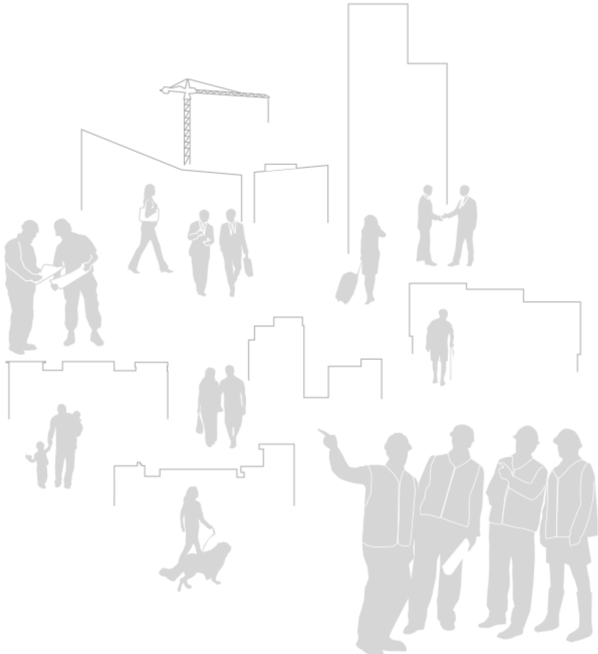
BUILDSMART

Energy efficient solutions ready for market



D5.5. Final report on monitoring results and evaluation of installed systems after one year in operation.

31 January 2017

Authors:

Carolina Faraguna, Rasmus Andersson - IVL Swedish Environmental Research Institute

Olga Macías, Victor Sanchez Zabala, – Tecnalia

Dissemination level	
	PU = **Public**
X	PP = **Restricted to other programme participants (including the JU)**
	RE = **Restricted to a group specified by the consortium (including the JU)**
	CO = **Confidential, only for members of the consortium (including the JU)**

Document history			
V	Date	Author	Description
1.0	2017-01-31	CF, RA, OM, VSZ	First version
2.0	2017-04-24	CF, RA	Reviewed version
3.0			

Disclaimer

Summary

Build Smart - Energy Efficient Solutions ready for the market"(BuildSmart) is a collaborative, demonstration project funded by the European Commission. The objective of BuildSmart is to demonstrate and mainstream cost effective techniques and methods for constructing buildings with very low energy demand. This is in accordance with the accepted EU directive regarding energy performance of buildings (EPBD II).BuildSmart includes low energy residential and commercial buildings constructed in Sweden and Spain.

The demonstration projects will be analysed according to developed methodology in BuildSmart. To fully evaluate the energy performance of a building it is important to look at both the hard facts (quantitative data) and the soft facts (qualitative data). Hard facts represent measured energy performance, i.e. measured data and the analysis of data. The BuildSmart project defines a common structure for measurement, monitoring and analysis of the energy performance of buildings. Measurements are reported for at least one year, starting from the day when the building is in operation. Furthermore, monitored energy data is transformed into energy performance indicators which are used to compare different buildings with each other. The measured energy is documented with two different indicators, i.e. final energy and primary energy. Finally, the climate impact related to the energy consumption is evaluated.

Soft facts represent qualitative information from, for example, experiences of involved teams/persons in the building process and end user behaviour. The information gathering from the building process is done by conducting interviews with key persons. The data from end users is collected by distributing questionnaires. The questionnaires cover users/residents opinion regarding the indoor environment, i.e. air quality, thermal environment, noise and light.

.

Contents

1 Background

The building sector is responsible for significant energy consumption. Construction and use of buildings within EU account for more than 40% of the total energy use [1][2]. Hence, the potential for energy efficiency measures is big.

EU has passed a directive to improve the energy performance of European buildings, the “Energy Performance of Buildings Directive” or “EPBD II” for short. Amongst other things, the directive requires that all new buildings that are used and owned by public institutions must be nearly zero-energy buildings from 2019. The nearly-zero standard applies to all other buildings from 2021 [3].

Build Smart - Energy Efficient Solutions ready for the market (BuildSmart) is a collaborative, demonstration project funded by the European Commission within the Seventh Framework Programme [4]. The city of Malmö in Sweden is running the project with a consortium including WSP, IVL Swedish Environmental Research Institute, the Basque government, Tecnalia, Codema and the construction development companies Skanska, Roth Fastigheter and FCC. The objective of BuildSmart is to demonstrate and mainstream cost effective techniques and methods for constructing very low energy buildings.

BuildSmart includes low-energy residential and commercial buildings constructed in Sweden and Spain [4]. The buildings are characterised by very low total energy consumption. Dense envelopes create high air tightness and low energy losses. Local renewable energy production in combination with energy efficient installations like heat recovery systems and heat exchangers, for heating and cooling ventilation air, reduce the need for bought energy [5]. The demonstration buildings will therefore act as important showcases for future building norms in the various countries.

2 Introduction and purpose of the report

The demonstration projects will be analysed according to developed methodology in BuildSmart. To fully evaluate the energy performance of a building it is important to look at both the hard facts (quantitative data) and the soft facts (qualitative data). Hard facts represent measured energy performance – measured data and the analysis of data. Soft facts represent qualitative information from, for example, experiences of involved teams/persons in the building process and end user behaviour.

The objective of this report is to compile and evaluate the buildings' performance and technology after one year in operation. Furthermore, the collected qualitative information is compiled and presented.

3 Case studies

The Build Smart project include six demonstration sites, four residential and two non-residential. One building is located in the north of Spain in the city Portogalete. The building in Portogalete is located in the in the neighbourhood of Repélega, in the city of Portugalete. The building is owned by the regional Basque Government and it has been erected for social housing purposes specifically oriented to low-income people.

The remaining buildings are located in Sweden, in the city of Malmö. It is a hotel, an office complex called Klipporna and three residential buildings named Sopranen, Tenoren and Finn. The hotel building, Sopranen and Tenoren are located within walking distance from the Central Station and the new City Tunnel station, between the old city centre and the new modern district Västra Hamnen (West Harbour). The sites have a very high level of accessibility by public transport, both train and busses.

The office building and the building Finn is located in the outskirt of Malmö, in Hyllie. Hyllie is a new city district in the south of Malmö and is built around a new rail station with rail links to central Malmö and Copenhagen.

3.1 Residential buildings

3.1.1 Finn

The residential building was ready for moving in, in November 2013. It consists of three houses with varying height and a total of 53 apartments, see Figure 1. The size of the apartments varies from one room apartments of 35 m^2 up to four room apartments of 119 m^2. However, the majority of the apartments are two room apartments of 63-72 m^2 and three room apartments of close to 90 m^2.

The building envelope is well insulated to reduce the need for heating. The house is equipped with just above 60 m^2 solar panels to heat hot water. The ventilation system is mechanical and has a heat recovery system, where the hot exhaust air is used to heat the incoming air. Furthermore, the air can be filtered in the heat exchanger unit. Temperatures, pressures and flows are set and monitored by a control system. The system is designed so that the temperature can be adjusted in all rooms and apartments. The lighting system is equipped with presence control to further reduce the energy need.

All apartments are equipped with washing machines, hence it is expected that common electricity usage will be lower than for residential properties with common laundry rooms. The energy consumption and cost thereof can be followed on information screens in the hallway or with a mobile app.

The building will be connected to the smart grid of the Hyllie area. The smart grid includes a load shift control system that steers energy use in the district for economic optimization.

Figure 1 The residential building Finn by Roth Fastigheter.

3.1.2 Sopranen

The residential building was ready for moving in during the summer of 2015. It is 14 storeys high and consists of 86 apartments and four premises for rent. The premises are not included in the project BuildSmart. The apartments vary from one and half room apartments of 46,5 m² up to four room apartments of 125 m².

District heating is used for heating and hot tap water. The building envelope is well insulated to reduce the need for heating. The ventilation system is mechanical and has a heat recovery system, where the hot exhaust air is used to heat the incoming air. Furthermore, the air can be filtered in the heat exchanger unit. Temperatures, pressures and flows are set and monitored by a control system. The system is designed so that the temperature can be adjusted in all rooms and apartments. The lighting system is equipped with presence control to further reduce the energy need.

Hot tap water, heat and electricity use is measured in each apartment. The energy consumption and cost thereof can be followed on information screens in the hallway, on the computer or with a mobile app.

Figure 2 The residential building Sopranen [6].

3.1.3 Tenoren

The residential building was ready for moving during summer of 2016. It is 19 storeys high and consists of 72 apartments and four premises for rent. The premises are not included in the project BuildSmart. The apartments vary from one room apartments of 31 m² up to five room apartments of 128 m².

District heating is used for heating and hot tap water. The building envelope is well insulated to reduce the need for heating. The ventilation system is mechanical and has a heat recovery system, where the hot exhaust air is used to heat the incoming air. Furthermore, the air can be filtered in the heat exchanger unit. Temperatures, pressures and flows are set and monitored by a control system. The system is designed so that the temperature can be adjusted in all rooms and apartments. The lighting system is equipped with presence control to further reduce the energy need.

Hot tap water, heat and electricity use is measured in each apartment. The energy consumption and cost thereof can be followed on information screens in the hallway, on the computer or with a mobile app.

Figure 3 The residential building Tenoren [7].

3.1.4 Portogalete

The residential building was ready for moving in at the end of July of 2016. The construction is formed by three blocks of 5 floors. Each of these blocks has 10 dwellings, 2 per floor, and two additional dwellings apartments on the ground floor of one of the blocks, giving a total number of 32 dwellings. Furthermore, the building includes 2 underground parking floors with 34 parking spaces and 32 storage rooms. Dwellings vary from two bedrooms apartments of 57,42 m^2, three bedroom apartments of 86,24 m^2 and two bedroom adapted apartments of 88,39 m^2.

The building envelope is well insulated to reduce the need for heating. In addition, passive solutions were integrated in the building façades in order to maximize the use and storage of solar energy (a trombe wall and a solar wall). Conditions of preheated air with passive façades are monitored.

The ventilation system is mechanical and has a heat recovery system, where the hot exhaust air is used to heat the incoming air. Air preheated through trombe wall could also be used to heat the incoming air if conditions are optimal. Temperatures, pressures and flows are set and monitored by a control system.

Heating energy provided by an advanced system integrating a cogeneration unit and a high efficiency heat pump. In addition a condensation boiler is installed to be used only when necessary. Energy consumption of all generation systems is monitored. Part of this generated heat is stored in water tanks for DHW consumption.

The heating system is designed so that the temperature can be adjusted in all dwellings. Hot tap water and heating use is measured in each dwelling. The energy consumption and cost thereof can be followed by users on information screens situated in their hall.

Figure 4 The residential building “Portogalete”.

3.2 Non-residential buildings

3.2.1 Hotel

Malmö Live consists of three buildings: a concert hall, a convention centre and a hotel. The three buildings are combined and form a unit. The hotel building is a demo site within the BuildSmart project. The hotel is 85 metres high divided into 25 storeys with 444 rooms.

The building is constructed with a heavy frame in which both walls and floors are composed of pre-casted concrete. The exterior walls are well insulated and the windows in the building envelope have low U-values giving the building a high thermal inertia.

The property is heated and cooled geothermally. A heat pump extracts heat and cooling, from seventy-five 280 m deep bore holes, during the winter and summer, respectively. An advanced control system senses presence and checks if hotel guests are checked-in or will be. The ventilation flow is reduced to a minimum when there are no activities.

Air exchange is made with mechanically driven supply and exhaust air. The heat from the exhaust air is recovered and transferred to the supply air, a so-called FTX system. The building's energy needs will be reduced by actively working with steering of the building’s installations. This will be mainly applied in order to regulate indoor temperature and ventilation flow but also for lighting.

The need for cooling is reduced with curtains and green roofs. Rainwater that is stored in the roof evaporates in the sun and results in further reduced cooling needs for the buildings. All water valves will be of a "resource efficient" model which means they have a lower water flow and reduces hot water use.

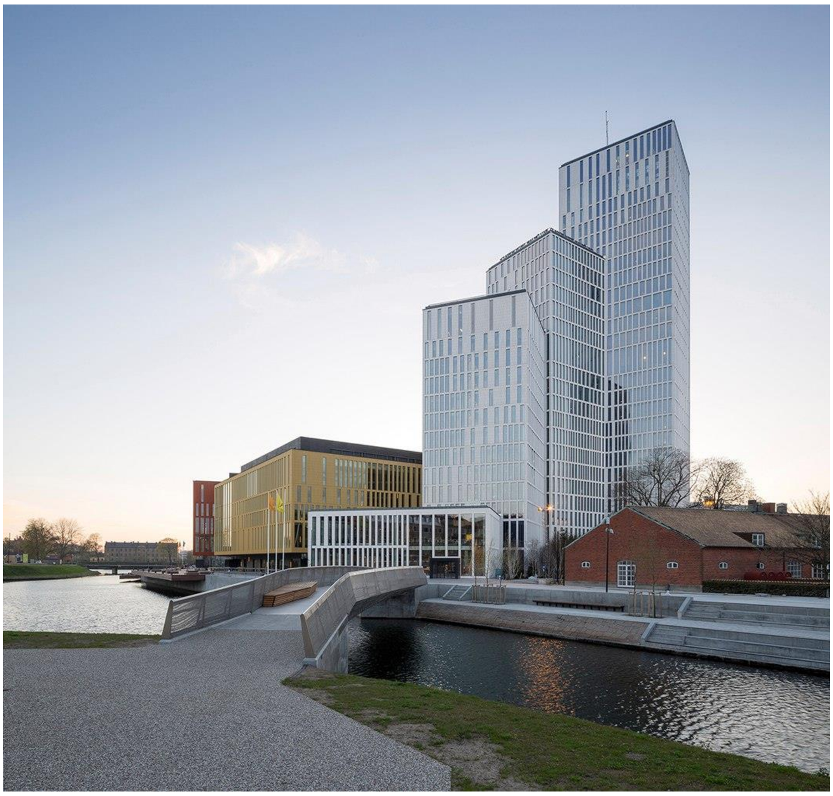


Figure 5 The hotel at Malmö Live [8].

