EEPOS - Energy management and decision support systems for energy positive neighbourhoods

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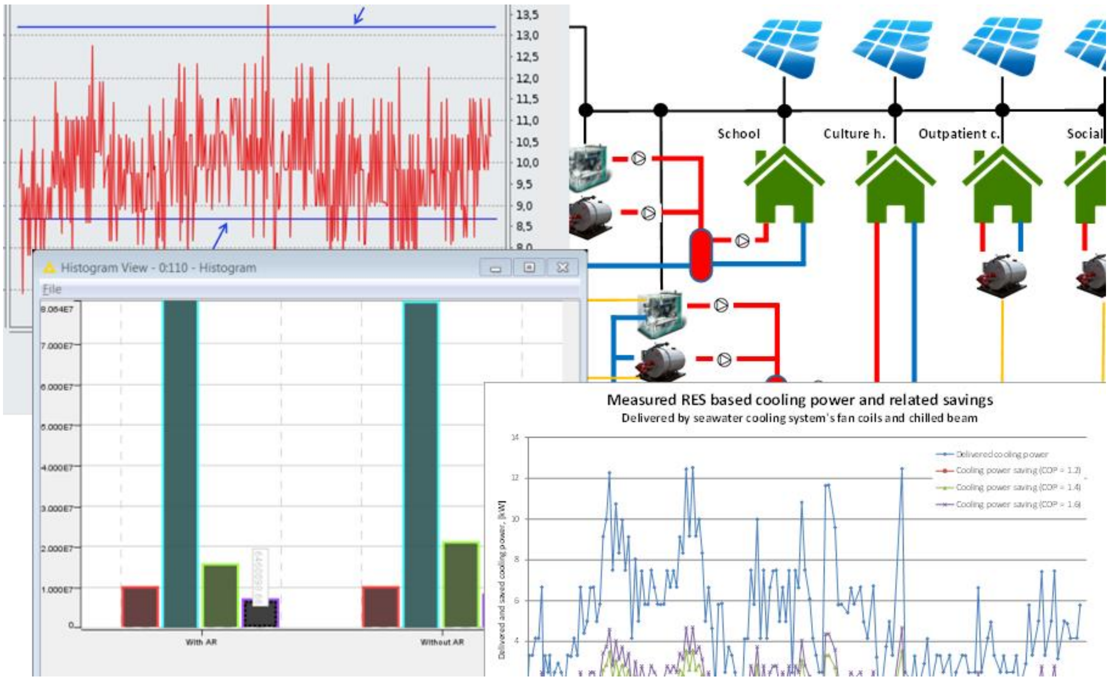

Final analysis and validation

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1. EXECUTIVE SUMMARY

To demonstrate the capabilities of the EEPOS approach, the EEPOS system was tested in 3 environments, with each demo site looking at different aspects of the systems to get to an overall estimate whether the EEPOS idea is feasible to actually reduce energy consumption and greenhouse gas (GHG) emissions in neighbourhoods.

In this document, the effects of the EEPOS system on three demo Sites in

- Lauttasaari, Finland
- Langefeld, Germany
- Araia, Spain

are quantified and discussed.

In the Finnish demo site, consisting of six fairly new (2007) to new (2014) buildings, the main energy consumers are space heating, air conditioning and a seawater based cooling systems, which has a large consumption in auxiliary. The aim was to show the possibility of increased integration of PV by load shifting through central energy management.

The German Demo site in Langenfeld consists of a social housing development with about 70 buildings which are supplied by a local heating plant. This heating plant has several heat generators with varying fuel sources and therefore GHG emissions. The target was adjusting the building loads through demand response to keep in a range where only the environment friendly heat sources have to be operated. The real demo site had to be replaced by a virtual one during the project to bankruptcy of the responsible project partner.

For the municipality of Araia in Spain, the main municipal buildings were modelled in a virtual demo site, and the possibility of a local heating grid powered by a CHP together with increased PV production was explored.

In all three cases, using the EEPOS approach for energy management on neighbourhood level was primarily used for demand response. In this capability, the effects on the EEPOS approach both in terms of CO_2 savings and financial gains could be demonstrated.

2. Introduction

2.1 Purpose and target group

D4.5 gives the overall quantitative results of the three EEPOS demonstrators. The approaches used in each experiment are shortly discussed, and allows for a direct comparison of the idea of the EEPOS approach on the different systems and sites. It is mainly addressing stakeholders on neighbourhood level, showing the possibilities that the EEPOS approach has in terms of CO_2 savings, but also in terms of financial results.

2.2 Relations to other activities

This document is the summary of the experiments done in T4.3 (Virtual Prototype) T5.1 (Finnish demo site) and T5.2 (German Demo site), and uses definitions from D4.4. The results partly entered T1.5 for the feasibility of the business cases envisioned within the EEPOS project.

3. SYNOPSIS OF THE DEMONSTRATORS

3.1 German/Austrian Demonstrator

3.1.1 Overview

Due to the insolvency of the Partner responsible for the physical demo site during the last project year, the Langenfeld neighbourhood was also redone as a virtual demo site. As described in Deliverable 5.4, based on GIS data the 72 buildings of “Bauverein Langenfeld” were recreated as Energy+ models provisioned for zone control were the temperatures setpoints could be set from outside the simulation software. Plant data from the actual heating plant was analyzed, showing very consistent behavior of the different heat generator over time. Base on this information, the load shifting control was designed.

3.1.2 Load Shifting

Based on the OGEMA-based adaption request application developed for D2.3, an application was developed for shifting thermal loads. The application used predictions for the thermal load of a variable number of households (73 were used in the simulations) in order to generate adaption requests. The goal of the adaption request was to minimize CO_2 production for the heating system used in the neighborhood, which were (in order of CO_2 production) CHP, biomass, and gas heating. Thus, while the overall demand for heating was expected to stay the same, the goal was to reduce heating “peaks” where biomass and gas heating would have to be used, and conversely use CHP to fulfill as much of the heating demand as possible. Since temperature in a household can vary within certain tolerances and will change only slowly over time, the individual households thus functioned as an energy storage system.

The following procedure was used:

1. The thermal load predictions for the individual households – providing the expected load for each household in 15 minute intervals - are pushed into OGEMA via the OGEMA REST interface.

2. The application calculates an averaged load prediction for all households, again dividing the load prediction into 15 minute intervals. Furthermore, it calculates the mean load for the span of the next 24 hours.

3. In order to ensure that most of the load shifting will focus on peak events, only a limited number of households will receive adaption requests for increasing or decreasing their thermal load at any one time. The number of households selected for this purpose during any given time interval is:

$$(Total\ number\ of\ households) \times \frac{|(Current\ Averaged\ Load) - (Mean\ Load)|}{Mean\ Load}$$

For periods when the selected number of households would exceed the total number of households (i.e. when the current averaged load for the 15 minute span is more than twice the mean load), all households are selected. Beyond that, the households which receive nonzero adaption requests are chosen randomly for each 15 minute interval.

The individual households receive the following adaption requests, which are published via the OGEMA REST interface and thus made available to the thermal simulations:

Adaption Request Value	**Condition**
-2	If chosen and Current Averaged Load > Mean Load
0	If not chosen for adaption requests
+2	If chosen and Current Averaged Load <= Mean Load

This parallels the adaption requests for electrical loads as outlined in D2.3, section 4.2.1, with the following differences:

- The -1/+1 values for adaption requests were removed, as the thermal simulations had no way of integrating "weak" recommendations for load shifting.
- A "0" value was added since, unlike with electrical loads, thermal loads are at least in theory completely controllable by central systems and it was feared that if all households received nonzero adaption requests it would lead to an "oscillation" in the heating systems when the thermal load approaches the lean value.

As the OGEMA application is running on a persistent server – the same used for the laboratory prototype – the adaption requests are continually updated as new thermal load predictions are submitted to the system.

A further OGEMA application was developed which provided historical weather data – in particular, outside temperatures - for Langenfeld for the thermal simulations, which likewise were made available via the REST interface. Current weather forecasts could also have been used via the OpenWeatherMap Connector, as explained in D4.2. However, since the purpose of the simulations was to study thermal load shifting, using current summer temperatures as input data for the thermal simulations would have been counter-productive.

3.1.2.1 Implementation

Several preconditions were necessary for calculating adaption requests. The Adaption Request application itself has no subpage in the OGEMA web portal. It assumes existing Region and Building OGEMA Resources (using the OGEMA classes `org.ogema.model.building.GeographicAddress` and `org.ogema.model.building.Building`) and generates adaption requests based on the algorithm described above.

The Region Resources are created by the „OpenWeatherMap Connector“ OGEMA application. The Class `GeographicAddress` is further extended by weather forecasts (based on OpenWeatherMap) and these, as well has historical data, are stored in a time series (OGEMA Class `org.ogema.core.model.schedule.ForecastSchedule`).

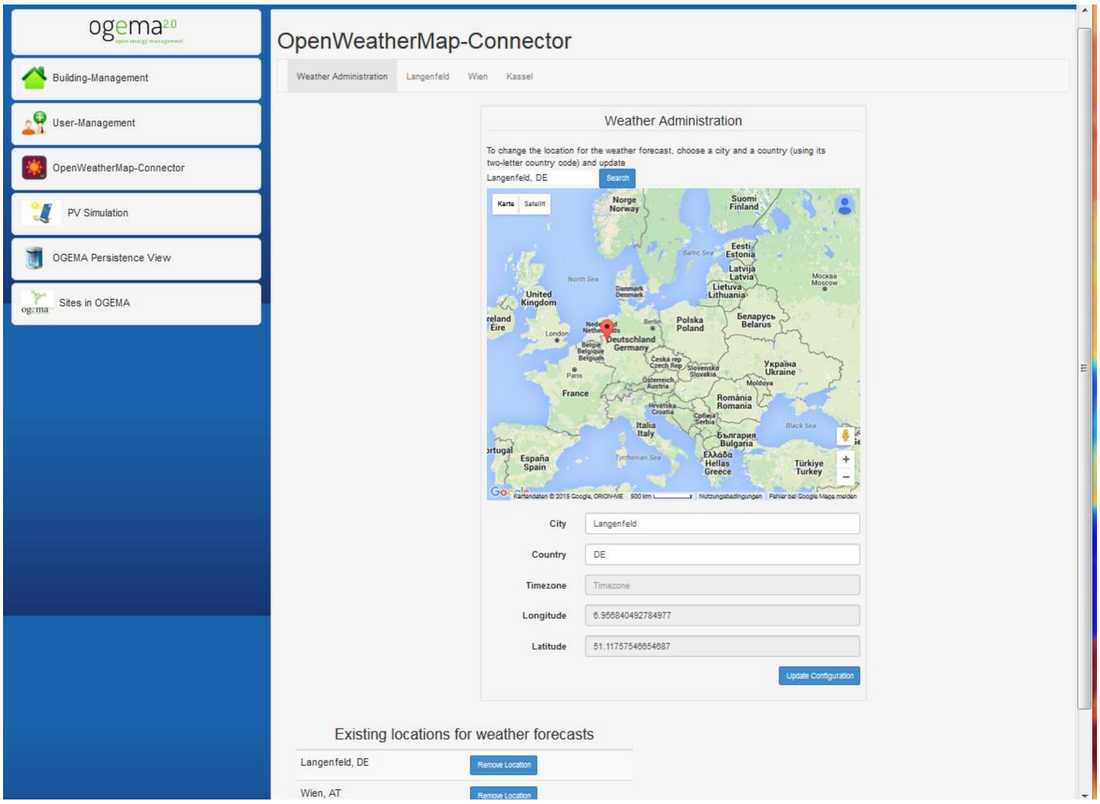

Figure 1: OpenWeathermap: Create Region

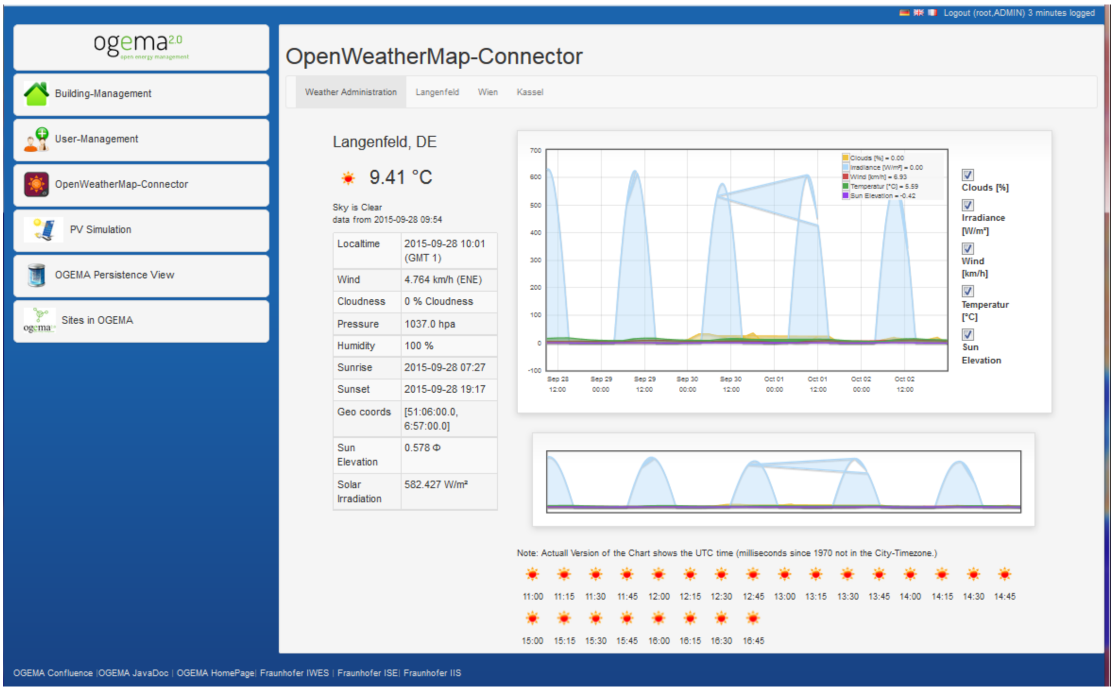

Figure 2: Region "Langenfeld"

The Building Resources themselves are generated in the „Building Management“ OGEMA Application (see screenshot below), in which the Buildings are mapped to the Region Resources. As nearly all OGEMA data classes and Resources are derived from the `org.ogema.core.model.Resource` - which also provides interfaces to map derived classes to each other – OGEMA Applications can communicate with other Applications using common Resources (as long as these Applications have the proper permissions for these Resources). The 72 simulated buildings used by the Adaption Request Application are thus generated by the Building Management Application and made available as OGEMA Resources which the Adaption Request Application has access to. For ease of configuration the names of these buildings can be loaded from an XML file, but the Building Management Application can also create individual Building Resources:

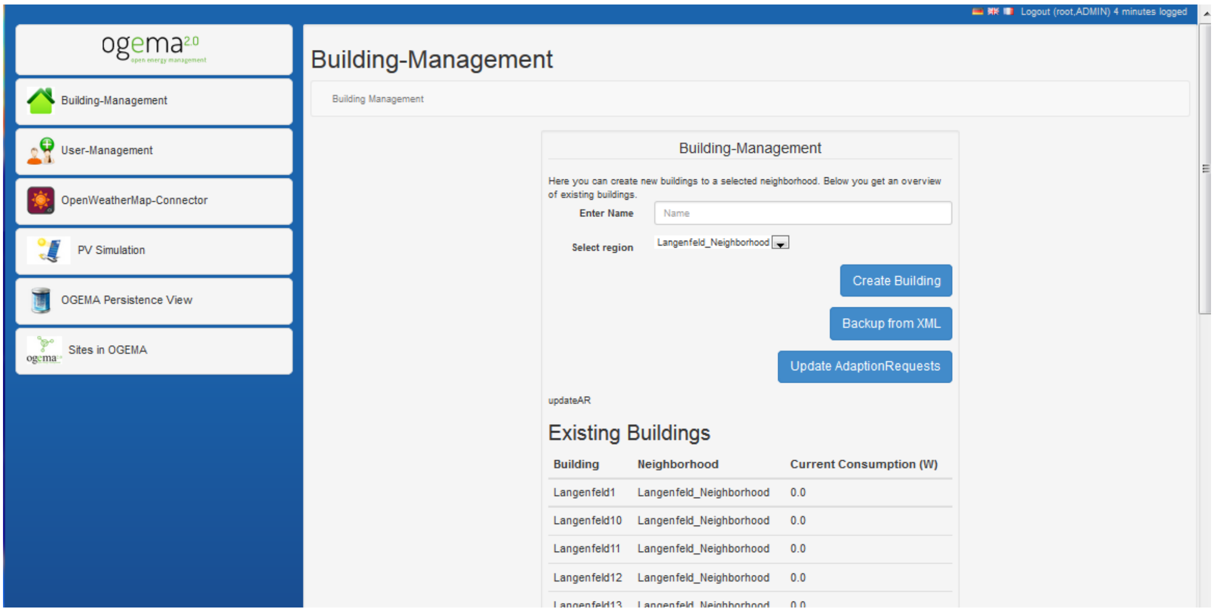

Figure 3:Create Building for Region

The Adaption Request Application itself only consists of a Start Class (`eu.eepos.nas.building.managemen.extension.ManagementApp`) which is found by OGEMA as an OSGi Service and establishes the necessary data and Resources used by the application, and a Logic Class (`eu.eepos.nas.building.management.extension.BuildingAdaptionRequesUtils`) which contain the actual algorithms. The Start Class also includes a timer, which executes the algorithm once after the Framework starts and then at each 15 minutes of system time (whenever the system time reaches a full hour, as well as 15, 30, and 45 minutes after a full hour.

The data transfer with external systems – that is, the retrieval of the thermal load prediction and the publication of the adaption requests – occurs via the OGEMA REST interface, which can be accessed via http (or https):

- `http://eepos.iwes.fraunhofer.de:8080/rest/resources/Langenfeld1/adaptionRequest/forecast`
- `https://eepos.iwes.fraunhofer.de:8443/rest/resources/Langenfeld72/adaptionRequest/forecast`

3.1.3 Results

A simulation experiment for load shifting on a daily basis was conducted for a whole year. Figure 4 shows the evaluation of a singel day, and the effect of the adaption request (AR) is immidiatly visible. The gas boiler (green) is running for a longer time without the AR (left side) while the biomass (cyan) is running less.

