0,09	0,80	1,78	5,49	2,26	5,74	6,44	4,23	2,06	0,84	0,22	0,19
10	0,08	0,25	2,34	5,49	3,68	2,48	8,11	6,15	2,09	0,45	0,16	0,07
11	0,08	0,37	2,62	1,42	5,97	8,28	7,19	3,99	3,13	1,47	0,08	0,05
12	0,33	0,18	2,54	1,73	1,97	1,41	5,90	5,04	3,24	0,57	0,44	0,02
13	0,39	0,49	2,96	0,94	1,93	2,42	5,61	4,17	4,10	0,37	0,16	0,10
14	0,49	0,29	2,75	2,98	6,93	4,73	5,40	1,83	2,54	0,60	0,12	0,10
15	0,51	0,26	0,84	3,96	7,32	7,12	3,78	5,10	3,97	0,53	0,12	0,03
16	0,57	0,19	1,78	5,80	3,68	4,35	2,67	4,66	3,74	0,84	0,46	0,28
17	0,55	0,32	3,45	3,63	7,66	5,57	7,11	4,92	3,77	2,02	0,27	0,24
18	0,52	0,33	1,55	5,07	6,23	4,52	7,27	2,53	3,68	1,95	0,16	0,16
19	0,45	0,50	3,25	5,66	6,32	3,32	7,44	2,13	3,37	0,11	0,23	0,05
20	0,48	0,38	2,92	5,94	6,54	4,49	4,83	2,37	3,24	0,45	0,11	0,13
21	0,47	0,83	2,07	5,92	1,54	5,31	7,56	3,24	2,19	0,27	0,05	0,14
22	0,83	0,24	3,82	5,91	7,42	3,72	6,96	5,05	0,44	1,49	0,32	0,15
23	0,88	0,47	0,66	6,48	7,44	6,39	6,71	2,74	1,56	0,35	0,23	0,15
24	0,33	1,04	3,58	6,44	7,34	3,74	6,61	5,18	3,23	1,06	0,09	0,06
25	0,32	1,04	1,91	6,52	6,49	3,67	7,01	1,26	0,71	0,51	0,04	0,32
26	0,23	0,83	4,39	5,83	7,76	2,93	7,05	2,92	1,10	0,10	0,11	0,18
27	0,21	0,39	4,23	5,99	1,61	6,35	6,84	3,45	2,93	0,17	0,03	0,29
28	0,30	0,26	4,23	5,71	1,85	8,20	6,14	3,11	2,73	0,20	0,08	0,14
29	0,93	0,00	4,08	3,64	1,22	0,95	4,66	3,64	2,57	1,00	0,06	0,35
30	0,95	0,00	2,76	4,87	3,11	1,77	5,13	3,63	2,77	1,29	0,17	0,08
31	0,35	0,00	4,45	0,00	4,35	0,00	3,83	4,25	0,00	0,78	0,00	0,19
	10,69	12,35	73,25	129,77	145,33	135,55	190,19	135,46	89,62	27,47	6,44	4,63
Highest	0,95	1,04	4,45	6,52	7,76	8,28	8,18	6,68	4,69	2,92	1,24	0,36
Average	0,34	0,40	2,36	4,19	4,69	4,37	6,14	4,37	2,89	0,89	0,21	0,15
Lowest	0,03	0,10	0,23	0,68	0,69	0,95	1,81	1,26	0,44	0,10	0,03	0,02

Figure 44 *Solar irradiance data from Kumpula weather station, sampling width: 1.1.2014 – 31.12.2014*

7. EEPOS DATA COLLECTED FROM END USER ACTIONS

7.1 Room temperature remote control unit

Each of the Merenkulkijanranta apartment rooms are equipped by room temperature remote control unit. The distribution of the switches is presented in the figure 45.

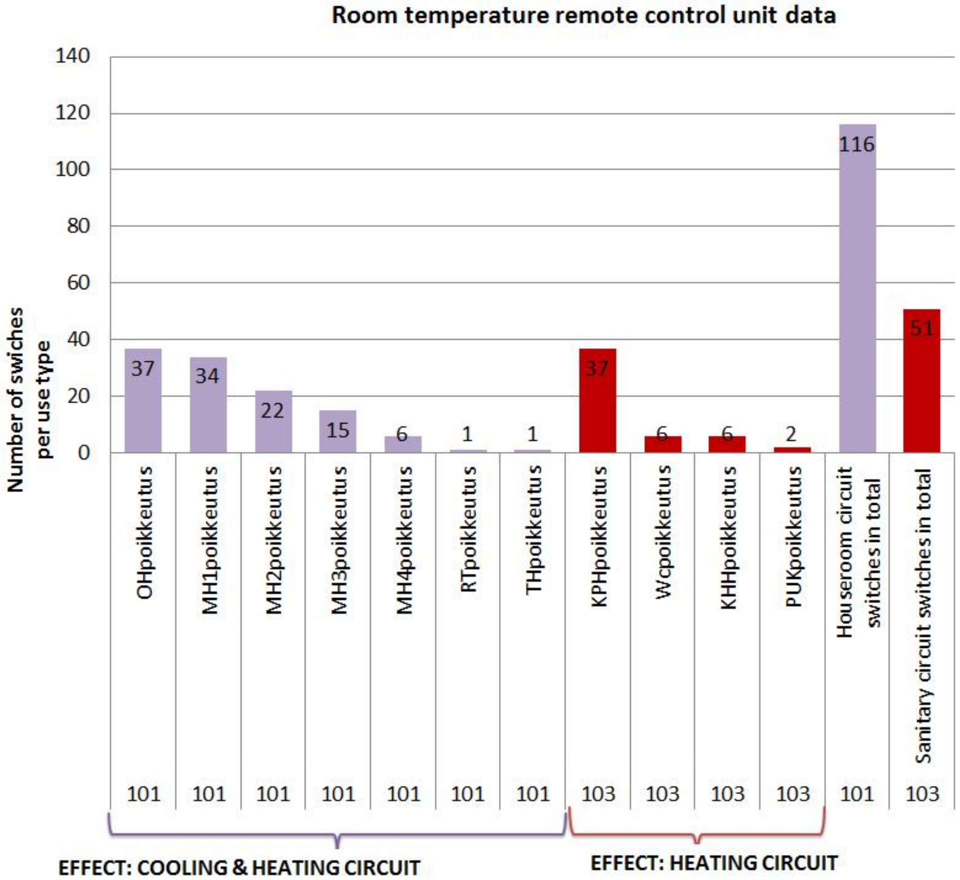


Figure 45 *Room temperature remote control unit switch types distributed by circuit type*

The switches are divided into two groups which are switches located in the houserooms heating & cooling circuit (101) and switched located in sanitary cabin heating circuit (103).

Both of the circuits 101 and 103 were analysed as their own group due to their different heating and cooling features.

After inventorying grouping the switches into groups was analysed how often and when the switches are used. In the appendixes 14 and 15 are presented on real-estate level use frequency of the switches. From the figure can be seen that approximately of the switches are in infrequent use.

After the use frequency was analysed further analysis how the switch changes were distributed by time category. In the appendixes 16 and 17 presented count of changes per time category. From the graph can be concluded that if change was done into the switch setting it was very likely that the inhabitant will readjust the setting during the same day.

NOTE: There exist slight mitch match with the findings between appendixes 14-15 and 16-17 since in appendix 16-17 is analysed by actual timestamp values and appendix 14-15 presents rough estimate.

In appendix 18 and 19 are presented the sum of time how long switches were kept in certain time usage category on real-estate level. The results were in alignment with the analysis presented in the previous appendix 16. As an conclusion of the switch usage is that whatever the initiator for the use of the temperature switch is it occurs in seldom, switch is set more than once during that specific day and then the switch is then forgotten into certain position for very long period of time.

After conducting analysis of the frequency of the switch use attention was given for which period of time switch was used. In appendix 20 and 21 are presented count of switch settings per month.

From the figure can be seen that during cold periods more changes are set for increasing the temperature and during the hot periods more settings are done do decrease the heat.

After the month specific change analysis was analysed in which outdoor and indoor temperature changes were mostly made. In appendix 22 and 23 are presented data when switch has been used and what the indoor and outdoor temperature has been at the specific moment. As from the figure can be seen that most of the switch use occur when outdoor temperature is positive and room temperature is above 20 degrees.

As next analysis was to analyse further what sort of temperatures were set by the switch when data was distributed by outdoor temperature.

In appendix 24 and 25 are presented the switch use distributed by outdoor temperature. As an interesting finding in this point was that even when outdoor temperature is near 20 degrees inhabitants have set increase in temperature. Further analyses from the behavioural pattern are needed to make final conclusions.

In appendix 26 and 27 are presented the indoor temperature at the moment when temperature switch has been used. From the appendix 28 and 29 can be seen that in number of cases temperature were set higher when room temperature is above 22 degrees. As a conclusion from the switch use is that A) Data or analysis is faulty, B) The experience of temperature is highly individual C) Possibility for faulty wiring or transmitting of the data D) Inhabitants misunderstand how to use the temperature switch.

After analysing the switch changes related to time and ambient conditions analysis regarding the supply and return temperatures in heating and cooling circuits was conducted. In appendix 30 and 31 are presented the supply and return temperatures of home rooms heating circuit.

Next similar supply and return analysis for sanitary heating circuit (103) was conducted. The results of analysis are presented in appendix 30 and 31. Both of the analysis presented in appendix 28/29 and 30/31 are in alignment with the knowledge how the circuits function. The supply temperature is higher than the return temperature. In order to make further conclusions from the data more complex would be needed with additional variables.

Similar introductory analysis regarding the fan coil supply and return temperatures were conducted. The analysis is presented in appendix 32 and 33.

As an interesting finding regarding the supply temperature is that the supply temperature is quite high. However in order to make further conclusions from the data more complex would be needed with additional variables.

Last of the supply return analyses was to evaluate the return and supply temperatures of the chilled beams. The analyses are presented in 16 and 16.1. As interesting finding regarding the graphs presented in appendix 34 and 35 is that the supply temperature data is most probably faulty one. Additional analysis regarding the matter is recommendable.

7.2 Room operating panel

Each of the inhabitants rooms are equipped with room operating panel which have home, away, intensified and night modes. The room operating panel usage rate analysis is presented in appendix 36 and 37. Initial analyse was to study what was the utilization rate of the switch. The appendix 36 is rough estimate created from the data. As can be seen the utility rate in general for the switch is low. In the appendix 37 is presented the overall count into which modes the switch usage is distributed.

Next was analysed the length of time, how long switch was kept in certain mode. First was counted how many of the setting were made in each time category. In appendix 38 and 39 are presented that most of the changes made last maximum day or less. The results are alignment with the findings of appendix 36. There was an active group, which uses intensified and night modes. In general the usage of switch is low.

Next was analysed the length of time that each mode was kept in. In figure 46 is presented the time length sum for each mode.

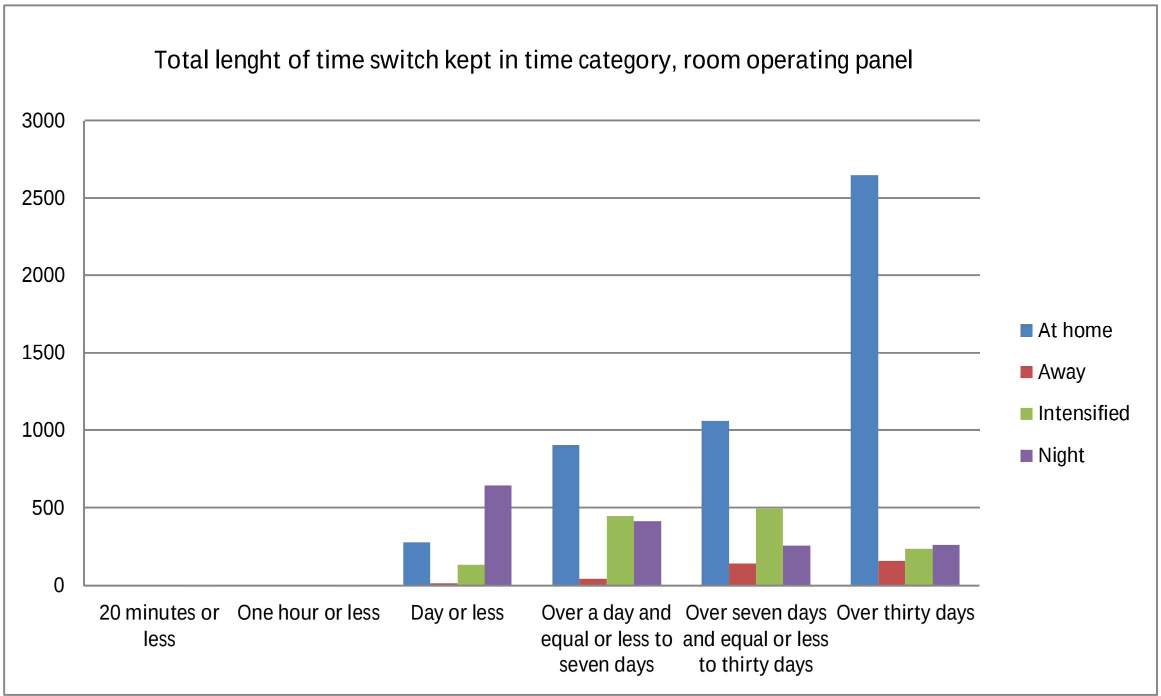


Figure 46 *Room operating panel usage time sum per mode.*

As a conclusion of the figure is that majority of the inhabitants keep the switch long periods of time in home mode. If mode is changed, in some cases it is forgotten into the changed mode for long period of time.

7.3 Usability

The usability of room temperature remote control unit and room operating panels are basically easy. Just rotate switch clockwise or anticlockwise. Moreover physical switches are available clock around without any delay. Despite of impression about easiness we were able to find several usability related issues during the pilot.

- Most of switches were used seldom. There were some exceptions but most of the time end users seem to be content with indoor conditions or they felt manual control useless.
- There were couple of short periods while switches were used extremely actively. There were reported building automation system malfunction, like blackout of cooling system, during those periods. Thus end user activity seems to indicate especially with poor indoor conditions.
- There was indicative information that activity seems to decrease during the measuring period.
- Use of room operating panel indicated laps of memory, like cases when the switch remains “night” position for a long time.
- Definitely location of switches was not always designed optionally.
- Boosting apartment’s ventilation during the first operational year may improve indoor air quality. Thus a group of end users avoided to use room operating panel.
- There was lot of unawareness about switch and their impacts. The issue that is obvious for a designer might not be obvious for an ordinary people, like if plus sign remarks more temperature or more cooling during cooling period. Moreover user guide that is located in housing company portal is not too widely known. There was different understanding about switches actual impacts within experts as well.
- We were not able to verify if all data connection was fully working all the testing period. Incomplete connection may explain some incoherent observations.

8. EEPOS IMPACT ON ENERGY

8.1 Energy production

The figures in the following chapter describe efficacy of cooling station. Thus energy used rotating seawater in pumping station is excluded. On yearly level this equivalent 22MWh of power. On the other hand period of free cooling energy is excluded as well. Thus the formula is valid during compressor’s working period only and it is not valid during season when seawater is relatively cold. As far as the entire year is concerned the formula results too low.

8.1.1 Seawater cooling

The Merenkulkijanranta is equipped with seawater pumping station in which sea water is used as condenser of cooling circuit compressor. In some cases when seawater is cool enough seawater is used as gravity-flow in the cooling circuit.

The gains of the system can be evaluated by Energy Efficiency Ratio (EER). The EER calculation is presented in formula 1.

$$\boldsymbol{\varepsilon = \Phi h / P} \quad (1)$$

ε = Cooling efficiency factor

Φh= Cooling power, kWh = (G401LM03 + G401LM04)

In which:

G401LM03= Energy consumption of cooling system, fan coil unit network

G401LM04= Energy consumption of cooling system, chilled beams

P= Amount of work by the compressor, kWh = H901EM04_1

In which:

H901EM04_1= Electricity consumption of cooling system, cold water station KYA01

The concept of the formula is that it presents the ratio from how cooling energy can be produced by certain amount of electricity. As an example if EER number is 2 then 1MWh of electricity produces cooling 2 MWh. The EER calculations are presented in table 6.

Table 6 The EER values in different sample widths

Sample width		EER
1.6.2015	30.6.2015	1,86
1.8.2015	24.8.2015	1,31
1.6.2015	24.8.2015	1,51
5.12.2014	24.8.2015	1,44

However the table shows EER only for the period, when compressors are running. Thus it excludes cooling energy obtained during free cooling period. Free cooling is available when seawater is around 15 centigrade or less. In the demonstration this practically covers fully cooling energy needed during April and May and 50% about the cooling during June. Totally 40-50% of cooling energy is covered by free cooling.

In addition to the EER calculation analyse from the solar irradiation, electricity consumption and cooling energy was conducted. The results of the analyses are presented in figure 47.

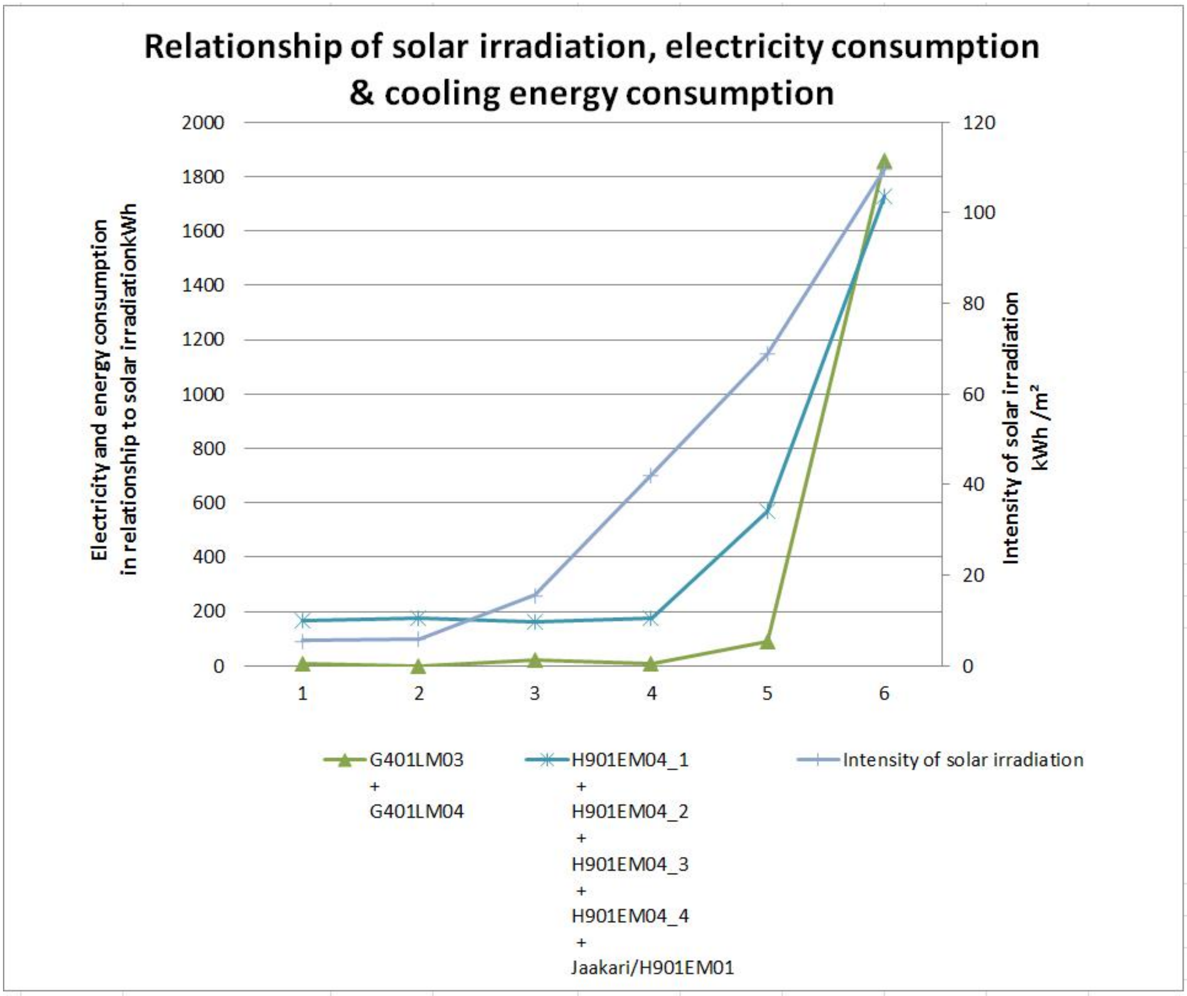


Figure 47 *Relationship of solar irradiation, cooling energy-, and electricity consumption.*

8.1.2 PV simulation

The PV simulation was calculated from perspective to cover one real-estate roof by PV panels. The gross area was estimated ~ 700m^2 and from the area could be used approximately 300m^2 for the PV instalments. As coefficient of efficiency for solar panels were used 15%.

In PV power production calculations were used W/m^2 measurement values from Merenkulkijanranta located weather station which were equipped with pyrometer. The PV power production equation were calculated by formula 2.From the calculated results were created in MS Access energy production curves that are presented in appendix 40 and 41.

$$E(Wh/m^2) = P(W/m^2) \times t(h) \qquad (2)$$

In which:

E(Wh/m^2)= Energy produced in hour per square meter

W/m^2= Watt per square metre

t(h) = Time, hour

Main conclusion from solar panel simulation was that during the winter the production is low and at summer high.

These photovoltaic curves are presented on daily level for two practical reasons. Firstly daily curves highlight incidental variation that is characteristic with solar power and wind powers as well. On the other hand consumption profiles are related with weekday. Thus we preferred to visualise both consumption and production profiles in the same format. The same format is in wind power figures as well.

Main conclusion from solar panel simulation was that during the winter the production is close to zero and at summer high. This profile is perfect to compensate power used for cooling.

To compensate the current cooling power within the local we need around $20kW_p$ equipment for the demonstration building and around $200kW_p$ equipment for the entire neighbourhood area. If polycarbonate photovoltaic panel are used this means around $120m^2$ and in the case of thin film panel around $220m^2$. Both solutions technically fit in available $300m^2$ roof area. By using current market price, local energy price and moderate prices estimate we conclude around 15 years return of investment time.

8.1.3 Solar thermal collector simulation

At the webpage of solar thermal supplier is mentioned that in Finnish conditions one TP-69C model vacuum tube produces energy approximately 2300 kWh/annually and that one tube requires 6,9 square meters installation space. If the suitable roof space ($300m^2$) that is for is used for vacuum tube installation then altogether 43 pcs of vacuum tubes can be installed. The number of vacuum tubes is reduced down to 35 pcs in order to leave space for installations and maintenance. 35 pcs * 2300 kWh = 80,5 MWh/a.