3.2.2 Klipporna

Klipporna consists of three buildings connected by a courtyard. District heating is used for heating and hot tap water. The well insulated building envelope reduces the need for heating during the firing season.

Cooling for office buildings usually requires a large amount of energy. Here cooling will be delivered from the natural ground water beneath the building with “Deep Green Cooling”. ”Deep Green Cooling” is Skanska’s patented cooling technique which uses the cold in the ground to cool the building during the summer. Seventy holes have been drilled 220 m down into the limestone. A pump circulates the water in a closed loop in the holes. The cold is transferred to the building with a heat exchanger and self-adjusting cooling baffles. Natural shading is integrated in the architectural design to reduce the need for cooling. Low energy lighting is used to further reduce the need for cooling. The lighting works separately for each work zone and uses presence control and light sensors to reduce use of energy.

The buildings are connected to the smart grid of the Hyllie area. The smart grid includes a load shift control system that steers energy use in the district for economic optimization.

Figure 6 The office building Klipporna [9].

4 Evaluation strategy

The evaluation process is divided in two parts – quantitative and qualitative evaluation.

The quantitative evaluation concerns analysis of measured data. Energy use is monitored and reported according to the BuildSmart monitoring strategy [4]. The energy performance is divided in the following four main categories: bought energy, sold energy, produced energy and used energy. When applicable, climate normalisation is done according to the method defined by SCIS [10].

The participating companies in Sweden have compiled measured data on a monthly basis and sent it to IVL Swedish Environmental Institute, for analysis. IVL is responsible for analysis and reporting to Smart Cities Information System, SCIS [11]. SCIS is supported by the European Commission and a continuation of the Concerto projects. Similarly FCC is reporting data to Tecnalia who is responsible for reporting the data from Portugalete to SCIS. After the BuildSmart project has finished, the respective partners are responsible for reporting remaining data points to SCIS.

The measured energy is documented with two different indicators, i.e. final energy and primary energy. Furthermore, the climate impact of the energy consumption is calculated.

The qualitative evaluation involves gathering the experience from the parties who are active in the building process, i.e. owners, project team and contractors. The information gathering is done by conducting interviews with key persons from the before mentioned parties. The evaluation also includes users/residents opinion concerning the indoor environment, i.e. air quality, thermal environment, noise and light.

4.1 Quantitative evaluation

Measured energy-related building data is used to verify the building's energy performance and operation and to analyse energy performance regarding environmental impact.

The BuildSmart project defines a strategy for evaluating the building energy performance for this evaluation, IVL has developed templates for reporting and comparing calculated and measured energy use, a CSV file and a yearly overview of the building energy use. It is however necessary to post-process the energy usage data and to take varying climate into consideration and compared to the predicted values.

A part of the evaluation is to verify that energy use estimated by simulations during the design phase can be achieved, that is measure that it works. An energy signature is one of several tools for evaluation. The signature, of a building, is a tool to gain knowledge about the energy relations existing in the building and to visualize its energy performance. The method is based on the buildings real energy balance and reflects its heating technical properties [13]. Here the energy signature is constructed by plotting the monthly energy consumption against average outside temperature for the month. Obviously the energy consumption varies with the size of the building. To enable comparison between buildings the energy consumption can easily be divided by the heated area. Here the Swedish definition of heated area is used, i.e. the interior area of all floors, attic floor and basement that is heated to more than 10°C [14]. Please note that energy signatures are drawn with data that hasn't been climate normalized.

Finally, energy data is transformed into energy performance indicators which are useful in comparison with other buildings. The resulting energy performance indicators for the BuildSmart project are final energy (kWh/m^2 year), primary energy (kWh/m^2 year) and emitted carbon dioxide (kg/m^2 year) in relation to the energy delivered to final customer.

More detailed information regarding calculated and measured results can be found the report for the respective demo sites; Finn [16], Sopranen [17], Tenoren [18], Hotel [19] and Klipporna [20].

4.1.1 Energy signatures for residential buildings

Figure 7, Figure 8 and Figure 9 display the residential buildings´ energy signatures for district heating energy, both calculated and measured. The figures display the energy signatures for heating energy used per month versus average outside temperature. Heating energy is here the sum of bought district heating and heating from solar panels minus the energy used for hot tap water. The blue markers show the calculated data points and green markers measured values. The respective signatures are indicated with blue and green lines. An offset of the horizontal part of the signature means that there losses in the system, since the energy for heating tap water has been subtracted. Note that for the building Tenoren, it is not possible to make an energy signature based on measured data due to the lack of data.

Figure 7 shows that the slopes of both signatures match. This means that heat losses, through climate envelope and ventilation, in the calculation is correct. The difference in the y-direction of the horizontal part of the signatures is because there are no climate independent losses in the simulation. Measurements show that there are losses and/or climate independent energy use that are not accounted for in the simulation. Furthermore, the signature based on calculated values is offset in the x-direction. According to the blue signature the heat will be switched off at approximately 8°C. But the measurements show it is at 14°C. Part of the observed difference between simulation and measured energy use, is because the indoor temperature in the simulation is 21°C. According to Roth Fastigheter the average indoor temperature is actually 22.7°C. The observed losses could be due to hot water circulation losses or heating of cellar. Finally, note that the horizontal part of the signature based on simulated data lies slightly below zero. This anomaly is probably a consequence of using a standard value for heating hot water.

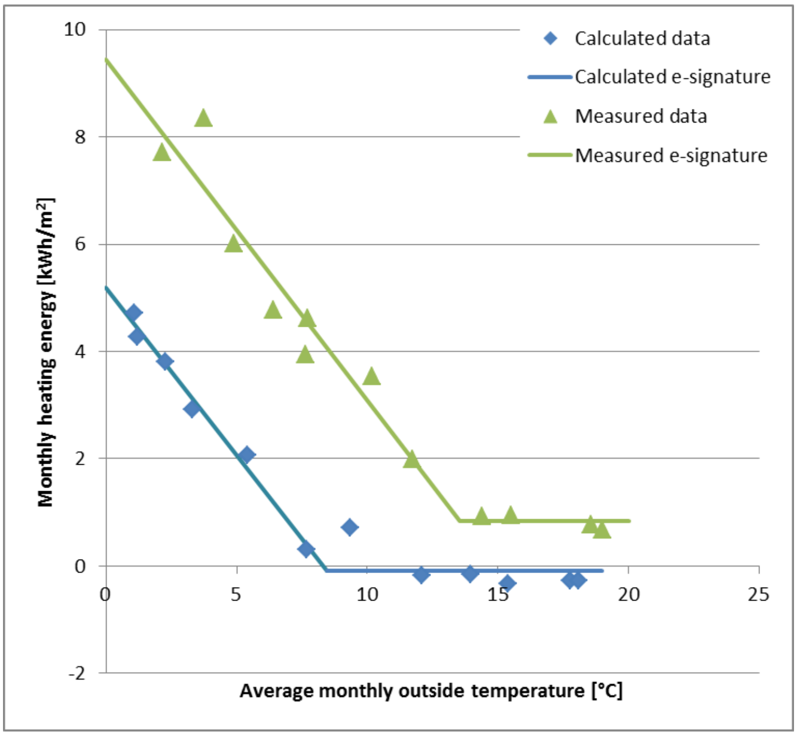


Figure 7 District heating energy signatures for the building Finn, calculated and measured.

Figure 8 shows the signature for the building Sopranen. It displays the same characteristics as for Finn. However, the climate independent energy use is lower, that is the horizontal line is lower. Sopranen has lower losses compared to Finn.

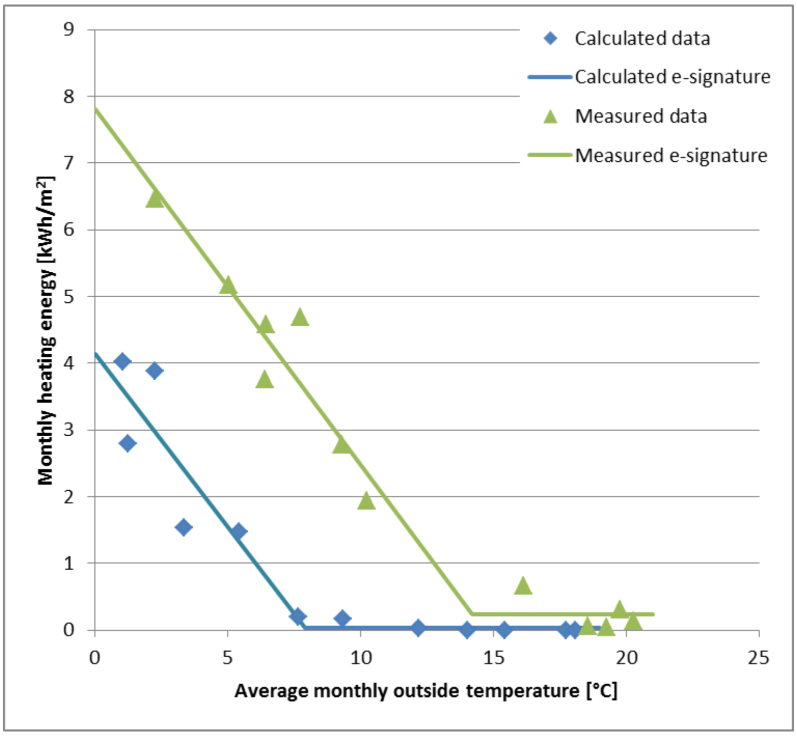


Figure 8 **Heating energy signatures for the building Sopranen, calculated and measured.**

Figure 9 shows the district heating energy signature of Tenoren. Only the signature based on values from the simulation is drawn, since there aren't enough measured data available.

Figure 10 shows an energy signature for the Portugalete building. The signature displays simulated data for space heating, which is comparable to simulated heating data for the other residential data (DHM - TDHW). Only simulated data is displayed since no measured values are available yet.

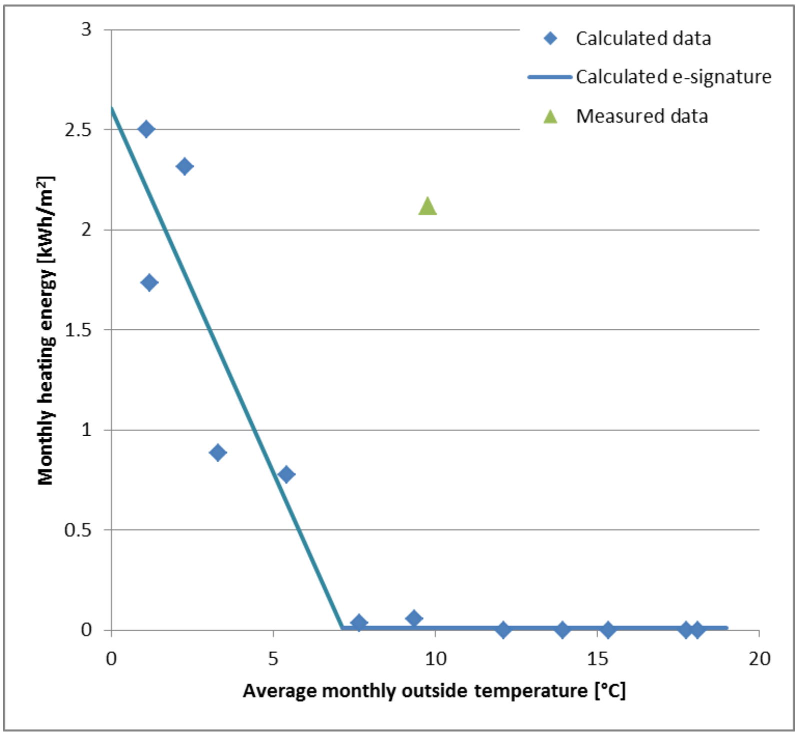


Figure 9 **Heating energy signatures for the building Tenoren, calculated.**

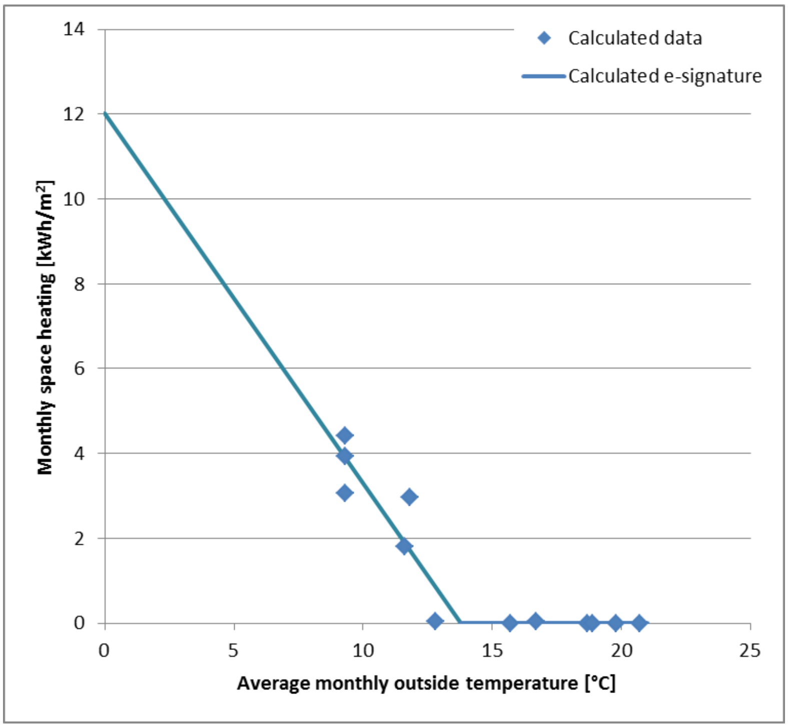


Figure 10 **Heating energy signatures for the building Portogalete, calculated.**

4.1.2 Energy signatures for non- residential buildings

This section presents the signatures for the non-residential buildings, the hotel and the office building Klipporna. The signatures are drawn using data for one year.