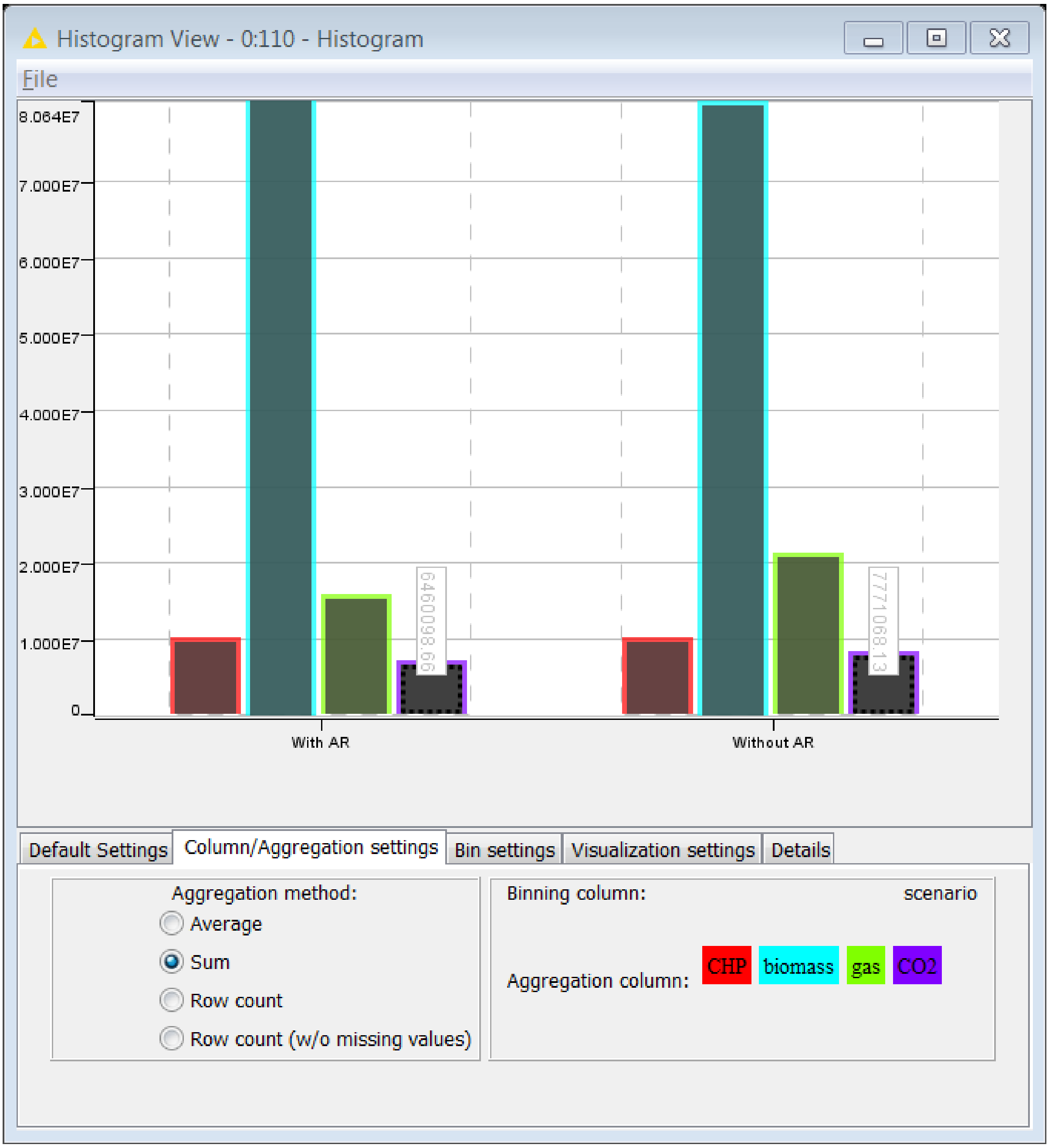

Figure 4: Evaluation of a sample day

When looking at the numbers in Table 1 one can see that the reduction of the use of the gas boiler can be directly translated into CO_2 reductions, as it is the major contributor to emissions. On the sample day, the AR led to a reduction of CO2 emissions by about 1.3 tons.

Scenario	CO_2 (kg)	Heat Energy from Gas (MWh)
Without AR	7840,19	20,731
With AR	6529,21	15,27

Table 1: Effect of adaption requests on emissions and production using the gas boiler

3.2 Finnish Demonstrator

3.2.1 Introduction

Finnish demonstration site has been started to build on 2007, six buildings are ready and the last building is under construction. A lot of EEPOS related energy and electricity meters and a local weather station were installed on 2014.

The seawater cooling system is the only RES based energy source in Finnish demonstrator. The most of the EEPOS seawater cooling system related energy meters were installed between September and October 2014 (after the latest cooling season). This means that the most important RES based experiment run (seawater cooling) is based on summer 2015 cooling season data. On the other hand summer 2014 was much warmer (more cooling was needed) than summer 2015 and that's why some RES based seawater cooling related energy saving analyses are made using summer 2014 cooling data with estimated pumping energies.

Other experiment runs done are energy saving potentials of space heating and domestic hot water. In addition, a study was done to find out the minimum level of additional RES based energy production (PV panels in demonstration site) to achieve energy positive neighborhood.

Load shifting potential estimation can be done based on raw measurement data analysis collected and classified separately from each technical system.

3.2.2 Energy Saving Potential

Sea water based space cooling

Two experiment runs for cooling related energy saving potential was done. The first run was done on summer 2014 (no data of pumping energy available, average outdoor temperature 17,2 °C) and the second one was done on summer 2015 (pumping energy data available, average outdoor temperature 15,7 °C). The cooling energy is produced by sea water based cooling system (local renewable energy source) and it is free for occupants.

Measured and saved cooling power (delivered by fan coil unit and chilled beam networks, case Klyyssi building) for first experiment run (27.6 – 22.9.2014) is shown in Figure 5.

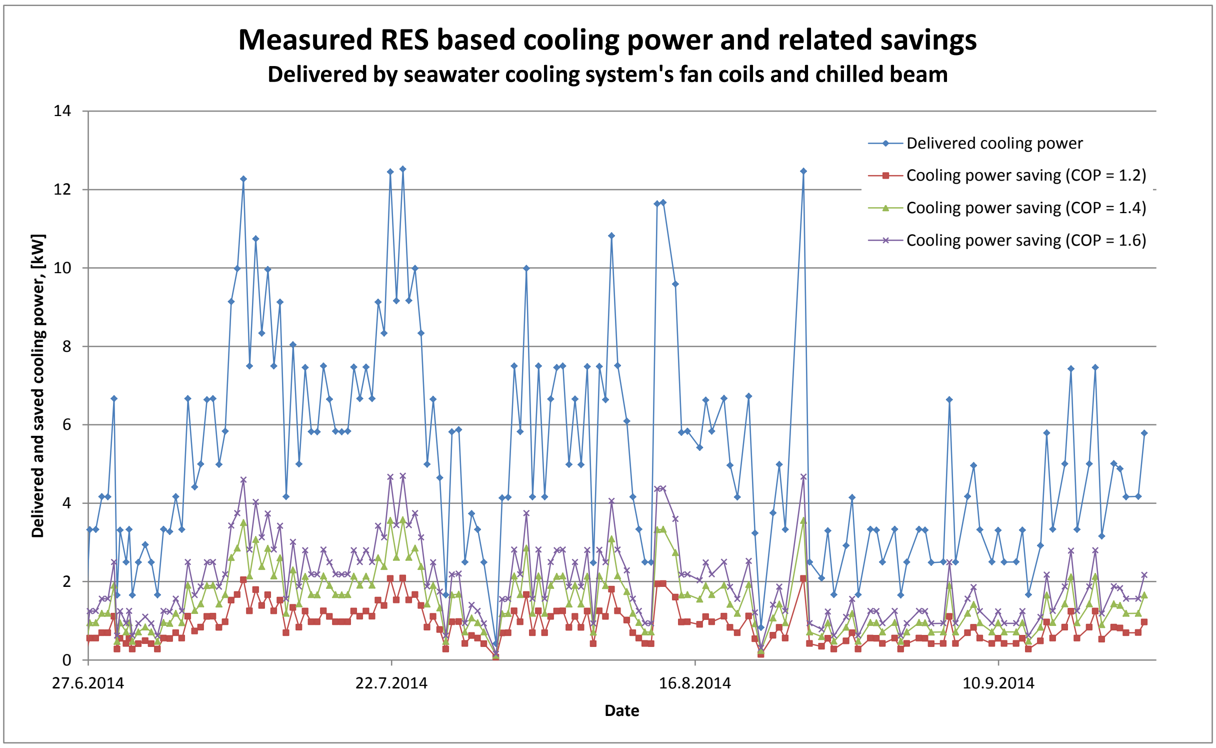

Figure 5: Measured and saved seawater based cooling power – case Klyyssi building, summer 2014

The total delivered cooling energy between 27.6 – 22.9.2014 in Klyyssi building was 10,8 MWh which means 3,4 kWh/m^2. On the other hand, the total cooling energy saving is smaller because extra electricity power is needed for cold water station (compressors, pumps, etc.) and other cooling network pumps (seawater system main pump, fan coil unit network circulation pump, chilled beam network circulation pump, air bleeder).

On summer 2014 cooling season the electricity meters of the cooling network pumps were not yet installed. Installation was done on September and October 2014 (after cooling season). This means that complete energy saving experiment run was not possible to execute before summer 2015. Because of that the summer 2014 related energy saving potential analyses was done using estimated pumping energies based on year 2015 cooling system's Coefficient Of Performance (COP) values as follows. If the cooling system's COP is 1,2 then the summer 2014 experiment run based Klyyssi building cooling energy saving is 1,8 MWh (0,6 kWh/m^2). For COP value 1,4 the energy saving is 3.1 MWh (1,0 kWh/m^2) and for COP value 1,6 the saving is 4,1 MWh (1,3 kWh/m^2).

In neighborhood level (6 apartment buildings) the seawater cooling based energy savings are something between 15 – 34 MWh in the studied cooling season (27.6 – 22.9.2014).

The second experiment run was done on summer 2015 (17.5. – 1.9.2015) and the related measured and saved cooling power (delivered by fan coil unit and chilled beam networks) data is shown in Figure 6

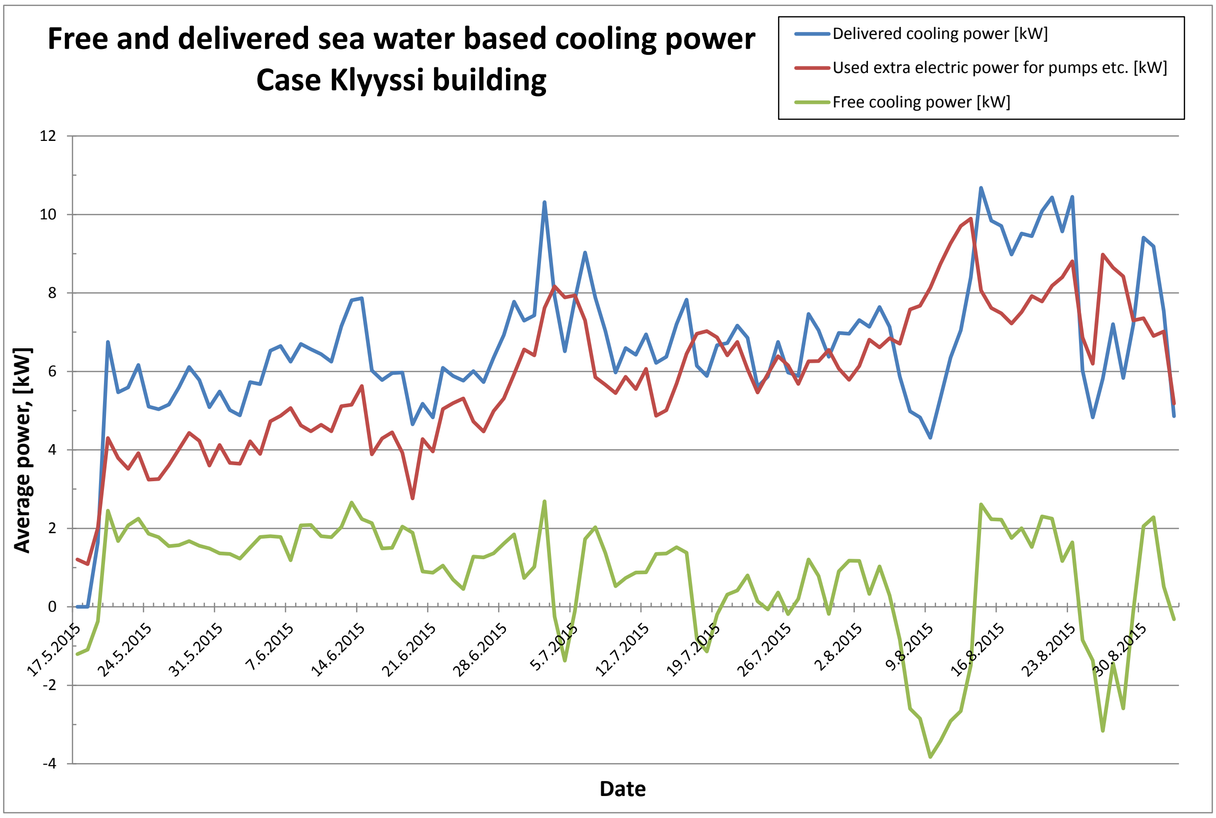

Figure 6: *Measured and saved (free) seawater based cooling power – case Klyyssi building, summer 2015.*

Based on summer 2015 data the delivered average (24 h) cooling power varies between 5 kW to 11 kW for Klyyssi building. For whole Finnish pilot area this means 42 kW to 92 kW cooling power. On the other hand the needed electric power for Klyyssi building related compressor and pumps varies between 3 kW to 10 kW (25 kW to 84 kW for the whole area). And the most important free cooling average power varies between –4 kW to 3 kW which means -33 kW to 25 kW for the whole area. Average saved cooling power is 0,8 kW and 7 kW for whole area.

The total delivered cooling energy for Klyyssi building in summer 2015 was 17 MWh and for the whole area 144 MWh. The used power consumption for compressor and pumps were 15 MWh for Klyyssi building and for whole area 127 MWh. The saved cooling energy for Klyyssi building was 2 MWh and for whole area estimated value is 17 MWh.

The distribution of electric power used in sea water cooling system is show in Figure 7.

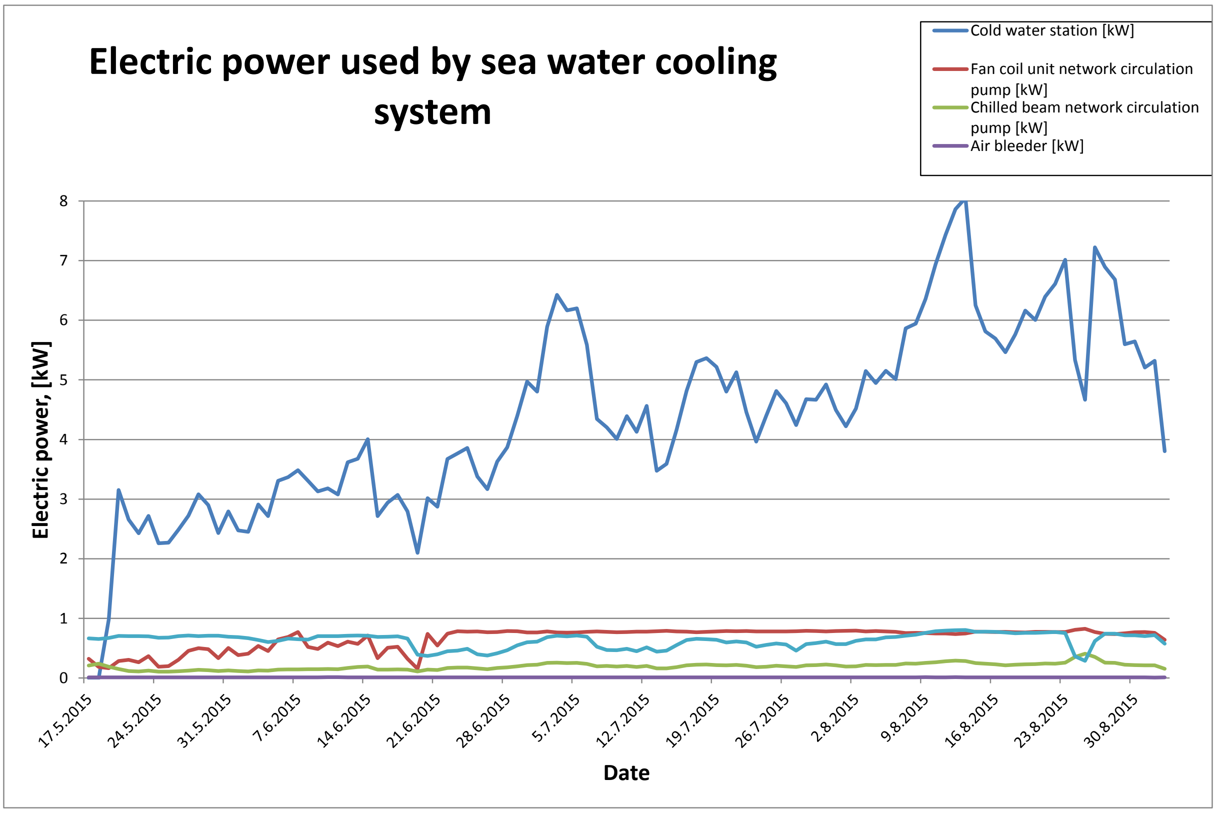

Figure 7: *Distribution of electric power used in sea water cooling system.*

As seen from the Figure 3, the cold water station (2 compressor, 2 pumps etc.) use the most of the extra electric power needed for sea water cooling system and related energy savings is dependent how well the control and related load shifting can be optimized.

COP values for Finnish pilot related seawater based cooling system and related outside air and sea water temperatures (case Klyyssi building, summer 2015) is shown inFigure 8. The sea water temperature is measured inside the sea water cooling system’s input pipe.

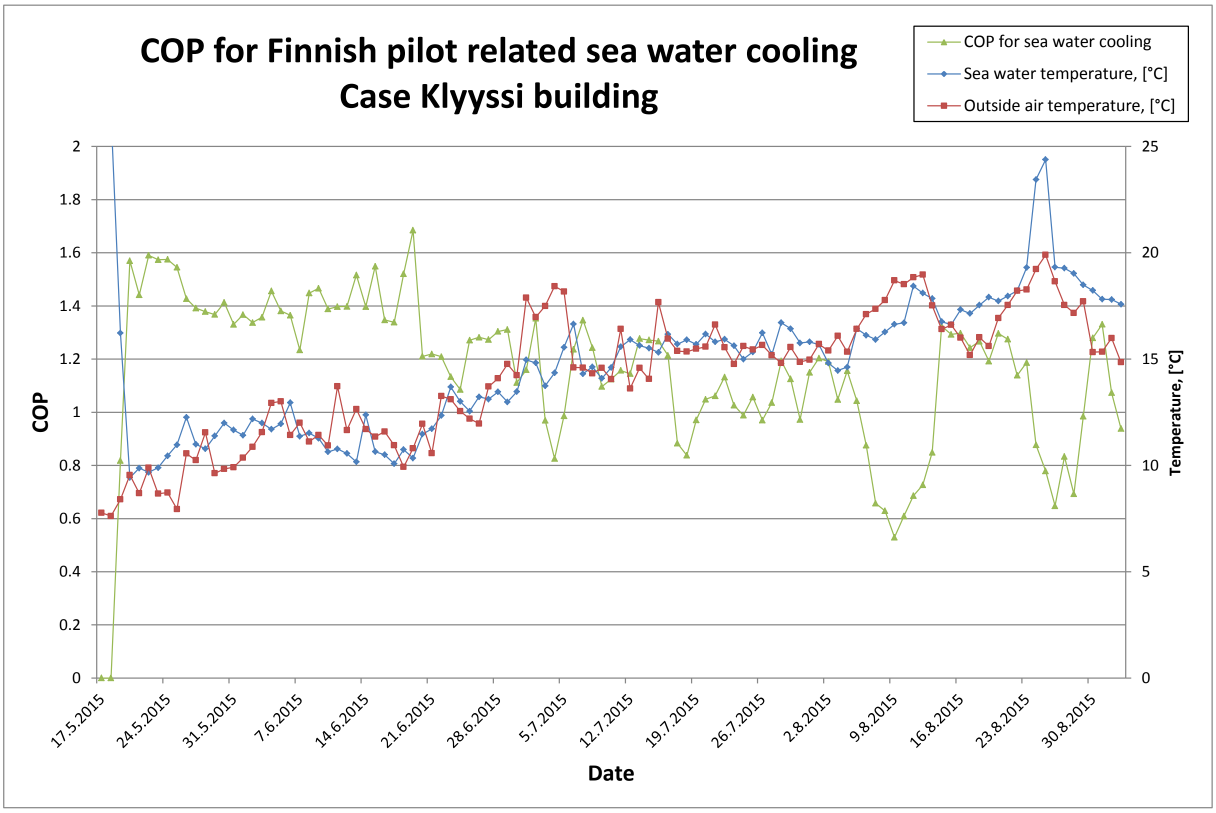

Figure 8: *COP for Finnish pilot related seawater based cooling sytem and related outside air and sea water temperature (measured inside input pipe) – case Klyyssi building, summer 2015.*

The COP for whole cooling system varies between 0,5 to 1,7. This means that sometimes the cooling system takes more electric power than it delivers as a cooling power. And the average delivered cooling power is only 1,2 times higher than the electric power it uses.