8.1.4 Urban wind turbine simulation

In the urban wind turbine simulation was used Merenkulkijanranta wind speed data. As a cut in speed for wind power production was used wind speed 2 m/s. The formulas used in the calculation will provide only suggestive approximate of the wind power potential.

The wind speed data collection started 9.9.2014. From the collected data two sample widths were taken sample width 9.9.2014 – 5.3.2015 present the whole sample width and sample 1.12.2014 – 28.2.2015 present winter period. Into the filtered (>2 m/s) into Merenkulkijanranta wind speed data were applied formula 3. For the simulation two turbine scenarios were calculated: Case where the wind turbine blade radius is 1 meter (realistic scenario) and case where the wind turbine blade radius is 4 meters (theoretical).

$$P = \frac{1}{2} * \rho * A * v^3 * Cp \qquad (3)$$

P = Power (w)

v = Wind speed m/s

ρ = Air density [kg/m^3]

Cp = Power Coefficient (Betz limit)

A = Area

$A = \pi * r^2$

π = Pi 3,141

r = Radius

In appendix 42 and 43 are presented power production curves by a weekday and hour. From the graph can be seen that the wind power production fluctuates by hour and by day. For each day there exist clear peak in production. Duo to the fluctuation in energy production it is recommendable to reconsider energy storing such as batteries or chemical storing (methanisation).

In appendix 44 and 45 presented theoretical wind power production it is remarkable how much the incensement of the wind turbine radius by 3 meters affect into the power production. The power production is close to tenfold when the blade was increased. Nevertheless the perspective is theoretical one: The increase of the blade increase also issues such as noise, vibrations and other mechanical issues.

8.2 Energy consumption

8.2.1 Electricity consumption

The Merenkulkijanranta energy consumption analyses began by benchmarking the district heat, electricity and water consumption of each real estate. The monthly consumption of each real estate was divided by the gross square meters case specifically. The results of energy consumption benchmarking are presented in appendix 46, 47 and 48.

As can be seen from the appendix 46 and 47 the electricity and district heat varies real estate specifically. Reason for the most remarkable differences can be explained by real estate specific construction component usage. In the earliest built buildings the sanitary cabin heating were built by heating resistors in addition also other building solutions varies.

The benchmarking provides very useful and clarifying perspective into the energy consumption. The baseline of the consumption is dictated already in the construction phase. What sort of components is used in the building, how much isolation is used etc. The Merenkulkijanranta neighbourhood energy classes are presented in table 7. The relatively low D energy class in the table is because there exists one brand new apartment which in construction phase has consumed in construction phase high amount of energy (plastic sheets in windows & heating).

Table 7 Energy classes calculated from empirical energy consumption

Building energy class	Building total annual energy consumption per building gross area [kWh/m^{2}a]	In merenkulkijanranta (pcs)
A	0 ... 75	
B	76 ... 100	1
C	101 ... 130	5
D	131 ... 160	1
E	161 ... 190	

Building energy class	Building total annual energy consumption per building gross area [kWh/m²a]	In merenkulkijanranta (pcs)
F	191 ... 240	
G	241 ...	

In Merenkulkijanranta exist some energy saving cases, for example in appendix 12 and 13 are presented the energy consumption of outdoor illumination. In the illumination is used conventional lamps, replacing the laps by LED- lamps would reduce electricity consumption during time when there is no day light. In Finland more than half of the year there exist need for illumination during the night time. In addition pumps and motors used in the real-estate should be equipped with micro frequency converters.

As an energy saving case for electricity was chosen case in which the heating resistor which heaths and removes humidity from the supplied air are replaced by distributed heat. There exist two reasons for selecting the specific topic. First of all ventilation is the biggest electricity consumer and second of all the distributed heat are in modern power plants plain side product of electricity production and considered “waste”. The electricity consumption related to ventilation is presented in appendix 49. The heating energy net need presented in appendix 49 is calculated by formulas presented in appendix 50, 51 and 52.

The energy saving potential can be argumented by analysis presented in the appendix 49. The usage of the room panel switch is very low and people in general are passive regarding the usage of the switches in apartments. In addition appendix 46 and 47 spell out that the baseline of the energy consumption builds up from constructional solutions.

In addition when considering the electricity consumption new built real-estate it is notable that not all the apartments are immediately occupied. The consumption of both electricity and distributed heat has been in consistent increase in Merenkulkijanranta. In appendix 53 is presented the inhabitants growth in demonstration building.

8.2.2 Cooling energy

Cooling energy during the summer season was used in the demonstarion building monthly between 4,5 and 5MWh. At the same period mean of room temperature remote control unit values was +0,15 degrees. This means slight energy saving compared with neutral setting totally between 0,1 and 0,15MWh/a. In the case is all end users would have permitted full temperature arise up to 2,5 centigrade there would effected about 1,5MWh/a saving potential in electricity.

8.2.3 Heating energy

During heating period heating energy consumption varied in the demonstration building monthly between 9 and 16MWh. Accordingly mean of room temperature remote control unit values was about +0,5 centigrade. This caused about 1,5MWh/a increase in used heating energy in the denobstration building compared with neutral settings. In the case of full temperature decrease by -2,5 centigrade means 11MWh/a saving potential in heating energy compared with the measured situation.

8.3 Effects on CO_2 emissions

As presented in chapter 8.2.1 Electricity consumption as CO_2 emission reduction case was chosen replacement of ventilation resistors (400W) into district heat. The results are presented in appendix 54, 55, 56 and 57.

As a conclusion of the appendix 54, 55, 56 and 57 are that use of electricity should be avoided if there exist substitutes such as distributed heat or renewables. In PV and wind power simulations were presented the potential availability of renewables. Due to the time pressure the most potential renewable in Finnish conditions, the geothermal energy was not simulated in this report.

9. CONCLUSIONS

Currently the available equipment for monitoring energy usage and system functions are out there in the markets. No new equipment needs to be developed in order to have the measurements needed for EEPOS to run. Other hardware instead, like decentralised air-handling units, are not design for operations with advanced building automation system. Thus optimal usage of the entire building system cannot be achieved so far. On the software side it is not that easy to find software or software vendors to full fill the needs for new kind of idea like EEPOS platform. There for new software has been developed to match the needs of EEPOS.

Together with the ideas of energy positivity, EEPOS system and equipment available the EEPOS team was able to set up measuring equipment and environment in the demonstration area. Working closely with the construction company, housing company and building systems company the EEPOS team was able to monitor data and adjust energy flows in respect of the KPI's considering also forecasts and user behaviour.

The data monitored was compared to buildings in the same neighbourhood area for calculating the energy efficiency. As for this calculation the made conclusions that the idea of energy positivity may be achieved up to limited extent. Full implementation would affect heavily on architecture. The remaining technical challenger is seasonal energy storage issue. The district heating (produced by nearby CHP facility) does not allow the Finnish Demonstration to achieve full energy positivity in the areal level but the need for renewable energy sources may be calculated upon the measurements gain using EEPOS system.

9.1 Summary of achievements

To the new high class apartments we were able to install the equipment necessary for monitoring energy consumption on different kind on energy environments. Both areal energy sources and local consumption points are now covered with monitoring and surveillance.

New equipment was installed to buildings as well as new methods of data transfer from measurement point were discovered. Programs have been developed in this EEPOS project to analyse and sophisticate data given by the measuring.

Mobile solutions for viewing problem areas were developed. By these new solutions both users and engineering personnel may easily discover location for non-conformity's of conditions. Mainly these mobile functions are presented at chapter 4.3.

The Seawater based cooling impact on energy consumption was measured and calculation of its impact on CO_2 was calculated

Simulation of solar energy. Local solar radiation was measured with a pyronometer the site. This was used to calculate what if scenarios. As a conclusion about 120m^2 is needed to compensate energy used in cooling in one company and around 550m^2 is needed to compensate the entire use of power. Corresponding figures from the entire neighbourhood area are 1200m^2 and 5700m^2.

Total energy usage based carbon footprint was calculated.

Provide information for tenants using the already installed infoscreen system

9.2 Other conclusions and lessons learned

In Finland it is not at all certain new methods and testing equipment may be placed on buildings. At construction phase the building inspector officials are looking closely the plans and drawings in order not to let the builder have too many changes to systems. Quite often the areal construction protocol is stating what kind of equipment must and must not be placed on the property. There for the construction companies together with the building inspector officials have to be persuaded to support new idea. As the new ideas are accepted it is then relative easy to set measuring equipment and monitor building level data.

To access the dwellings with monitoring and measuring equipment the inhabitant of the dwelling need to accept the idea to be monitored. Access to the data collected from apartment may cause a privacy issue. This project is giving much information to the user about how to enhance the living conditions and make savings simultaneously. Therefor the EEPOS team has been able to attract tenants to participate. But it is not enough to have access to an individual dwelling because the inhabitant of the apartment not really owns the apartment but shares of the whole housing company. Any equipment that is attached to the building is owned not by inhabitants but by the housing company (closets, building system components, etc.). So the housing company also has to accept and adopt the new ideas (e.g. new equipment owned and in responsibility of the housing company). In a housing company board all inhabitants of the company are to be heard and discussed. Without this discussion and voted acceptance from the board no extra equipment can be installed. This means it is both time consuming and taking negotiation skills from the personnel willing to have equipment and monitoring in the housing company premises. For the EEPOS team it took quite an effort to have these entire parties acceptance to benefit EEPOS project. This acceptance procedure was started already in the phase where EEPOS DoW was written.

As a positive lesson there is a positive impact of the EEPOS group visiting to the housing company’s meetings. Even though the new interface (gaming type) is not yet in the end-user testing phase, there has been request by the inhabitants that they would like to join the test. The inhabitants already have the eTalo view for residents for the own dwelling data. Obviously- as anticipated in the DoW- they are interested to have more info and additional interface.

Energy usage is always a mean to gains some other objective. Thus it is challenging to motivate inhabitants to change their courses of actions. Minor savings in terms of energy are counterbalanced with indoor climate, healthy and comfort. According to the measured data the main influence can be made by automated operations focusing in three technical disciplines: heating, cooling and ventilation. This requires that all key equipment is compatible with the entire building system and is design for demand based operations.

Photovoltaic proved to be the only reasonable option for renewable power generation in the Finnish demonstration. Bio-fuel was practically excluded due to available CPH based district heating and reasonable wind power capacity would require too big windmills too close to residential area.

10. Acronyms and terms

CHP ....Combined Heat and Power.

EBT.............................Energy Brokering Tool.

eTalo ....eHouse, Neigbourhood area level intranet.

HVAC..........................Air condition system.

Jace ....Java applicEation Control Engine.

oBIX ....Open Building Information Xchange system.

ROI ....Return of investment.

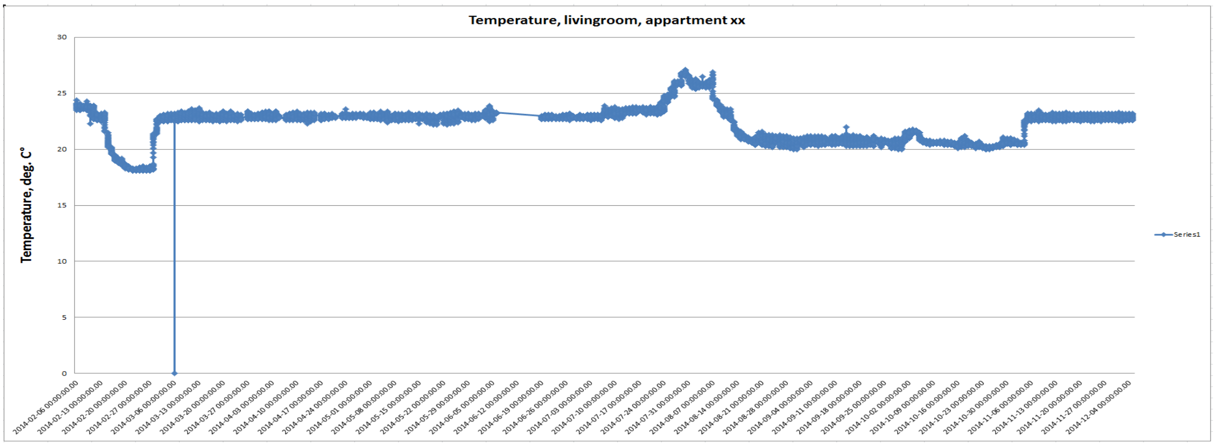
YIT RAMI ....Reporting And Monitoring Instrument.

11. REFERENCES

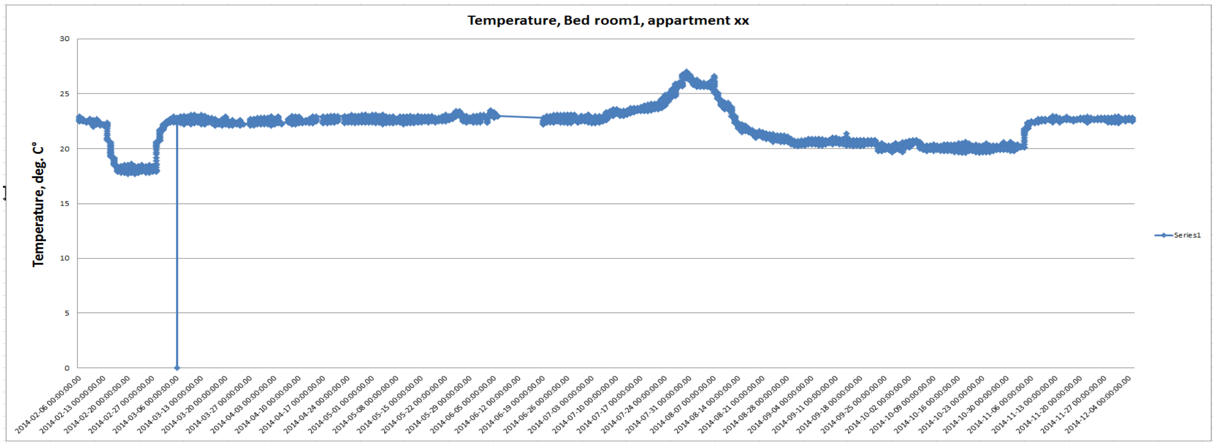
[1] Uotila, Ulrika. 2012. Korjaustoimien vaikutukset lähiökerrostalon todelliseen energiankulutukseen. Tampereen Teknillinen Yliopisto. Diplomityö. http://dspace.cc.tut.fi/dpub/bitstream/handle/123456789/21141/uotila.pdf?sequence=1