The hotel uses heat pumps for heating and cooling the building. This means that bought electricity is used for heating and cooling. For the hotel two different signatures are drawn to illustrate the thermal characteristic of the building, se Figure 11 and Figure 12.

The first signature, Figure 11, is drawn using calculated and measured space heating data. The slopes of two signatures do not match. This indicates that transmission losses through the building envelope and the ventilation are lower in the calculation than reality. However, note that the steeper slope found for the measured data is influenced by the high energy use measured in January 2016. Above the balance temperature there is no need to heat the building to maintain the desired indoor temperature. The heating is turned on/ switched off at 11°C in the simulation and measurement shows it is at 9.7°C. There is also a minor difference in the y-direction at the horizontal part of the signatures, however very low.

The second signature, Figure 12, is drawn using data for distributed cooling. The slopes of the two signatures for cooling don't match. The slopes show that the transmissions losses are lower in the calculations. The signatures show that there also is a difference in the y-direction. The losses that are independent of the outdoor climate are overestimated in the simulation. However, the differences are not large. The offset in the x-direction shows that the cooling is turned on at a lower temperature than in the calculations, 9°C instead of 11.4°C.

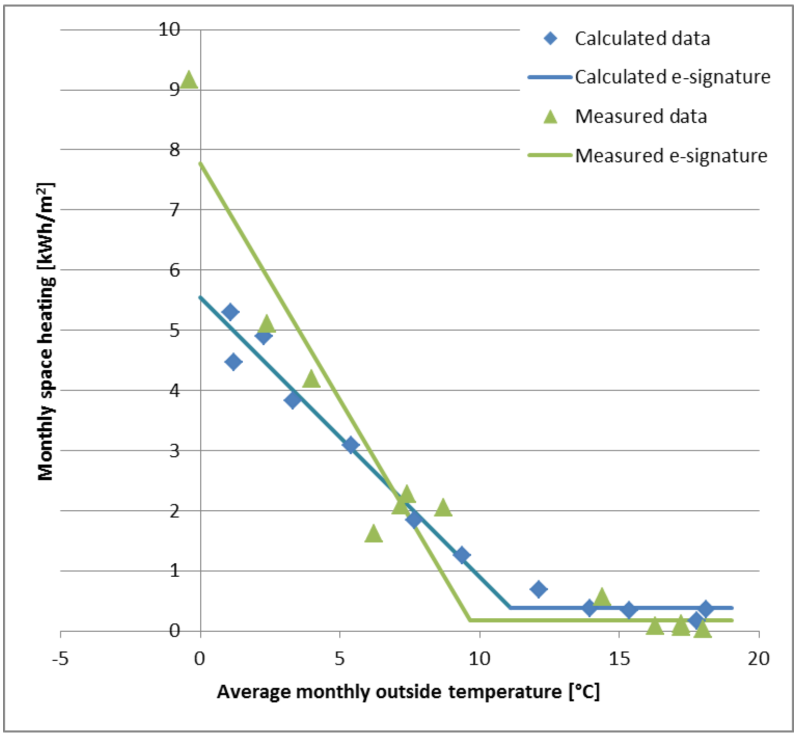


Figure 11 Energy signatures of the hotel, calculated and measured, for space heating.

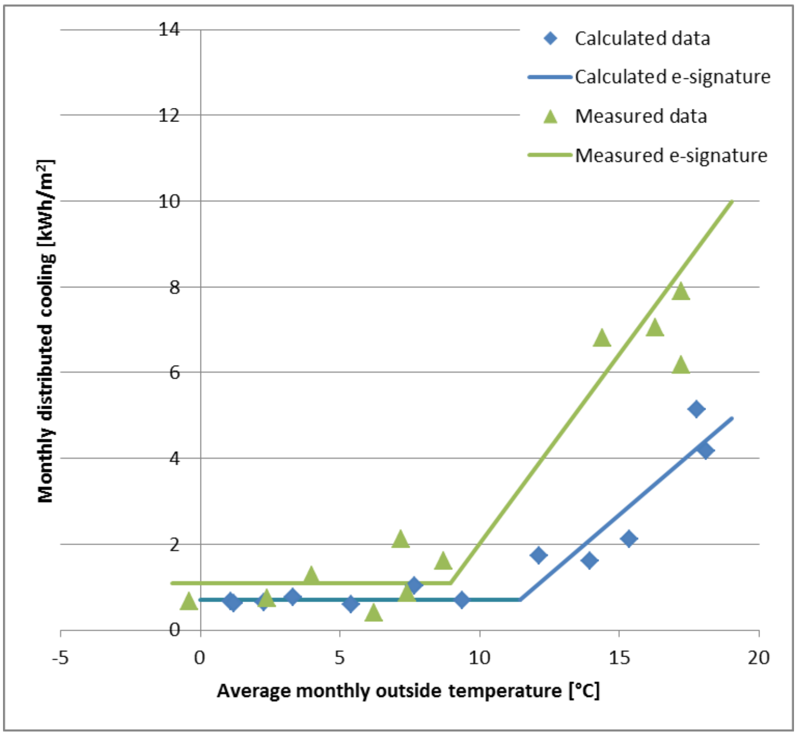


Figure 12 Energy signatures of the hotel, calculated and measured, for distributed cooling.

Klipporna use district heating for heating the buildings and the Deep Green Cooling system to cool the building when necessary (sec. 3.2.2), i.e. electricity is used to cool the building. For Klipporna two different signatures, space heating and space cooling, are drawn to illustrate the thermal characteristic of the building.

The first signature (Figure 13 and Figure 14) is drawn using data for space heating. The differences between the first and second set of signatures indicate that some data points are questionable, see report [20].

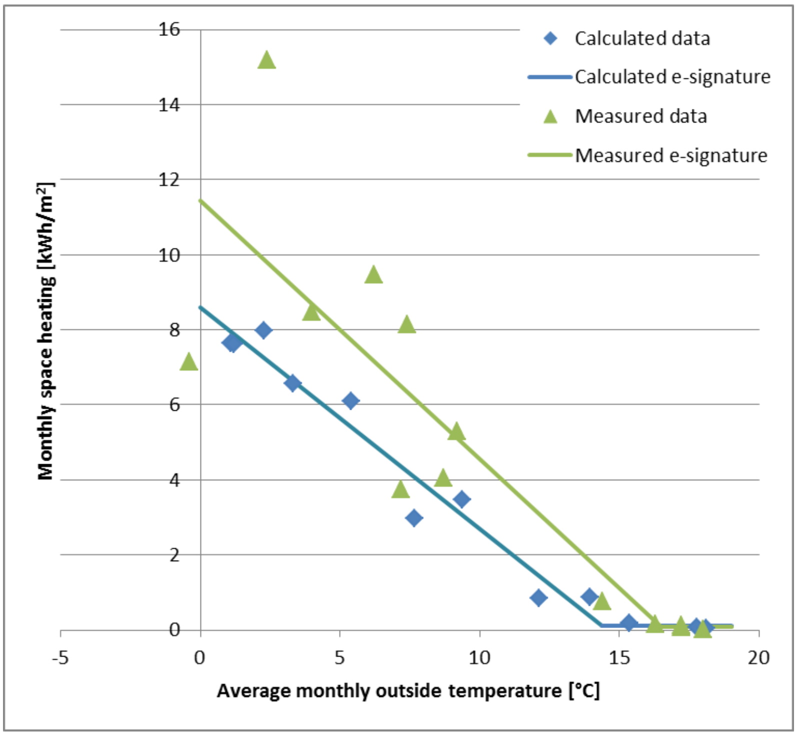


Figure 13 Energy signatures for house 1 of Klipporna, calculated and measured, for space heating.

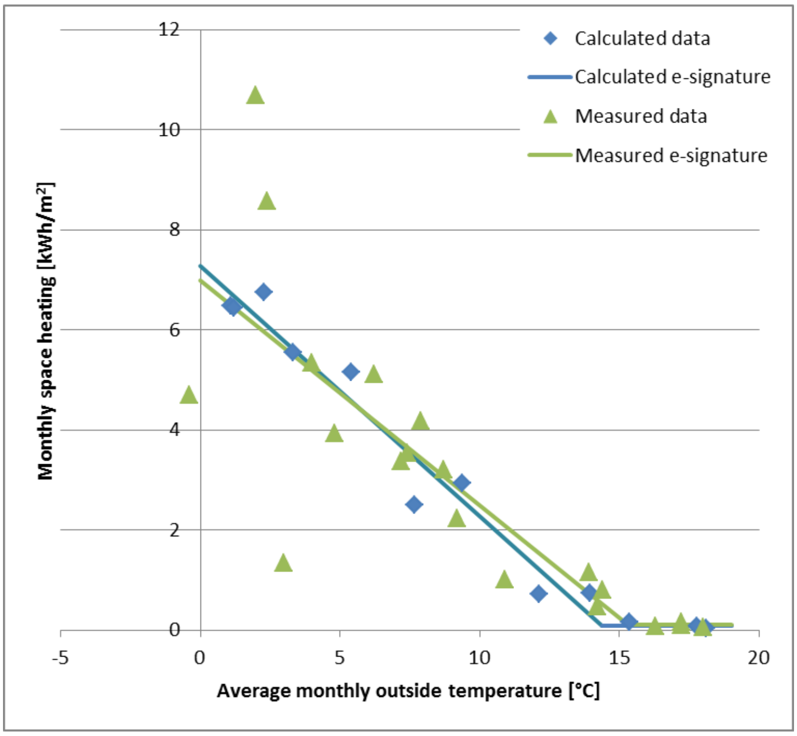


Figure 14 Energy signatures for house 2 of Klipporna, calculated and measured, for space heating.

The second signature (Figure 15 and Figure 16) is drawn using data distributed cooling. The simulated data display the expected behaviour, i.e. a low and constant energy use up to a point where the outside temperature exceeds a balance temperature, 8.9°C, and the need for cooling increases. The measured data, on the other hand, shows a V-like pattern indicating a high need for cooling also at low temperatures. Fitting a horizontal line followed by an inclined line to this data set will not lead to useful numbers except to visualise that the measured data deviate significantly form the expected behaviour.

The data indicates that there is a simultaneous need for cooling and heating at low temperatures for the office buildings of Klipporna.