One reason for COP values under 1,0 is a fault in system like blockage in sea water pipe's inlet (e.g the values between 23.8 - 27.8.2015). Other reason for low COP values can be too high sea water temperature or used control strategy and related end user's way of using apartment level cooling set points.

As seen from the Figure 4, the correlation between sea water temperature in cooling system's input pipe and outdoor air temperature is rather high. On the other hand the sea water cooling system's input pipe is 5 m below sea surface. There may be some flows which circulate the surface water so efficiently that the temperature changes rather fast also in 5 m below the surface. In that case one solution for more energy savings would be to find better place (deeper) where to take cooling system sea water.

Sea water temperature before and after the heat exchanger which is connected between cold water station's condenser circuit and seawater circuit is shown in *Figure 10*Figure 9.

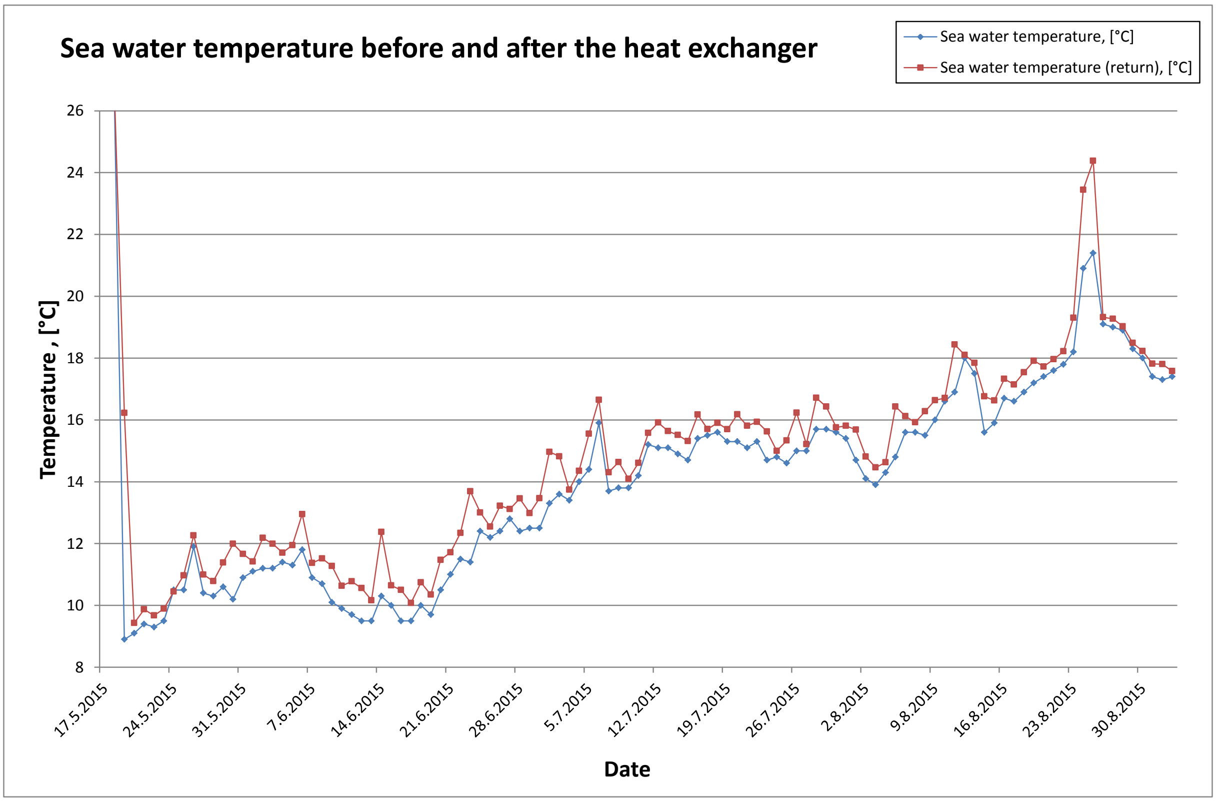

Figure 9: *Sea water temperature before and after the heat exchanger.*

As seen from the Figure 5, the temperature drop of sea water in the heat exchanger (which is connected between cold water station's condenser circuit and sea water circuit) is about 0,9 °C. On the other hand the sea water flow is much higher than the condenser circuit flow and the sea water pumping related energy consumption per building is much lower than the cold water station related energy consumption (see figure 3). This means that the seawater pumping related energy saving by ICT is not very significant and fault detection (e.g. see figure 4 COP values under 1,0 and peak in sea water input temperature) and right control strategy is the best way to avoid extra energy use in that part of the cooling system.

As a conclusion, the sea water based cooling system is not very efficient solution from energy saving point of view. ICT based energy saving is the most effective if the sea water cooling system control strategies are optimal, related load shifting can be optimized and the ICT based monitoring and related fault detection algorithms (e.g. EEPOS fault detection engine) can find faults (e.g. blockages in sea water pipe's inlet) as soon as possible.

Air conditioning

Experiment run for air conditioning related saving potential was done between September 2014 and August 2015. Air conditioning systems' related measured average electric power values is shown in Figure 10

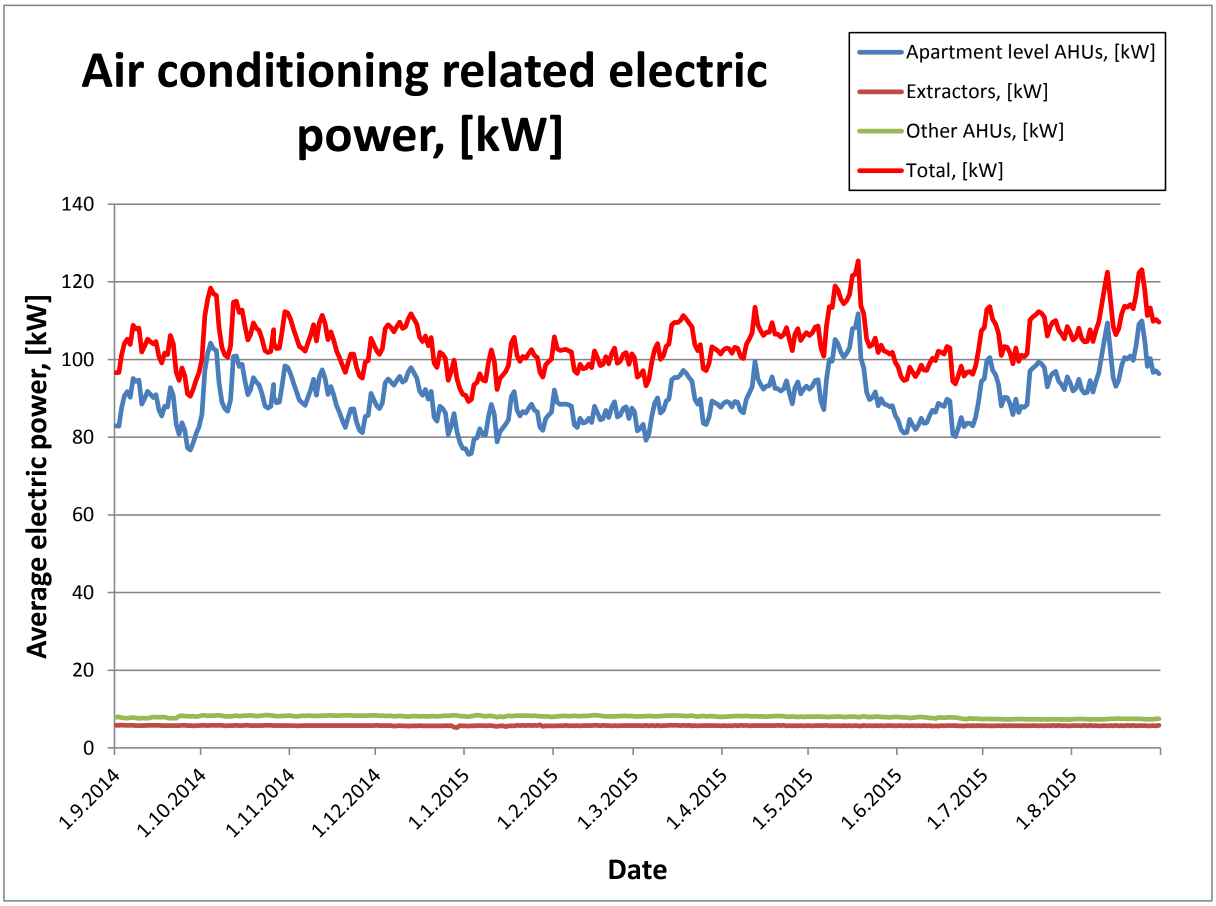

Figure 10: Measured air conditioning related average electric power – case Klyyssi building.

ICT based air conditioning based savings are based mainly on load shifting. The theoretical maximum load shifting potential for Klyyssi building is about 110 kW (for whole neighbourhood 920 kW), but all air conditioning is not good to put totally off so 80 kW (for whole neighbourhood 670 kW) is more realistic value for short time load shifting. This means that air handling is the most potential electric power related energy saving energy saving for EEPOS ICT.

Space heating

Space heating energy saving potential related experiment run was done between September 2014 and May 2015. Related energy saving potential was studied by comparing the measurement values and estimated optimal space heating energy consumption in building level (Figure 26).

The estimated space heating was done by EEPOS ICT system connected external web service based space heating calculation model based on EN ISO 13790:2008 [1] (*Energy performance of buildings: Calculation of energy use for space heating and cooling*) and EN 15241:2007 [2] (*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.

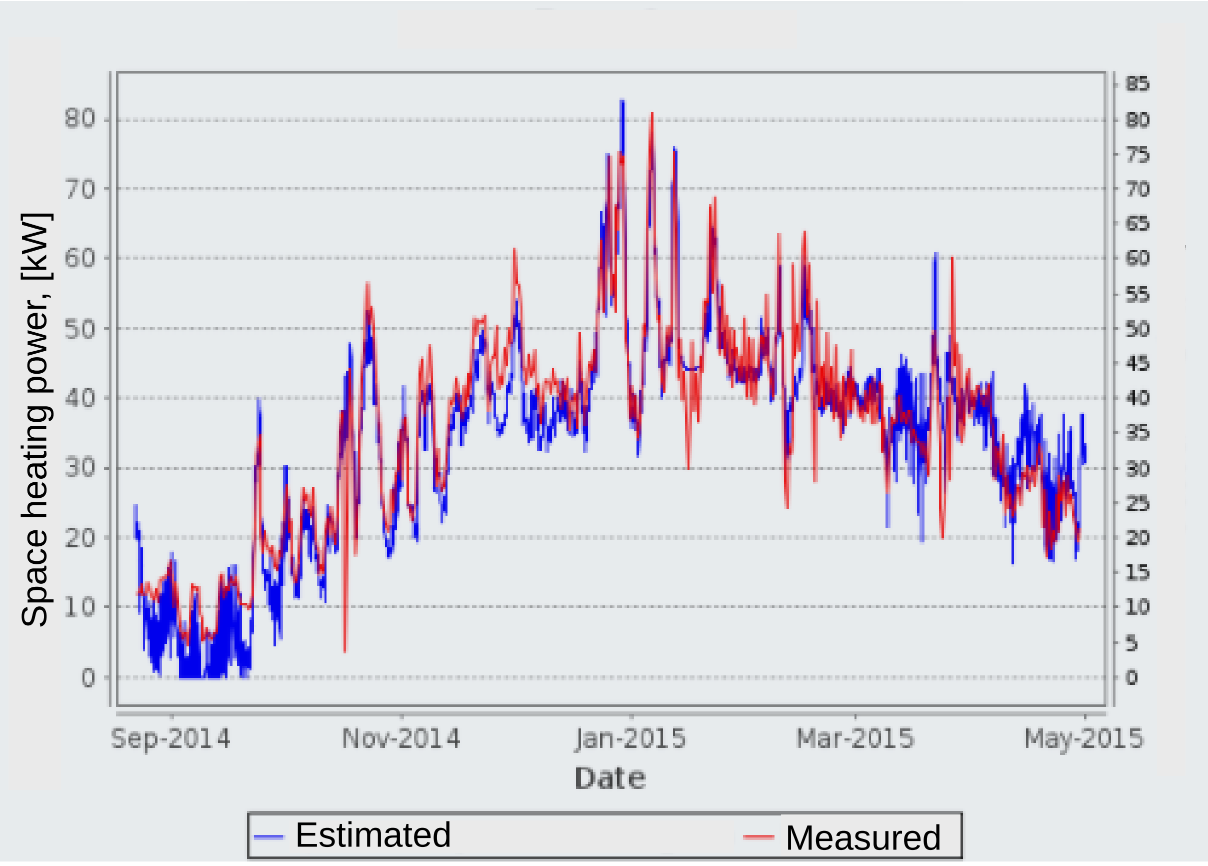

Figure 11: Measured vs. estimated optimal space heating energy consumption – case Klyyssi building

As seen from theFigure 11, the measured space heating is rather optimal and there is not much to do space heating related energy savings by EEPOS ICT. On the other hand, if the district heating based energy price would vary by hours and cheap energy could be stored (e.g. by overheating when energy is cheap) money savings is possible (see chapter load shifting potential).

<u>Domestic hot water</u>

Domestic hot water heating energy saving related experiment run was done between November 2014 and May 2015. In this experiment run no reference data was available before EEPOS so the values are compared to the estimated value. The estimated hot water energy consumption in building level is calculated using equation

$$Q_{hotWater} = \dot{m}_{perPerson} * x_{quotaOfHotWater} * N_{numberOfPersons} * c_p * (T_{hot}-T_{cold})$$

where

$Q_{hotWater}$ is estimated domestic hot water energy (delivered) in the building [W]

$\dot{m}_{perPerson}$ is used hot water per person [kg/s]

$x_{quotaOfHotWater}$ is hot water quota of used water

$N_{numberOfPersons}$ is number of occupants in the building

c_p is water specific heat capacity [J/kg°C]

T_{hot} is hot water temperature [°C]

T_{cold} is cold water temperature [°C]

Typical value for one person water consumption is 140 l/day. Estimation for building level hot water energy consumption is

$Q_{hotWater}$ = 140 l/day,person / (24*3600) s/day * 0,4 * 64 person * 4190 J/kg°C * (57 - 7)°C = 8690 W

Measured vs. estimated domestic hot water heating energy consumption is shown on Figure 12

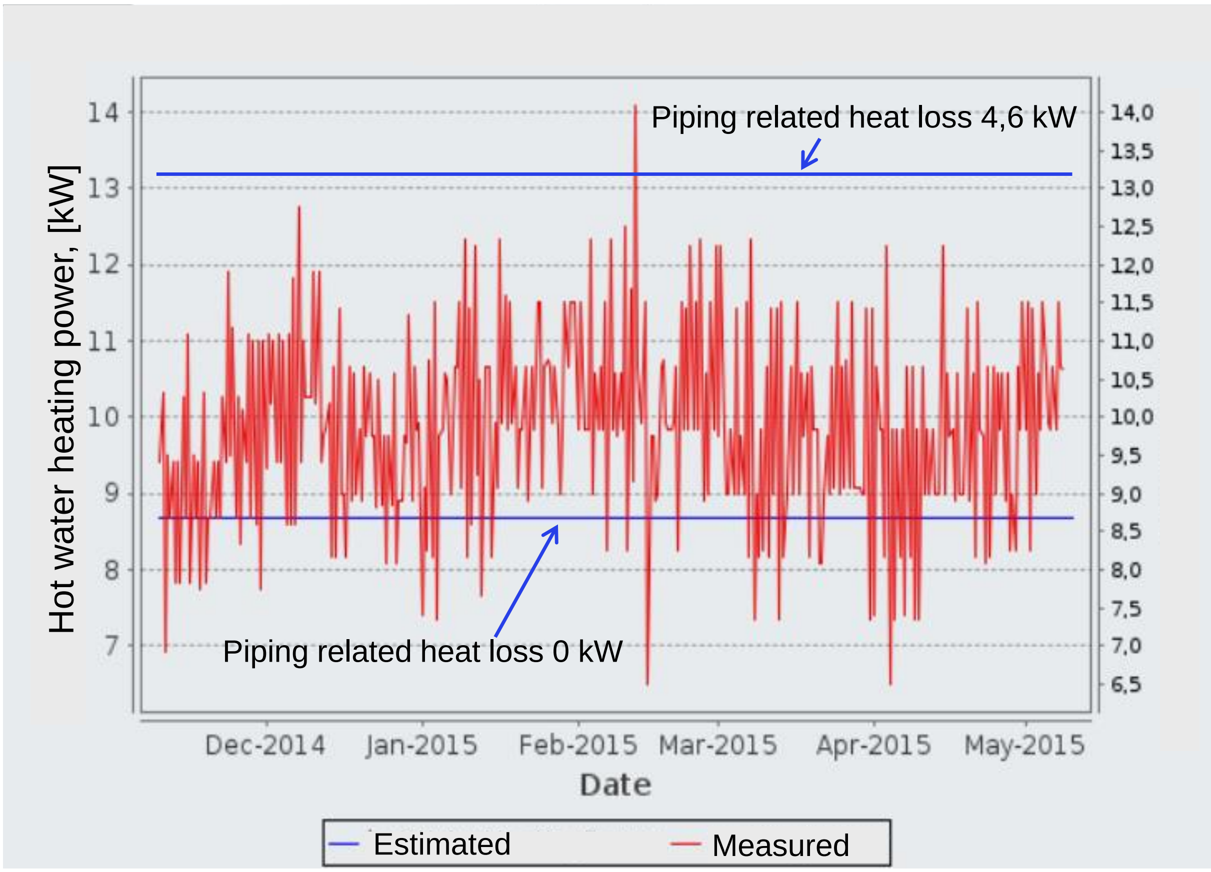

Figure 12: Measured vs. estimated domestic hot water heating energy – case Klyyssi building.