12. APPENDIX

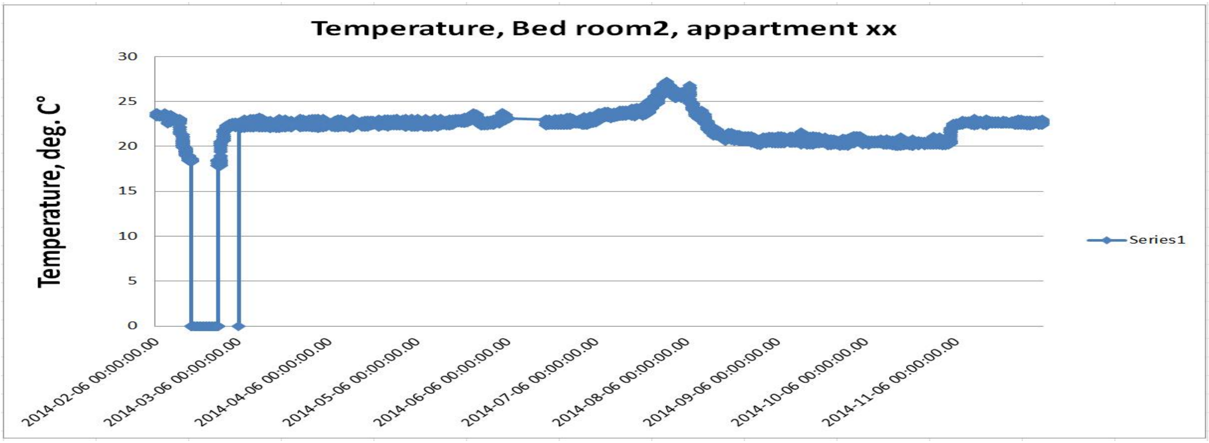
12.1 Temperature, livingroom



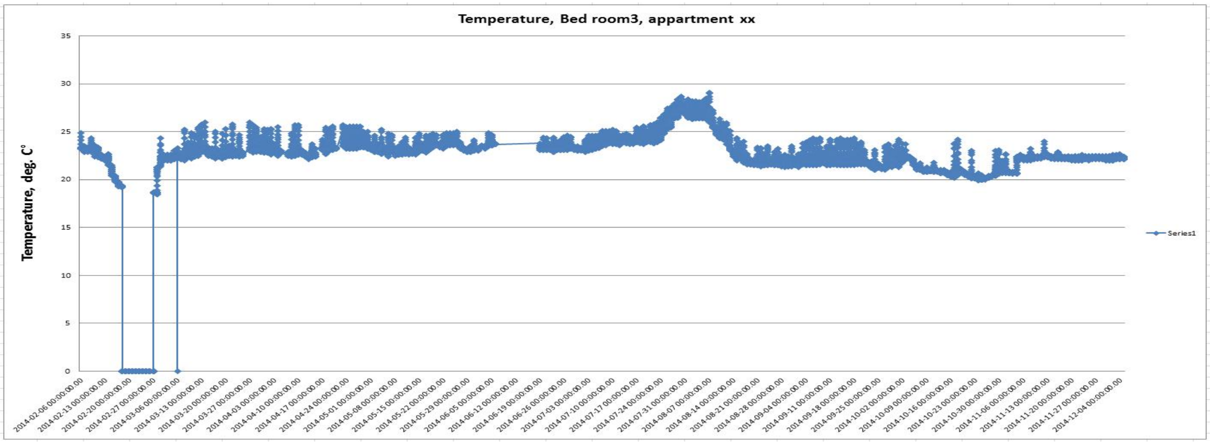
12.2 Temperature, bedroom1



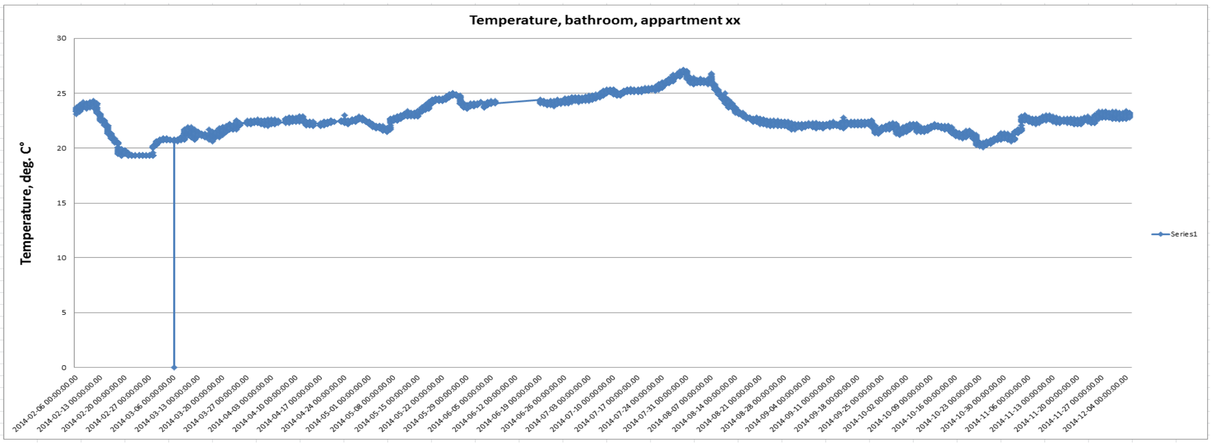
12.3 Temperature, bedroom2



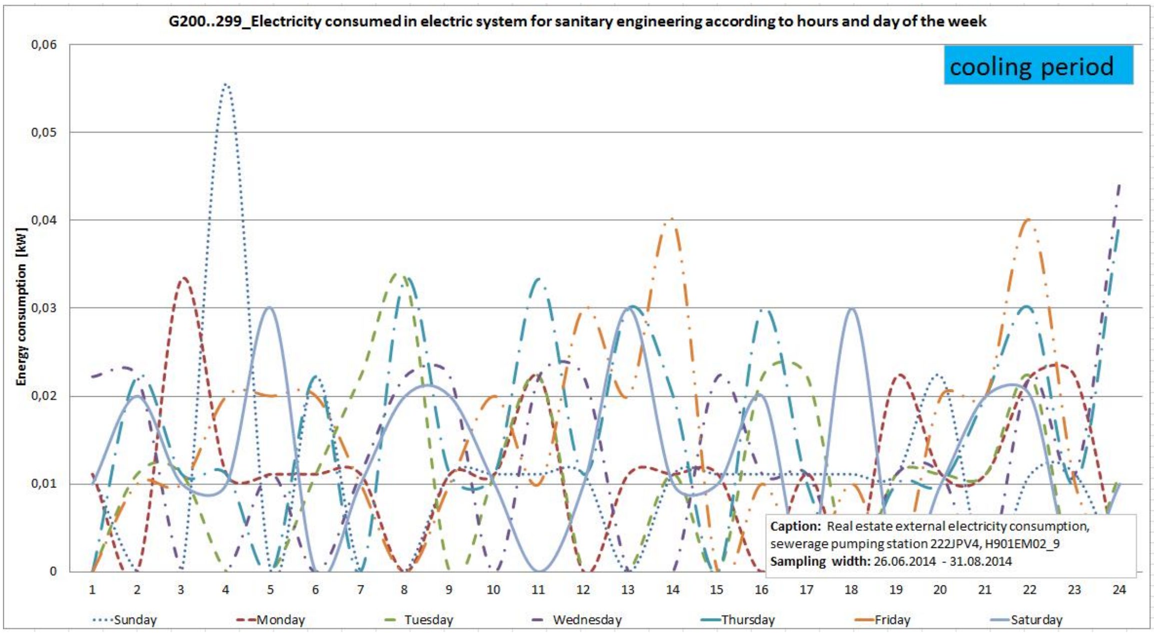
12.4 Temperature, bedroom3



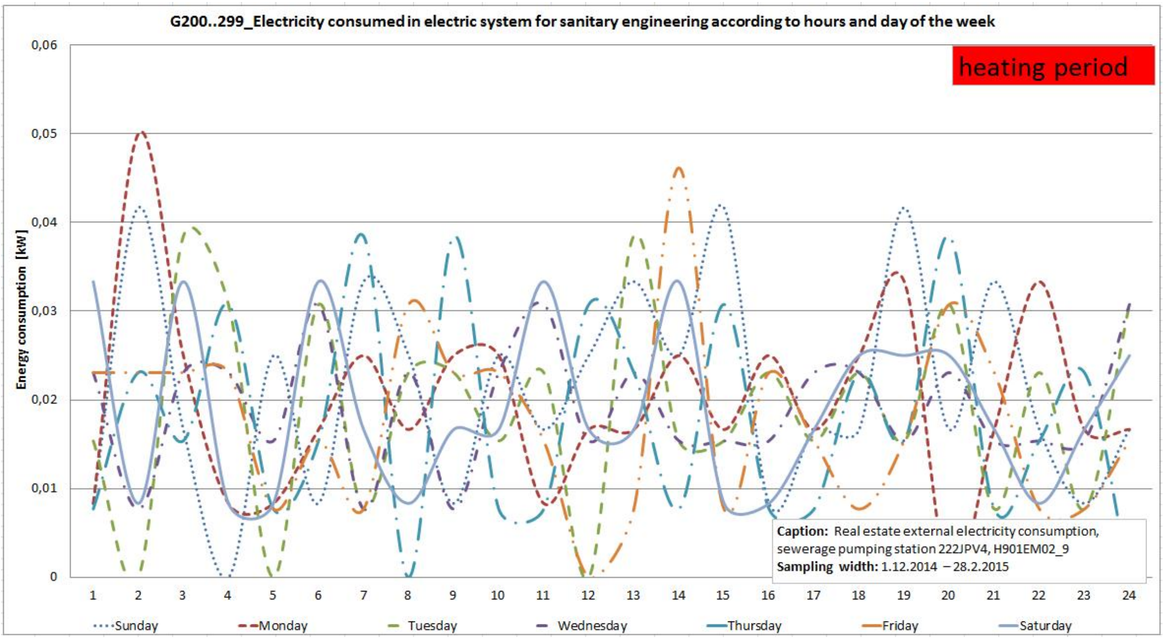
12.5 Temperature, bathroom



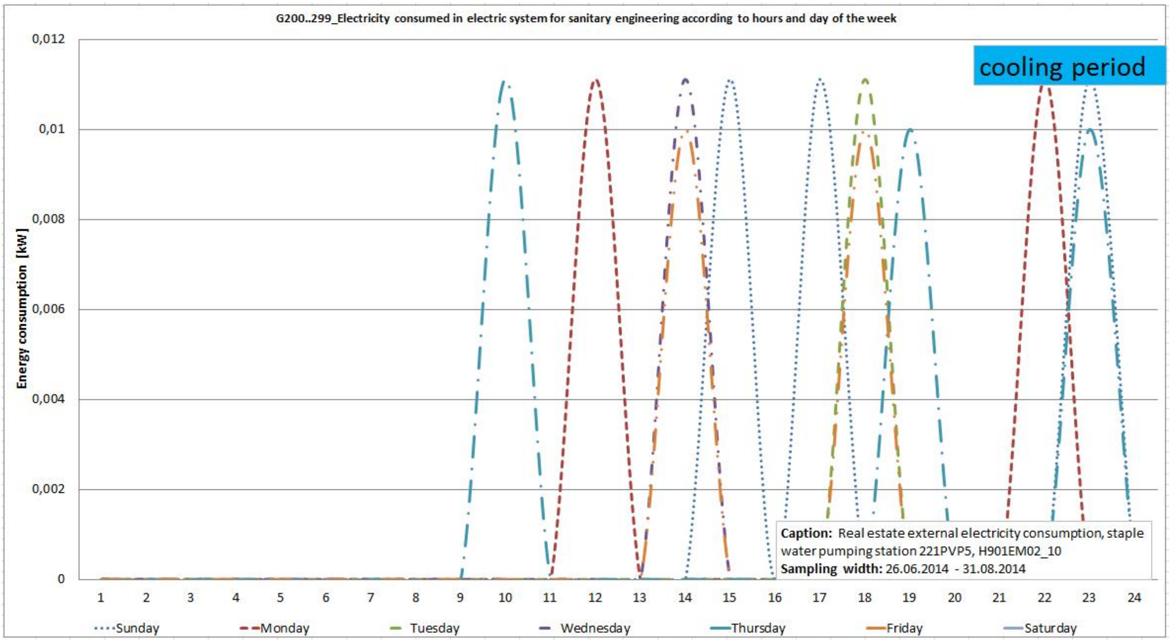
12.6 Real estate external electricity consumption, sewerage pumping station 02_9, cooling period



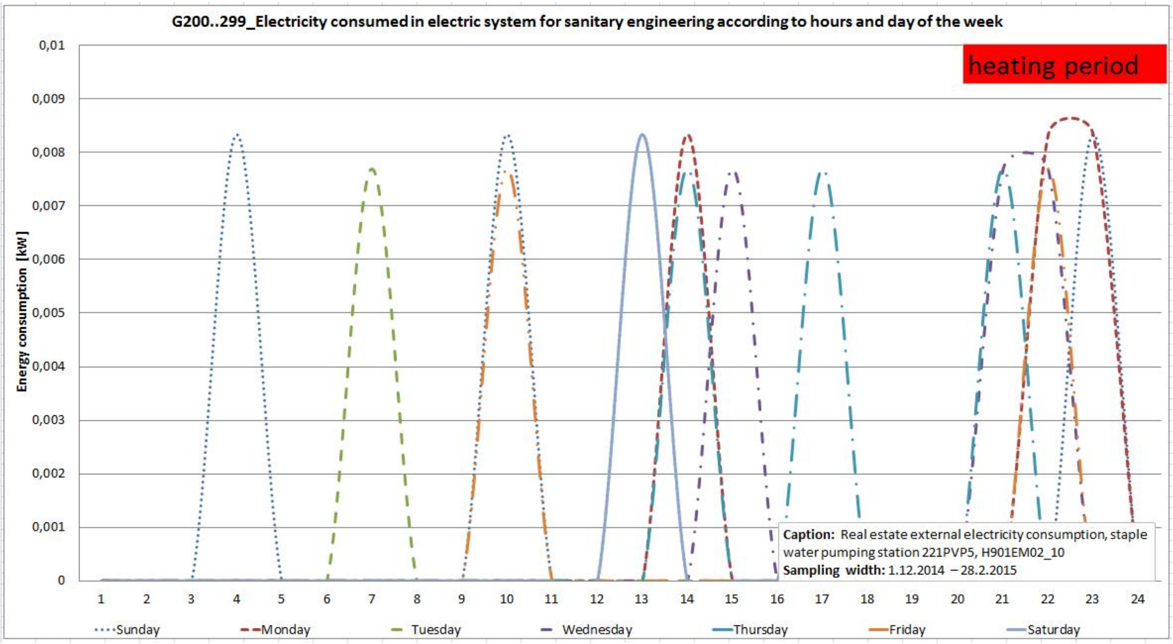
12.7 Real estate external electricity consumption, sewerage pumping station 02_9, heating period



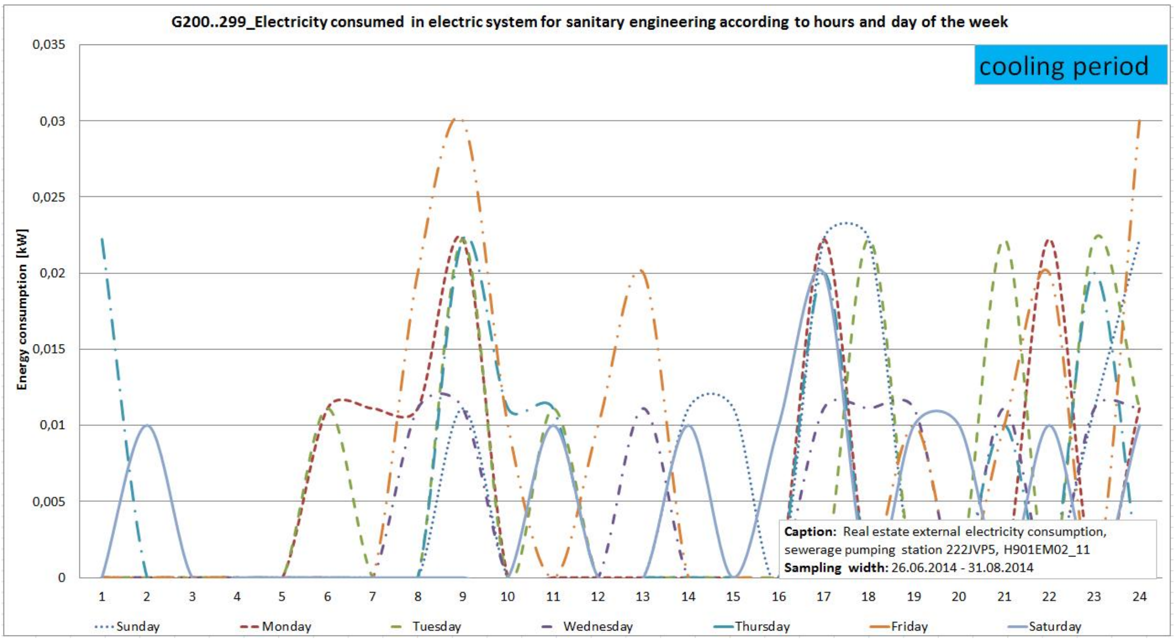
12.8 Real estate external electricity consumption, sewerage pumping station 02_10, cooling period



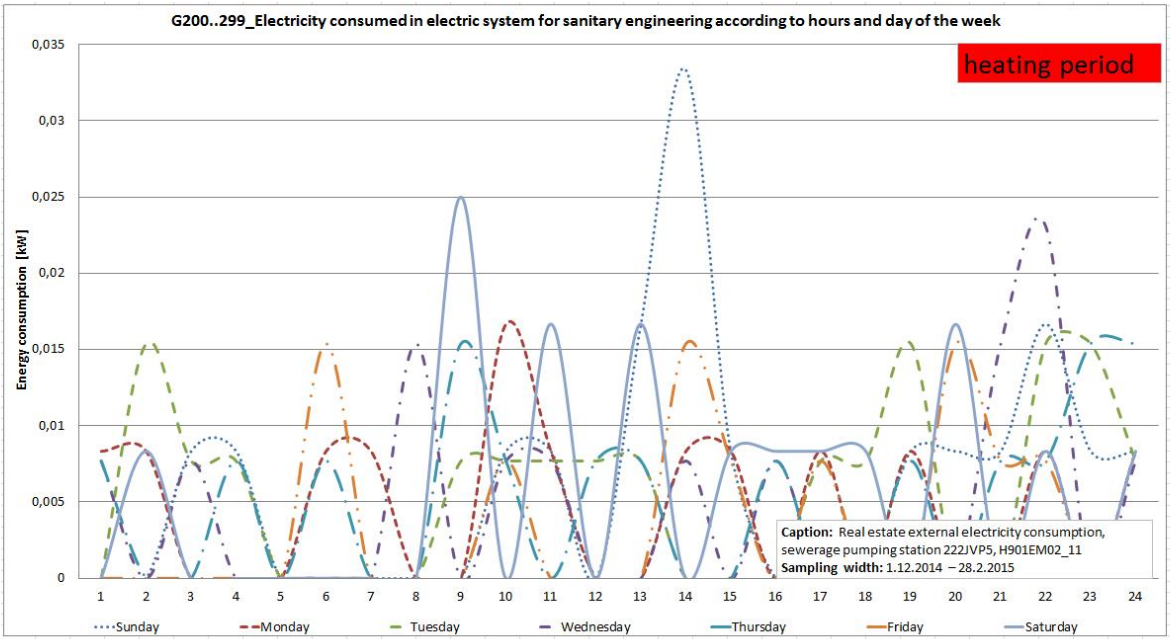
12.9 Real estate external electricity consumption, sewerage pumping station 02_10, heating period



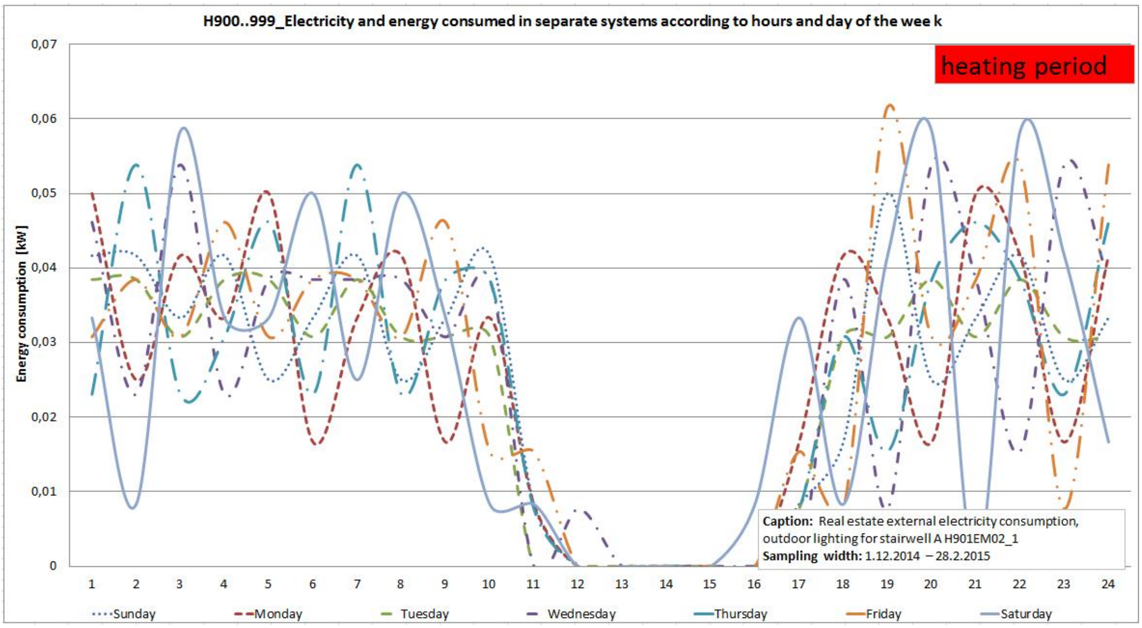
12.10 Real estate external electricity consumption, sewerage pumping station 02_11, cooling period



12.11 Real estate external electricity consumption, sewerage pumping station 02_11, heating period

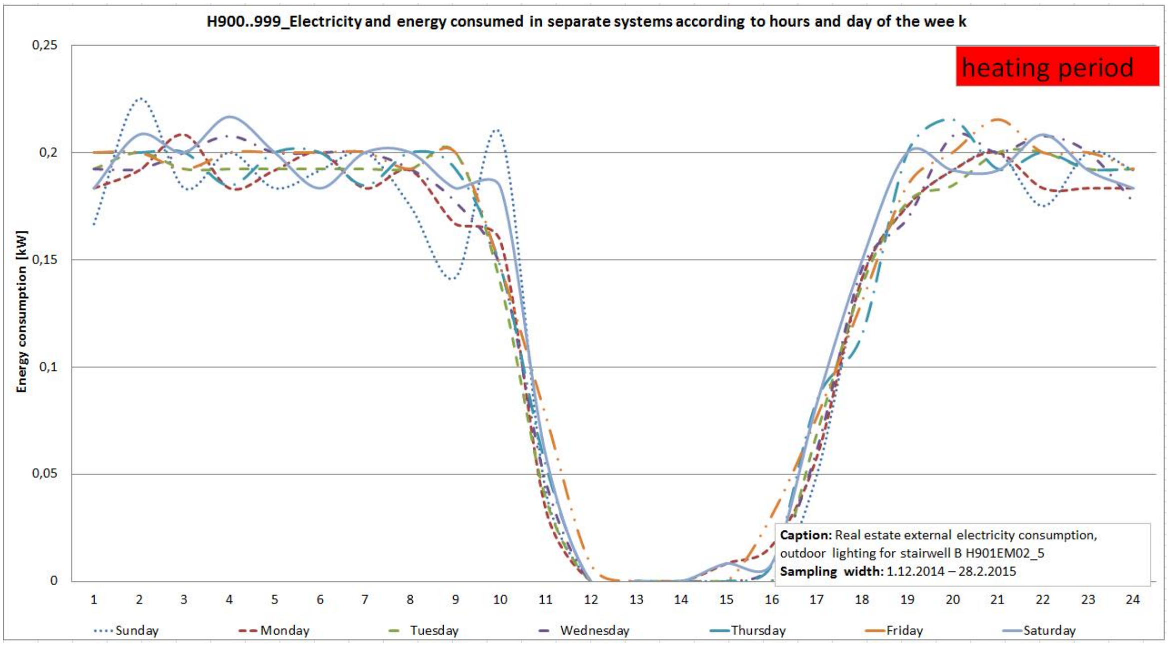


12.12 Real estate external electricity consumption, outdoor lightning stairwell a h901em02_1



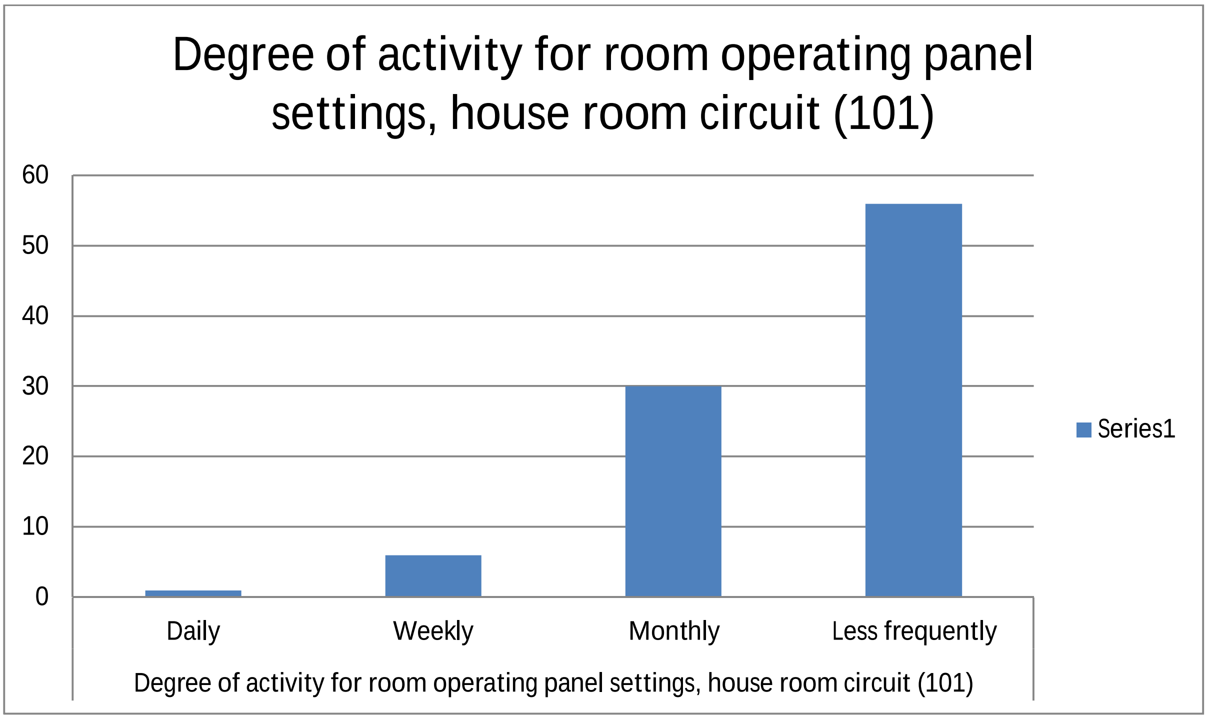
Caption: Real estate external electricity consumption, outdoor lighting for stairwell A H901EM02_1
Sampling width: 1.12.2014 – 28.2.2015

12.13 Real estate external electricity consumption, outdoor lightning stairwell b h901em02_5



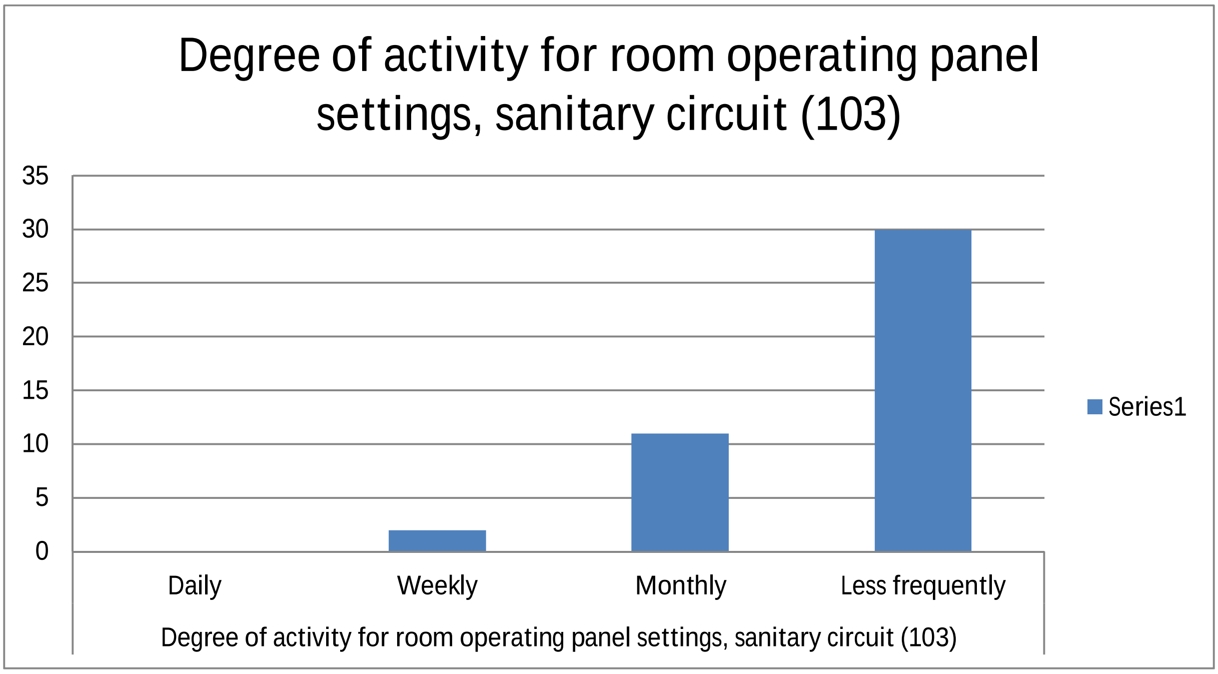
Caption: Real estate external electricity consumption, outdoor lighting for stairwell B H901EM02_5
Sampling width: 1.12.2014 – 28.2.2015