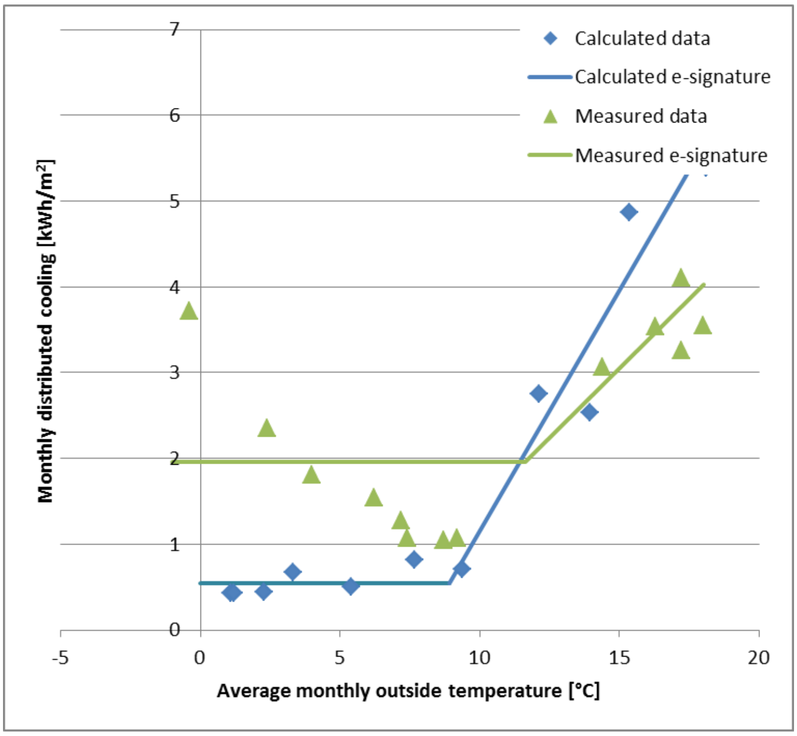


Figure 15 **Energy signatures for house 1 of Klipporna, calculated and measured, for distributed cooling.**

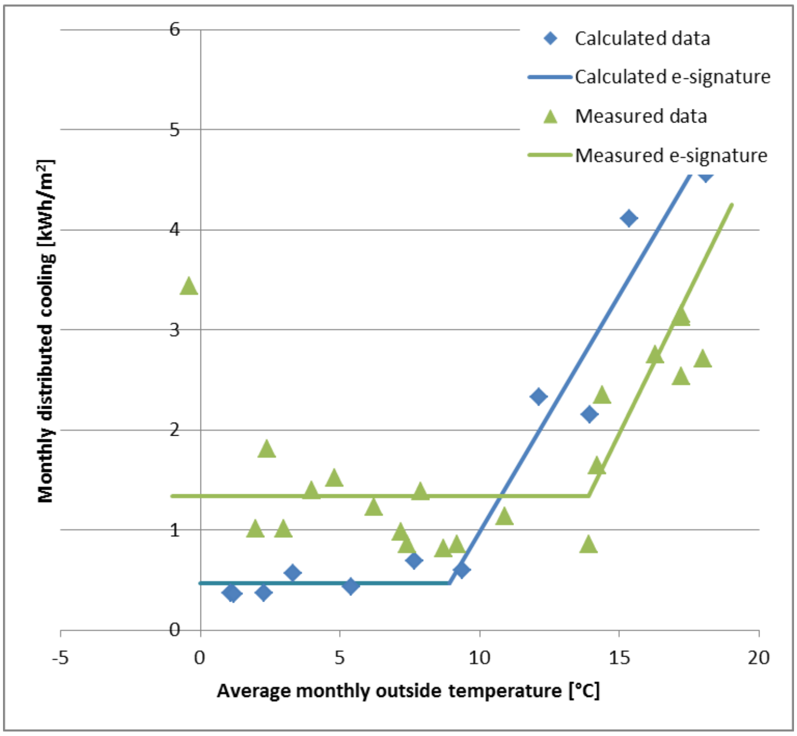


Figure 16 Energy signatures for house 2 of Klipporna, calculated and measured, for distributed cooling.

4.1.3 Indicators

The measured energy is documented with two different indicators, i.e. final energy and primary energy. Figure 17 and Figure 18 shows the final energy and primary energy, respectively, for the residential buildings. Corresponding data for non-residential buildings are displayed in Figure 19 and Figure 20.

The measurements indicate that the final energy use is underestimated in the energy calculations, see Figure 17. The difference measured and calculated value is greater for the building Finn than the building Sopranen, 35 kWh/m^2 compared to 13 kWh/m^2.

Also the non-residential building show the same behaviour, see Figure 19. The difference varies from 18 kWh/m^2 for the hotel to 16 – 28 kWh/m^2 for Klipporna.

The primary energy indicator (Figure 18 and Figure 20) is also underestimated in the calculations, except for the office building Klipporna. This is a consequence of a high measured district heating usage and low electric energy usage compared to the calculations, see Table 1. The use of district heating is underestimated with more than 20 kWh/m^2 in the calculations.

The Portugalete demo site uses a gas fuelled cogeneration plant to provide heat and electricity to for the building. Primary energy is found by multiplying the fuel meter data with the PE-factor for natural gas, see Table 2.

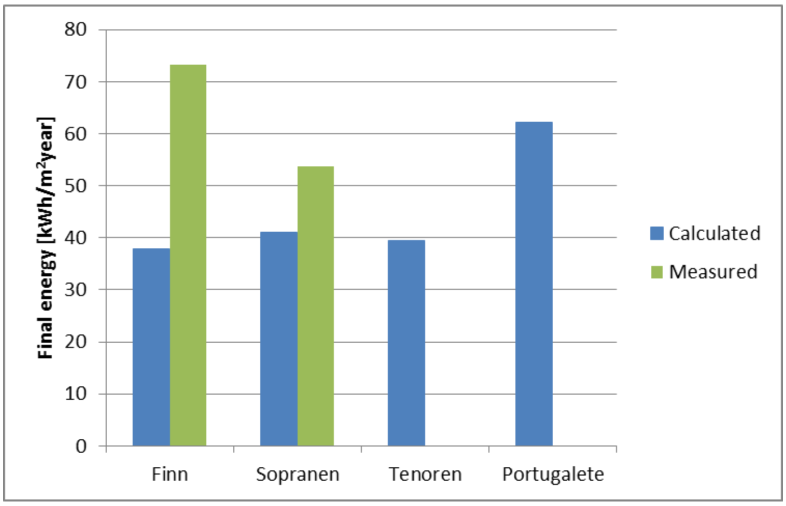


Figure 17 **Final energy, calculated and measured, for residential buildings.**

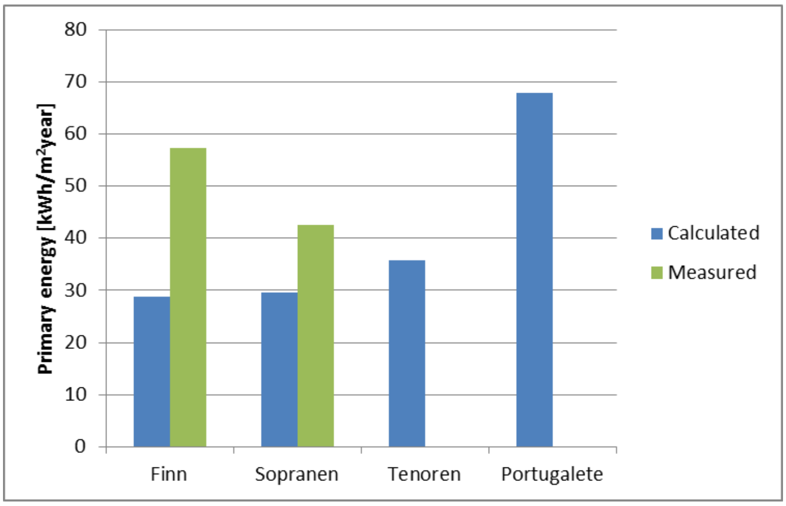


Figure 18 **Primary energy, calculated and measured, for residential buildings.**

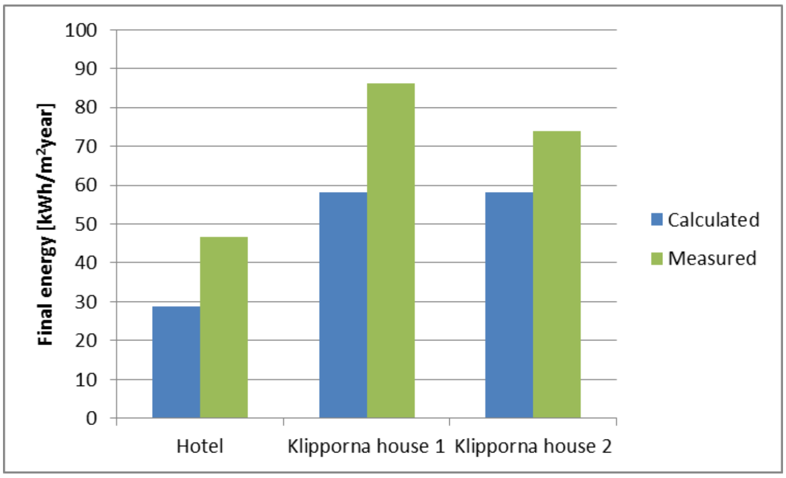


Figure 19 **Final energy, calculated and measured, for non-residential buildings.**

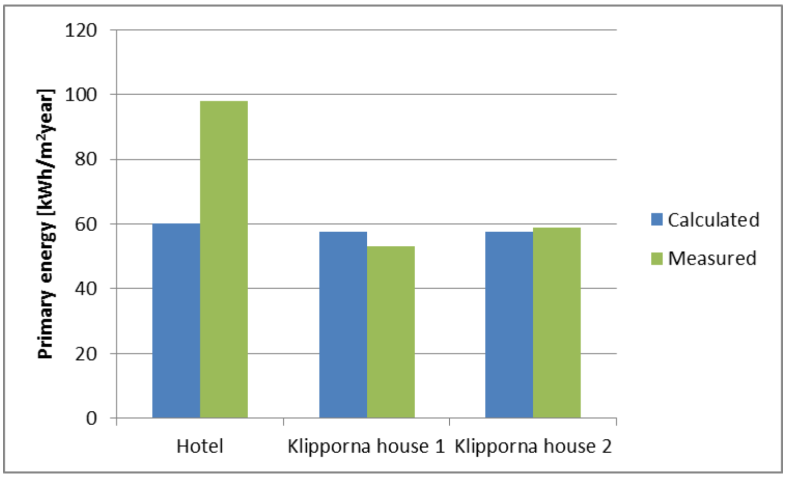


Figure 20 **Primary energy, calculated and measured, for non-residential buildings.**

Table 1 **Final energy of demonstration projects**

Demostration sites	Def. final energy	EUM / EUM-IE [kWh/m^2 year]		FM		DHM [kWh/m^2 year]		Final energy [kWh/m^2 year]	
		Calculated	Measured	Calculated	Measured	Calculated	Measured	Calculated	Measured
Finn	EUM+ DHM	5.8	12.3			32.0	61.0	37.8	73.3
Sopranen	EUM+ DHM	5.6	9.7			37.1	46.2	42.7	55.9
Tenoren	EUM+ DHM	10.2				31.2		41.4	
Potogalete	FM			62.3				62.3	
Hotell	EUM-IE	28.6	46.6					28.6	46.6
Klipporna, house 1	(EUM-IE) +DHM		5.6				80.5		86.1
Klipporna, house 2	(EUM-IE) +DHM	17.5	13.0			40.5	60.8	58.0	73.8

The climate impact is given as an equivalent emitted carbon dioxide. Figure 21 shows the CO_2 emissions for the residential buildings and Figure 22 display the emissions for the non-residential buildings. The CO_2 emissions based on measured values is always exceeding the estimated. The emissions show similar behaviour as the results for final energy since the CO_2 emissions factor for district heating in Malmö and electricity are almost equal, see Table 2. The difference between the calculated value and the measured value is larger for the residential building Finn than Sopranen. Finn has 5.4 kg/m^2 and Sopranen 2.0 kg/m^2. For the non-residential buildings the difference is close to 3 kg/m^2. Similar to primary energy, the CO_2 emissions for Portugalete is found by multiplying the fuel meter data with the GWP-factor for natural gas in Table 2.

Table 2 PE and GWP factors [12][21].

	PE factor [-]	GWP factor [ton CO_2/GWh]
District heating	0.52	151
Electricity	2.1	160
Natural gas	1.09	248

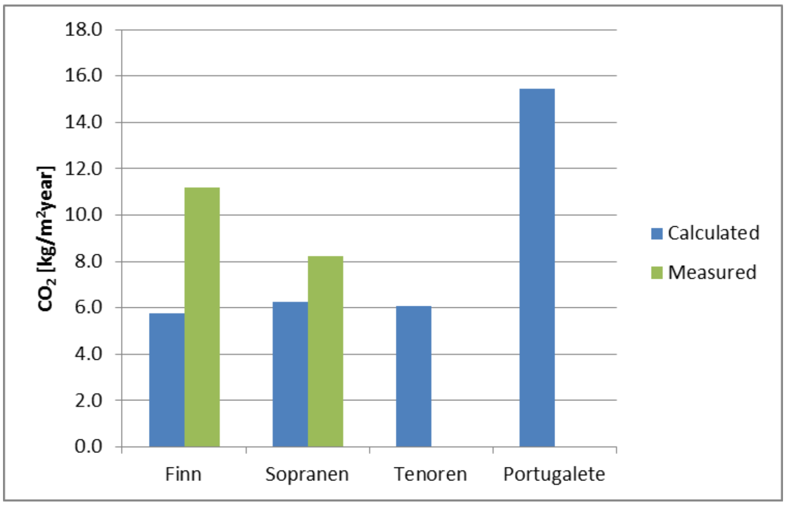


Figure 21 CO_2 emissions, calculated and measured, for residential buildings.

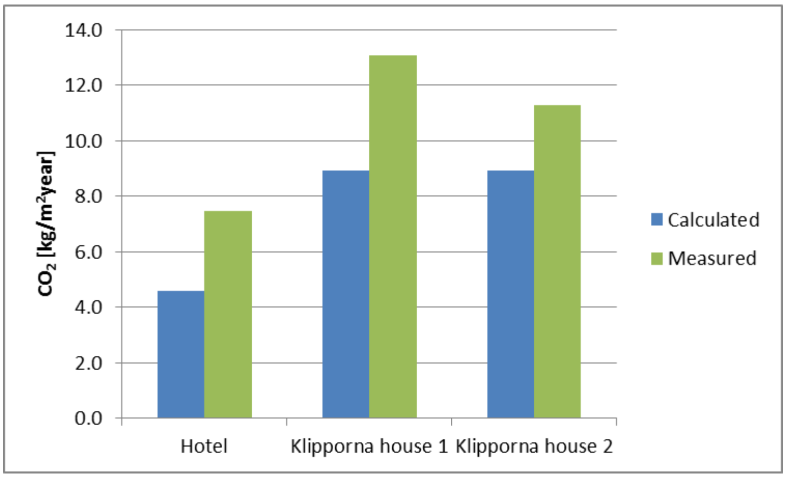


Figure 22 **CO_2 emissions, calculated and measured, for non-residential buildings.**

4.1.4 Comparison of case studies in BuildSmart

Figure 23 and Figure 24 show calculated and measured district heating energy signatures for the residential buildings Finn, Sopranen and Tenoren. The energy simulations (Figure 23) indicate that losses through the climate envelop and ventilation are highest for Portugalete and lowest for Tenoren. The buildings Finn and Sopranen are similar; however Finn has slightly higher losses. This is confirmed in the measurements (Figure 24).