The experiment run related measurements includes also hot water circulation pipe related heat loss. If the heat losses are 0 kW the real domestic hot water use is higher than the average, but if the heat loss is 4,6 kW (typical value) then the real consumption is lower.

This experiment run shows that the measured hot water energy consumption is average. This means that there may be some energy saving potential but not much. In addition, domestic hot water related energy consumption is dependent on occupant's behavior and in this building are living very rich people who typically don't think money as much as average people.

On the other hand, if the thermal energy price would vary hour by hour then the cost savings are possible by load shifting (see chapter load shifting potential) in the way that occupants even don't notice it.

Additional RES needed to achieve energy positive neighborhood

The aim of this experiment run was to study how much more local RES based energy production (Photo Voltage panels) is needed to achieve energy positive neighborhood.

Electricity produced by the photovoltaic system $E_{el,pv,out}$ is calculated by [3]:

$E_{sol,pv,out} = E_{sol} * P_{pk} * f_{perf} / I_{ref}$

where

E_{sol} is the annual solar irradiation on the photovoltaic system [(kWh/m^2)/year]

P_{pk} is the peak power [kW], represents the electrical power of a photovoltaic system with a given surface and for a solar irradiance of 1 kW/m^2 on this surface (at 25 °C)

f_{perf} is the system performance factor [-]

I_{ref} is the reference solar irradiance equal to 1 kW/m^2

Solar radiation for horizontal surface ($E_{sol,hor}$) in South Finland is 975 kWh/m^2 per year [4]. If the solar panel tilt angle is e.g. 45° then the solar radiation E_{sol} in Helsinki is

E_{sol} = 1,2 * $E_{sol,hor}$ = 1,2 * 975 [(kWh/m^2)/year] = 1170 [(kWh/m^2)/year].

And the annual electric energy produced by the photovoltaic system per m^2 is

$E_{sol,pv,out}$ = 1170 [(kWh/m^2)/year] * (0,15 kW/m^2 * 1,0 m^2) * 0,75 / 1,0 [kW/m^2] = 132 [kWh/year]

The annual energy consumption in the Klyyssi building is as follows

- space heating and domestic hot water 347 MWh
- real estate electricity consumption 91 MWh (household electricity not included)

The total energy need in this already build Finnish demonstration area is 2500 MWh. The delivered energy by RES based seawater cooling is 144 MWh. This means that for energy positive neighborhood there is need for 2360 MWh of new RES based energy production installed in the demonstration area. If this is done by PV panels (132 kWh/m^2 per year in Helsinki) this means that there is a need to install 17800 m^2 PV panels to achieve energy positive neighborhood. That is over 4 times more than the available roof area.

The efficiency of thermal solar system is much higher than using PV panel based system. If the heating is done by thermal solar collectors and electricity part using PV panels so less area for solar energy system will be needed.

3.2.3 Load Shifting Potential

Load shifting is a very complicated challenge. Although in theory all technical systems can be totally shut down or run up to full blast, in practice we have multiple boundaries that limits load shifting potential. The most important boundary is indoor climate. Indoor climate must meet pre-set limits all the time. It is unacceptable if inhabitants feel indoor conditions uncomfortable. On the other hand while apartment is empty there could be options to deviate from those limits.

The most reliable way to estimate potential is to analyse realised raw data. Firstly load shifting potential is collected and classified separately from each technical system. Classification is based on time range of potential load shifting where

- Short term mean 1 minute load shifting potential. These systems are crucial and they can be manipulated extremely short time only before those make effect on circumstances.
- Medium term means 1 hour load shifting. These systems take much more time to make effect.
- Long term means 4 hours or more. These systems, such as floor heating system, make effect very slowly.

Load shifting estimate is based on realised consumption data coming from sensors. The data is categorised according to time on hourly basis. Base on this data three values calculated.

- Median value that means the most typical consumption
- Maximum value that is close to practical realised maximum consumption, 99,5% of values are below this value
- Minimum value that is close to practical realised minimum consumption, 99,5% of values are above this value

Practical load delaying potential is the median value minus minimum value.

Practical load advancing potential is the maximum value minus median value. Some systems, like heating system and cooling system, data analysis is limited to relevant seasons only. Shift loading potential for the entire building is calculated figures from the system level. This figure gives us realistic input to business models. In the case that the figures are used for on-time adjustment of building automation system we should uses on-time consumption values instead of median values.

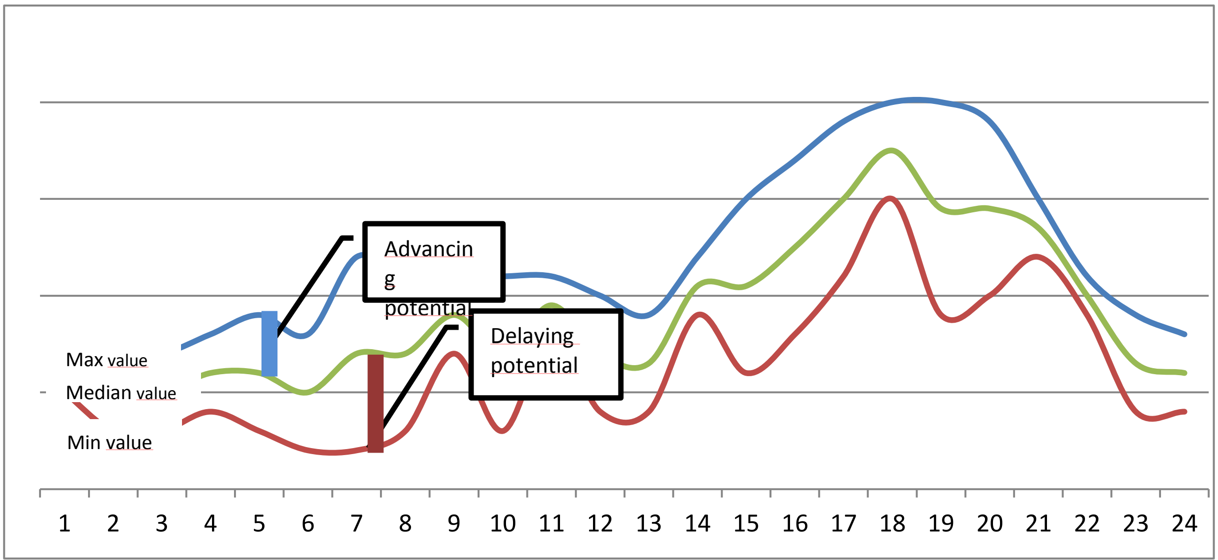

Figure 13: Load shifting potential

The load shifting economical potential was calculated from the highest individual measurement point (ventilation system, heat recovery, H901EM03_1) in Merenkulkijaranta,

As the initial step for shift potential was created energy consumption profile which is presented in Figure 14.

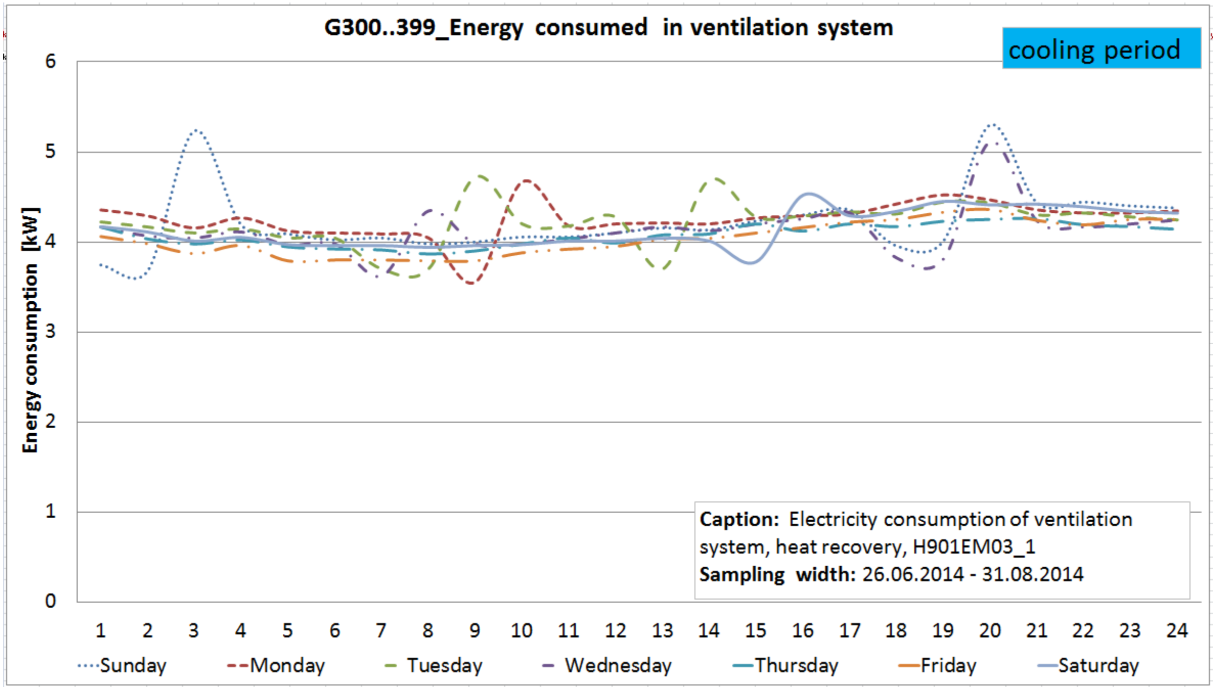

Figure 14: Energy consumption profile, heat recovery, H901EM03_1

Then from the daily hours were calculated separately by MAX IF and MIN IF hourly minimum and maximum energy consumption. The hourly minimum and maximum energy consumption are presented in Figure 15

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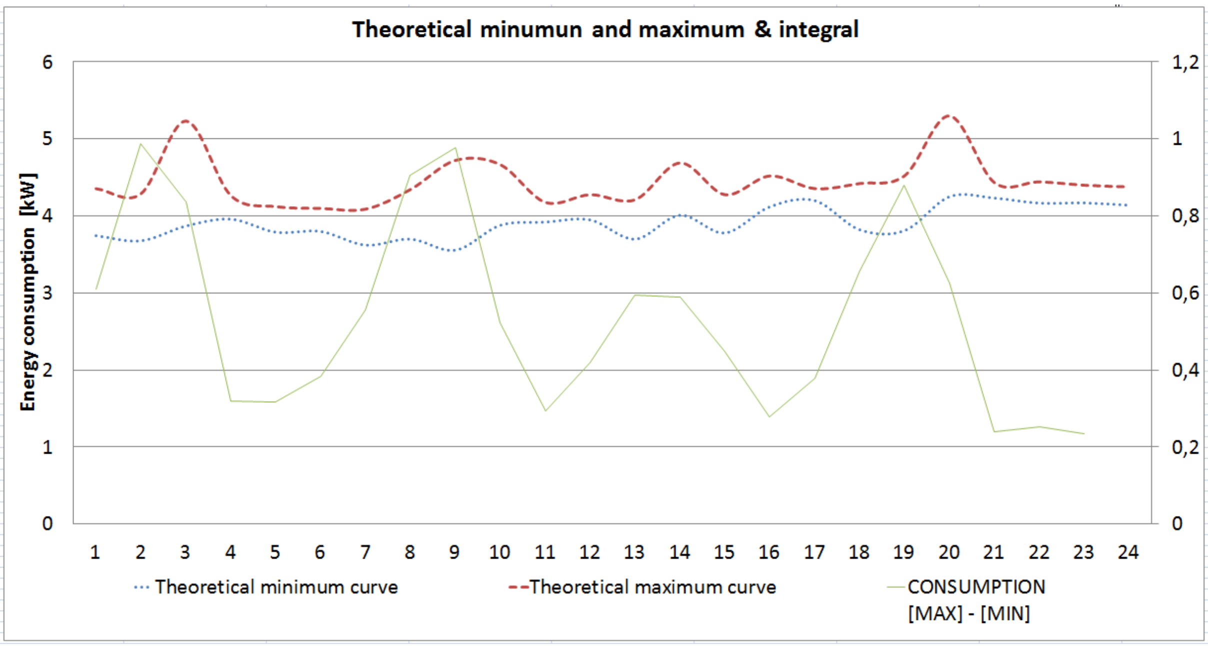

Figure 15:*Energy consumption, min-mas and integrl, heat recovery* H901EM03_1

Into the minimum and maximum consumption were applied trapezoidal rule by following equation:

$$\int_a^b f(x)dx \approx (b-a)\frac{f(a)+f(b)}{2}$$

Then the calculated trapezoid value of minimum and maximum consumption were subtracted. The reminder is the theoretical load shifting potential within the baseline of existing energy consumption.

After the calculable consumption latitude were specified similar evaluation were performed for the Nordpool spot price. The Nordpool weekly. daily and hourly price profile is presented in Figure 16.

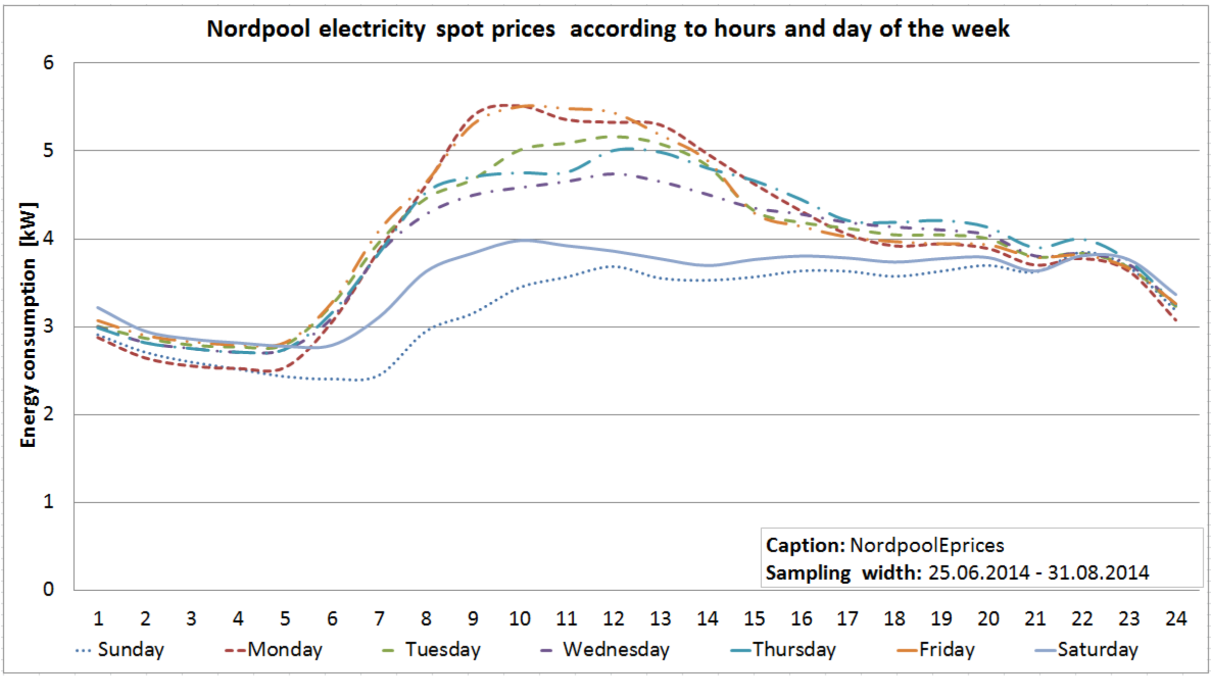

Figure 16: Nordpool price profile 25.06.2014 - 31.08.2014

By repeating the similar calculation procedure & evaluation for the spot prices were created theoretical financial value for load shifting. The theoretical load shifting value is presented in Figure 17

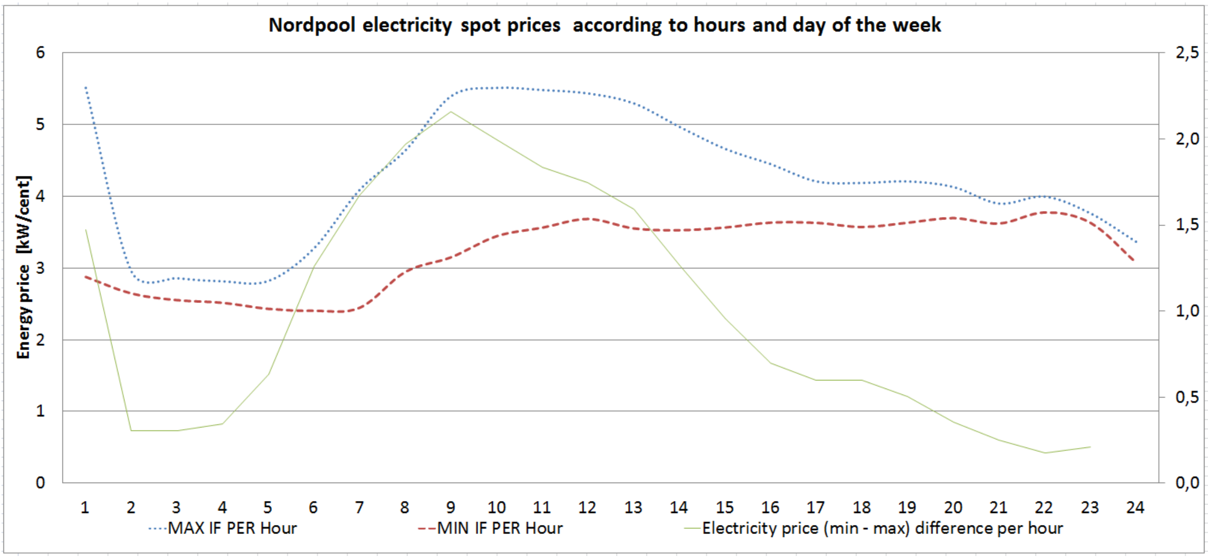

Figure 17: Theoretical economic value for hourly load shifting

When the latitude of consumption and the monetary value of the latitude is know the total hourly economical value of individual consumption can be calculated by multiplying the factors. The multilayers and the results per hour are presented

3.3 **Virtual prototype**

3.3.1 Introduction

The results obtained by the virtual prototype in Araia, obtained in *D4.3 "Virtual Prototype"* will be further detailed here, describing the environmental impact as well as the economic indicators in depth.

In *D4.3 "Virtual Prototype"* it was concluded that the district heating cost was too high compared to potential savings. Therefore, an alternative way of connection was proposed, where the CHP units were directly connected to the bigger buildings: school and culture house (one unit per building). Therefore, in this configuration CHP heat cannot be transferred to other buildings but there is a private electrical grid connecting "prosumers" between them and with the main grid.