12.14 Degree of activity for room panel, house room circuit (101)



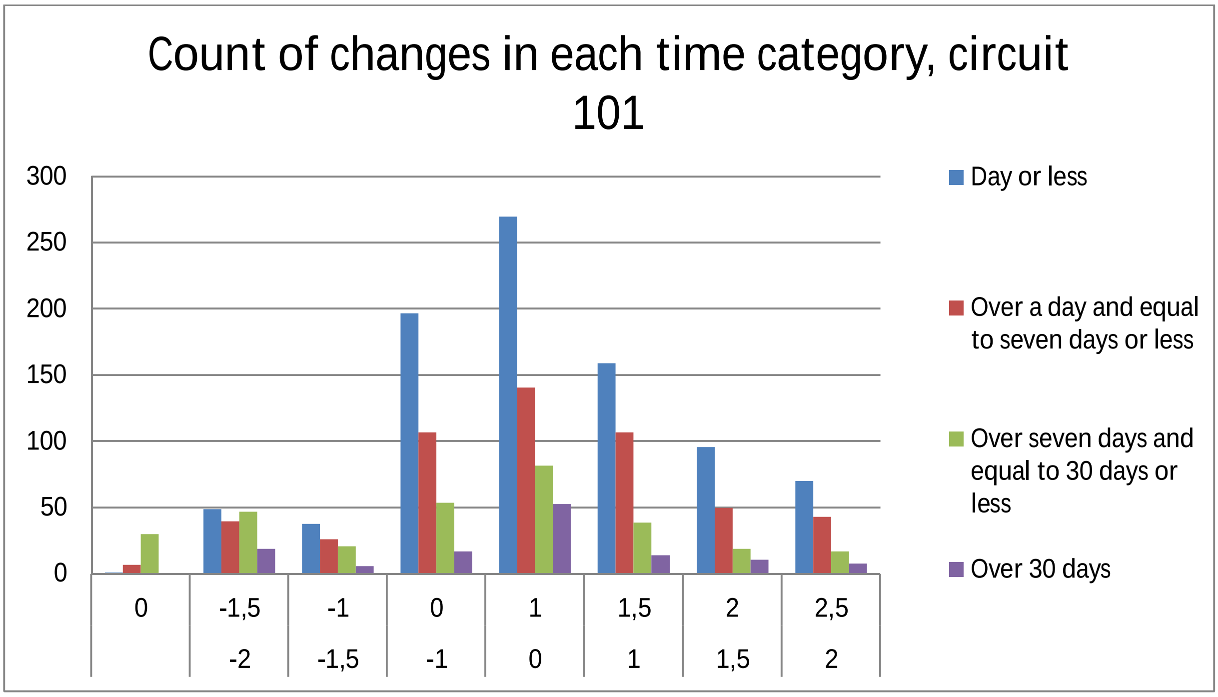
Frequency of the room operating panel use

12.15 Degree of activity for room panel, sanitary circuit (103)



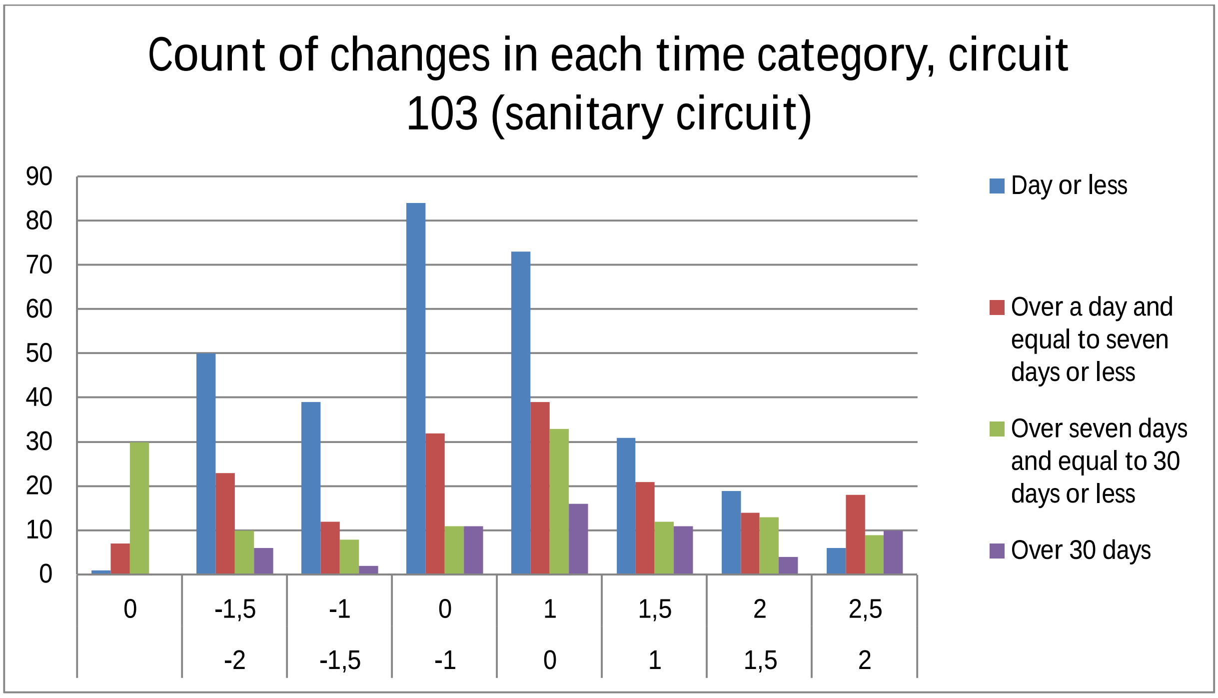
Frequency of the room operating panel use

12.16 Count of changes in each time category, circuit 101



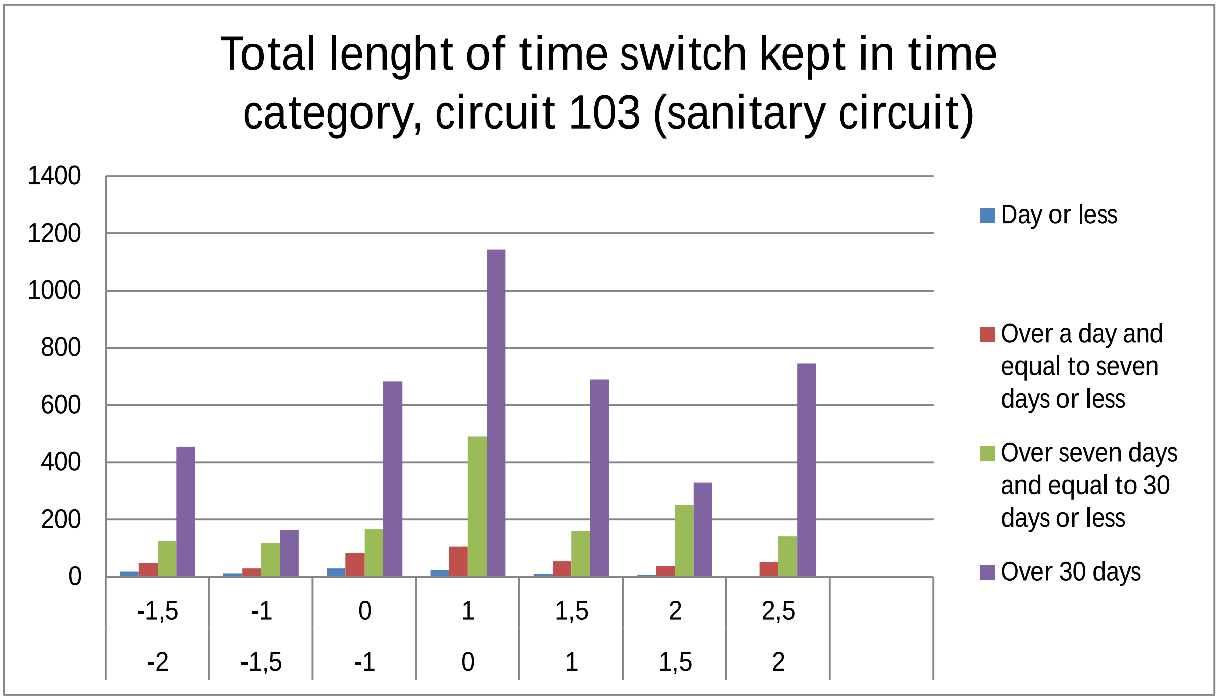
Frequency of the room operating panel use

12.17 Count of changes in each time category, circuit 103 (sanitary circuit)



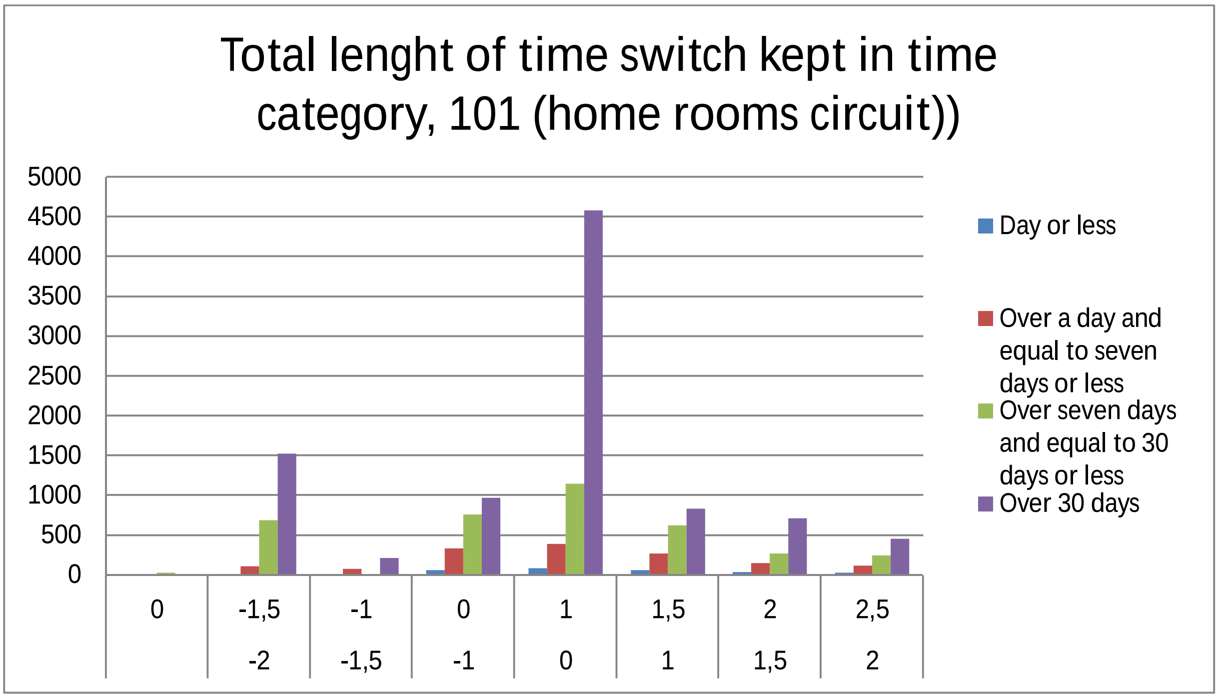
Frequency of the room operating panel use

12.18 Total lenght of time switch kept in time category, circuit 103 (sanitary circuit)



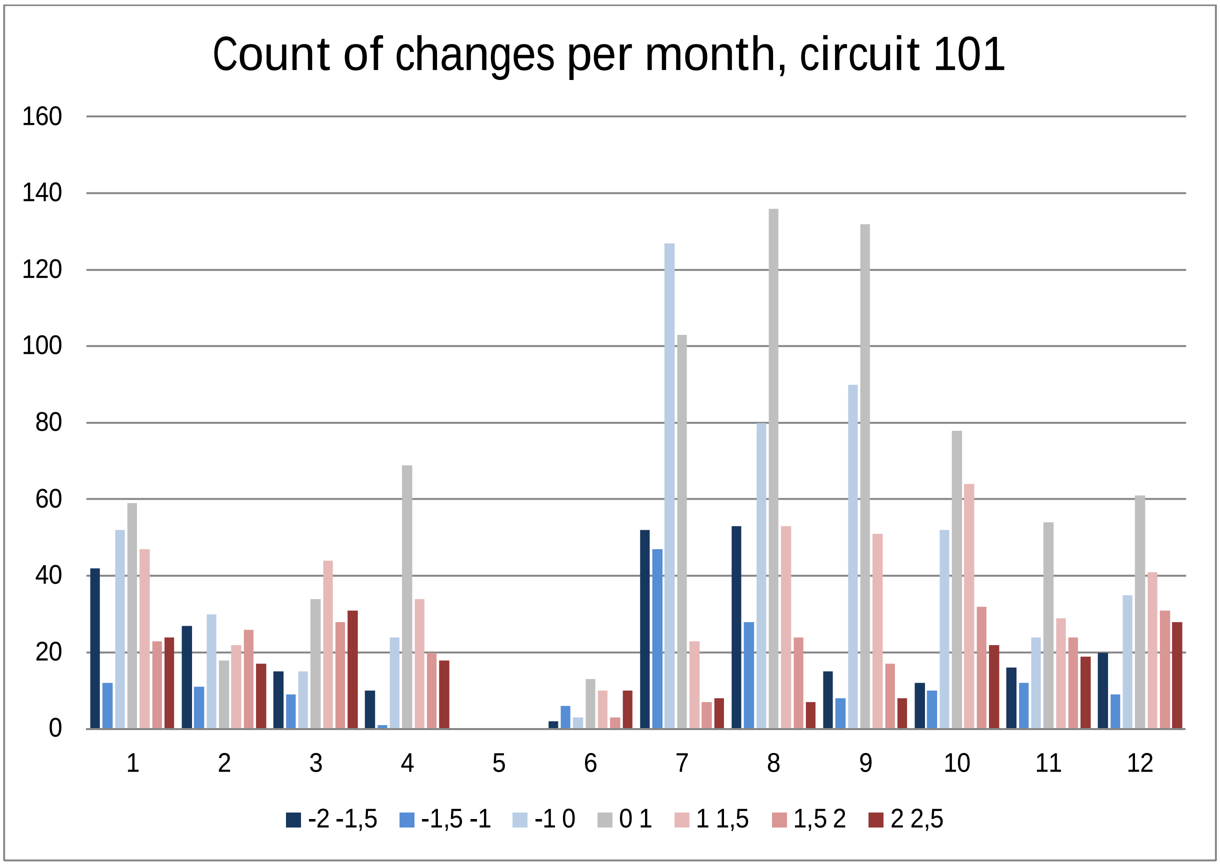
Frequency of the room operating panel use

12.19 Total lenght of time switch kept in time category, 101 (home rooms circuit))

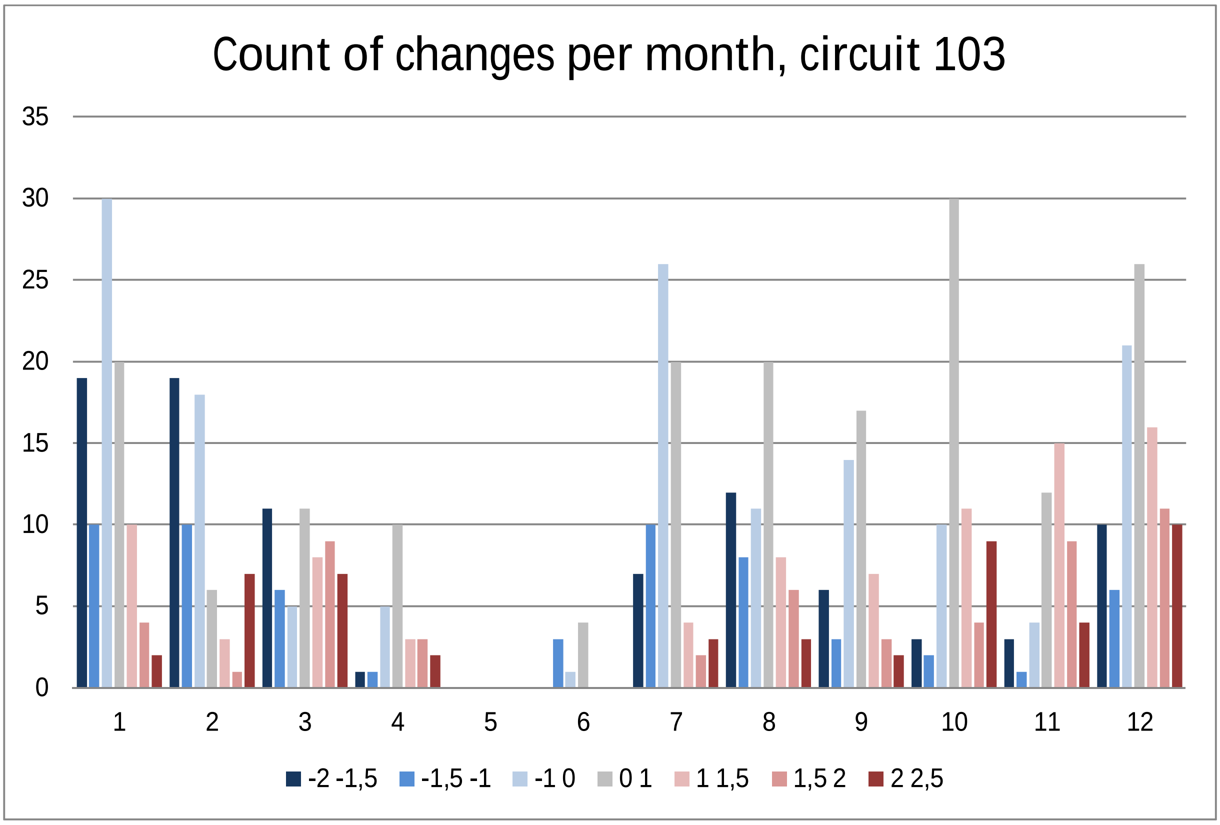


Frequency of the room operating panel use

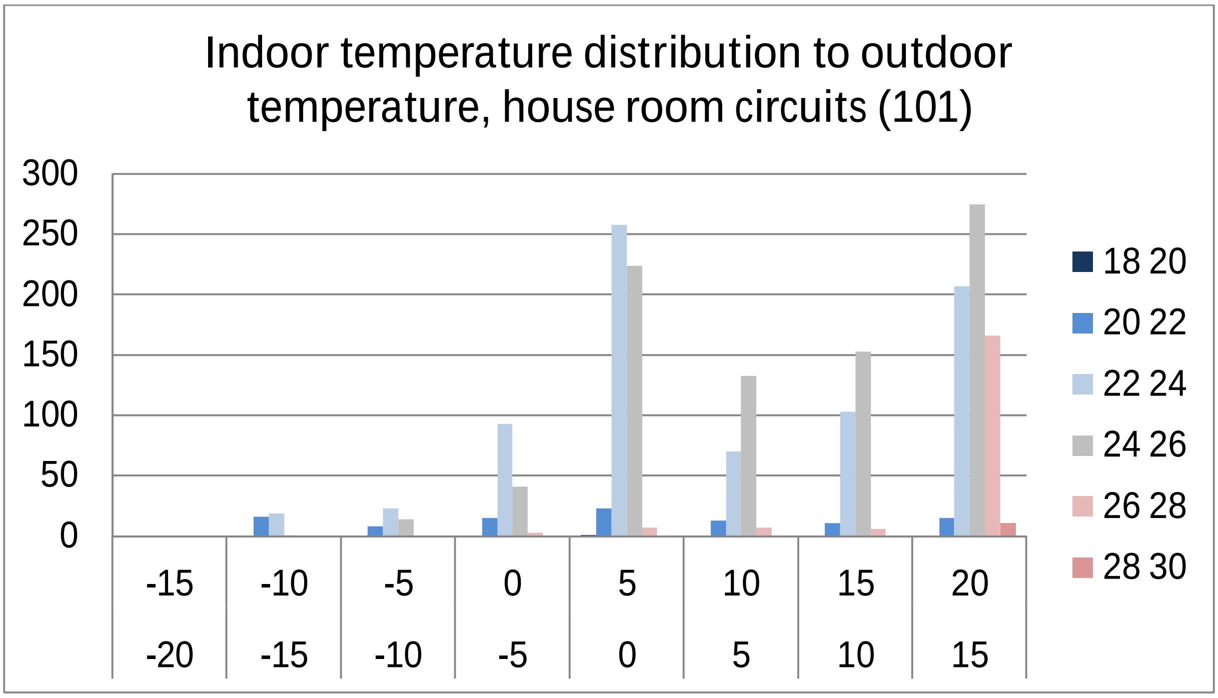
12.20 Temperature switch usage per month, circuit 101



12.21 Temperature switch usage per month, circuit 103

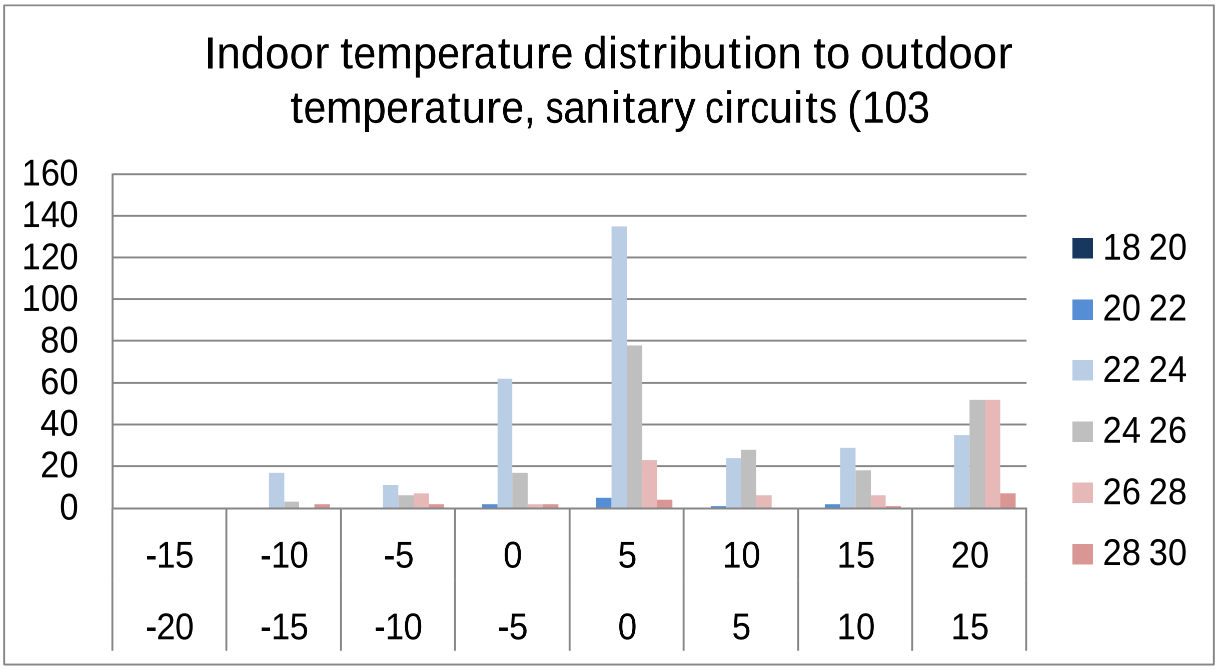


12.22 Room temperature remote control unit use per outdoor temperature, circuit 101



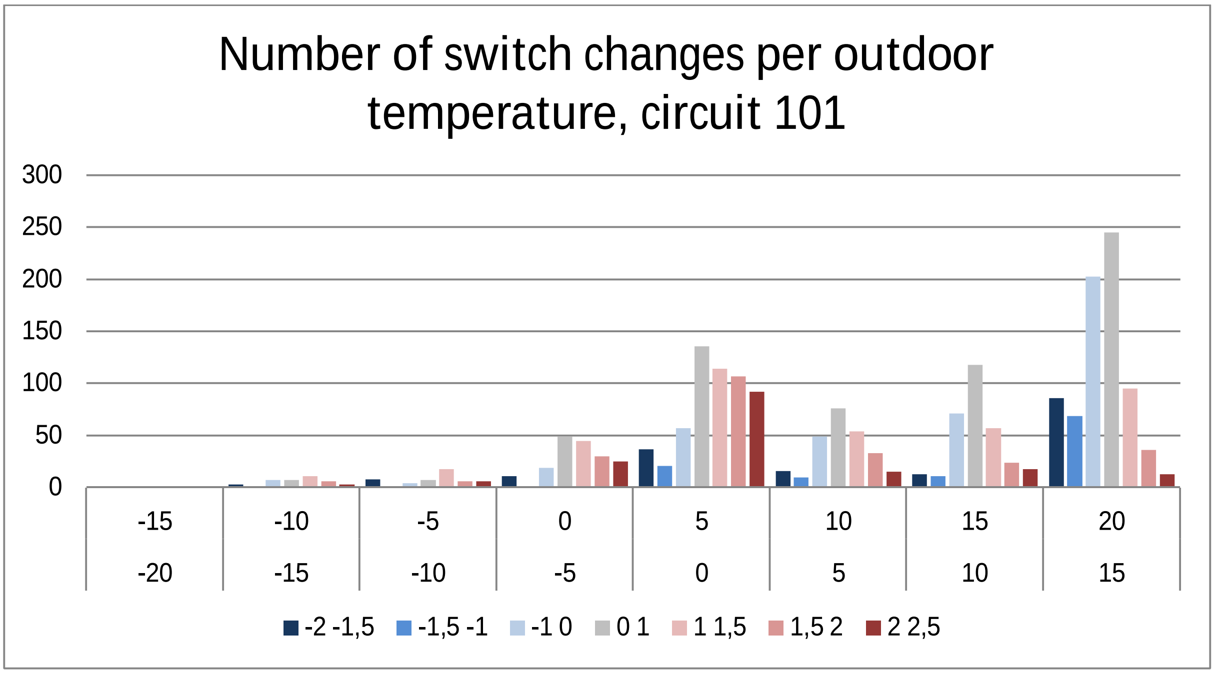
Room temperature remote control unit use per outdoor temperature