The right parts of the simulated signatures, the horizontal parts, indicate that there are almost no climate independent heat losses. According to the measurements (Figure 24) this assumption is not correct. The shift in y-direction shows that losses are greater for Finn than Sopranen.

The crossing of the lines represents the set points or balance temperatures where heating is switched on and off. The simulations (Figure 23) indicate that heating is switched off at a lower outdoor temperature than Finn and Sopranen. The measurements (Figure 24) show that heating is switched off at higher outdoor temperature than estimated in the simulations: Sopranen at 14.2°C instead of 7.9°C and Finn at 13.6°C instead of 8.5°C.

The simulations indicate that the balance temperature is significantly higher for Portugalete than simulations for the other buildings (Figure 23). The measurements on the other hand (Figure 24) give a balance temperature in same region as predicted in the Spanish energy simulation.

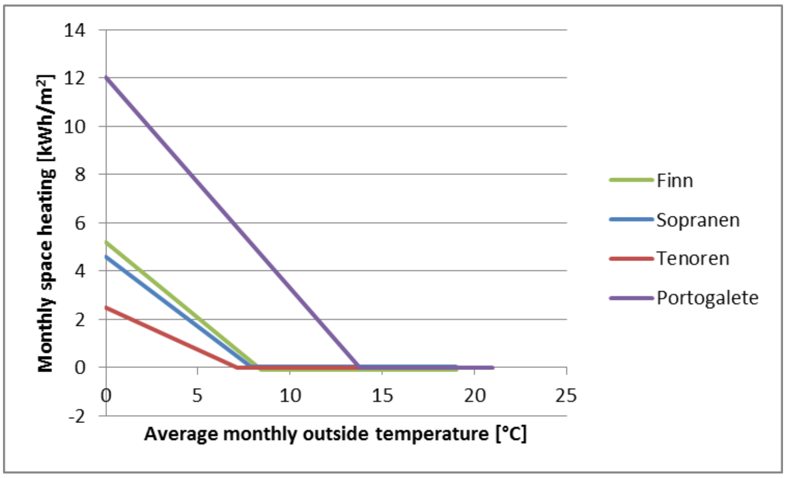


Figure 23 **Residential, calculated, space heating energy**

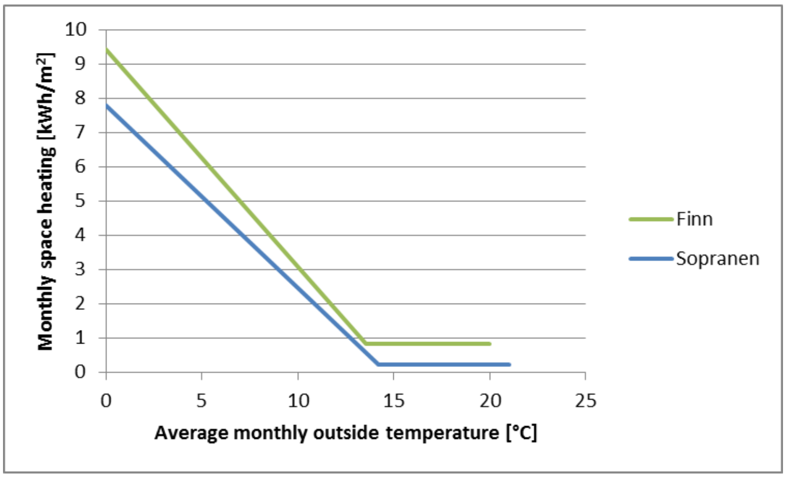


Figure 24 **Residential, measured, space heating energy**

Figure 25 and Figure 26 show the space heating energy signatures for the non-residential buildings. The first figure is generated with simulated values and the second one is based on measured data. Comparing the two calculated signatures it can be seen that the left part of the signatures, the slope, is similar. This means that the losses through the climate envelop and ventilation are similar for the buildings. The measurements on the other hand show a somewhat steeper slope for the hotel compared to both the simulations and the office buildings. The two slopes of the signatures for the office buildings differ more than expected. This can be the result of problems with the measurement equipment.

The set points in Figure 25 are different for Klipporna and the hotel. The calculations indicate that Klipporna stops heating at 14.4°C and the hotel at 11.1°C. Figure 26 shows that the hotel switches off the heating at 9.7°C, lower than estimated in the simulation. For the office building the situation is opposite, that is the heating is switched off at a higher temperature (>15°C) than estimate in the simulation.

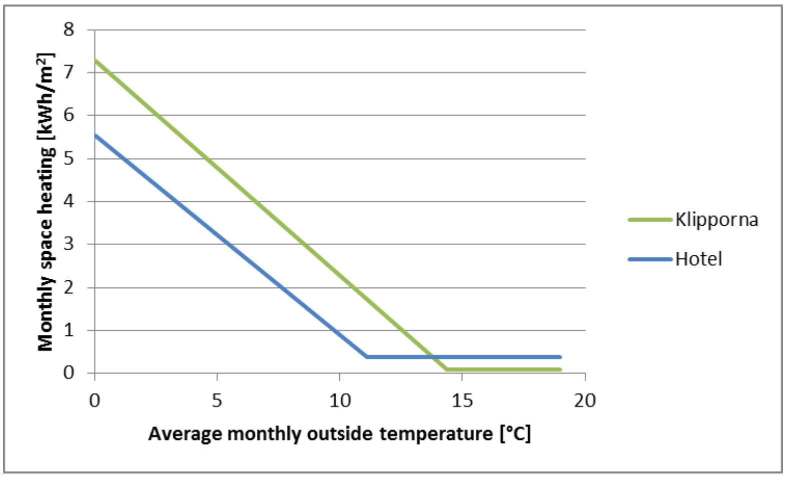


Figure 25 **Non-residential, calculated, space heating energy**

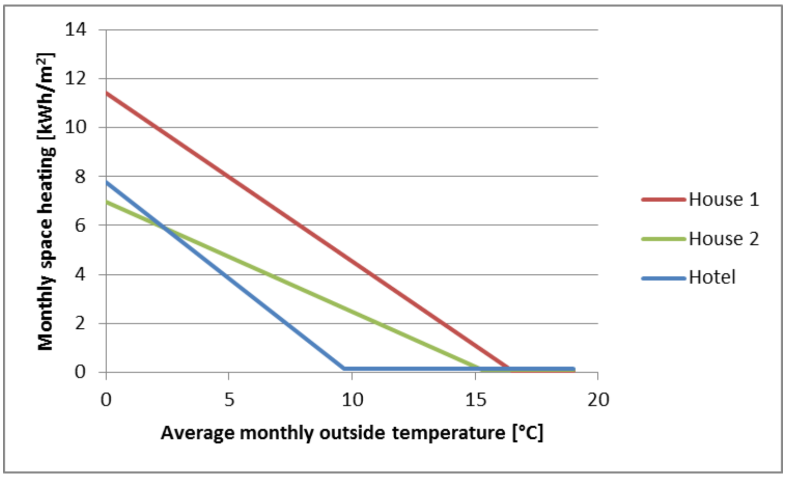


Figure 26 **Non-residential, measured, space heating energy**

4.1.5 Comparison with reported case studies from SCIS database

The demonstration projects are not only compared with each other, but also with other reported cases in the SCIS database. Three demo projects have been selected with the help of SCIS, two non-residential and one residential. The hotel and Klipporna are compared to a building with office and laboratory premises named "CARTIF III", located in the Spanish city Valladolid, and an office building in the German city München called "NU-office". BuildSmarts residential buildings are compared with a residential building in the Slovenian town Ljubljana called "ECO Silver House". The SCIS database characterises the demo sites in the form of savings of the three studied indicators: final energy, primary energy and CO_2-emissions.

Since all the buildings in BuildSmart are new buildings, the savings are computed in relation to the national requirement for respective building. Table 3 lists the national requirement on energy consumption together with simulated and measured final energy. The reference primary energy is found by multiplying the national requirement with the PE-factor for the respective building. The PE-factor is found by dividing the primary energy with the final energy. The CO_2-emissions is handled in the same way.

Figure 27 and Figure 28 show the final energy savings for the residential and non-residential buildings, respectively. The primary energy savings are shown in Figure 29 and Figure 30 and finally the CO_2-emissions savings are shown in Figure 31 and Figure 32. One trend is obvious, the savings predicted in the energy simulations cannot be found in the measurements. Another observation is that the CO_2-emissions savings for the SCIS reference buildings are higher than the all demonstration projects in the BuildSmart project.

Table 3 National requirements and simulated and measured final energy for the BuildSmart demo sites.

Demo sites	National requirements [kWh/m^2 year]	Simulated [kWh/m^2 year]	Mesurments [kWh/m^2 year]
Finn	110	37.8	73.3
Sopranen	91	42.7	55.9
Tenoren	92	41.4	
Portugalete*	50	62.3	
Hotel	76.7	28.7	46.6
Klipporna, house 1	108		86.1
Klipporna, house 2	113	58.0	73.8

*) The national requirement for the Spanish demo site has changed during the project. In 2013 it was lowered from 60 to 50 kWh/m^2 year. The simulated value has been divided with the heated area 2303 m^2 to be comparable with the Swedish demo sites.

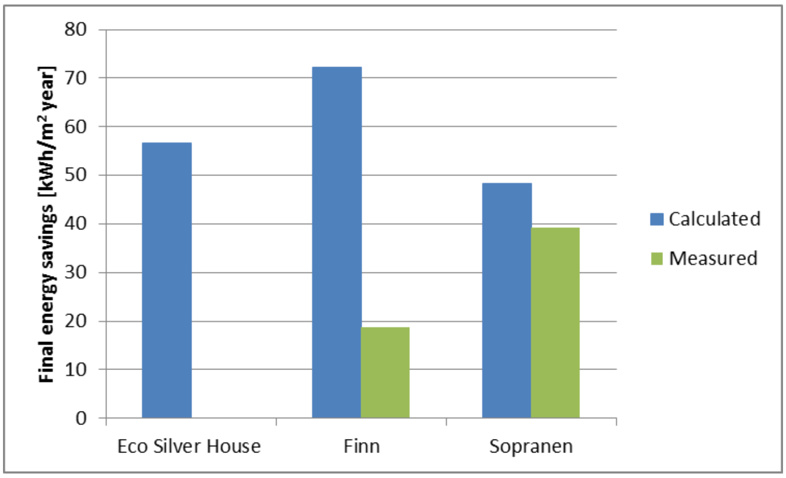


Figure 27 Final energy savings for residential buildings.

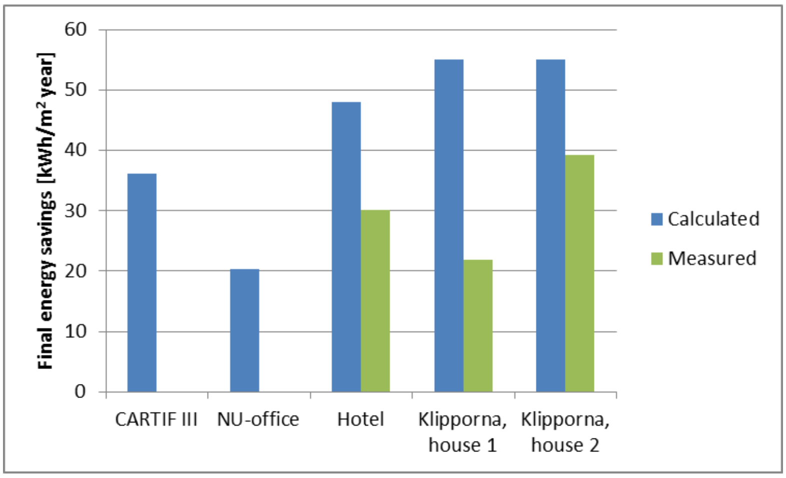


Figure 28 Final energy savings for residential non-residential buildings.

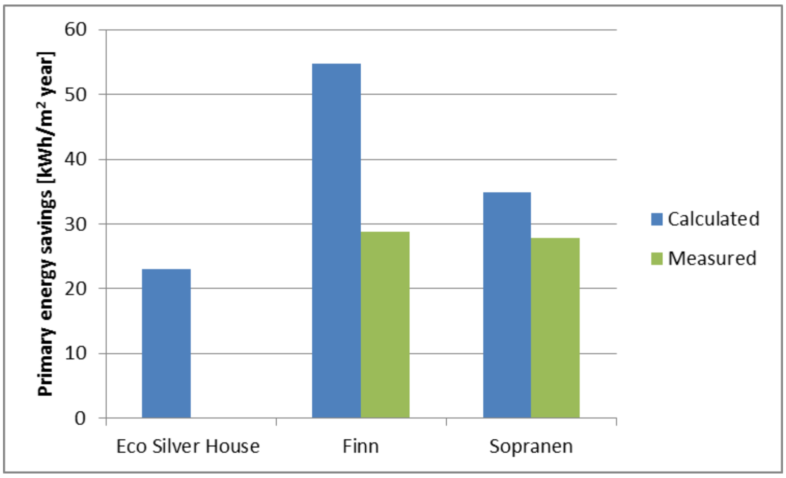


Figure 29 Primary energy savings for residential buildings.