This alternative layout will be used for the analysis (see next figure):

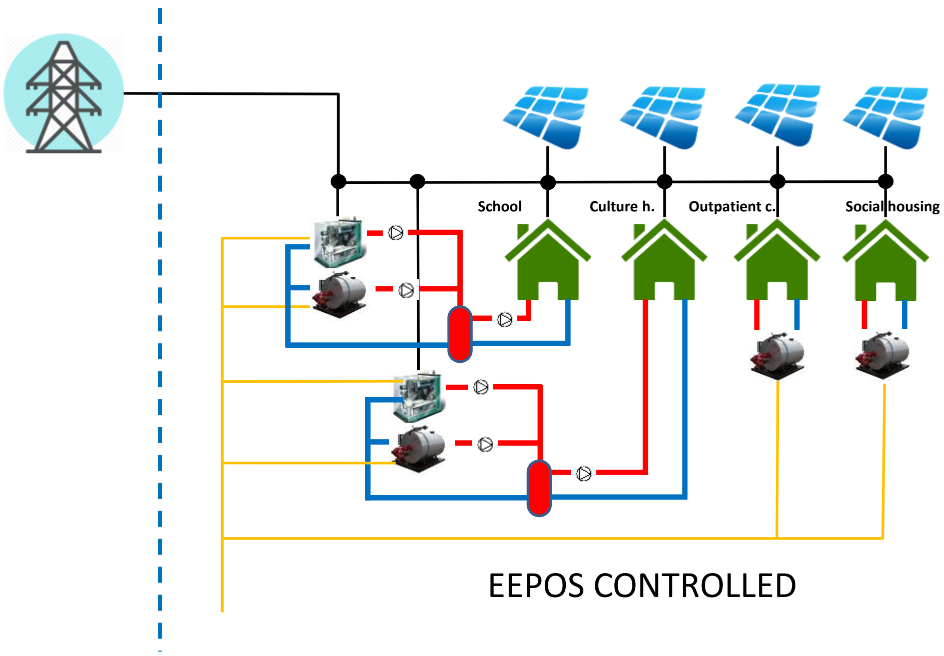

Figure 18: Alternative layout considered

As the main difference between weeks is the heating demand and heating is mostly related to the external temperature, different weeks with different average temperatures have been solved and results are shown now. Solving the energy management for different weeks during the year will be useful to understand how the EEPOS system evolves when the boundary conditions change.

A standard weather file from Araia has been analysed. This file has been composed by using weather data obtained from different years. It does not represent any year in particular, but it is representative of the weather conditions of Araia.

When plotting the average daily temperature for the whole year, the following graph is obtained.

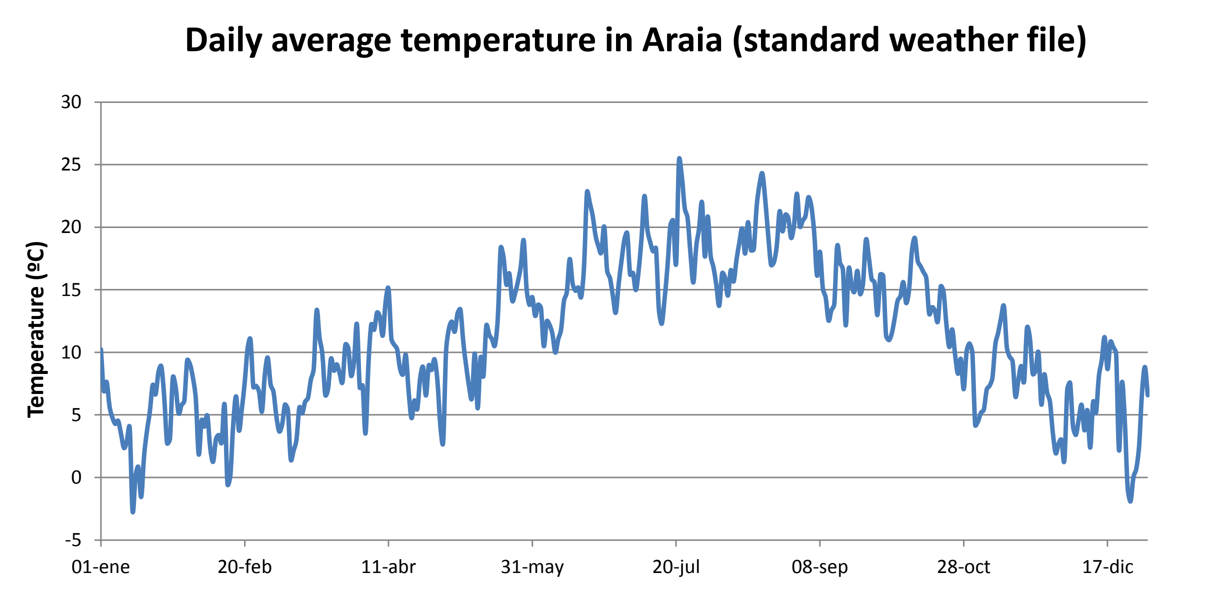

Figure 19: Daily average temperature in Araia (standard weather file)

By taking the same values and ordering the values, a monotonically decreasing curve is created. According to the experimental data regarding heating, when the average ambient temperature is around 15ºC or higher there are no heating needs and the boilers and CHP units should be off during this period (summer period). The remaining days with daily average temperatures lower than 15ºC have been subdivided in four periods (same days per period). The average daily temperature of the "very cold weather" is 3.4ºC, for the "cold weather" is 6.9 ºC, for the “mildly cold weather” is 9.8ºC and for the “mild weather” is 13.3ºC. This can be seen in the next graph.

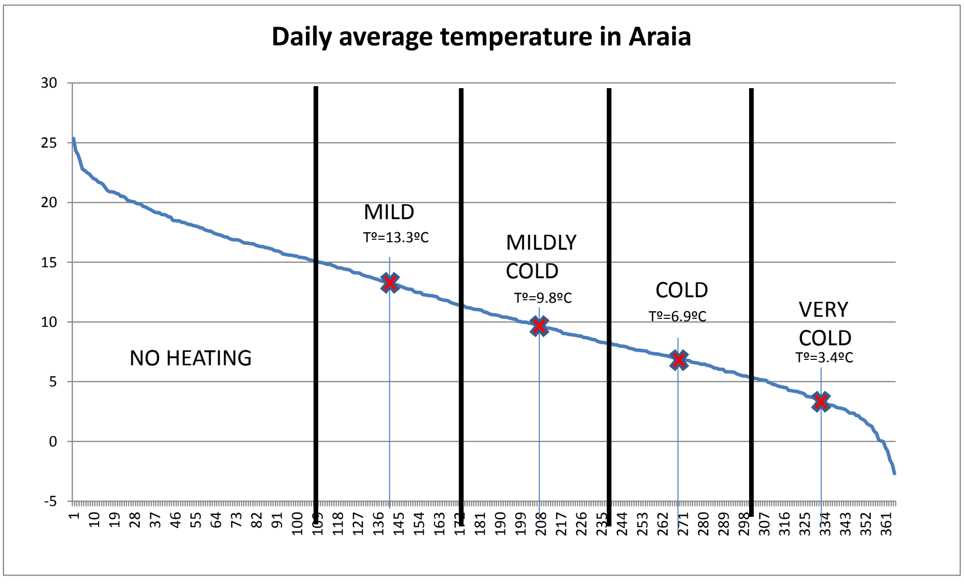

Figure 20. Monotonic decreasing curve of average daily temperature in Araia (standard weather file).

A week representing the "very cold weather" should have an average temperature around 3.4ºC. Having a look to the standard weather file, the week going from the 5th of February to the 11th of February has an average temperature of 3.4ºC. This week will be used to simulate the "very cold weather" conditions. In order to use realistic electricity prices, real Spanish electricity prices from 2013 will be used. As this particular week started on Tuesday in 2013, the electricity demands of Araia buildings will be adapted consequently.

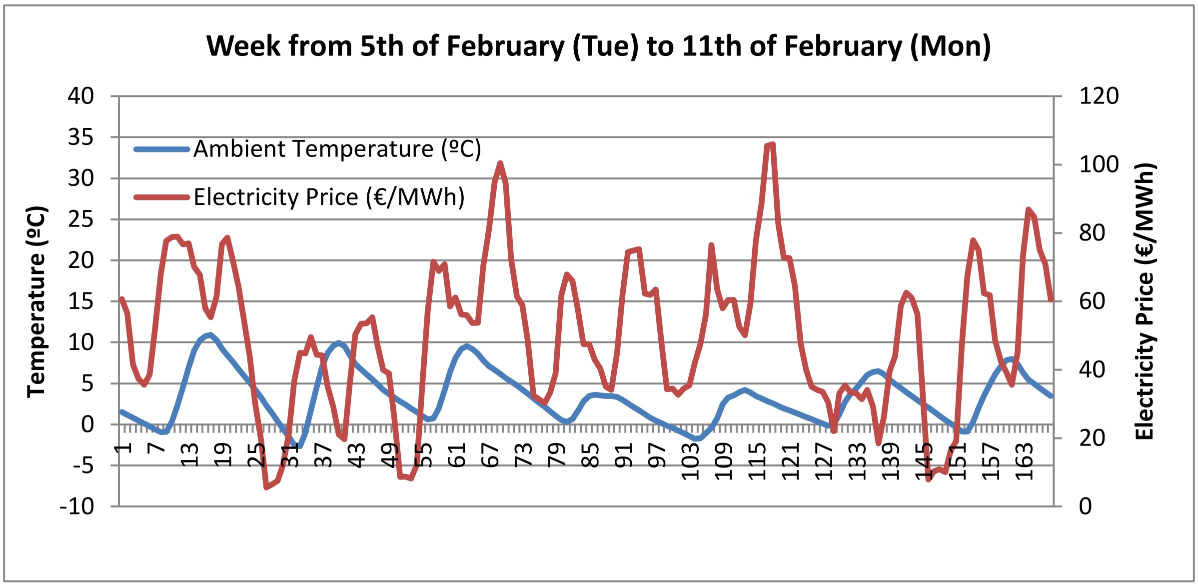

Figure 21: Ambient Temperature and Electricity Price for the "very cold weather" week

A week representing the "cold weather" should have an average temperature around 6.9ºC. Having a look to the standard weather file, the week going from the 10th of December to the 21th of December has an average temperature of 6.8ºC. This week will be used to simulate the "cold weather" conditions. In order to use realistic electricity prices, real Spanish electricity prices from 2013 will be used. As this particular week also started on Tuesday in 2013, the electricity demands of Araia will be adapted consequently.

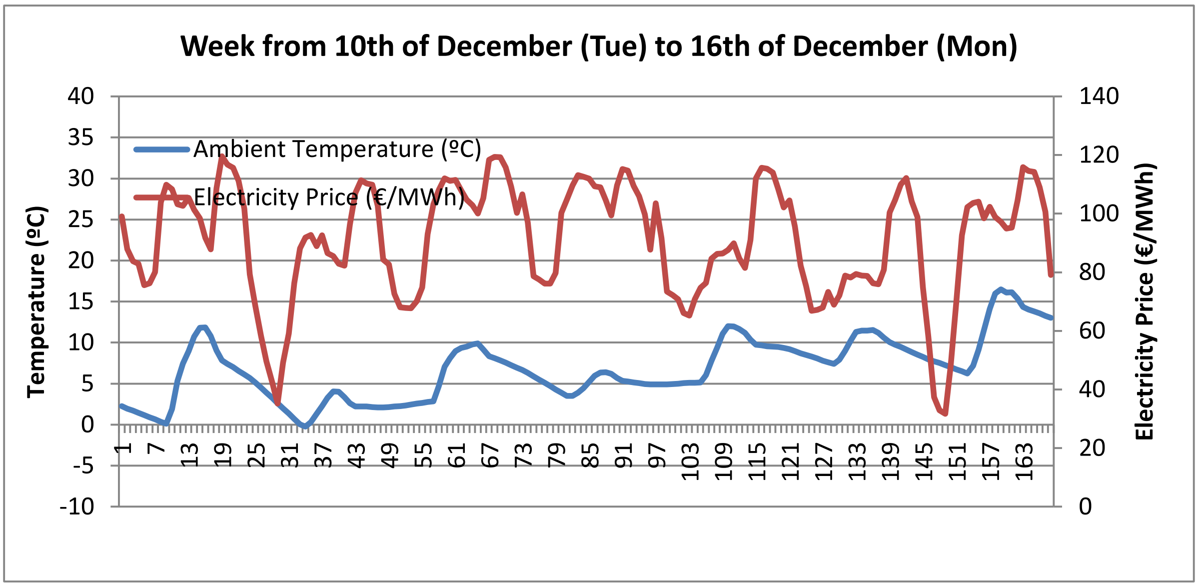

Figure 22: Ambient Temperature and Electricity Price for the "cold weather" week

A week representing the "mildly cold weather" should have an average temperature around 9.8ºC. Having a look to the standard weather file, the week going from the 22th of October to the 28th of October has an average temperature of 9.9ºC. This week will be used to simulate the "mildly cold weather" conditions. In order to use realistic electricity prices, real Spanish electricity prices from 2013 will be used.

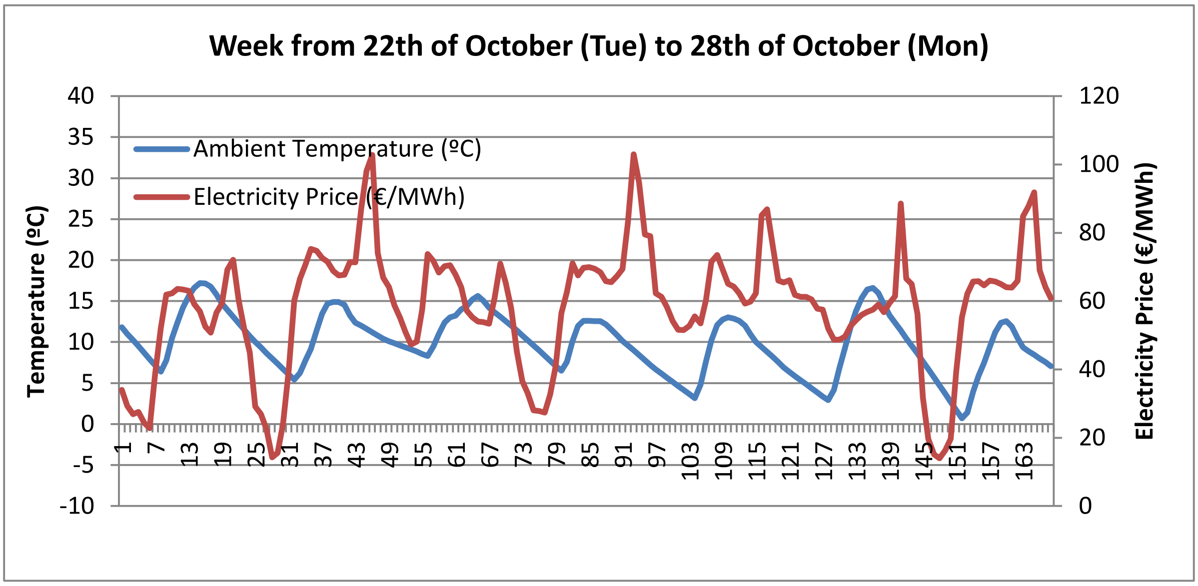

Figure 23: Ambient Temperature and Electricity Price for the "mildly cold weather" week

A week representing the "mild weather" should have an average temperature around 13.3ºC. Having a look to the standard weather file, the week going from the 1st of October to the 7th of October has an average temperature of 13.0ºC. This week will be used to simulate the "mild weather" conditions. In order to use realistic electricity prices, real Spanish electricity prices from 2013 will be used.

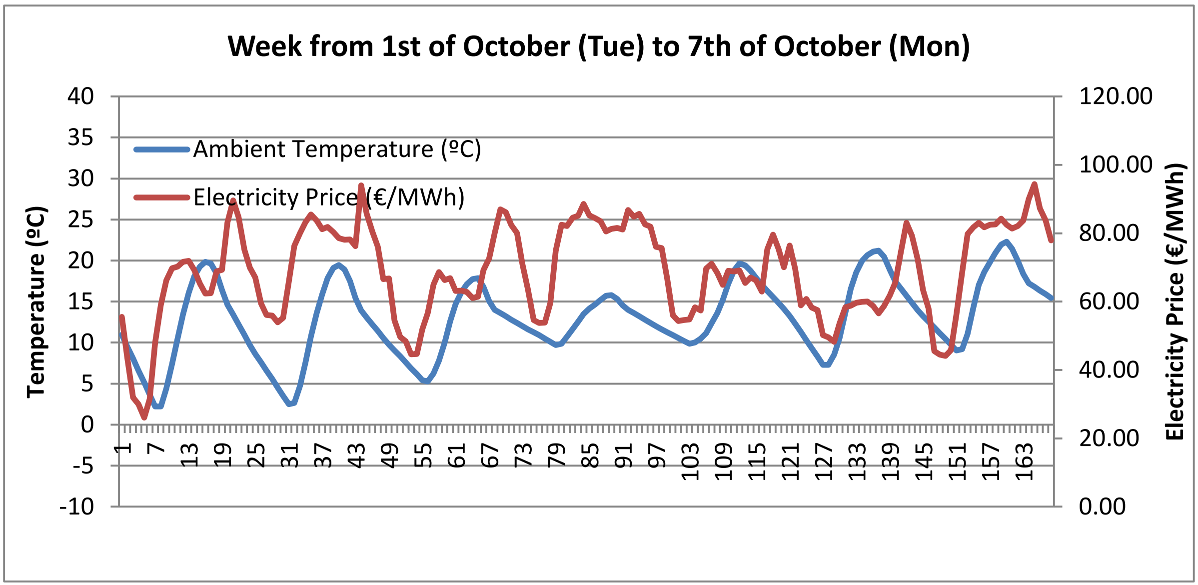

Figure 24: Ambient Temperature and Electricity Price for the "mild weather" week

3.3.2 Baseline

The baseline case considers that the buildings are connected to the main electric grid and each one of them has an individual gas natural boiler (efficiency = 85%), providing the heating required per building. Therefore, there is no district heating in the case.

The following graph represents the electrical energy demanded by the buildings for a standard week. As this is the baseline case (no CHP and no PV), the same amount of energy (and peak power) will be extracted from the main grid.

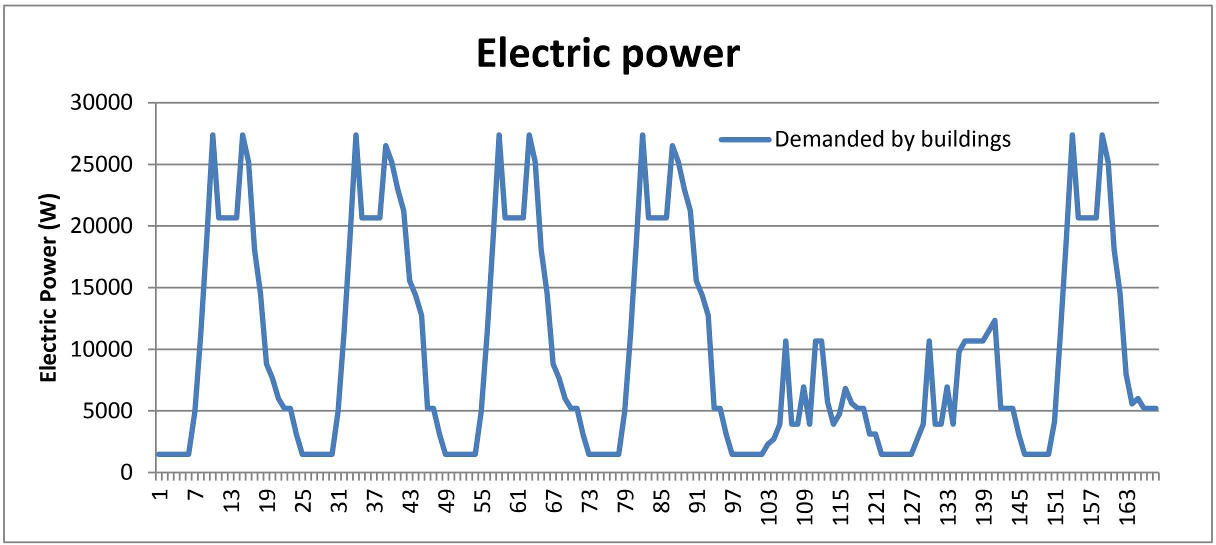

Figure 25: Electric power for a standard week

The amount of thermal energy needed for all the buildings is plotted in the following graph.