12.23 Room temperature remote control unit use per outdoor temperature, circuit 103

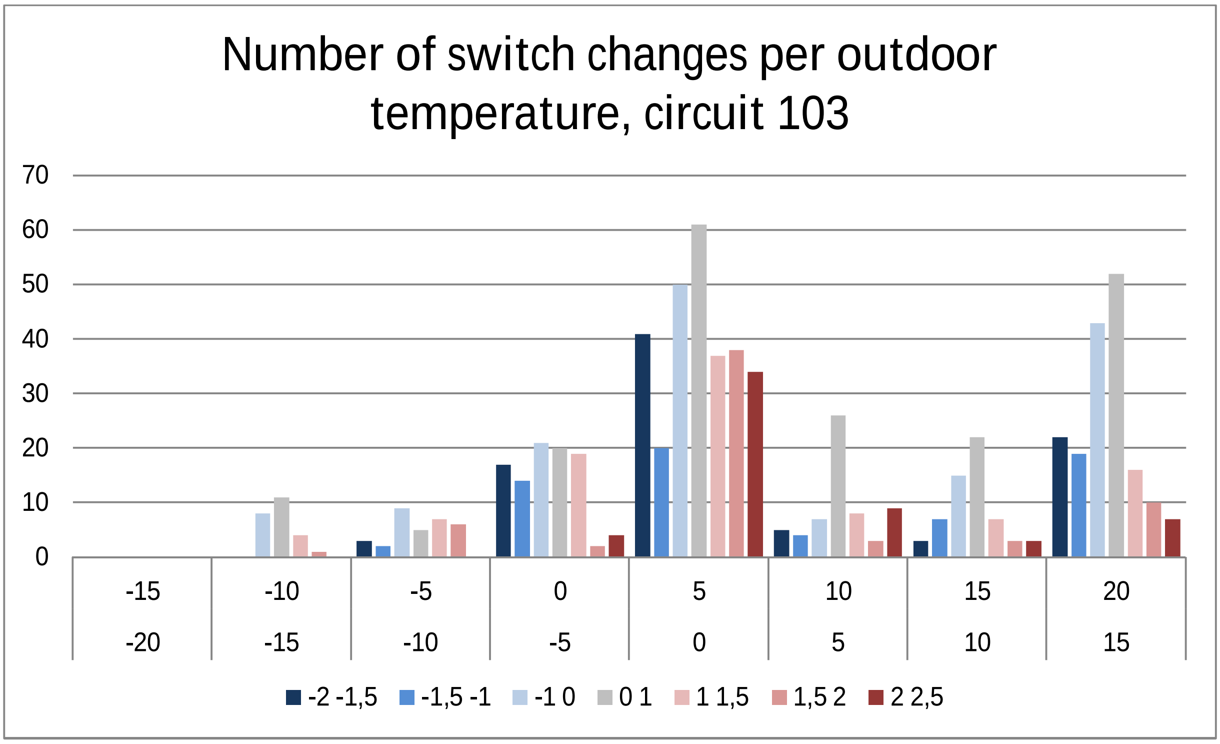


Room temperature remote control unit use per outdoor temperature

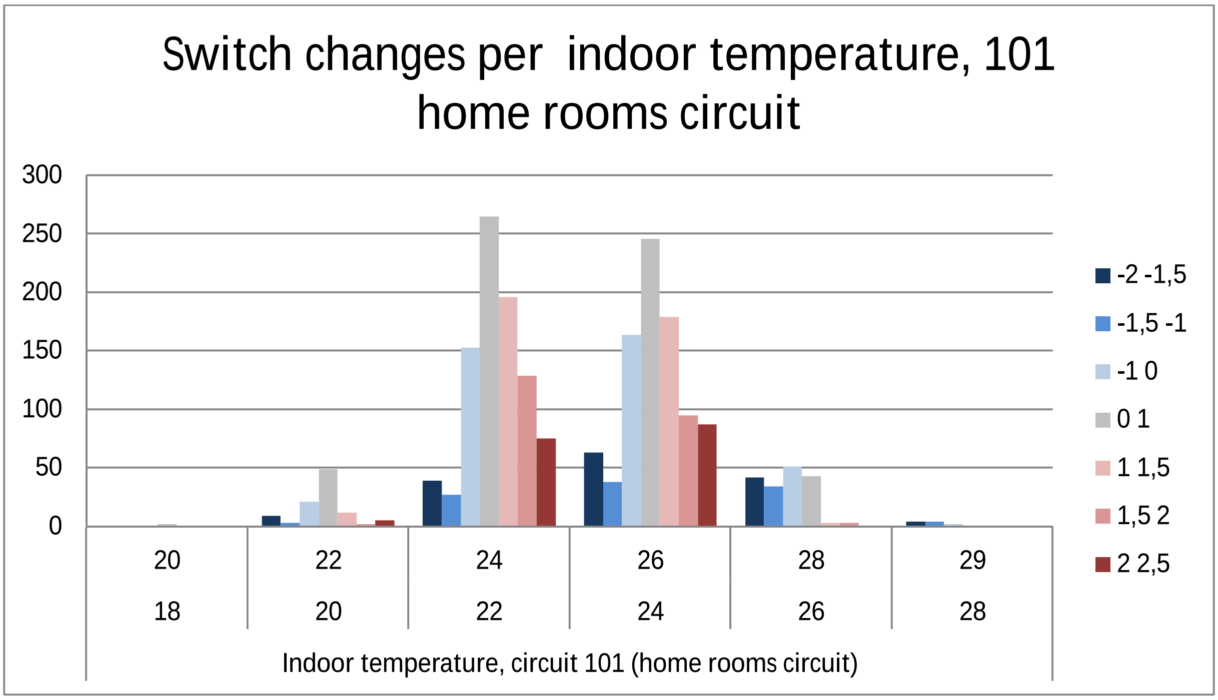
12.24 Switch changes per outdoor temperature, circuit 101



12.25 Switch changes per outdoor temperature, circuit 103

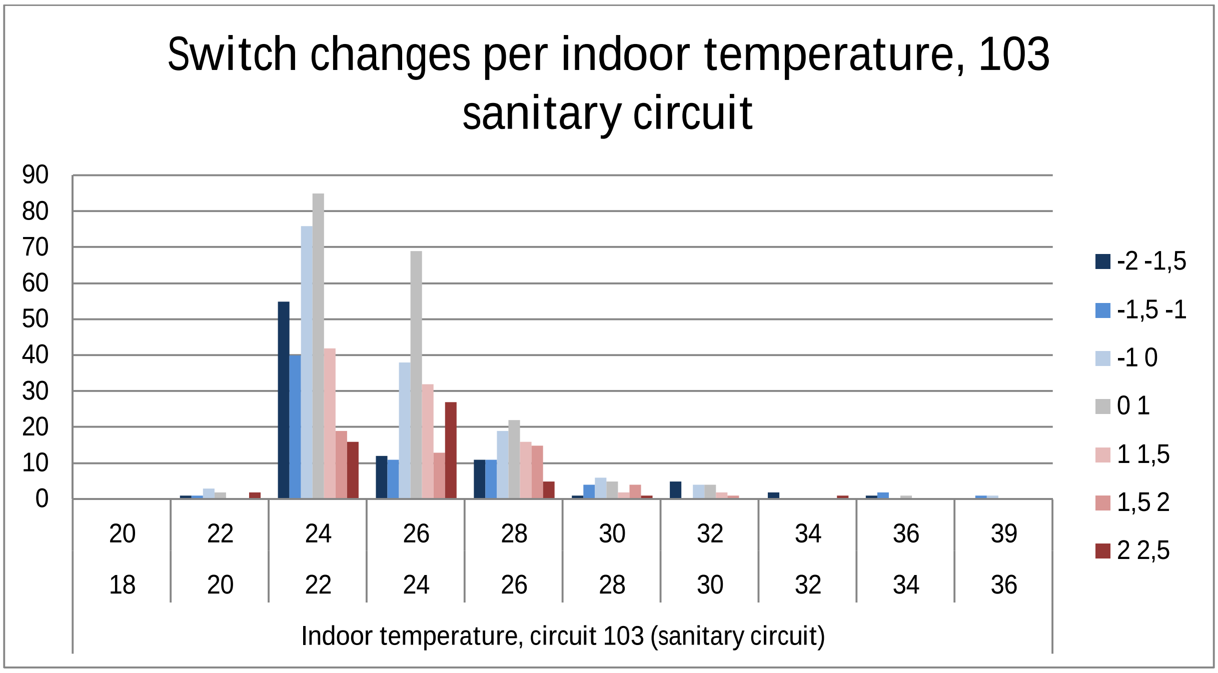


12.26 Switch changes per outdoor temperature, circuit 101



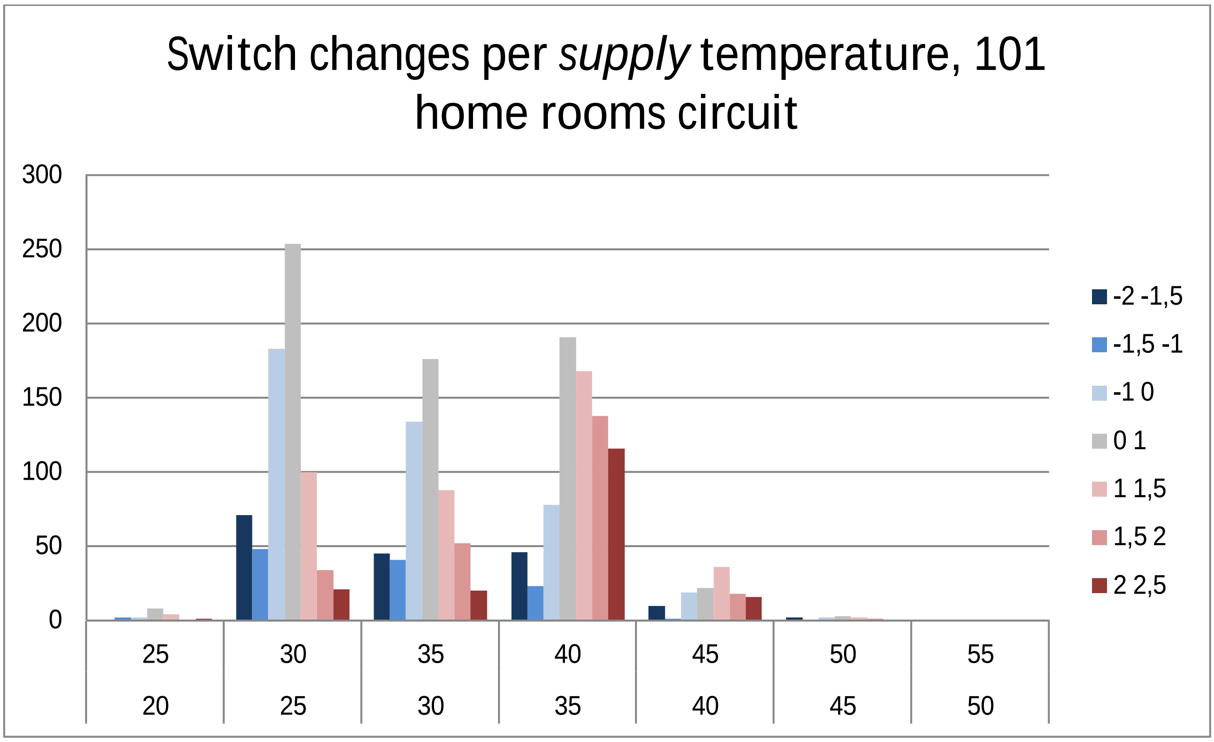
Switch changes per outdoor temperature

12.27 Switch changes per outdoor temperature, circuit 103



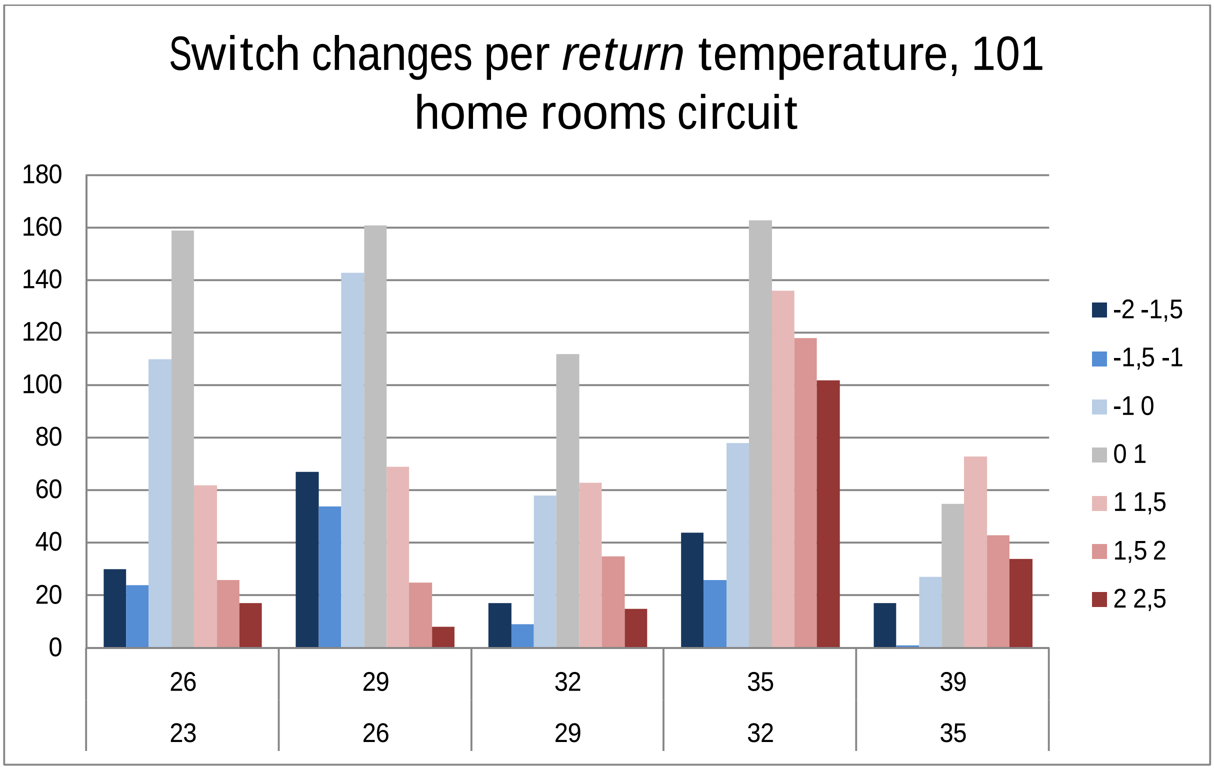
Switch changes per outdoor temperature

12.28 Switch changes per supply temperature, 101 home rooms circuit



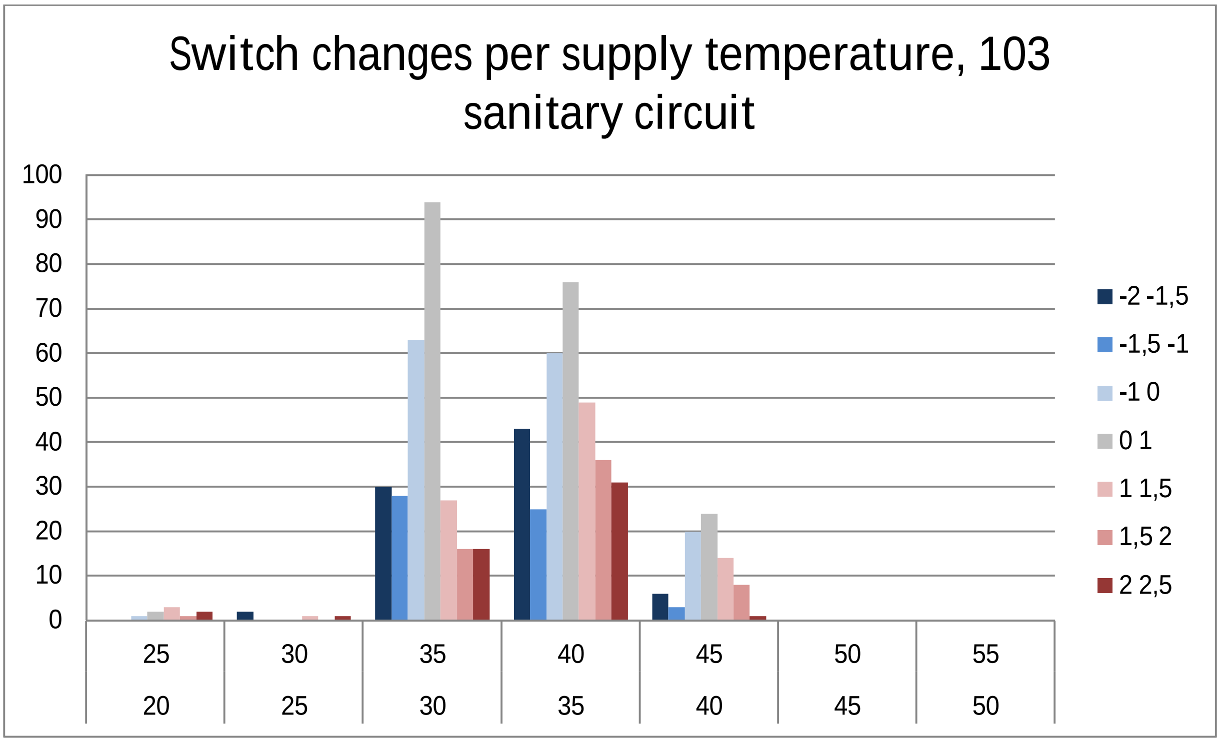
Switch changes per home room heating circuit (101) supply and return temperature