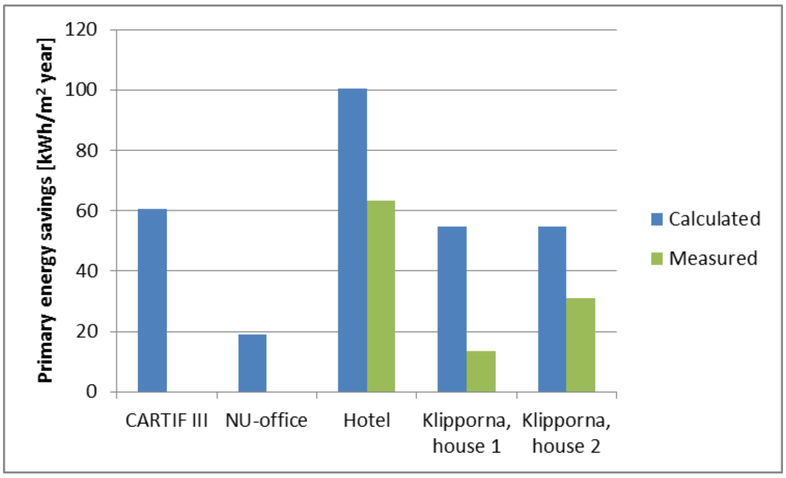


Figure 30 **Primary energy savings for residential non-residential buildings.**

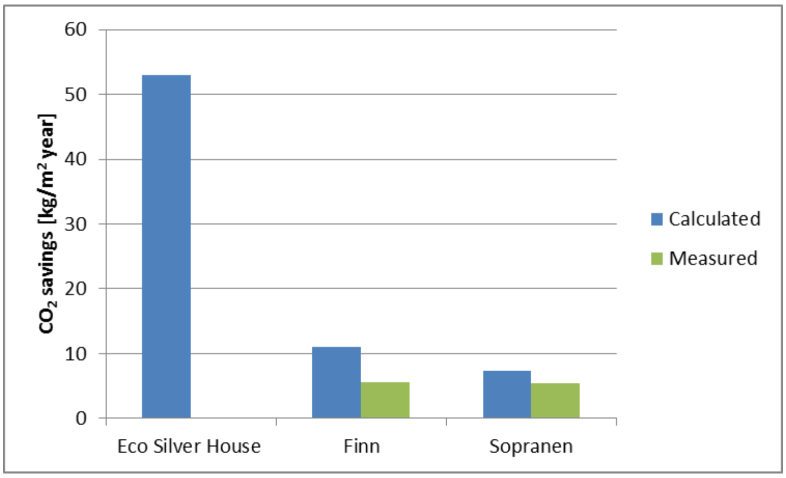


Figure 31 **CO_2 savings for residential buildings.**

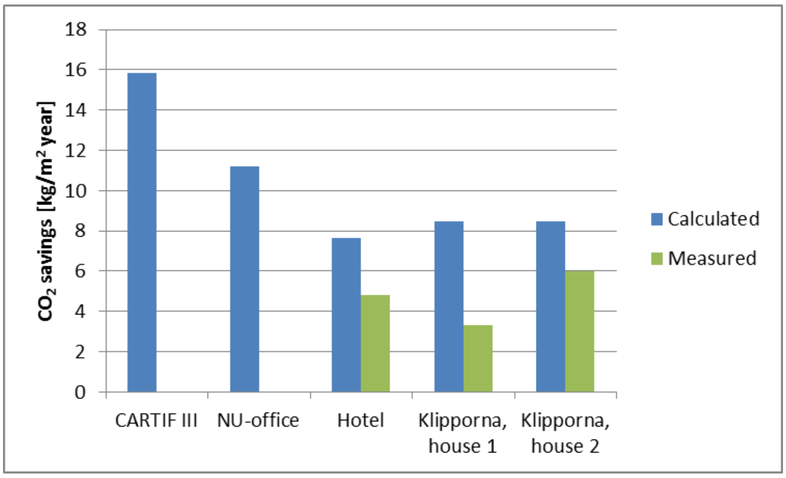


Figure 32 **CO_2 savings for residential non-residential buildings.**

4.1.6 Comments

The demonstration projects in BuildSmart show that there is discrepancy between simulated and measured energy consumption.

The measurements show that final energy is underestimated in the energy simulations for both residential and non-residential buildings. The simulated value deviates from the measured value by 21% to 48%, see Figure 33.

The primary energy indicator is also underestimated in the energy simulation. The deviation for the buildings Finn, Sopranen and the hotel varies between 30 to 50%. For the office building Klipporna the situation looks different at first glance. House 2 has deviates 2% and for house 1 the simulated value is 8% higher than the measured, see Figure 34. However, the apparent good estimate of primary energy is a consequence of a higher predicted use of electric energy and a high primary energy factor (PE factor = 2,1), see section 4.1.3 and Table 2. The use of district heating for heating and hot tap water is also underestimated in the energy simulations for Klipporna.

There are several possible explanations for the observed discrepancy. One cause is that input data used in the simulations deviates from reality. For Finn measurements showed that the indoor temperature was actually 22,7°C but in the simulation this value was set to 21°C [16]. Note, that this particular error source has been ruled out for Klipporna. The energy signature based on measured values for the Finn building showed that there where climate independent losses that where not accounted for in the energy simulation.

It is important to realise that the external climate has less influence on the total energy usage in low-energy houses compared to conventional houses. The activities inside the house become more important for the energy usage. User related energy items such as household electricity and hot tap water usage constitute a large part of the total energy usage. Studies have shown that there are large variations in household energy usage [15]. This means that energy simulations where the users influence is estimated using literature data can deviate from the measured. Note that, literature values can be correct for one building but wrong for another.

Before concluding that the energy simulations are wrong it is necessary to get passed the adjustment period. Heating and ventilation systems must be adjusted, moist concrete must dry out, etc. However, it is possible to conclude that the energy simulations are unable to correctly predict the energy usage during the first years of operation.

Furthermore, it should be noted that several demos have had problem with the measuring equipment, transmission of measure data and measurements that have been reset. The BuildSmart project shows that evaluation during the first year of operation is difficult. It is therefore important, but beyond the scope of BuildSmart, that the measurements are continued over the following years and that data is evaluated again using the developed methodology. This would give important insights concerning energy simulations and actual energy usage of low energy buildings.

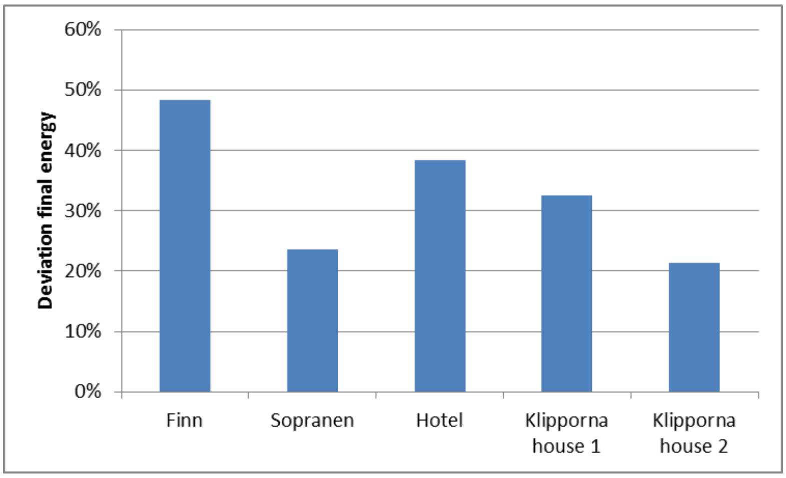


Figure 33 **Relative deviation of simulated final energy from measurement.**

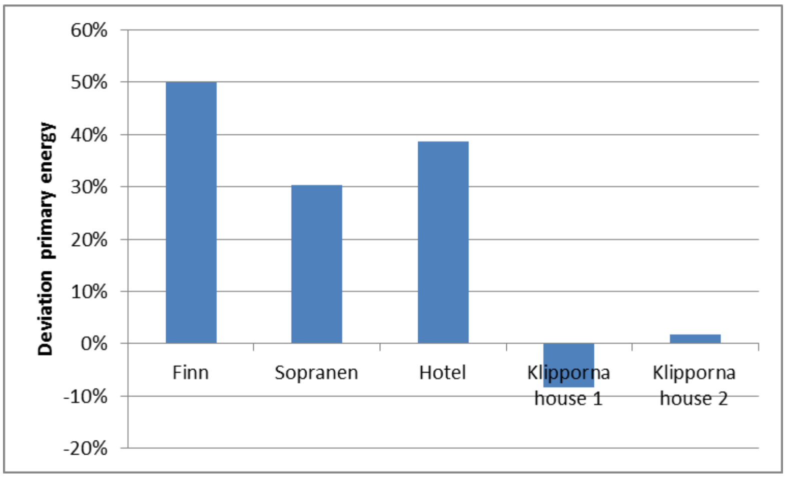


Figure 34 **Relative deviation of simulated primary energy from measurement.**

4.2 Qualitative evaluation

The building process is evaluated in the qualitative evaluation. The evaluation involves gathering the experience from the parties who are active in the building process, i.e. owners, project team and contractors. The information gathering is done by conducting interviews with key persons from the before mentioned parties. The project leaders have also exchanged and discussed these experiences and solutions furtherly over the whole project period at breakfast meetings, as well as at the project meetings. To get comparable data from all demo sites in the BuildSmart project IVL has compiled six questionnaires to assist during the interviews. The questionnaires are available in Appendix A.

4.2.1 Instructions for interviews

The building process is divided into four stages: design, construction, commissioning and operation. Different parties are involved at the different stages. Table 4 shows which stage is relevant for which party.

Table 4 Building process stage and relevant party

	Project team	Contractor	Property owner
Design and planning	x		x
Construction	x	x	x
Commissioning	x	x	
Operation		x	x

In collaboration with the parties, three to five key members are identified and chosen for an interview. It is an advantage if the chosen members come from different parties and cover as many stages as possible. There are different questionnaires depending on party and construction stage. Table 5 lists the different questionnaires and connects the questionnaires to the respective party.

Table 5 Questionnaires for the partners to be interviewed.

Questionnaire	Phase	Target group/groups
1	Planning and design	Project team and property owner
2	Construction	Project team and property owner
3	Construction	Property owner
4	Commissioning	Project team and contractor
5	Operation	Contractor
6	Operation	Property owner

4.2.2 Observed challenges and obstacles during development, installation, and operational stages of the advanced ICT Systems

The input from the project team has given an overview of the barriers and obstacles of the ICT systems applied in the project see Table 6.

One of the main conclusions is that the complexity of the applied ICT systems gives additional costs in all project phases – development, installation and operation – compared to “standard” solutions within energy monitoring and controlling. These additional costs need to be justified by the economic benefits of the systems, which include reduced energy consumption, increased will-to-pay from customers from an improved indoor climate and the increased possibilities to evaluate the solutions. For acknowledging the benefits, a generally long perspective on profitability has been advocated by the BuildSmart stakeholders for applying these solutions.

Furthermore, a pro-active approach should be used for avoiding complex technical challenges and costs in the installation and operation phase. When procuring monitoring equipment, careful choices need to be made for ensuring that the devices will be technically compatible with each other. This must be considered particularly if the devices are procured in several procurements over a longer time period, due to the continuous model adjustments of e.g. signal transmissions that can make them incompatible. Through initial evaluations and decisions on which monitoring equipment that are necessary, many problems can be solved at an early stage, and significant costs in a longer perspective can be avoided.

Table 6 The studied and implemented ICT systems

ICT systems
Monitoring systems of delivered thermal and electrical energy at building level
Monitoring systems for domestic hot water use of individual households
Monitoring systems for indoor temperature (sensors in individual apartments)
Controlling systems for heating and ventilation (including advanced presence controlled systems)
Controlling systems for balancing the supply of imported and locally supplied energy (e.g. from solar thermal panels and photovoltaics)
Visualization and information systems for tenants - info on their individual consumption of energy (e.g. on small screens in the apartments and on log-in websites)

The identified barriers and challenges cover a broad perspective of technical and economic issues in the three phases of the building projects (development, installation and operation). The main barriers are presented in sections 4.2.2.1 - 4.2.2.3 below, and pinpoint important issues to consider in the application of these ICT systems for future, comparable building projects. For a further description and analysis on the obstacles and barriers, see Ref [22].

4.2.2.1 Technical barriers

The technical barriers of the ICT systems have an impact on all phases of the building projects including the development, installation and operational phase.

Many of the technical challenges in implementing the systems should be addressed early in the development phase for simplifying the installation phase and avoiding additional works and costs. The technical practicability and routines that are necessary during the operation phase also have a large impact on which ICT systems that are applied within monitoring, controlling and visualization.