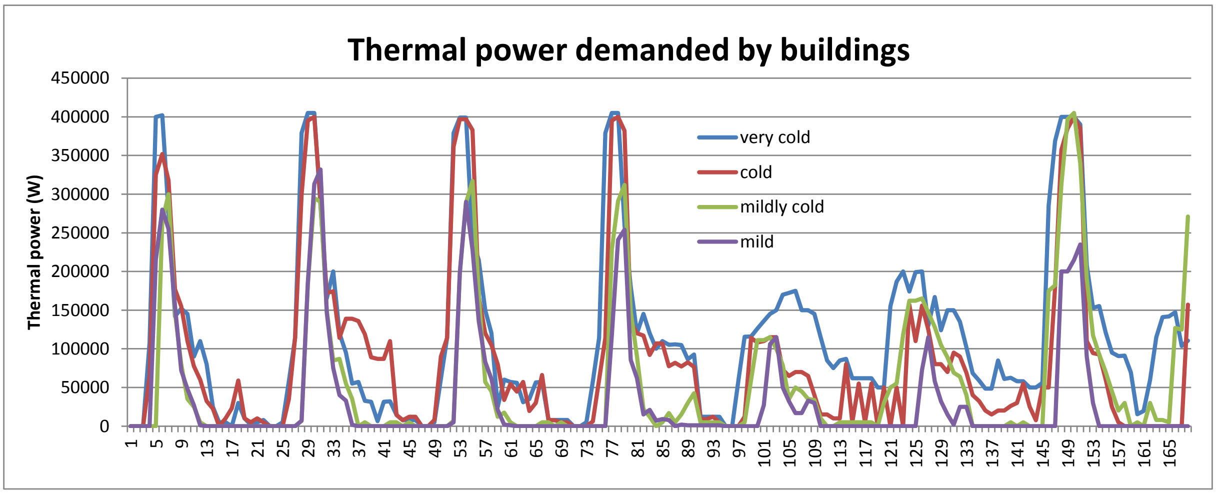

Figure 26: Thermal power demanded by buildings for the different standard weeks

By providing this total thermal power, which is independently produced in each building by independent boilers, the indoor temperature of each building fulfills the set-point requirements. Indoor temperature of the public school and culture house are the most interesting to plot because the set-point flexibility will be used later on those buildings. The following graphs show the indoor temperatures and temperature limits for those buildings.

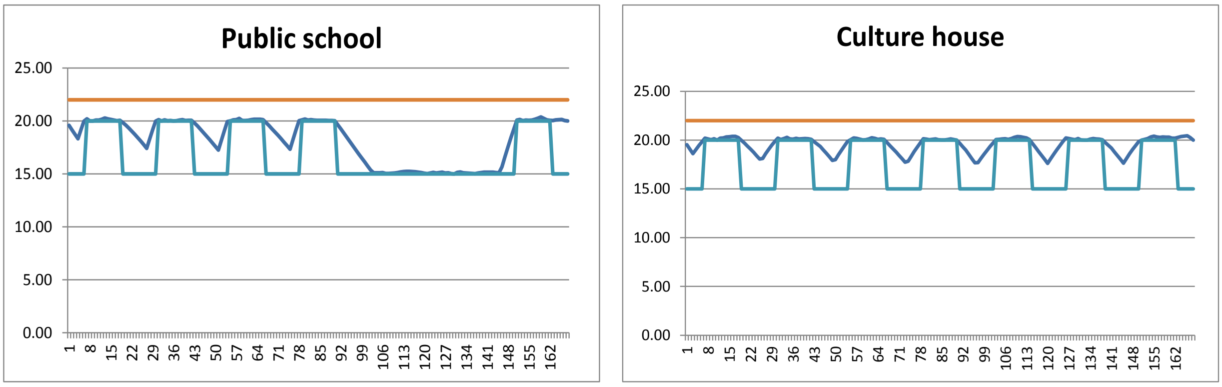

Figure 27. Indoor temperature and set-points for the simulated week (very cold weather – baseline)

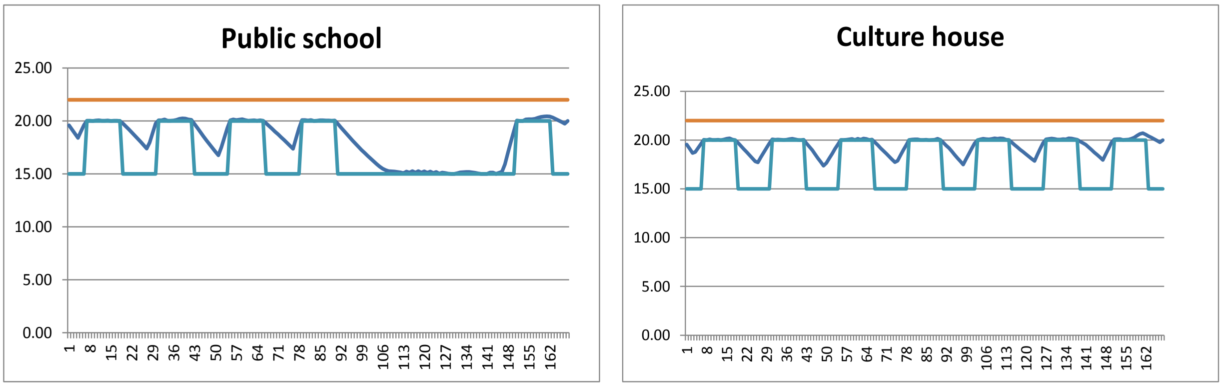

Figure 28: Indoor temperature and set-points for the simulated week (cold weather – baseline)

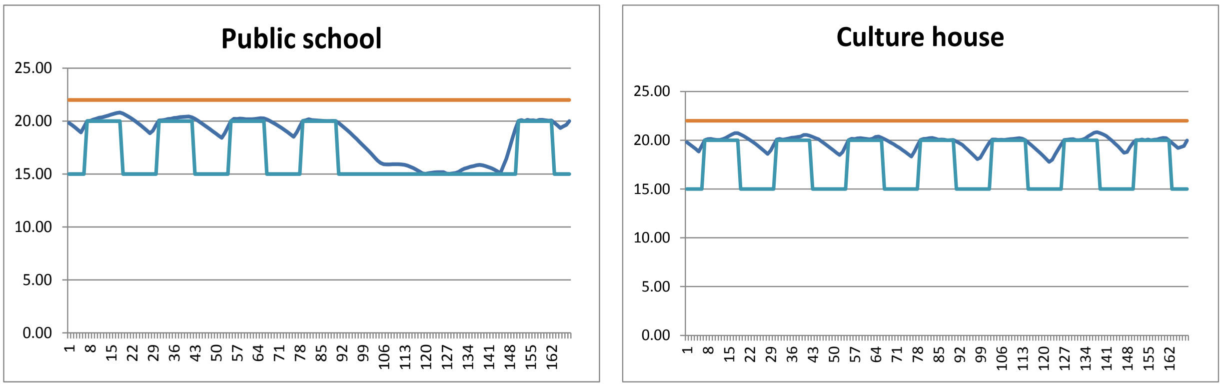

Figure 29: Indoor temperature and set-points for the simulated week (mildly cold weather – baseline)

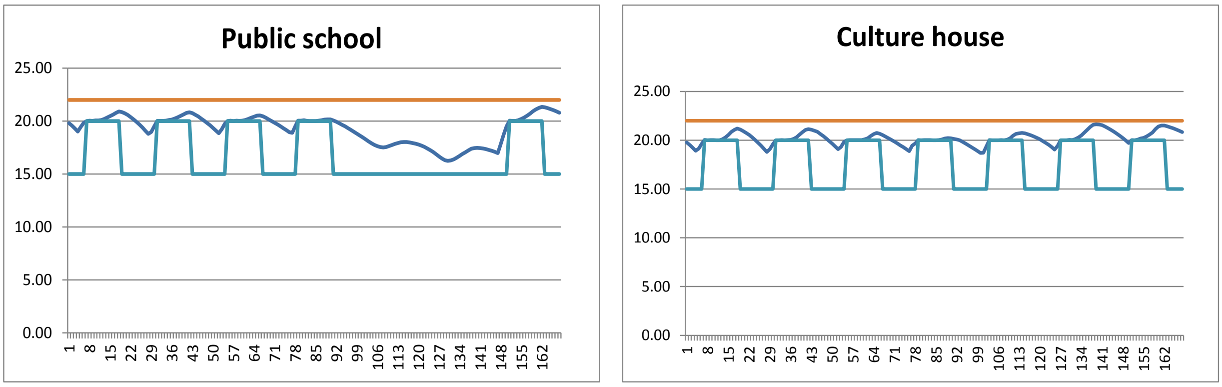

Figure 30: Indoor temperature and set-points for the simulated week (mild weather – baseline)

The five periods previously presented (no heating, mild, mildly cold, cold and very cold) have been used to extrapolate the energy needs of the district. A standard boiler efficiency of 85% has been considered for all the boilers to convert the thermal needs into gas consumption. The energy consumption is shown in the next graph.

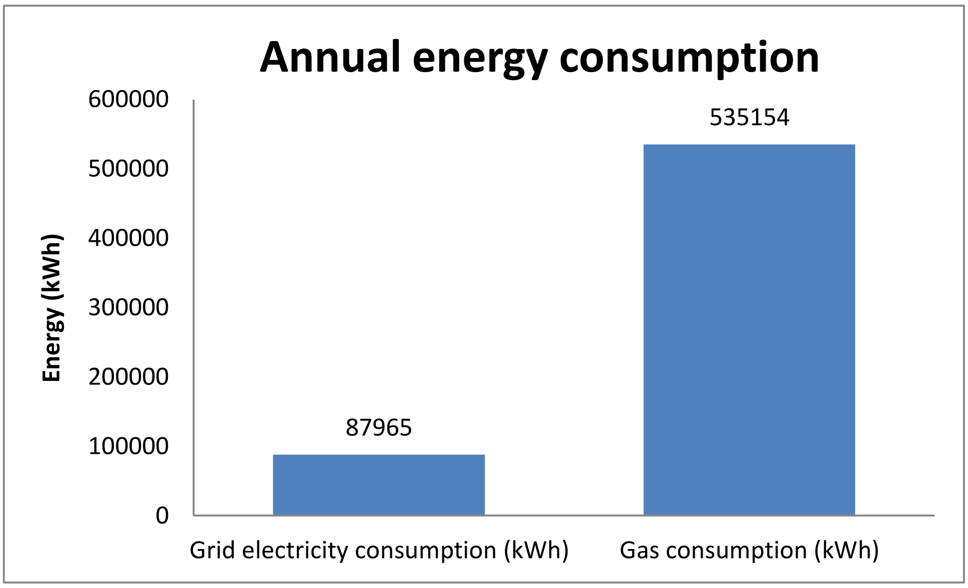

Figure 31: Annual energy consumption (baseline)

3.3.3 Scenario 1: CHP and control through the EEPOS system

In this section, it is considered that the CHP units are directly connected to the bigger buildings: school and culture house (one unit per building). Therefore, in this configuration CHP heat cannot be transferred to other buildings but there is a private electrical grid connecting “prosumers” between them and with the main grid.

The following graph shows the aggregated electric power demanded by the buildings and the electric power that is drawn from the grid, taking into consideration the CHP energy that is produced within the district according to the EEPOS control strategy.

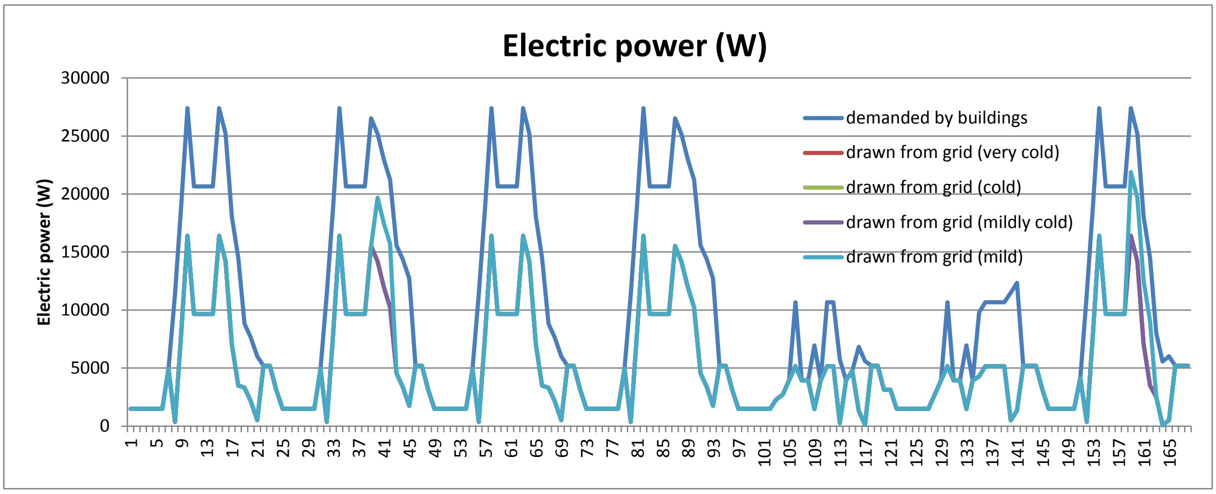

Figure 32: Electric power for a week

It can be also observed in Figure 32 that the CHP units can shave the electric peak demands when the weather conditions are “very cold”, “cold” and “mildly cold”. This is because the CHP heat can be used in the target buildings without exceeding the set-point limits. However, for the mild weather conditions, the CHP unit serving the culture house was not turned on in some particular days because no more heat can be stored. This can be appreciated in Figure 36 (red circles).

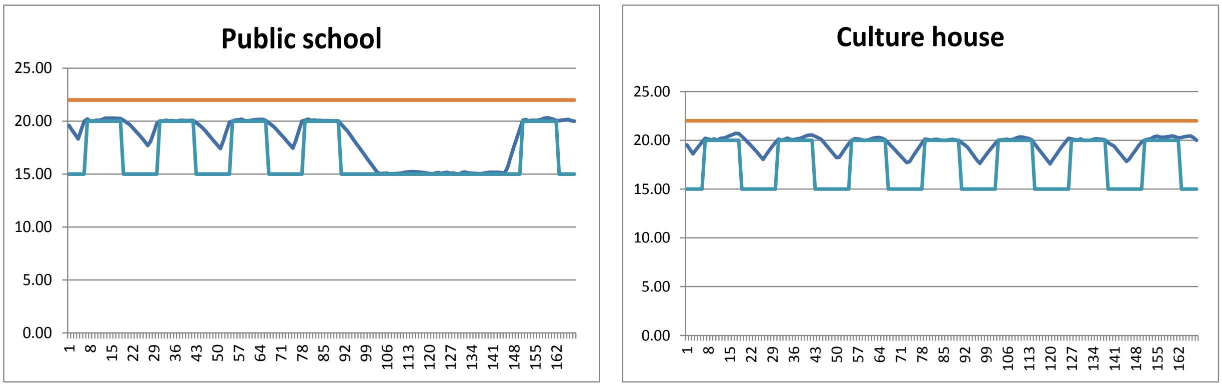

Figure 33:Indoor temperature and set-points for the simulated week (very cold weather – CHP + EEPOS)

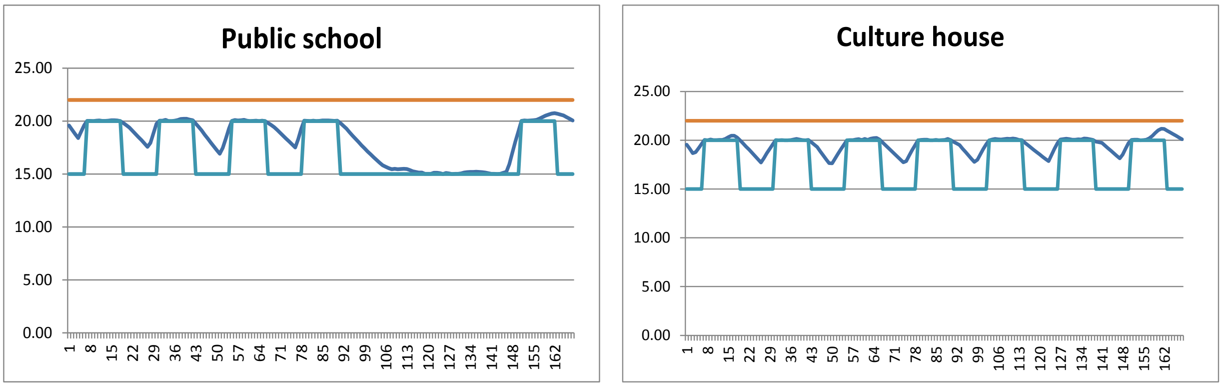

Figure 34: Indoor temperature and set-points for the simulated week (cold weather – CHP+EEPOS)

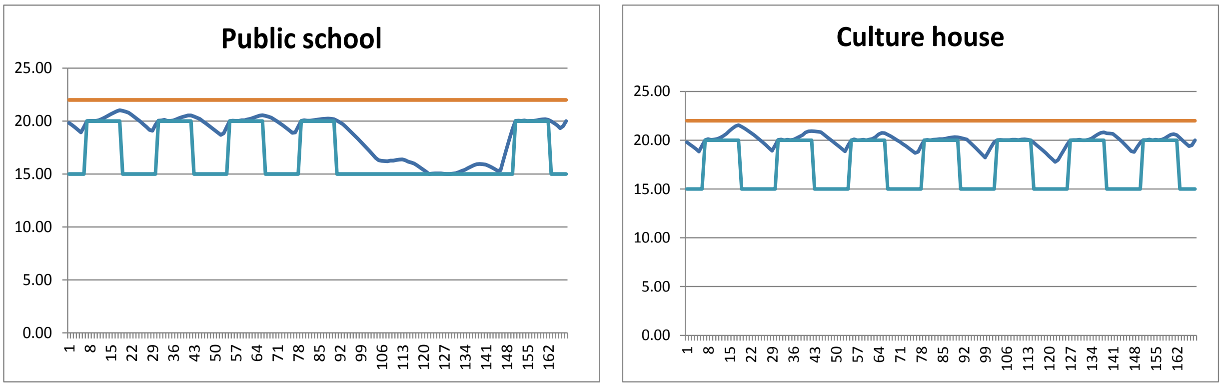

Figure 35. Indoor temperature and set-points for the simulated week (mildly cold weather – CHP+EEPOS)

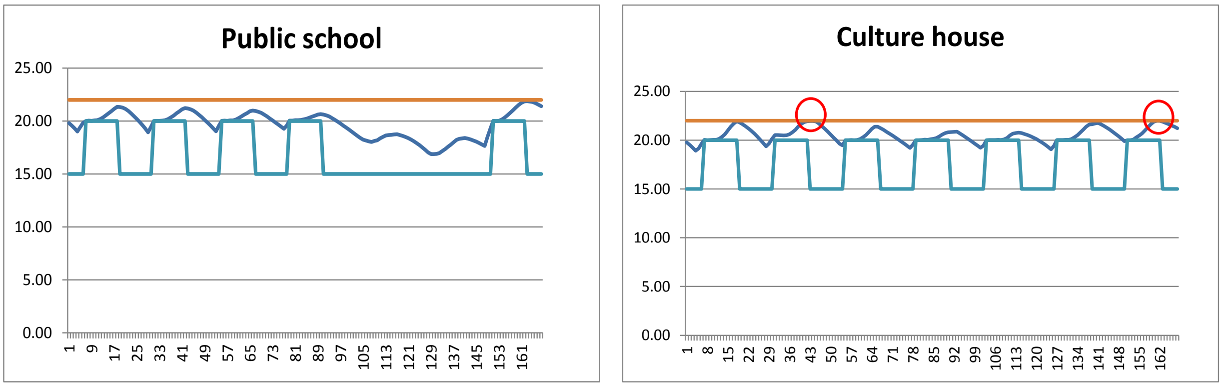

Figure 36. Indoor temperature and set-points for the simulated week (mild weather – CHP+EEPOS)

The five periods previously presented (no heating, mild, mildly cold, cold and very cold) have been used again to extrapolate the energy needs of the district. It has been considered that the CHP units consume 20.5 kW of natural gas, supplying 5.5 kW of electricity and 12.5 kW of thermal energy. A standard boiler efficiency of 85% has been considered for all the boilers. The annual energy consumption is shown in the next graph.