12.29 Switch changes per return temperature, 101 home rooms circuit

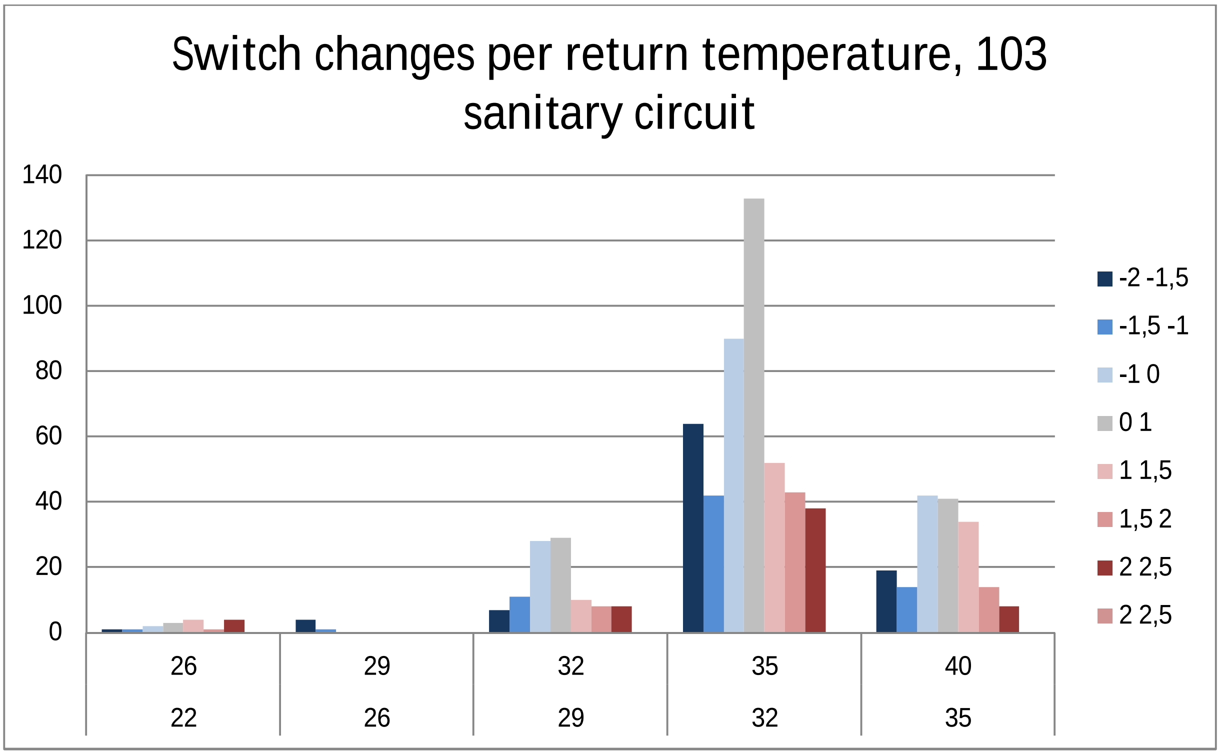


Switch changes per home room heating circuit (101) supply and return temperature

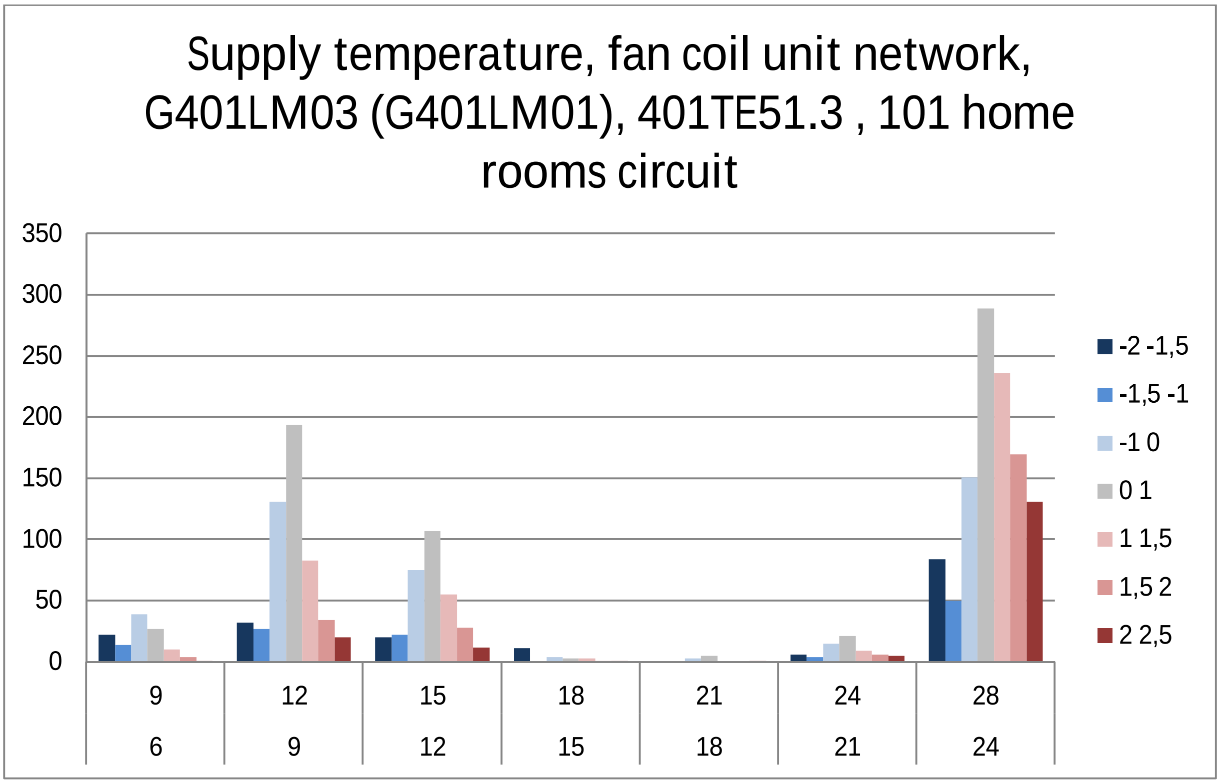
12.30 Switch changes per sanitary heating circuit (103) supply and return temperature



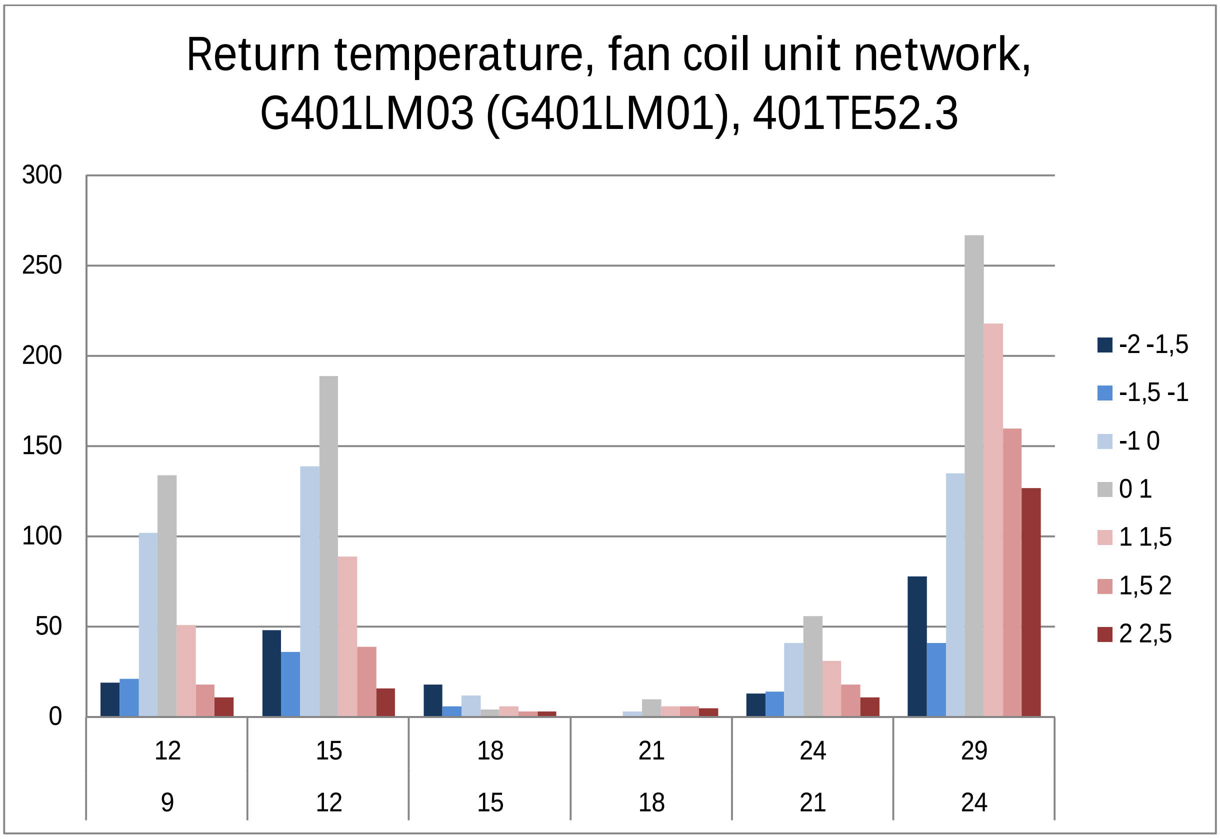
12.31 Switch changes per sanitary heating circuit (103) return temperature



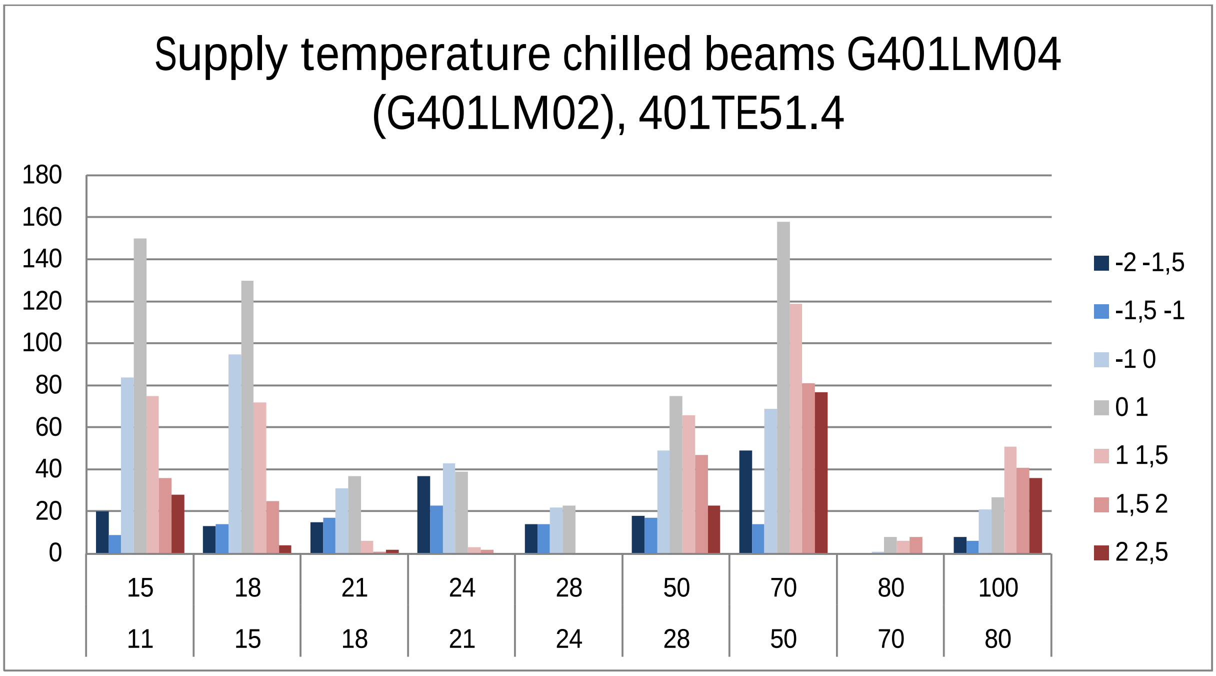
12.32 Switch changes per fan coil unit network (G401LM03) supply temperature



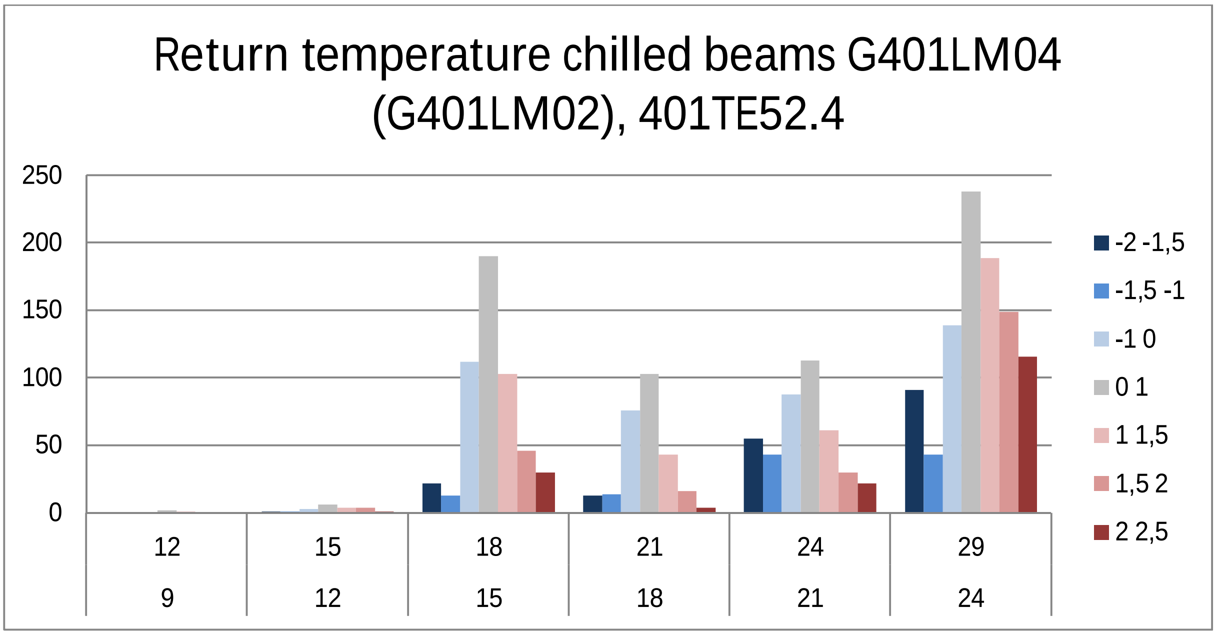
12.33 Switch changes per fan coil unit network (G401LM03) return temperature



12.34 Switch changes per fan coil unit network (G401LM04) supply temperature

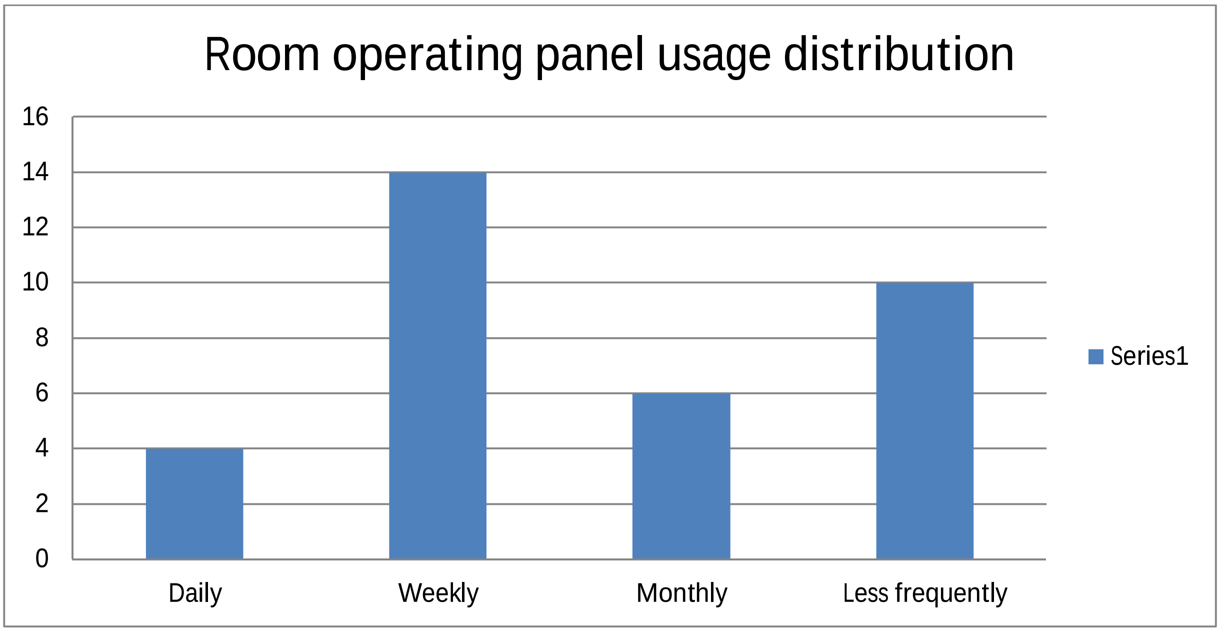


12.35 Switch changes per fan coil unit network (G401LM04 return temperature

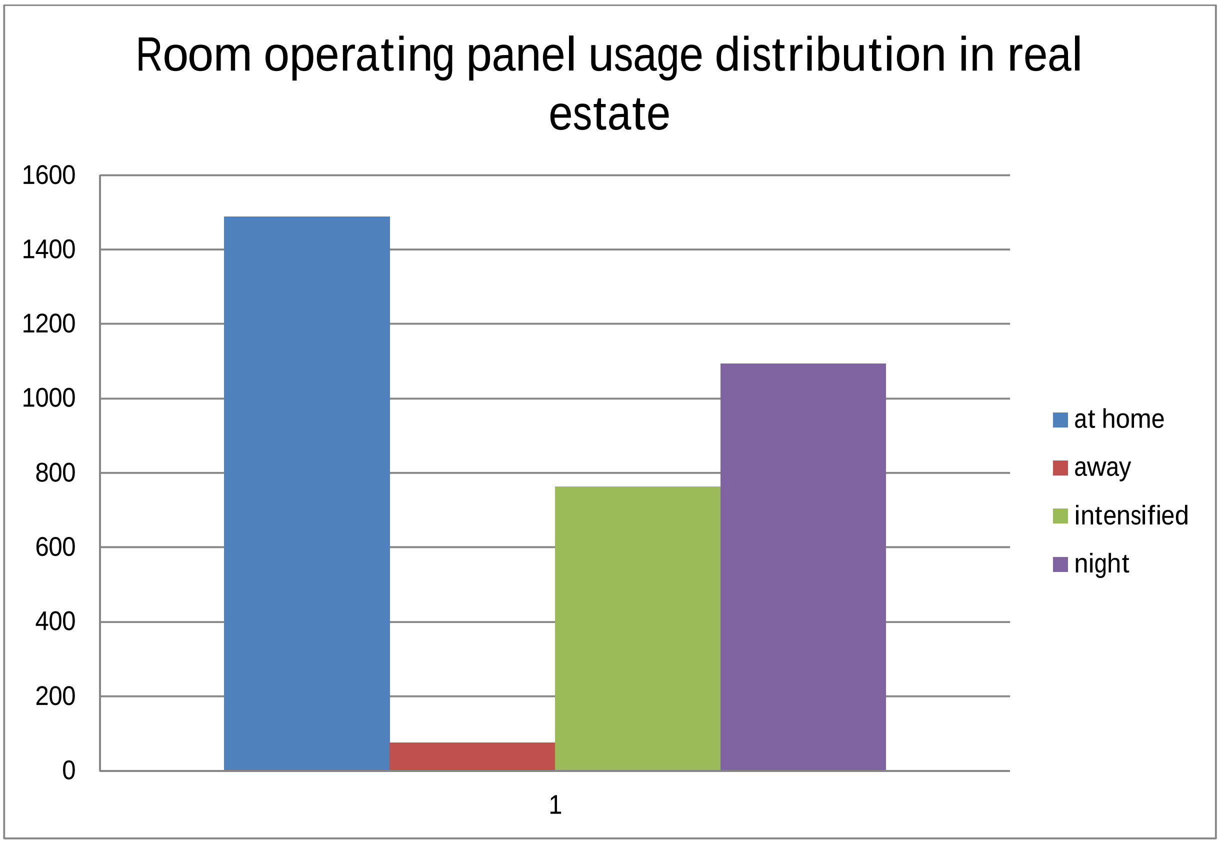


Switch changes per fan coil unit network (G401LM04) supply and return temperature