Sweden

Procurement and technical compatibility

A general barrier in the development phase is the difficulty to have a procurement of monitoring devices that can send and receive signals in compatible ways. Sometimes the devices of different manufacturers are not compatible with each other and in some cases it could be problematic just to order the different equipment during a longer period of time (e.g. some equipment this year and some next year). This is since the devices might be updated and not compatible with what is already procured. These challenges demand a consciousness in the development and product procurement phase. The products might have to be specified in detail and, possibly, the ambitions of the monitoring program must be clarified early on, for ensuring that the equipment and systems can be procured and installed with compatible devices.

Maintaining a consistently good indoor comfort makes control systems complex

In the development and design phase, some technical barriers related to indoor comfort have made impact on the choices of heating systems. For example, it was considered too uncertain out of a comfort perspective (risks for uncomfortably high air-flows) to go for solely air-borne, re-cycled heating in the Malmö Live Residential buildings. This created the solution of both air-borne heating and additional small radiators connected to the district heating system. Maintaining the temperature comfort level around certain temperatures and still avoiding high air-flows thus created a need for more complex systems and investments for more than one heating supply system. This raises the question of which comfort problems that must be solved technically or could be handled by accepting temporarily divergent indoor climate conditions.

Tight building envelope and large window area increase risk for over-temperatures at summer

A significant risk in designing tight heat-efficient building envelopes is over-temperatures at summer, during which the good insulation performance could be a drawback. This problem has occurred within the BuildSmart demos, and especially the Roth demo site has raised the need to enable a good air circulation and preferably possibilities for cross-ventilation [23]. The problem at hand could also be intensified when applying large window areas resulting in a large inlet of solar radiation.

Further technical solutions and key issues in handling these problems have been external solar shading techniques. Solar shading has been described as a key technical possibility, but has in some of the demo cases not been permitted out of architectural concerns by the urban planning office [23]. This pinpoints an important issue of balance between energy efficiency, indoor climate and architectural preferences.

Barriers for individual metering and debiting (IMD) of space heating

A technical and theoretical obstacle for individual metering and debiting (IMD) systems has been widely described in the case of IMD for space heating. Some apartments consume more than others for heating due to their position in the house, making this an obstacle of paying strictly after the individual consumption. Billing systems that instead is based on indoor temperature can be considered fair, but can still be problematic due to that “operative” (or “experienced”) temperature often is considered the important issue for the customer. If an apartment has more cold facade elements (e.g. windows), the experienced (or “operative”) temperature could be lower than for an equally warm apartment with less cold facade elements. A temperature based billing system could also unfairly disfavor apartment households with high internal loads of heat (e.g. many people living in the apartment or many heat transferring electrical devices), since the internal loads in fact decreases the heating demand of this household.

Some smart control systems for thermal energy more difficult to apply in office or residential buildings than in hotels

An additional benefit of controlling systems for *hotels* compared to office or residential buildings is related to the booking systems of hotels, which clearly define when the different rooms are used. This creates opportunity to control the energy use for indoor climate in an efficient way, by reducing ventilation flows and energy for heating or cooling when the room is not booked.

In the Malmö Live Hotel, an energy saving heating and cooling control system is applied where the temperature is allowed to vary significantly when the room is not booked. In winter time, the temperature is allowed to decrease to 14˚C, and correspondingly the temperature is also allowed to increase to 30˚C during summer time. If the room is booked, the temperature is kept between approximately 18 to 25˚C from the day before check-in, and when the person checks in, the temperature is kept between 20 and 23˚C.

These types of controlling systems are not as easy to apply in office or residential buildings, since there is very seldom a booking system (or similar systems) displaying when the spaces will be used. A way towards a solution can be to connect energy control functions with computer systems in which the office employees can register their planned room occupation time.

The operation phase of buildings and building integrated energy generation units is uncertain - monitored data could differ significantly to the calculated

Generally it is hard to predict the energy use of a new building due to uncertainties in e.g. how the building will be operated and in the real technical performance of energy reducing measures and generation units. These general uncertainties and deviations between calculated and monitored results is an obstacle for convincing building owners to invest extra for an energy efficient building with the consideration on expected lower energy costs.

A notable example is the solar thermal panels installed for the Roth Residential building. The generation performance and anticipated profitability has not been as predicted, although the hot water generation increased significantly during an adjustment work period of approximately 2 years after the finalization of the buildings. During 2015 (second year of building operation) the panels reached approximately 61 % of the predicted heat energy generation [16].

Household energy visualisation devices could have a too complex interface and require a high initial interest among the tenants

In the Roth Residential building, a “visualizing device” reminiscent of a tablet or iPod is installed in every apartment visualizing the hot and cold water use, electricity use, heating energy use and how much of the used hot water that is generated by the solar thermal panels.

The feasibility and complexity of applying this technique have mainly been discussed out of the end-user perspective. The discussions have been on a rather general and perceived level by the interviewed stakeholders’ experiences so far during the building operation stage. Foremost, it has been described that a very high initial level of interest by the end-users is a prerequisite for using the visualization info and for altering the energy behaviour. The visualization tools have been described to have a limited impact on the energy use.

Also, it has been denoted that the interface complexity must be kept low for these products for being widely used by tenants, exemplified by that elderly people with a low level of technical interest and knowledge can find it hard to understand and use this type of devices.

Challenging to gather and process large amounts of monitoring data

The installation phase of the monitoring systems includes challenges such as the ability to gather and process all data digitally. In parts of the BuildSmart demonstrations, a lot of time has had to be spent on adjusting signals for the full data to be gathered.

A more detailed and informative system for monitoring data, visualization and control systems includes these more extensive challenges of installing the digital processing and making the signals work, than a project with a lower amount of monitoring data and follow-up. This contributes to the time and costs needed for advanced monitoring and controlling system, and highlights the need for building developers to see long-term benefits in designing an extensive follow-up.

The technical feasability of "Deep Green Cooling" depend on geological characteristics which could be difficult to survey

Deep Green Cooling is the Skanska patent applied at Klipporna for geothermal cooling and heating supply and storage based on cooling water in the buildings of about 20˚C, which is circulated in a rock borehole system to restore the temperature of the cooling water. To restore the temperature balance of the rock heat can be taken out of the rock during the winter. Whether to apply techniques in line with DGC or not depends on a variety of project specific conditions such as the geological characteristics in the specific area and the availability of district cooling in the nearby area. Test drilling for analyzing geological characteristics in geothermal energy storage areas is vital, but include uncertainties no matter how careful it is made, as expressed by the project manager. This makes the installation costs and time plan uncertain, and it is advisable to have a comprehensive plan for possible difficulties and delays.

Spain

Dealing with different energy generation systems and free energy concept management

One of the main challenges that the ICT systems' development had to overcome in the Spanish case was the capacity to manage the different options to energy generation, combining renewable with commercial energy sources. Moreover, special characteristics of the future users of the building (with low incomes profile) demand ICT systems appropriate for ensuring total control of the building facilities taking the best from it at every moment.

Due to these special characteristics, two systems were developed to supply energy: one free of charge, to provide all dwellings with minimum comfort conditions; and another supplementary system to complement the energy supply to users who want to improve their comfort conditions, assuming themselves the economic cost.

Extension of monitoring aim and market delay

Other relevant technical difficulty was the redefinition of the monitoring and control goal which includes not only registration of the necessary parameters to perform control strategies, but also to provide building users with useful information about their energy consumption, to assist energy billing, provide data about building performance to make possible the case replication, etc.

In general, residential buildings in Spain are not provided with such completed monitoring system, therefore in BuildSmart project special effort was made in order to adapt solutions usually used in tertiary sector where ICT systems are more extended to residential sector.

Ensuring technical compatibility and need of flexibility

Lessons learned from BuildSmart experience results in a general recommendation about the importance of monitoring plan. It was essential to define a general monitoring strategy from the beginning of the project in order to ensure compatibility between different devices and control systems later. This monitoring strategy included key parameters to be monitored, main requirements for monitoring equipment such as accuracy, communication protocols and strategy (wireless devices or not), frequency, information channels, etc.

In addition to the above, ICT project had to be technically open and flexible to any possible change in the course of the development phase of the building.

Continuous improvement on ICT technologies

It is necessary to avoid problems because of incompatibilities regard with continuous new advances in ICT field. New included elements had to permit to be adapted to the existing general system.

Installation of a complex wired monitoring system

The process to place the sensors physically, wires, display systems and other auxiliary devices interfered with the construction processes. Extra provision was required in order to facilitate the wiring and to prepare the future positions of the sensors ensuring the accessibility to all of them when necessary.

Complex commissioning phase

The main challenge to overcome during installation phase was to reach the successful integration of all sensors from different suppliers and types, ensure proper connections with acquisition data systems, and ultimately make the system work properly.

Management of different generation system

Maybe the main challenge for monitoring and control systems in Spanish building is the management of the different generation systems installed to provide heating and domestic hot water to the tenants. The control system has to select the most appropriate control strategies in order to make the best use of existing energy sources, and at the same time, provide dwellings with the desired comfort conditions. Especially critical is ensuring correct management of the preheated air coming from the envelope´s passive solutions.

Maintenance requirements, risk of obsolescence.

In order to achieve high performance of the whole building during future years it is required to establish maintenance planning. The system has to be flexible enough to face obsolescence of the equipment and to be readapted to new circumstances (technical or legal conditions).

Need of energy manager

The complexity of the system requires the introduction of professionals specialised in energy management in order to optimize the energy performance of the building. In Spanish residential building energy manager is not very common.

4.2.2.2 Financial barriers

Financial limitations and barriers are highly critical to the decisions made on technical solutions and ICT systems within monitoring, controlling and visualization. Every partial investment is in one way or another evaluated in a profitability perspective by the developer, and future implementation of ICT systems depend on ideas and solutions that can solve the profitability obstacles.

Since the application of advanced ICT systems for monitoring, controlling and visualization make the installation and maintenance costs higher than for “standard solutions”, the economic benefits of the systems must be highly acknowledged by the developers.

Sweden

Costs for advanced indoor climate control must be balanced with energy efficiency and the economic benefits

The development phase of the BuildSmart buildings have been characterized by a balance between comfort requests, design requests and energy efficiency. These balances impact investment amounts and operation costs and are thus of large financial importance. Comfort improving installations often increase both the investment amount and the energy use, while the property value and will-to-pay (WTP) from customers might increase.

Technical solutions for solving comfort issues are often prioritized in Sweden according to the interviewed stakeholders in BuildSmart. One example from BuildSmart is the radiators that have been installed in the Malmö Live Residential Buildings, for increasing the controlling ability for heating and avoiding possible comfort problems from purely air-borne heating. Other “solutions” could instead have been to avoid the highest air-flows and, for the tenants, to adapt to some short periods of lower indoor temperature; or to always maintain the normal temperature and adapt to the higher air-flows.

Effects on individual energy use from investing in IMD is uncertain

A financial barrier of operating systems such as IMD for domestic hot water is that the extra investments compared to a collective metering and billing system will not for certain give a reduced individual energy use. The generally low energy costs in Sweden have been described as an obstacle for making the tenants save energy, despite having an individual bill. As described in the project team interviews, being informed that you as a tenant have consumed energy for 200 SEK this month (approximately 20 EUR) and the "best" apartment has consumed energy for 160 SEK does not have a great impact on the tenant.

Recommendable to settle and procure monitoring systems in one single process

In the development phase, a larger financial effort could be needed to strictly settle and procure the monitoring system in an early stage of the project instead of gradually during the project. This includes resources for investigating the data need, deciding which equipment that is required and making sure that they are compatible with each other. Since the monitoring devices of different manufacturers might not be compatible, it is complex trying to cut the costs by ordering cheapest alternatives for the different devices from different manufacturers or contractors and still make the system function holistically.

There is nevertheless also a risk from procuring a system from a single contractor, which is that it possibly could be only this contractor that can maintain the system during the operation phase. This is e.g. if the system devices are specific for the contractor and not "open" for a replacement of contractor when discontented or when the contractor gets out of business.

These difficulties demands a conscious monitoring procurement process, and the BuildSmart stakeholders and project developers have emphasized the need of high knowledge in the monitoring program design.

Challenging to enable fair distributions of energy costs between customers

The importance of ensuring "fair" energy billing systems has been highlighted by the BuildSmart project team. In buildings used by several organizations or companies it could be of great importance to make clear what energy systems that belong to each of these and which energy use each are responsible for. This can require an extensive energy sub-metering system. The issue is of importance both for a fair distribution of the energy costs and for having clear responsibilities in paying for maintenance and reparation work of the systems.

It has been recommended to deeply consider the use of *one* energy system per paying owner/customer for avoiding the aforementioned problems. A potential financial disadvantage of separated energy systems is that some systems can be operated with more large-scale effectiveness if being common for all building users and thereby larger dimensioned.

Spain

Preconceived notion of budget increase

In general, one of the main barriers that are hindering the integration of smarter, more complex and polifunctional ICT systems in residential buildings in Spain is the potential building´s budget increase. The extra cost is associated with the requirement of skilled personal, costs of ICT devices and software, and required maintenance.

Different figures for investment and payback

In general, in Spain the costs for purchasing and installing ICT systems in a new building are assumed by the promoter while end users benefit from the energy savings achieved due to these ICT systems. This implies that in general it is very difficult for private promoters to think on future benefits and the initial budget is what most influences the choice of solutions.