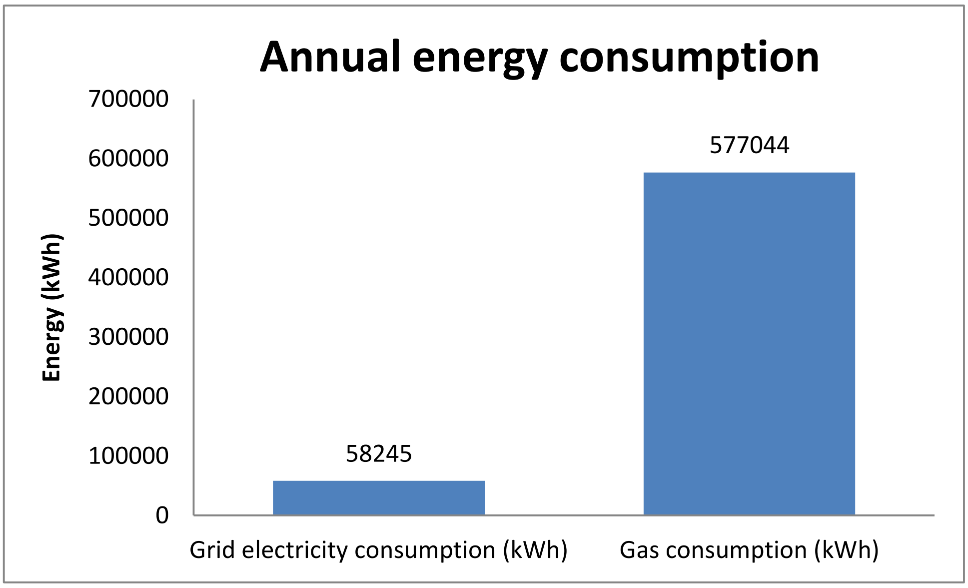

Figure 37: Annual energy consumption (CHP+EEPOS)

3.3.4 Scenario 2: CHP, control through the EEPOS system and introduction of PV

This scenario is similar to the previous one with the addition of PV panels. What the EEPOS system is going to control in this case is the CHP operation (first CHP unit is at the school and the second CHP unit at the culture house), the boiler operation, and the thermal energy supplied to each building, taking into account the PV production forecast. The PV generation forecast application has been developed and explained in D2.3 “Supervisory and Predictive Control Methods and Applications: Technical documentation & Implementation", so the EEPOS system will have a PV production forecast in order to properly make energy management decisions. This control is simulated here.

A PV installation of 5 kWp installation, South oriented with a tilt angle of 45º has been considered in the simulation. This system has been dimensioned in order to use the PV energy within the district. Therefore the daily production forecast has been compared to the typical electrical demand in order to not have a PV energy surplus, although this can happen occasionally.

The following graph shows the aggregated electric power demanded by the buildings and the electric power that is drawn from the grid, taking into consideration the PV production and the CHP energy that is produced within the district according to the EEPOS control strategy.

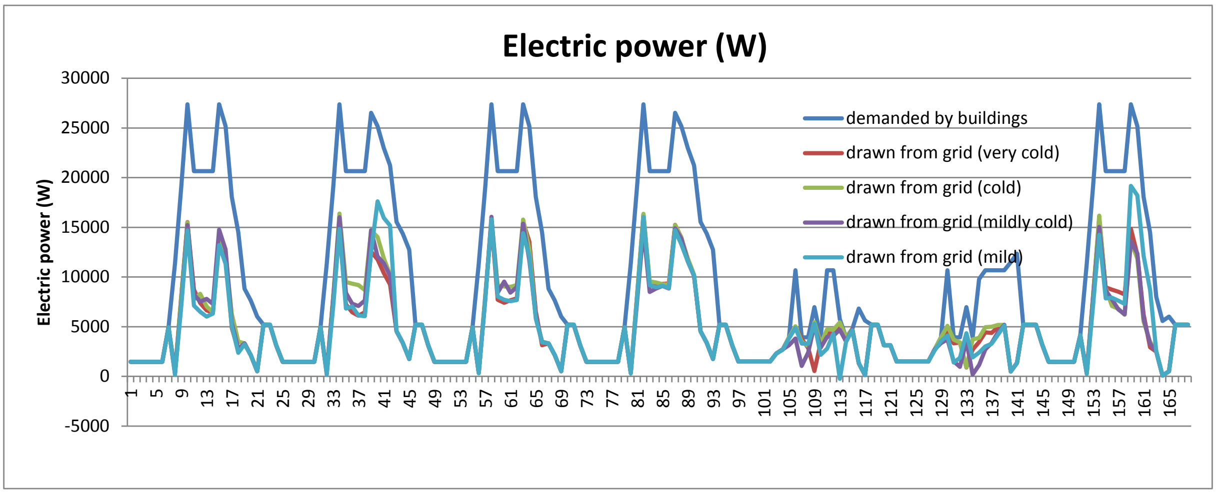

Figure 38: Electric power for a week

As happened in the previous case, the CHP units can shave the electric peak demands when the weather conditions are “very cold”, “cold” and “mildly cold”. This is because the CHP heat can be used in the target buildings without exceeding the set-point limits. However, for the mild weather conditions, the CHP unit serving the culture house should not be turned on in some particular days because no more heat was necessary.

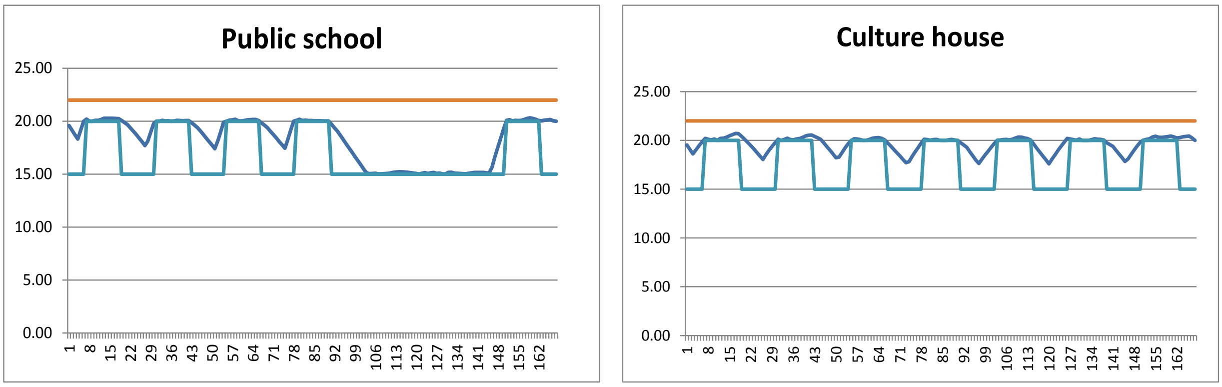

Figure 39. Indoor temperature and set-points for the simulated week (very cold weather – CHP + PV+EEPOS)

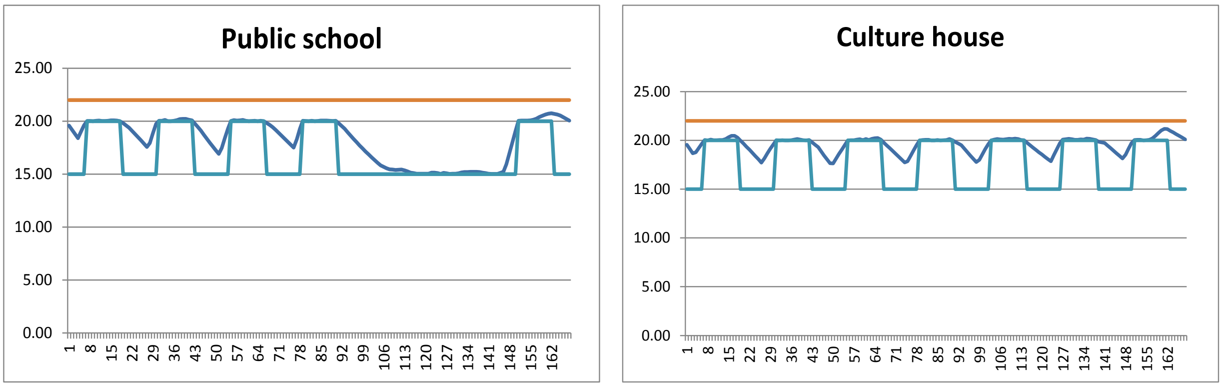

Figure 40: Indoor temperature and set-points for the simulated week (cold weather – CHP+PV+EEPOS)

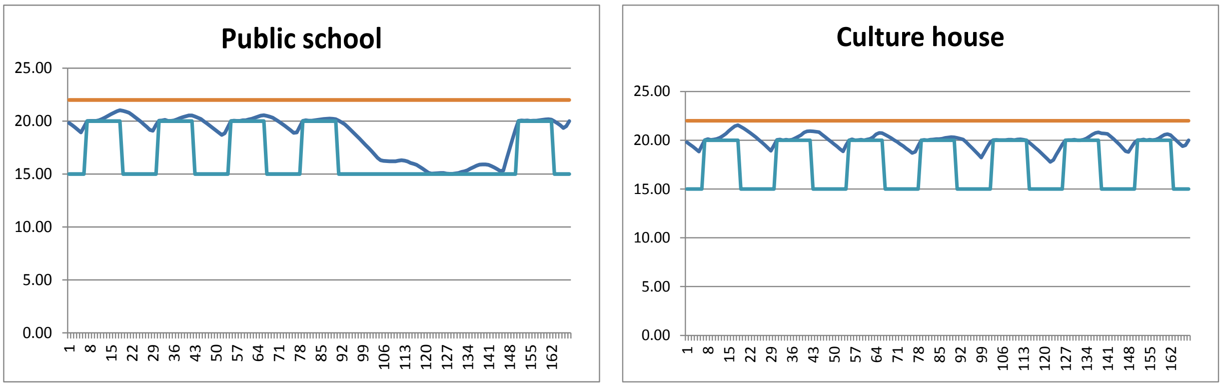

Figure 41: Indoor temperature and set-points for the simulated week (mildly cold weather – CHP+PV+EEPOS)

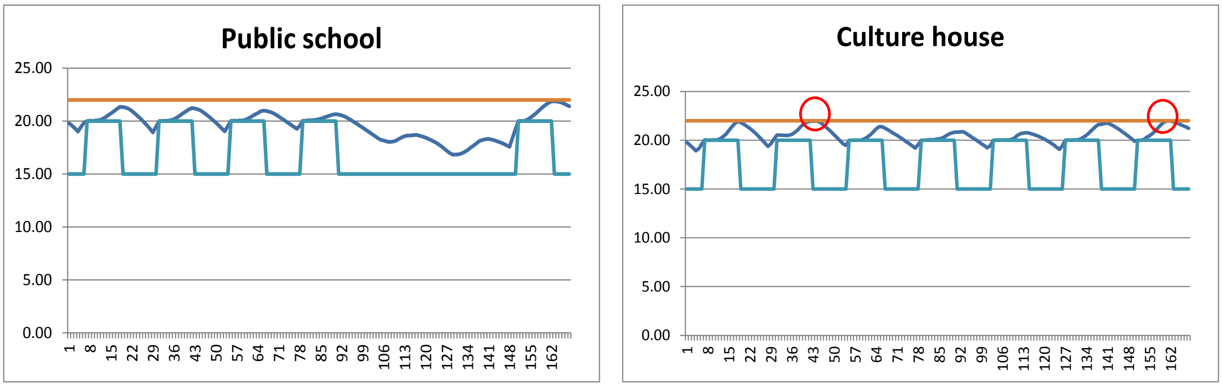

Figure 42: Indoor temperature and set-points for the simulated week (mild weather – CHP+PV+EEPOS)

The five periods previously presented (no heating, mild, mildly cold, cold and very cold) have been used again to extrapolate the energy needs of the district. It has been considered that the CHP units consume 20.5 kW of natural gas, supplying 5.5 kW of electricity and 12.5 kW of thermal energy. A standard boiler efficiency of 85% has been considered for all the boilers. The annual energy consumption is shown in the next graph.

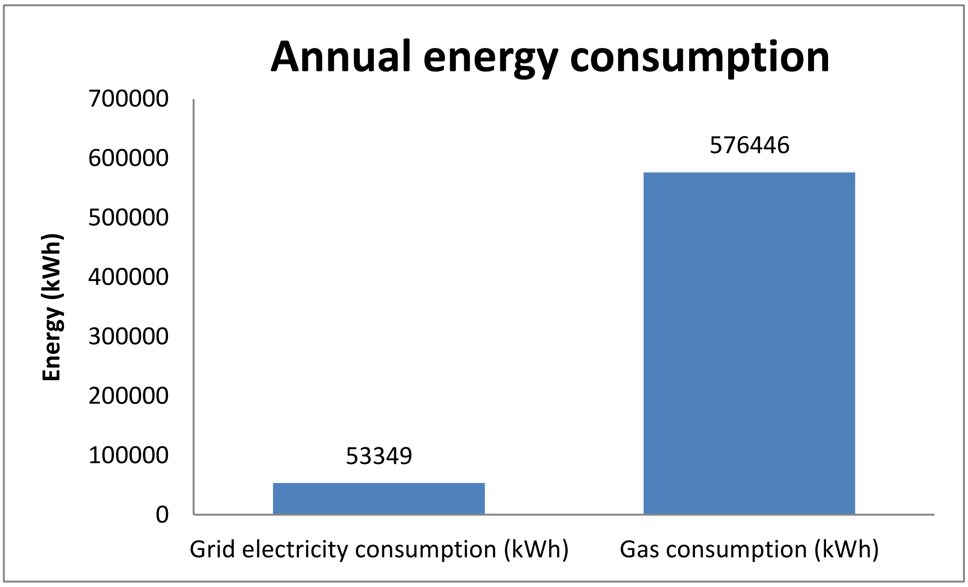

Figure 43: Annual energy consumption (CHP+PV+EEPOS)

3.3.5 Results

The following table shows the annual energy consumption for the three scenarios.

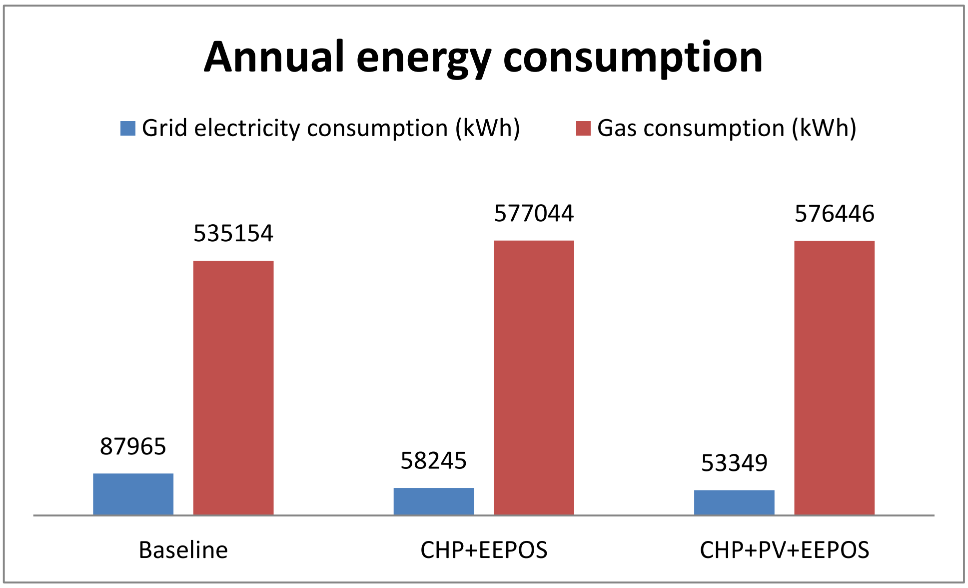

Figure 44: Annual energy consumption

As it is difficult to compare energy efficiency when using more than one energy source, the CO_2 emissions will be used to compare the three scenarios.

In Spain, the official factor in order to convert grid electricity into CO_2 emissions is over 600 $gCO_2/kWhe$. However there is a solid proposal document [1] to change this value in order to reflect the current amount of renewable energy that the national grid delivers nowadays.

According to this document, the CO_2 factors to use are the following:

	Emissions factor (kg CO_2 / kWh)
Spanish National grid electricity	0.399
Natural gas	0.252

Table 2. Emissions factors

When using these factors to convert energy into emissions, the following annual emissions are obtained for the Araia district.

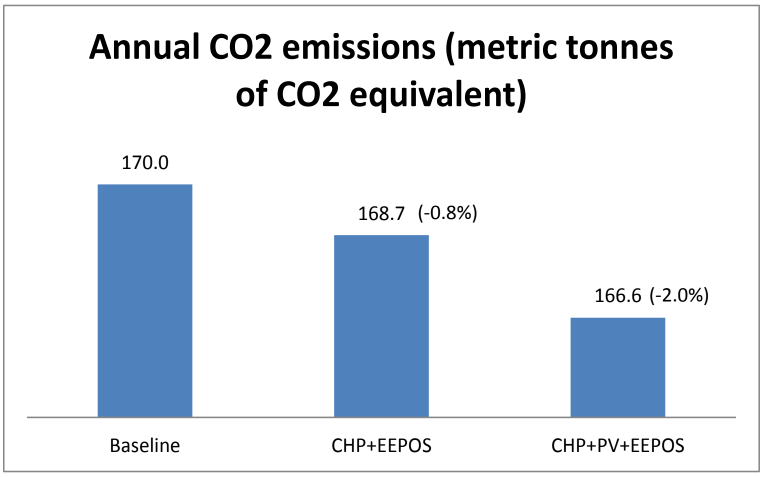

Figure 45: Annual CO_2 emissions

In order to calculate the cost of the energy that is consumed in each scenario, the amount of grid electricity consumed at each time has been multiplied for the specific electricity price per hour of each week type. A grid access fee of 44.027 €/MWh has also been considered.