12.36 Room operating panel usage distribution 1/2

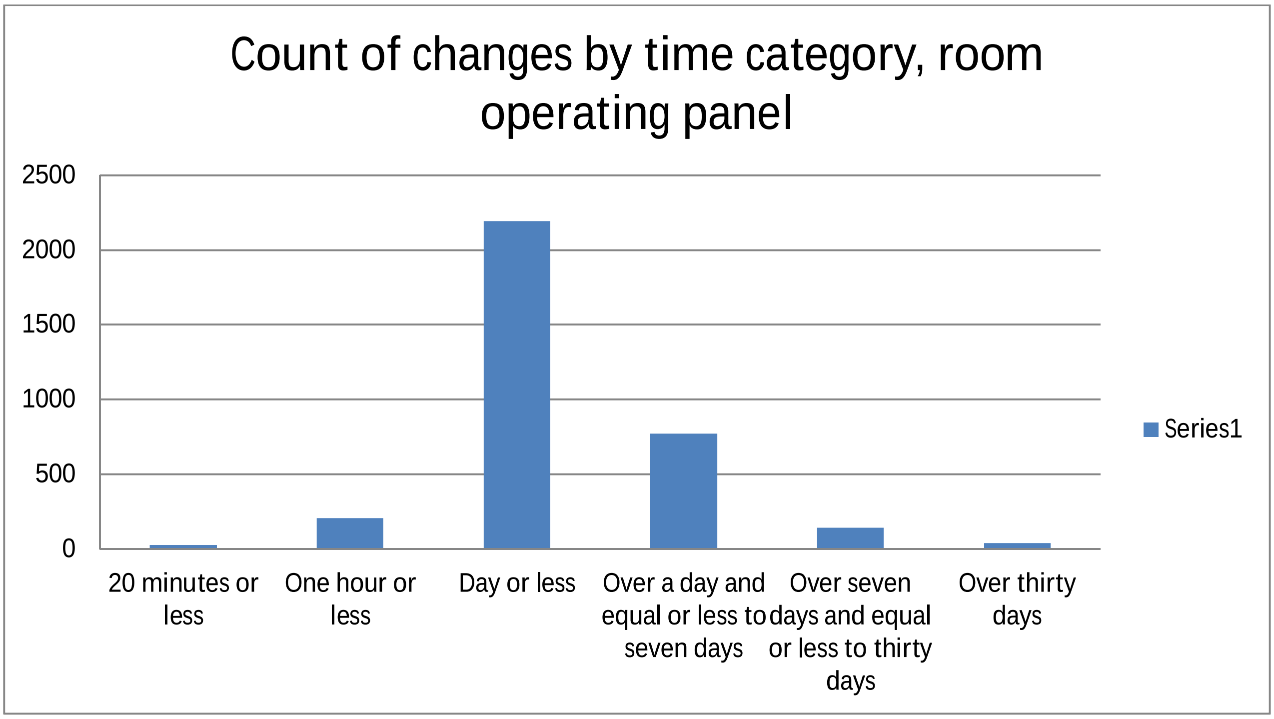


12.37 Room operating panel usage distribution 2/2



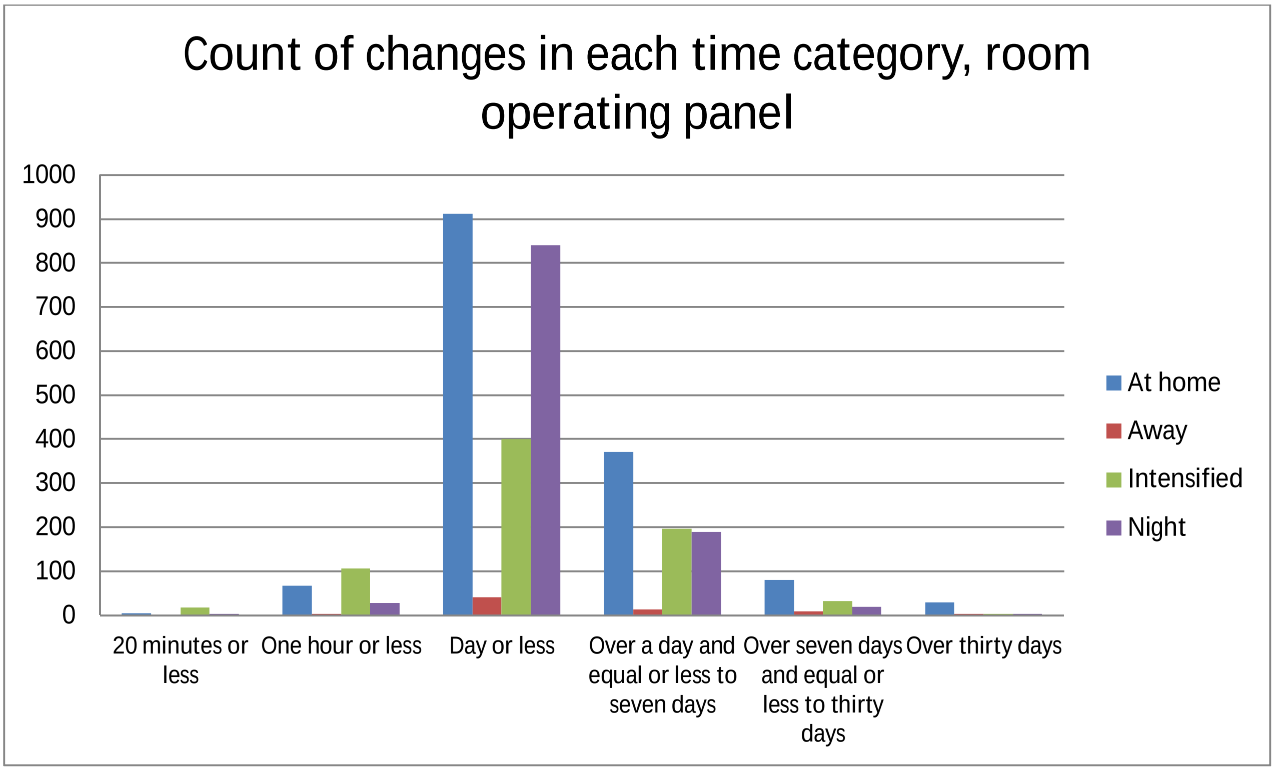
Room operating panel usage distribution

12.38 Count of changes by time category, room operating panel



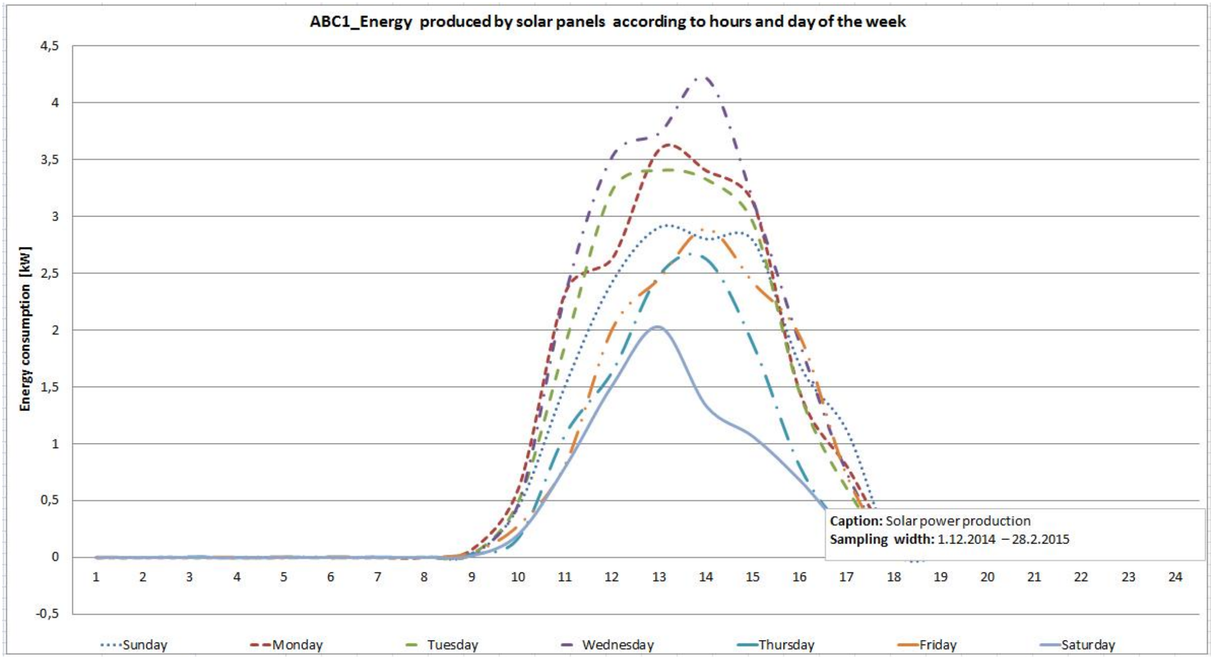
Room operating panel usage count by length of time

12.39 Count of changes in each time category, room operating panel

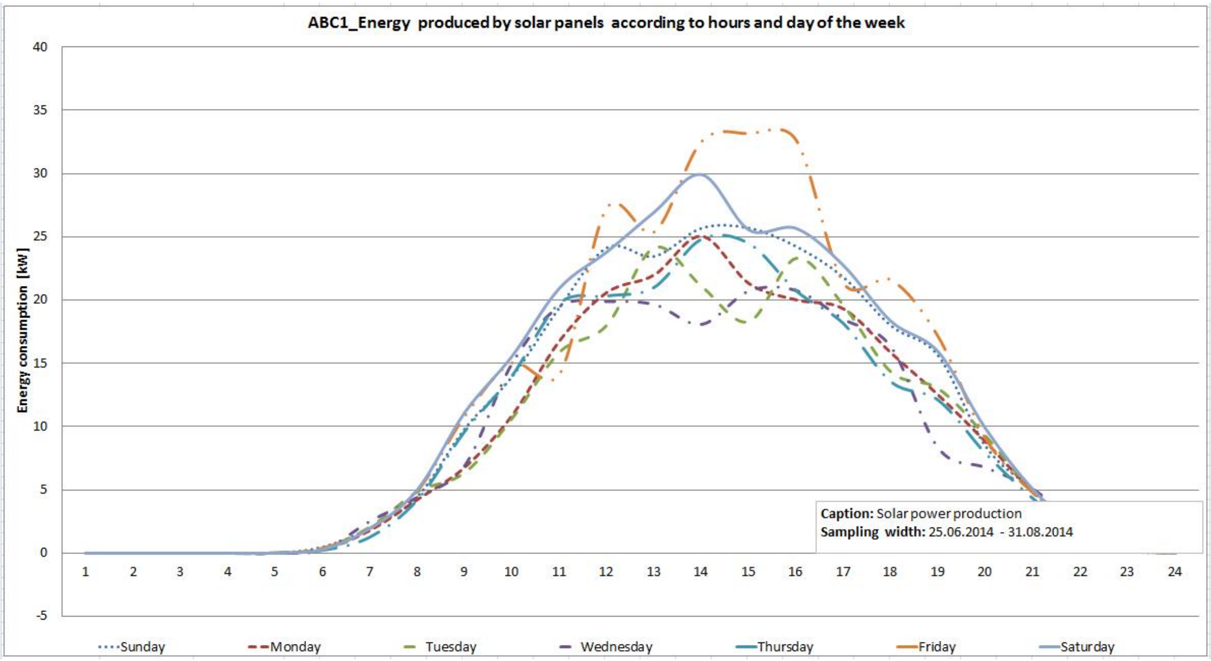


Room operating panel usage count by length of time

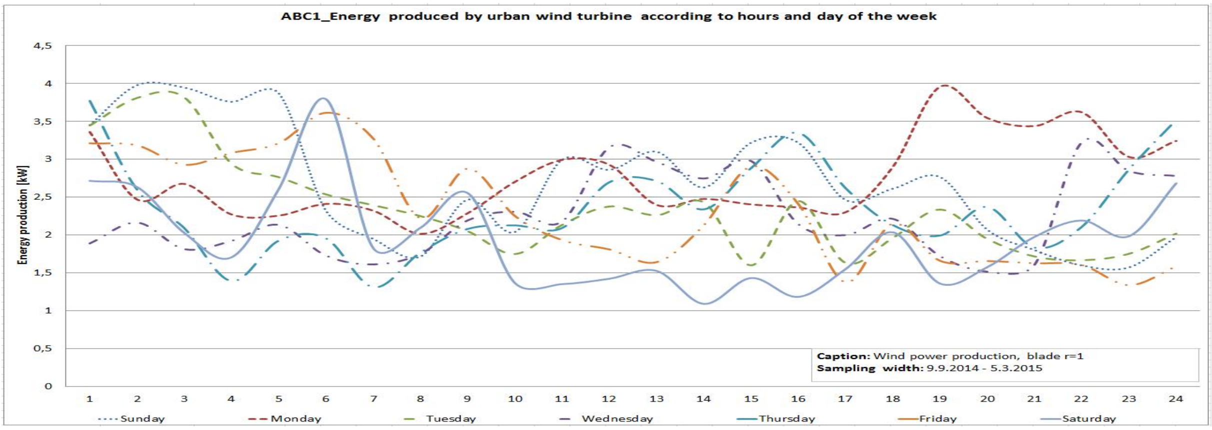
12.40 300m² solar panel power production during sample width 1.12.2014- 28.2.2015



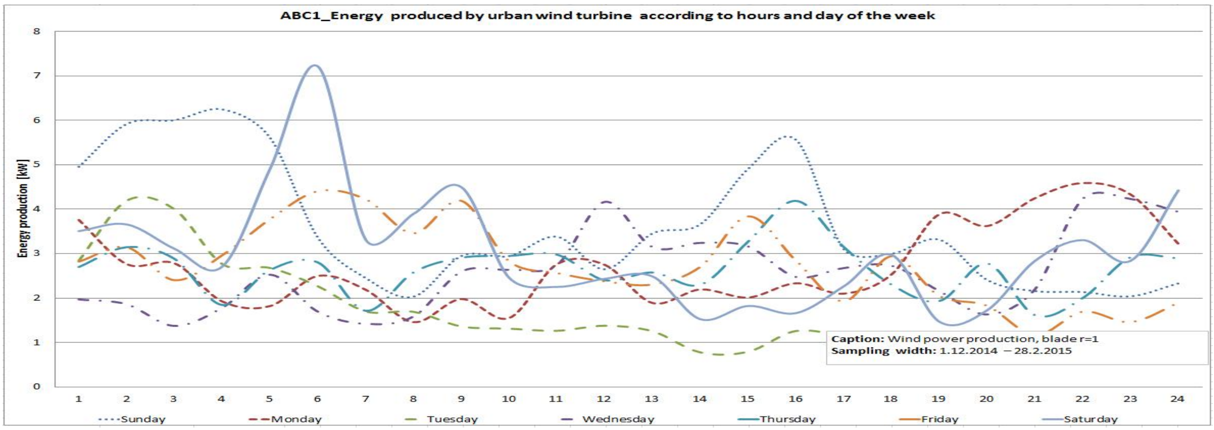
12.41 300m² solar panel power production during sample width 25.06.2014- 31.8.2015.



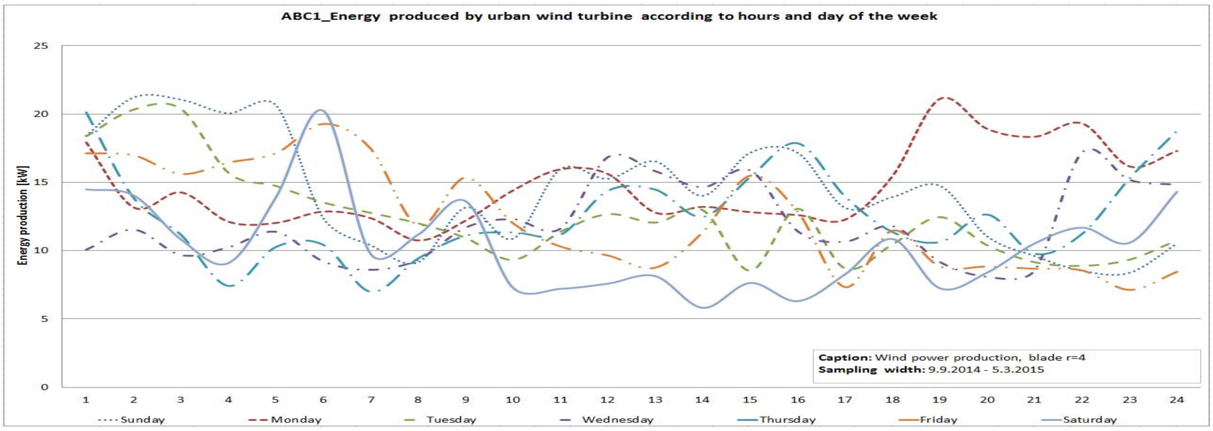
12.42 Wind power production curve, blade r=1 sample width 9.9.2014 – 5.3.2015



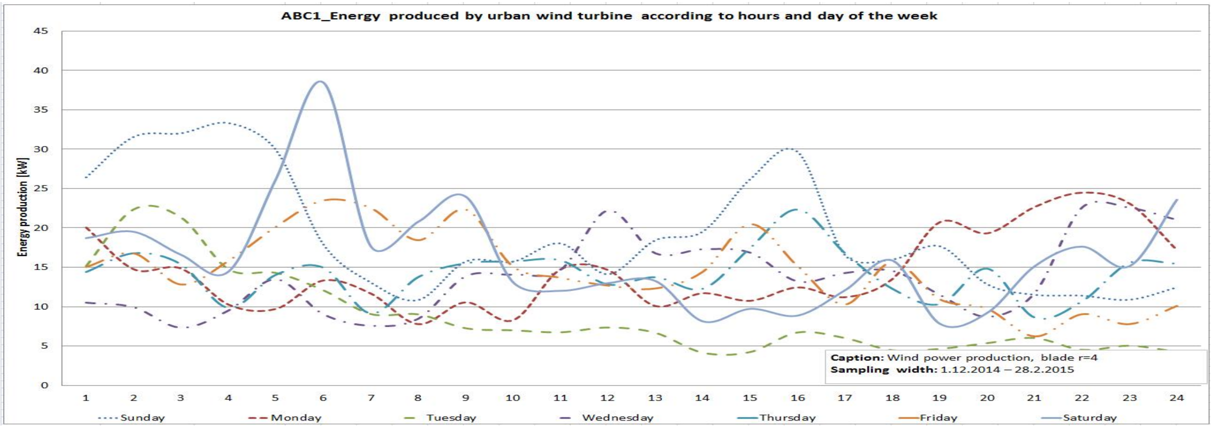
12.43 Wind power production curve, blade r=1 sample width 1.12.2014 – 28.2.2015



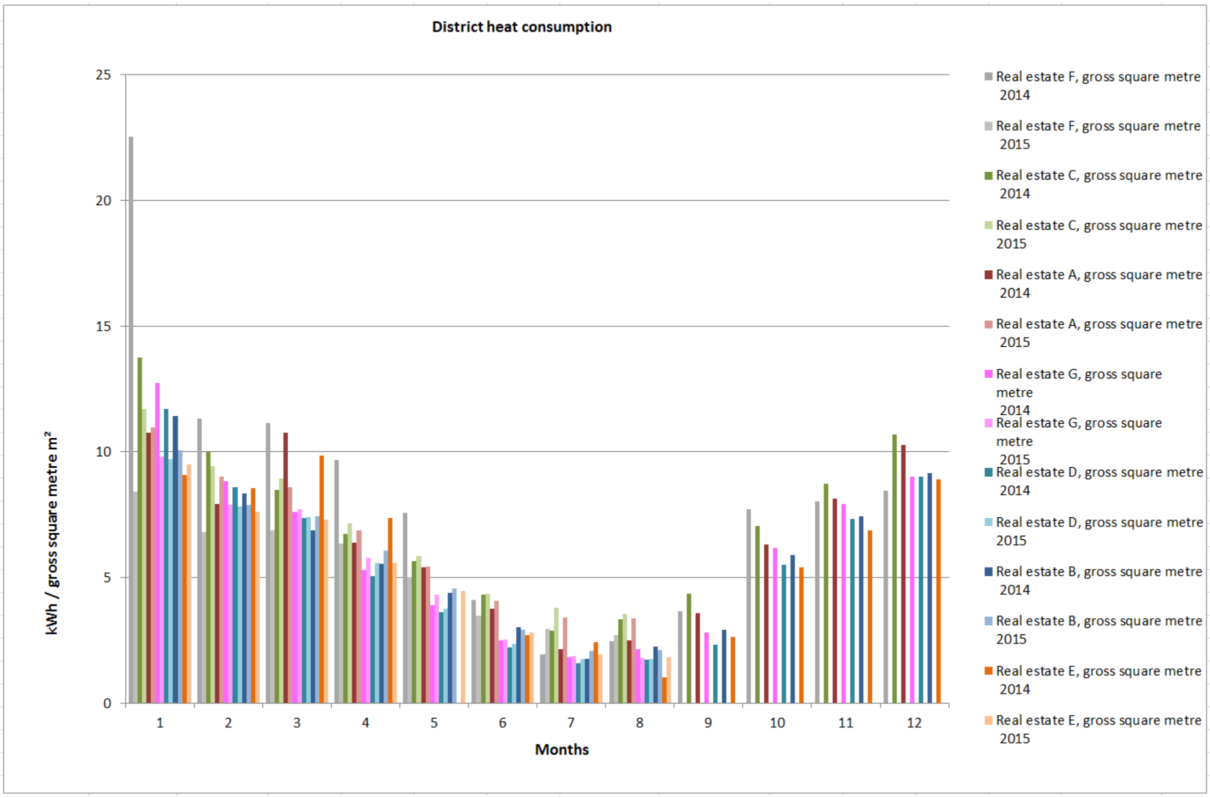
12.44 Wind power production curve, blade r=4 sample width 9.9.2014 – 5.3.2015



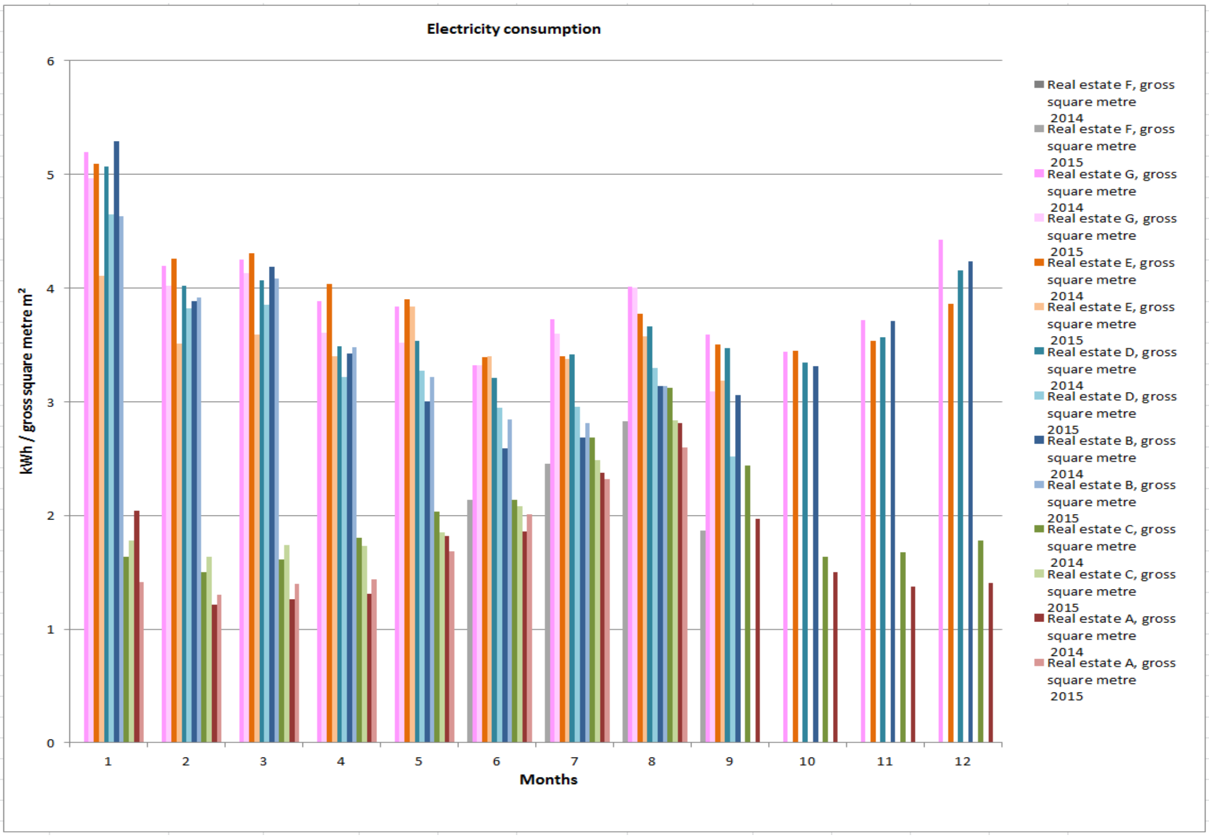
12.45 Wind power production curve, blade r=4 sample width 1.12.2014 – 28.2.2015



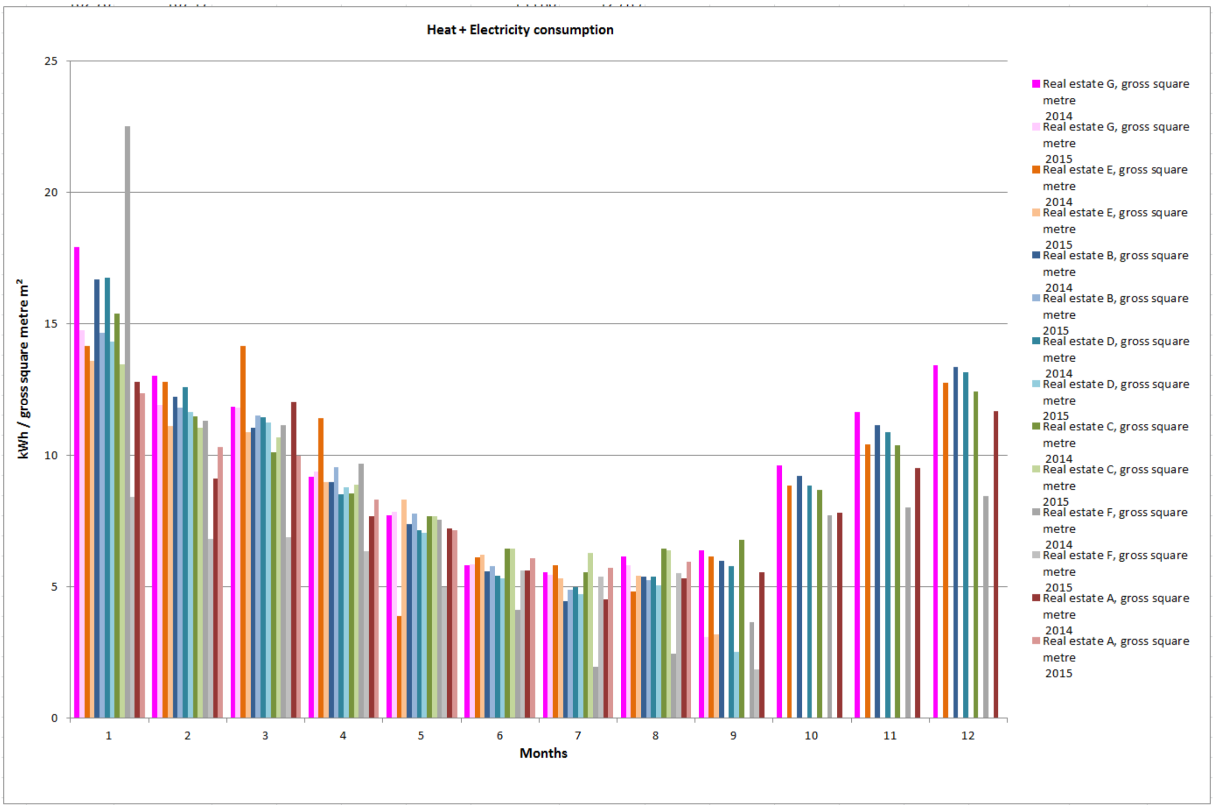
12.46 District heat consumptions of demonstration real-estates