A realistic average cost of 0.06 €/kWh for natural gas (obtained from Araia's utility bills) has been also considered. Vat is not included in any case.

When using these energy costs, the following annual energy costs are obtained for the Araia district.

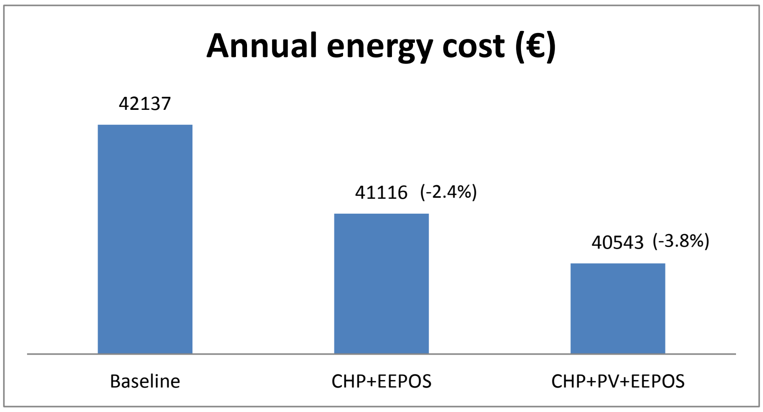

Figure 46: Annual energy cost

The following table contains realistic cost estimations to develop the CHP system that has been explained in this section.

Alternative system		**Cost (€)**
HVAC equipment and CHP	CHP#1	20000
	CHP#2	20000
	Thermal Storage tank	3200
	Hydraulic installation	2500
	Electric and control installation	2000
Engineering		3000
Total		**50700**

Table 3. District heating capital cost – alternative system

In order to buy and install a 5 kWp PV plant, the estimated capital cost is the following:

PV system (5kWp)	**Cost (€)**
Total	**11700**

Table 4. PV plant capital cost

Taking into account this info, the payback periods are calculated (see next table).

	Annual savings (€)	Capital cost (€)	Payback period (years)
Baseline	-	-	-
CHP+EEPOS	1021	50700	49.7
CHP+PV+EEPOS	1594	62400	39.1

Table 5: Payback period

Regarding peak shaving, the following data has been obtained (see next table).

	Peak electricity consumed (kW)				
	very cold weather	cold weather	mildly cold weather	mild weather	Summer
Baseline	27.4	27.4	27.4	27.4	27.4
CHP+EEPOS	16.4 (-40.1%)	16.4 (-40.1%)	16.4 (-40.1%)	19.9 (-27.4%)	27.4 (0%)
CHP+PV+EEPOS	16.4 (-40.1%)	16.4 (-40.1%)	16.4 (-40.1%)	19.9 (-27.4%)	27.4 (0%)

Table 6: Peak electricity consumed

3.3.6 Conclusions from the virtual demo site

A neighbourhood energy management and decision support systems like EEPOS can be very useful to shave the peaks of a neighbourhood like this, when combined with CHP units. The EEPOS system also allows generating a big part of the electric energy needed by the district, when it is really needed, diminishing the amount of electric energy drawn from the main grid.

After applying the EEPOS philosophy to the existing buildings of Araia, by using a virtual prototype, it can be said that the main EEPOS targets are fulfilled:

- Maximum utilisation of local DER in the neighbourhood: the distributed energy resources were dimensioned accordingly to the district needs. District electric consumption was the limiting factor for sizing the CHP. Regarding the PV panels, the peak power was chosen to avoid PV electricity surplus at any time of the year. However this could happen occasionally when some buildings do not consume electricity as usual (e.g. buildings are not occupied).

- Electricity market support (balancing market): in this virtual prototype scenario, the district demands more electric energy during the daytime. For the particular weeks that have been analysed, the grid electricity price is over the CHP profitability threshold when the CHP is on. Therefore the CHP is producing electric energy when it is more expensive, helping to balance the market.

- Distribution grid support (congestion management and peak load shaving): as a result of the EEPOS control, the electric peak load has been reduced by 40% (from 27kW to 16kW) during the very cold, cold and mildly cold seasons, when the CHP heat can be used. As the EEPOS system tries to maximize the local DER in the neighbourhood, the energy surplus that is sent to the grid is minimum, to avoid any grid congestion. The grid electric consumption can be reduced more than 30% in a yearly basis. Reducing consumption supports the main distribution grid.

Regarding CO_2 emissions, the Spanish grid electricity has a low CO_2 impact when compared to other countries. This is the reason why the amount of CO_2 that is shaved when using local CHP units + EEPOS is not very significant. However, it has to be said that shaving peaks

locally helps the national grid to not use inefficient fossil fuel generators, usually connected at peak time. This will mean a lower CO_2 conversion factor for the grid electricity.
The layout analysed provides some economic savings in terms of annual energy cost.
However, the equipment cost is too high to recoup the funds expended in the investment, in a reasonable period of time. This can change with a suitable legislation that fosters this kind of solutions (peak shaving).

4. CONCLUSIONS

It has been shown in all three demo sites that central energy management systems can have a major impact on the distribution of the energy consumption in time. The actual energy savings such management systems enable are therefore actually not their main purpose. Reducing CO_2 emissions on the other hand is well within the capabilities of neighbourhood energy management.

This is mainly done by demand response, therefore shaping the energy consumption in such a way that it follows RES as close as possible, up to a point that an increase in RES is possible within a neighbourhood, e.g. through enhanced capability of integration intermittent sources like PV into a local grid without the distribution grid on the level above the neighbourhood actually noticing.

This approach of self-consumption optimization, trying to consume the energy from all RES sources on the same level as the entity producing them is in many cases already a feasible business model. This is because the feed-in tariffs are usually lower than the tariffs for energy supplied from the grid.

5. REFERENCES

[1] EN ISO 13790:2008 (2008): Energy performance of buildings - Calculation of energy use for space heating and cooling, ISO/TC 163 and CEN/TC 89, March 2008.

[2] EN 15241:2007 (2007): Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in commercial buildings, CEN/TC 156, May 2007.

[3] EN 15316-4-6; 2007. Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Part 4-6: Heat generation systems, photovoltaic systems. 18 p.

[4] http://www.ym.fi/download/noname/%7BF4F73E83-56AF-4112-AD7B-0E1F1804D38B%7D/30750

[5] Propuesta de documento reconocido: factores de emisión de co2 y coeficientes de paso a energía primaria de diferentes fuentes de energía final consumidas en el sector edificios en España (versión 03/03/2014). IDAE. Ministerio de industria, energía y turismo.

6. Acronyms and Terms

AR	adaption request
CHP	combined heat and power
COP	coefficient of performance
DER	distributed energy resources
GHG	greenhouse gasses
HVAC	heating, ventilation and air conditioning
ICT	information and communication technology
OGEMA	open gateway energy management
PV	photovoltaics
RES	renewable energy source
REST	representational state transfer

APPENDIX 1 AVAILABLE DATA

6.1 Available Data at German / Austrian Demonstrator

Data	Unit	Resolution (minutes)	Availability
Heat output CHP	kWh	1	not yet installed
Power output CHP	kWh	1	not yet installed
Gas consumption CHP	kWh	1	not yet installed
Gas consumption heating 2	kWh	1	not yet installed
Oil consumption heating 1	kWh	1	not yet installed
Heat output whole facility	kWh	1	not yet installed
Heat output biomass heating unit	kWh	1	not yet installed
CO2 emissions (calculated)	g/kWh	1	not yet installed
Flow temperatures of all units	°C	15	not yet installed
Return temperatures of all units	°C	15	not yet installed
outside temperature	°C	15	not yet installed

Table 7. The available historic at German demonstrator in the local district heating facility

Data	Unit	Resolution (minutes)	Availability
Electricity consumption	kWh	1	Not yet installed
Thermal energy consumption	kWh	15	available
Electric power	kW	1	Not yet installed
Thermal energy power	kW	15	available
Forecast of electricity demand	kWh	60 (at least 24h)	Not yet installed
Forecast of thermal energydemand	kWh	60 (at least 24h)	Not yet installed
CO2 emissions	g	60	Not yet installed
Load shifting done	kWh	1	Not yet installed
Flow temperatures of all units	°C	15	available
Return temperatures of all units	°C	15	available
outside temperature	°C	15	available
Regulation parameters of the central heat exchanger	-	15	available for 1 building, others

			will follow

Table 8: The available historic data at German demonstrator on building level

6.2 **Availiable Data at Finnish Demonstrator**

The available data at Finnish demonstrator in apartment level are shown in

Data	Unit	Resolution (minutes)	Availability
Electricity consumption	kWh	-	Not available (privacy)
Thermal energy consumption	kWh	-	Not available (privacy)
Cost of the use of electricity	€	-	Not available (privacy)
Cost of the use of thermal energy	€	-	Not available (privacy)
Electric power	kW	-	Not available (privacy)
Thermal energy power	kW	-	Not available (privacy)
CO2 emissions	g	-	Not available (privacy)
Load shifting done	kWh	-	Not available
Cost savings of load shifting	€	-	Not available
Indoor air temperature	°C	10	Available to use
Indoor air CO2 levels	ppm	-	Not available (privacy)
Indoor air relative humidity	%	-	Not available (privacy)

Table 9. The available data at Finnish demonstrator in apartment level

The available data at Finnish demonstrator in building level are shown in Table 2.

Data	Unit	Resolution (minutes)	Availability
Electricity consumption	kWh	60/1440	Available to use
Space heating energy	kWh	60	Available to use
Domestic hot water heating energy	kWh	60	Available to use
Space cooling energy	kWh	60	Available to use
Electric power	kW	60/1440	Estimated
Space heating power	kW	60	Estimated
Domestic hot water heating power	kW	60	Estimated
Space cooling power	kW	60	Estimated
Forecast of electricity demand	kWh	-	Not available
Forecast of space heating demand	kWh	60 (for next 48h)	Estimated
CO2 emissions	kg	60	Estimated

Load shifting done	kWh	-	Not available
Cost savings of load shifting	€	-	Not available
Free cooling energy	kWh	60	Estimated
48 hour forecast of heating energy consumption	kWh	60	Estimated
Space heating related energy fault detection	Boolean	60	Estimated

Table 10. The available data at Finnish demonstrator in building level

The available data at Finnish demonstrator in neighbourhood level are shown in Table 3.

Data	Unit	Resolution (minutes)	Availability
Electricity consumption	kWh	60	Estimated
Space heating energy	kWh	60	Estimated
Domestic hot water energy	kWh	60	Estimated
Space cooling energy	kWh	60	Estimated
Electric power	kW	60	Estimated
Space heating power	kW	60	Estimated
Domestic hot water power	kW	60	Estimated
Space cooling power	kW	60	Estimated
Electricity price (neighbourhood)	€/kWh	-	Not available
Thermal energy price	€/kWh	-	Not available
Electricity price forecast (neighbourhood)	€/kWh	-	Not available
Thermal energy price forecast	€/kWh	-	Not available
Forecast of electricity demand	kWh	-	Not available
Forecast of space heating energy demand	kWh	60 (for next 48h)	Estimated
Sold electrical energy	kWh	-	Not available
Purchased electrical energy	kWh	60	Estimated
Sold thermal energy	kWh	-	Not available
Purchased thermal energy	kWh	60	Estimated
Seawater based energy production	kWh	60	Estimated
Total CO2 emissions	kg	60	Estimated
Total load shifting done	kWh	-	Not available
Cost savings of load shifting	€	-	Not available
Weather data	different	30	Available to use
Weather forecast	different	60 (for next 48h)	Available to use (FMI's open data as a data source)
Nord Pool electricity price	€/kWh	60	Available by Nord Pool
Nord Pool electricity price forecast	€/kWh	60	Available by Nord Pool

Table 11.The available data at Finnish demonstrator in neighbourhood level

6.3 Availiable Data at Araia for the virtual demonstrator

Data	**Approx. Average**	**Unit**	**Resolutions**	**Availiability**
Electrical Consumption	10.318,00	kWh	1 month	Already installed counters
Gas Consumption	10.043,00	kWh	1 month	Already installed counters
CO_2 emissions associated at electricity	16,35	$kgCO_2/m^2$	1 year	Available conversion factors of energy and CO_2
CO_2 emissions associated at electricity	9,42	$kgCO_2/m^2$	1 year	Available conversion factors of energy and CO_2
Cost of the contracted electricity*	1,8064 (I tariff) 1,1139 (II tariff) 0,2554 (III tariff)	€/kWh	1 month	
Cost of the consumed electricity	0,2041 (I tariff) 0,1590 (II tariff) 0,0877 (III tariff)	€/kWh	1 month	
Cost of the gas natural	0,05156	€/kWh	1 month	

Table 12: Availiable Data at Araia for the virtual demonstrator

APPENDIX 2: NATIONAL STANDARDS RELEVANT TO THE DEMONSTRATION

6.4 German National Standards

In Germany the Institute for Living and Environment (Institut für Wohnen und Umwelt – IWU) provides on its website www.iwu.de an frequently updated list with primary energy and CO2 emission factors for different types of energy as well as local- and district heating systems based on the Global Emissions-Model of Integrated Systems GEMIS. The following table shows the CO2-equivalents selected for this project:

Type of energy	CO2-equivalent [g/kWhEnd]
Heating oil EL	302
Natural gas H	244
Wood chips	35
Electric energy mix	633

Table 13: CO2 equivalents as valid for the german demo site

6.5 Spanish National Standards

The energy efficiency of a building in **Spain** is determined by calculating or measuring the consumption of power to satisfy the annual energy demand of the building under normal operating conditions, and occupation. The energy efficiency of a building usually expressed qualitatively or quantitatively different ways: by indicators, indices, or letters of a scale rating ranging from high to low efficiency, determined conventionally. Below are sets out the methodology to perform an energy rating expressible in the form of letters and indicators give relevant information to end users of the buildings form expressible synthetic energy label[1].

Energy indicators

The energy rating is expressed through various indicators to explain the reasons for good or bad behaviour and provide building energy useful information about the aspects, taking into account when proposing recommendations to improve such behaviour.

These indicators are based on an annual basis and referred to the **unit floor area** of the building, obtained from the energy consumed by the building to satisfy, in certain climate conditions, the needs associated with normal conditions operation and occupation, including, among other things, the energy consumed in heating, cooling, ventilation, hot water production and illumination, in order to maintain comfort conditions and temperature and light quality indoor air.

The main or global energy indicator will correspond to the annual emissions of CO_2, expressed in **kg** per **m^2** of floor area of the building. Complementary indicators will be prioritized as follows:

- Annual non-renewable primary energy, in kWh per m^2 of building surface.
- Annual total primary energy, in kWh per m^2 of floor area of the building.

[1] Real Decreto 235/2013; BOE 89 (13/04/2013); http://www.boe.es/boe/dias/2013/04/13/pdfs/BOE-A-2013-3904.pdf

- Percentage of annual primary energy from renewable energy sources regarding the annual total primary energy.
- Annual primary energy from renewable sources, in kWh per m^2 of surface of the building.
- Annual total primary energy disaggregated by use of heating, cooling, hot water production and lighting in kWh per m^2 of floor area of building.
- Annual heating energy demand in kWh per m^2 of floor area of the building.
- Annual cooling energy demand in kWh per m^2 of floor area of the building.
- Annual CO_2 emissions expressed in kg per m^2 of floor area of the building, disaggregated by use of heating, cooling, hot water production health and enlightenment.

Normal operating conditions and building occupancy

The calculation of the energy efficiency rating will be considering under normal operating conditions of the building, based on the requests internal and external stresses operating conditions, and normal conditions occupation of the building, which are included in the recognized document "Conditions of acceptance of alternative procedures," according to the different uses of buildings.

Calculation of energy consumption and demand

The calculation methodology shall provide the calculation of the final energy consumption up to time, by calculating the hourly demand and calculating the average performance schedule systems which meet the needs described above.

The calculation must meet the minimum level of modeling required in Basic Document DB HE "*Ahorro de energía*" (“Energy Saving”) from the Technical Building Code book, approved by *Real Decreto* (Spanish Royal Decree Law) 314/2006, of March 17.

Scope and characteristics of computing systems

Calculation systems should be considered, either detailed or simplified, the following aspects:

- Design, location and orientation of the building.
- Environmental conditions indoor and outdoor climate.
- Thermal characteristics of the enclosures, taking into account the heat capacity, the isolation, the passive heating, cooling elements, and thermal bridges, etc.
- Passive solar systems and solar protection.
- Thermal installations of individual and collective buildings (heating, cooling and hot water) and heating and cooling; including the insulation of pipes and conduits.
- Natural and mechanical ventilation.
- Installation of artificial indoor lighting.
- Natural lighting.
- Active solar systems and other heating and electricity systems based on renewable energy sources.
- Electricity produced by cogeneration.

The software must include sufficient technical documentation for your correct use, which should at least include the following:

- Scope of the program, including what types of buildings, systems and equipment are included as well as its geographical scope.
- Restrictions on the use of the software as constructive solutions or systems that cannot be entered into the computer program.
- Assumptions and default values to take for those variables that were not requested directly to the user.
- Climate data used by default.
- Procedure, as appropriate, to generate the reference building.
- Administrative documentation.

Alternative software validation

In order that the various computer programs may be accepted as valid alternative programs in the recognized document "Terms of Alternative software acceptance", it is establishes the requirements and specifications that they must satisfy.

6.6 **Finnish National Legislation**

The Energy Performance of Building Directive and energy efficiency of buildings in **Finland** is implemented in the national building code. EPBD recast (DIRECTIVE 2010/31/EU) has catalyzed the latest renewal in the national Building Code taken place in year 2012, and the next update is estimated to be made in year 2015.

Probably the most essential new feature in the Finnish Building Code, related to energy efficiency of buildings, is a compulsory Energy Clarification for each new building and construction project. This Energy Clarification includes the following aspects

- Heat loss calculations (showing fulfilment of insulation level requirements)
- Dimensioning heating power
- Estimation of summer time room temperatures and cooling power if necessary
- Energy consumption and purchased energy
- Energy Certificate
- Specific Fan Power of mechanical ventilation system [kW / (m^3/s)]

Among other things, the Energy Certificate classifies buildings in different energy efficiency categories (from A to G) according to value of an *E* number [kWh/m^2]. Firstly, when defining this *E* number, the renewed Finnish Building Code gives guidelines for estimating total energy consumption (including heating and cooling, ventilation, lighting, electric appliances, and domestic hot water). After total (purchased) energy consumption has been estimated, it will be multiplied by a conversion factor giving the final *E* number can be calculated total (purchased) energy consumption.

Adopted values for different conversion factors (indicating environmental impact of alternative energy source) are

- electricity – 1.7
- fossil fuels – 1.0
- district heat – 0.7
- renewable energy sources – 0.5

In the near future, possibly in year 2015, the requirement mentioned above will probably become compulsory also for such existing buildings which will be renovated in larger extend. In addition, there also might become some requirements regarding to proportion of renewable energy sources reducing emissions and other impacts to environment.