12.47 Electricity consumptions of demonstration real-estates

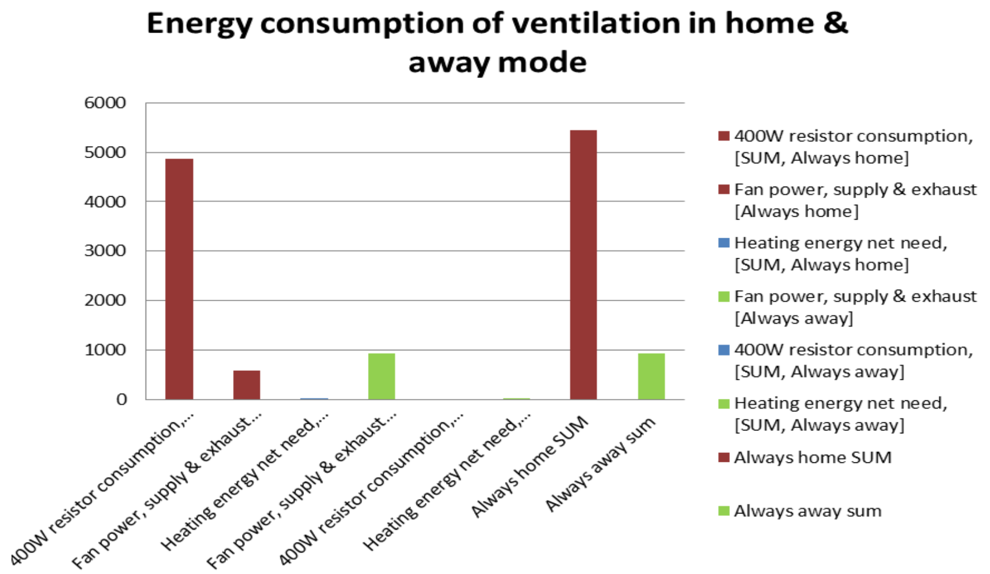


12.48 District heat + electricity consumptions of demonstration real-estates



12.49 Electricity consumptions of ventilation in demonstration real-estate.

					Staircase A ventilation machines [pcs]	Number of days in month	Number of hours in day	
					12	31	24	
Staircase A & B ventilation machines resistor share of electricity consumption	Staircase A ventilation machines resistor share of electricity consumption	Metered electricity consumption - Overall, Supply fan- & Exhaust fan electricity consumption [kWh] /kk	Number of month	Metered electricity consumption, staircase A [kWh]	Electricity consumption per ventilation machine [kWh]	Electricity consumption per day and ventilation machine [kWh]	Per hour & ventilation machine [W]	
		483,8	**6**					
5 087,5	2 543,8	2 543,8	**7**	3 027,6	252,3	8,1	0,3	
5 506,1	2 753,1	2 753,1	**8**	3 236,9	269,7	8,7	362,6	
4 255,7	2 127,9	2 127,9	**9**	2 611,7	217,6	7,0	292,5	
4 871,1	2 435,6	2 435,6	**10**	2 919,4	243,3	7,8	327,0	
4 399,7	2 199,9	2 199,9	**11**	2 683,7	223,6	7,2	300,6	
4 604,3	2 302,2	2 302,2	**12**	2 786,0	232,2	7,5	312,1	
4 222,3	2 111,2	2 111,2	**1**	2 595,0	216,2	7,0	290,7	
3 873,3	1 936,7	1 936,7	**2**	2 420,5	201,7	6,5	271,1	



12.50 Ventilation heating energy net need formula

$$Q_{iv} = t_d t_V \rho_i c_{pi} q_{v,tulo}\left((T_{sp} - \Delta T_{puhallin}) - T_{lto}\right)\Delta t / 1000$$

Q_{iv}= Ventilation heating energy net need, kWh

t_d= Ventilation plant average day operating time ratio, h/24h

t_V= Ventilation plant weekly operating time ratio, d/ 7 d

ρ_i= Air density, 1,2 kg/m³

c_{pi}= Air specific heat capacity, 1000 J/(kg K)

$q_{v,tulo}$= Supply air flow rate , m³/s

T_{sp}= In-blast temperature, ºC

$\Delta T_{puhallin}$= Temperature increase in blower, ºC

T_{lto}= Temperature after heat recovery device, ºC

Δt= Length of time frame

1000= Factor for kWh conversion

12.51 formula, temperature after hear recovery

$$T_{lto} = T_u + \frac{\Phi_{lto}}{t_d t_V \rho_i c_{pi} q_{v,tulo}}$$

T_{lto}= Temperature after heat recovery device, ºC

T_u= outdoor temperature

Φ_{lto}= Monthly average power recovered by heat recovery device, W

t_d= Ventilation plant average day operating time ratio, h/24h

t_V= Ventilation plant weekly operating time ratio, d/ 7 d

ρ_i= Air density, 1,2 kg/m³

c_{pi}= Air specific heat capacity, 1000 J/(kg K)

$q_{v,tulo}$= Supply air flow rate , m³/s

12.52 formula, monthly average power recovered by heat recovery device

$$\Phi_{lto} = \eta_{na,ivkone}\, t_d t_V \rho_i c_{pi} q_{v,poisto}(T_s - T_u)$$

Φ_{lto}= Monthly average power recovered by heat recovery device, W

$\eta_{na,ivkone}$= air supply unit's heat recovery device's annual efficiency

t_d= Ventilation plant average day operating time ratio, h/24h

t_V= Ventilation plant weekly operating time ratio, d/ 7 d

ρ_i= Air density, 1,2 kg/m³

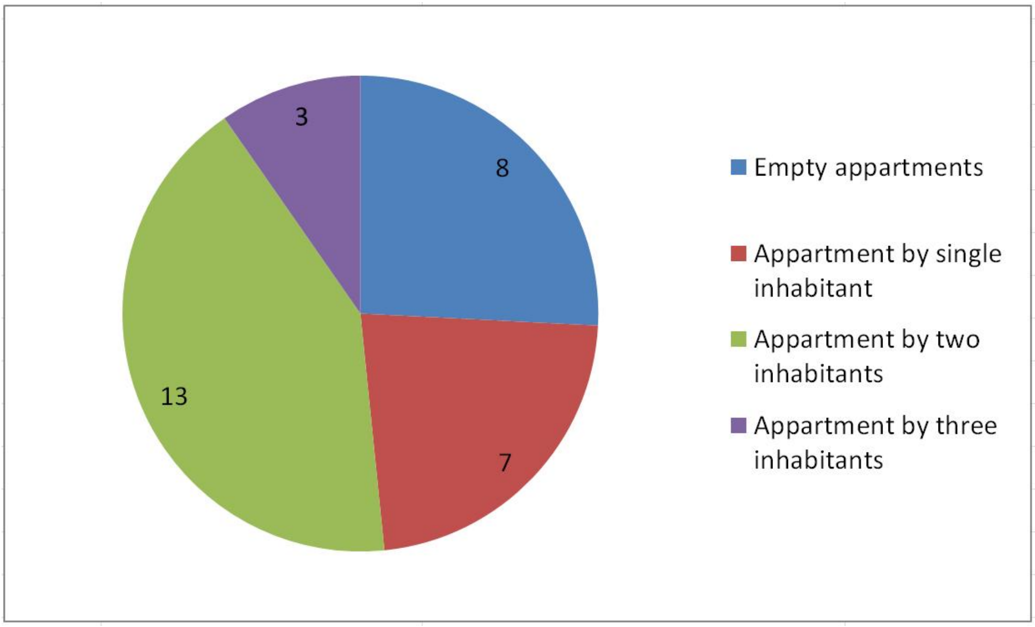
c_{pi}= Air specific heat capacity, 1000 J/(kg K)

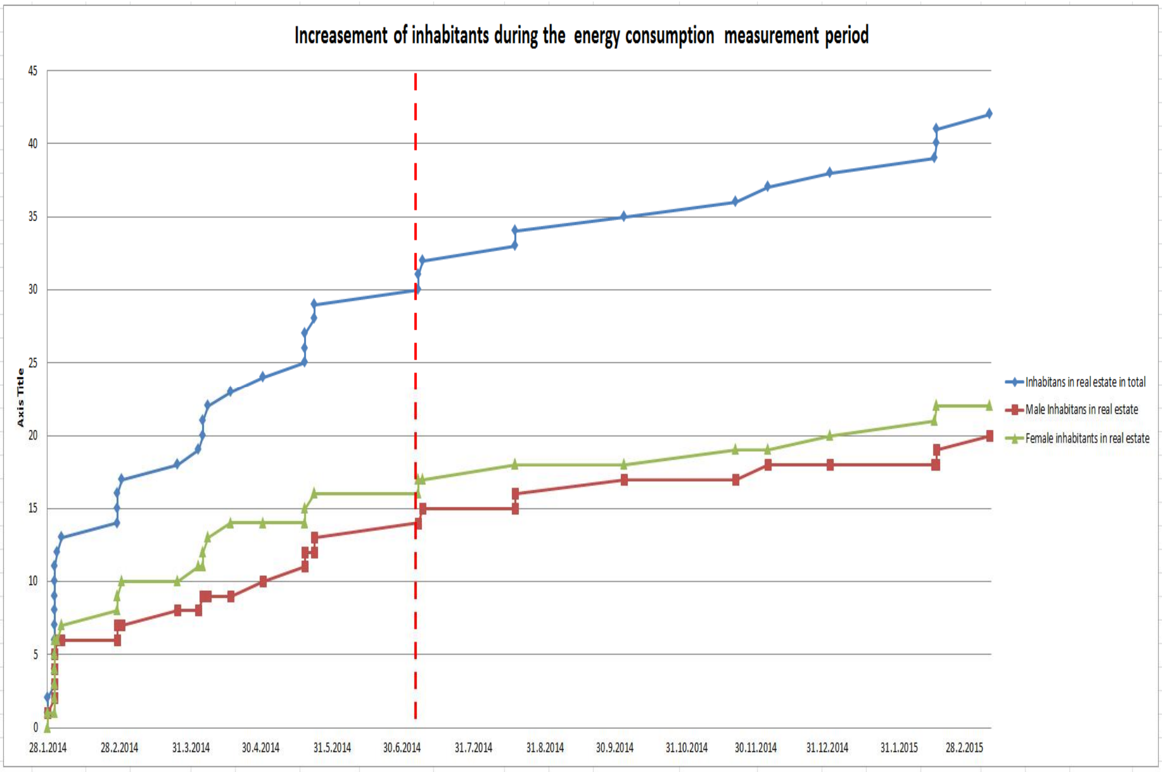
$q_{v,poisto}$= Exhaust air flow rate, m³/s

T_s= inside temperature

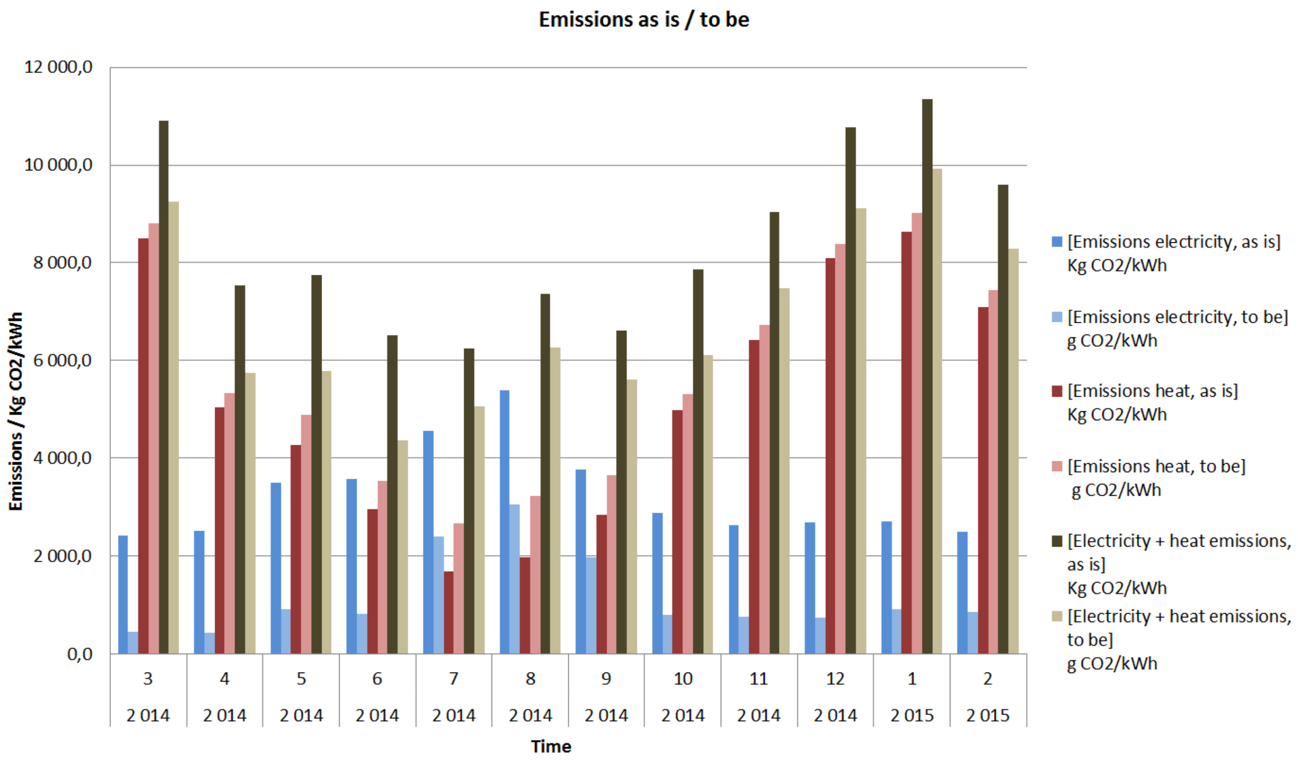
T_u= outdoor temperature

12.53 Residentials in demonstration real-estate28.02.2015



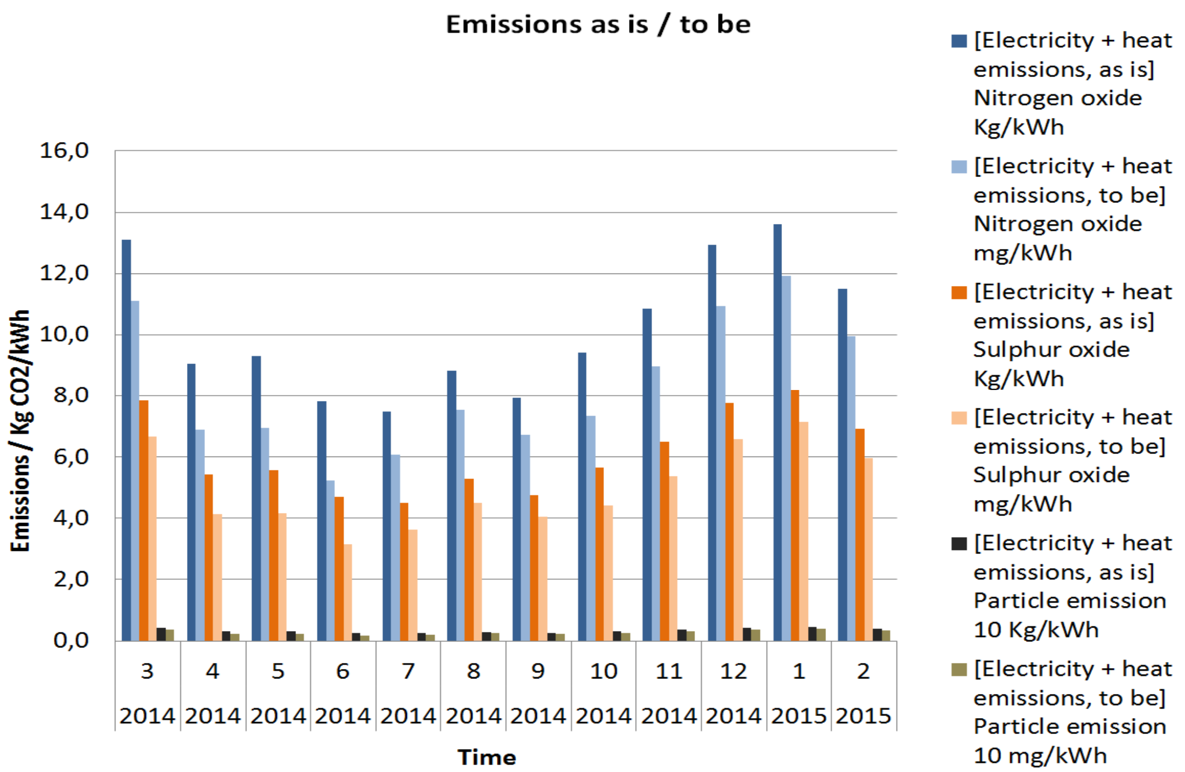


12.54 Monthly emission reduction potential CO_2, sample width 1.3.2015- 1.2.2015



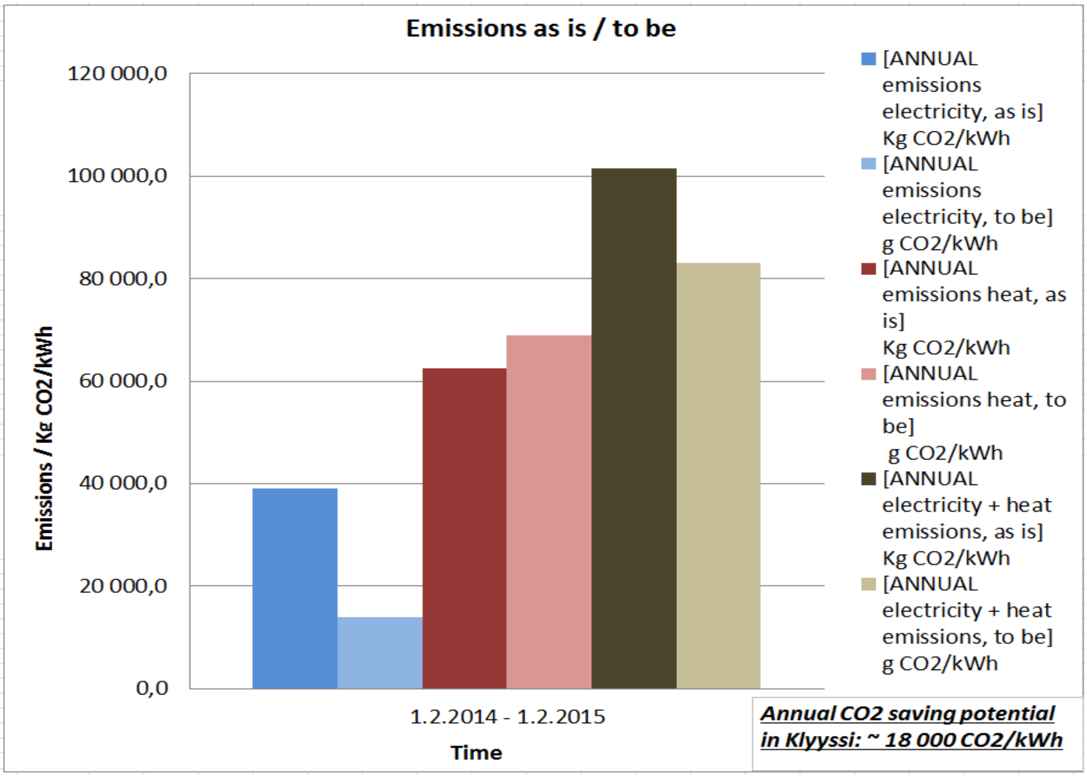
Case 400w ventilation heater

12.55 Monthly emission reduction potential other pollution, sample width 1.3.2015- 1.2.2015



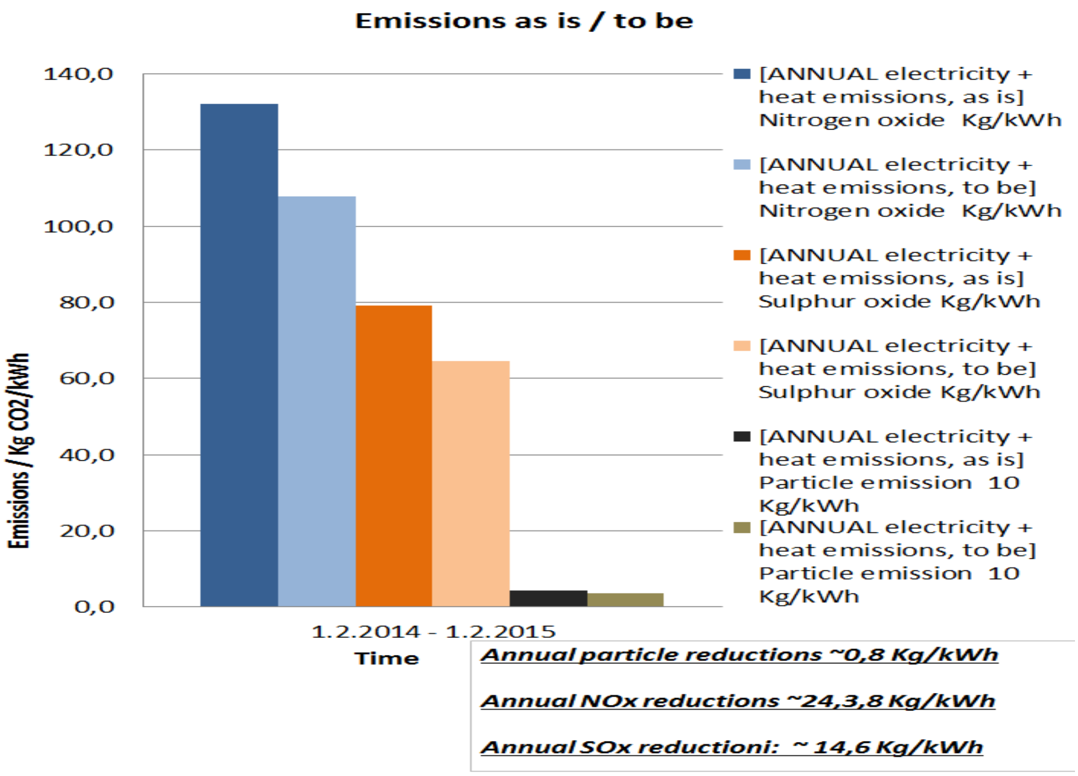
Case 400w ventilation heater

12.56 Annual emission reduction, co_2



Case 400w ventilation heater

12.57 Annual emission reduction, other pollution



Case 400w ventilation heater