Energy costs distribution

A future cost-sharing procedure has to be developed from the development phase. One economical challenge for BuildSmart ICT systems in Portugalete Building is related with providing enough information to all stakeholders in order to facilitate the distribution of energy costs, even further considering the idea of free energy for all tenants.

Increase of installation costs

The economic cost of ICT advanced systems is higher than a traditional installation due to the cost of materials, the need of skilled professionals and the required extra previsions.

High economical cost of changes during construction phase

In Portugalete building, some decisions were taken in a late phase of the project which implied changes in physical equipment and monitoring and control systems. These changes increased expected costs.

High maintenance costs

The complexity of the systems causes the maintenance cost to be higher than in average residential buildings in Spain. But at the same time, smart metering allows the users to interactively follow their energy use and understand which actions result in best energy practices. Therefore, ICT systems have a priceless educational value increasing users´ awareness in energy efficiency.

Financial viability variable according to regulation changes

The profitability of some integrated solution is related with regulations. ICT systems have to be open and accessible enough to make the pertinent modifications in case of changes in legal framework.

4.2.2.3 Other barriers

Some ICT system barriers identified in BuildSmart cannot be categorized as ”technical” or ”economic”, and have therefore been summarized under the term “Other barriers” in this deliverable and in D5.3.

The barriers include social needs to spread energy awareness to tenants and the need to standardize ICT solutions for facilitating implementation. Furtherly, the difficulty for companies or organizations to use building energy visualization solutions in an environmental marketing perspective and a general preference for conventional solutions by certain stakeholders have been discussed.

Sweden

Sometimes low interest from tenants towards visualization systems and its impact on energy use uncertain

A significant barrier of visualization systems and IMD systems is a sometimes low interest from the tenants on information about their energy use and the sources of the energy supply. The BuildSmart project team has expressed uncertainty on both whether IMD of domestic hot water really will decrease the energy use compared to a collective billing system, and that the visualization info requires a very high interest from the tenant.

Since the energy costs in Sweden are generally low (as described by the project team), the IMD solutions might have to be built on saving incentives of an environmental perspective rather than a cost saving perspective. It could be hard for tenants to relate to savings in kWh of energy and to see the benefits of these savings. For obtaining the saving incentive, the environmental impact of the choices should be informed in a way that is relatable for the tenant. A potential development discussed in the project team is to direct the information more towards e.g. impacts of having the light bulb turned on or off, impacts of connecting the charger for this certain time period and the difference in impacts of having a 3-minute or 5-minute shower, rather than at savings in kWh. Energy figures could also be translated into an amount of reduced fossil fuel consumption, and energy reductions can be reported as reductions corresponding to e.g. a 10 mile car drive or 10 hot showers.

Difficult to use visualization solutions in a marketing perspective

The BuildSmart project team has described a difficulty for companies or organizations to display environmental awareness through their use of energy efficient buildings. Green vehicles have been described as an easy way to display environmental awareness while the awareness is not as visible through “green buildings”. One tool is to clearly demonstrate the energy and environmental performance on visualization screens, but this information is confined to the actual site. There is also need to build larger understanding for visualized data according to the project team.

Optimization of technical systems in low-energy building might need 1-2 years

A barrier for wide implementation of advanced ICT systems is the amount of time that can be needed to optimize them. According to the BuildSmart project team, optimization of technical systems could require 1-2 year in a modern low-energy building. This impacts both the possibilities to evaluate the technical solutions in an early operation stage and the time needed before dwellings are ready for rental.

Spain

Lack of standardization

In Spain, in general, there is a lack of normalization for most of the ICT systems in residential buildings. The lack of standardization makes the integration process more difficult and a special effort had to be made in order to ensure the correct integration of all solutions.

Social role

ICT systems have to involve building tenants on consumption, ensuring their interest and awareness of energy efficiency and promoting energy savings. Therefore, the display to be installed in each dwelling was designed to be sufficiently attractive, simple and easy to understand.

Planning and coordination of different professionals

Coordination of different professionals is necessary in order to avoid work delays. The installation of certain elements affects other facilities, and time deviations could result in possible delays not only on the affected element, but also on the rest of the construction project. It is important to adjust installation times to make construction work as a whole.

Construction delays due to changes during installation phase

Spanish demo´s initial project suffered changes during installation phase regarding both passive and active energy solutions. These changes also affected to the required ICT systems. Due to these modifications in the construction planning, important delays had to be faced.

Need of social acceptance

Stakeholders are worried about the tenants´ potential negative answer to the general system. The main fear is that users might have doubts about the operation of non-conventional solutions. These doubts might result on continuous complaints to the building owner. It is very important to make training sessions addressed to the inhabitants in order to explain how the building works, the special features and the energy efficiency potential it has. They have to realise how useful the visualization system could be, and how they could take advantage of it.

Preference for conventional solutions vs innovative solutions

Another identified barrier is the general preference for conventional solutions in order to avoid unknown problems with innovative solutions. If these difficulties are not addressed properly, there is a risk of leaving behind the innovative solutions to be substituted by conventional energy systems.

Total dependency on ICT systems

The proper functioning of the building is conditioned by the ICT systems. In case of technical problems or errors, the building will not operate as a whole. It is a challenge to offer a quick response for covering building users' energy demands.

4.3 Cost analysis and effectiveness

In a procurement process it is common to focus on the investment cost. To only focus on the first cost lead to higher total cost. An economic assessment should take into account all the costs of a product or a system throughout its life, from installation until it is out of use. This means accounting for energy and maintenance costs.

An assessment of the installations chosen within the BuildSmart project is currently difficult. The buildings have been in operation for a short period of time. Adjustments of the installed systems have taken place during the measurement period and after the measurement period. It is therefore very difficult to assess cost efficiency at the present time since the performance of the installations have not stabilised yet. Calculating cost-effectiveness is also dependent on future energy prices which are also difficult to predict in a longer perspective.

4.3.1 Building envelope

In the residential building Tenoren the heat losses through the climate screen are reduced by choosing insulation with higher insulation capacity, so called PIR insulation, and low U-window windows. The interviews indicate that the investment in improved insulation is profitable, and the pay-back time is short. The insulation increases the insulated surface area compared to conventional insulation. The Tenoren building is designed to meet the standard for passive houses.

This means that windows with the U-value 0,8 needed to be installed.

The range of windows with the U value 0.8 available on the market is much smaller than for example, windows with U-value 0.9. In general a smaller range translates to a higher price which can affect cost effectiveness.

4.3.2 Geothermal reversible heat pump

The hotel is heated and cooled geothermally. A heat pump extracts heat and cooling, from seventy-five 280 m deep bore holes, during the winter and summer, respectively. The heat pump is not yet fully adjusted. The commissioning process can take several years. Skanska reports that the electric energy use is about twice as high as estimated. The measurements within the BuildSmart project show that 35% more electric energy, on a yearly basis, is used in the conversion (EUM-DE) than estimated. Please note that this measure also includes losses. Furthermore, if individual months are compared both over- and underestimations can be found. More energy than estimated is used from May to August. This indicates that the need for cooling is underestimated. A possible explanation for the low efficiency is that the temperature in ground has not stabilized. However, based on the current measurements, Skanska assesses that the heat pump is underperforming and that the cost efficiency will be lower than expected.

The residential building Finn is equipped with 60 m^2 solar panels used for heating water. The measurements in BuildSmart show that the panels are underperforming. The efficiency of the panels is approximately half of the predicted. This means that the energy consumption and consequently cost of district heating will be higher than estimated.

There have also been problems with adjusting the panels. According to Roth fastigheter, solar panels have not been a profitable investment and have never been possible without external funding. One explanation of the lack of profitability of the panels is that the energy price is currently low in Sweden.

4.3.3 Individual metering and visualisation

In accordance with the energy directive, hot tap water, heat and electricity use is measured in each apartment in the residential buildings. The energy consumption and cost thereof can be followed on information screens in the hallway, on the computer or with a mobile app. The purpose is to make the tenants aware of their energy consumption and promote energy efficient habits and behaviour. The interviews indicate that the cost of individual metering exceeds the savings. The root cause is probably the low energy price. The saving is so low that incentive to change behaviour disappears.

Roth fastigheter invested in developing a visualization app for a device similar to a tablet or iPod installed in each apartment. Their conclusion is that it is more cost efficient to use a web page to visualize the tenants' energy consumption. The argument is that the technology development of hand held devices is so fast that maintenance cost increases and the chosen solution become outdated.

4.4 Evaluation of the indoor environment

One task in the BuildSmart project is to evaluate the tenants/residents experience of the indoor environment (thermal environment, air quality, sound and light) in a very low-energy house. Questionnaires have been developed to fulfil this task, one for residential (Appendix B) and non-residential buildings (Appendix C), respectively. Questionnaires were distributed to the residents/tenants one year after the building was commissioned.

Please note that no questionnaire has been distributed to the tenants of Portogalete and Tenoren. This is because the time of operation is less than the required one year at the time of compiling this report. Questionnaires have been sent to the other demo sites. The response rate has been very low for Sopranen and the hotel, two and zero responses, respectively. This is too few to draw any conclusions. The residents of Finn and the tenants of Klipporna have given a sufficient foundation for analysis. The responses show that the users of the buildings are content with the thermal comfort (Figure 35 and Figure 36), air quality (Figure 37 and Figure 38) and sound environment (Figure 39 and Figure 40). The only negative aspect found in the survey is that residential buildings can have problems with to hot indoor temperatures during the summer.

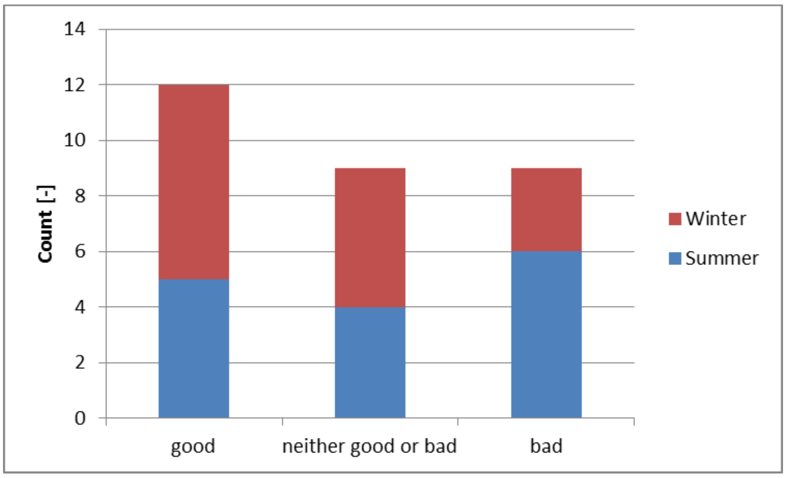


Figure 35 Thermal comfort, for residential buildings.

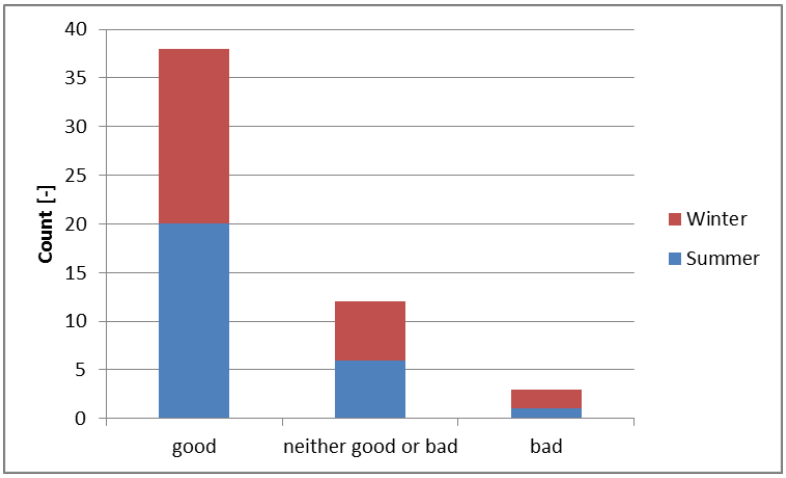


Figure 36 Thermal comfort, for non-residential buildings.

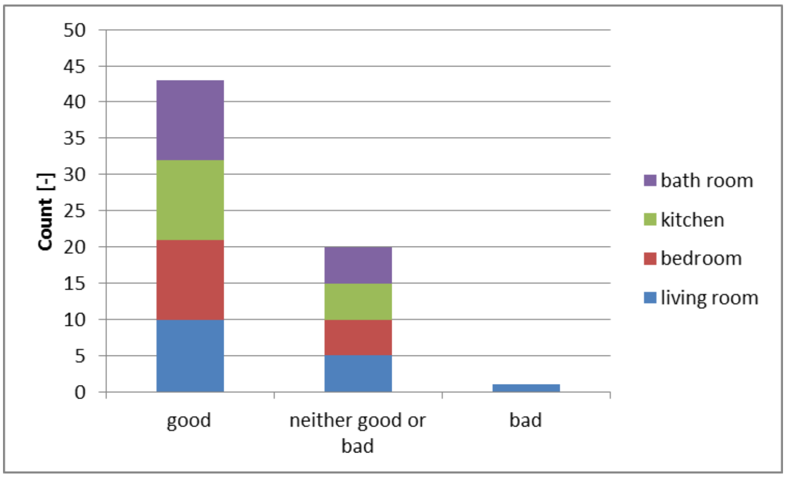


Figure 37 Air quality, for residential buildings.

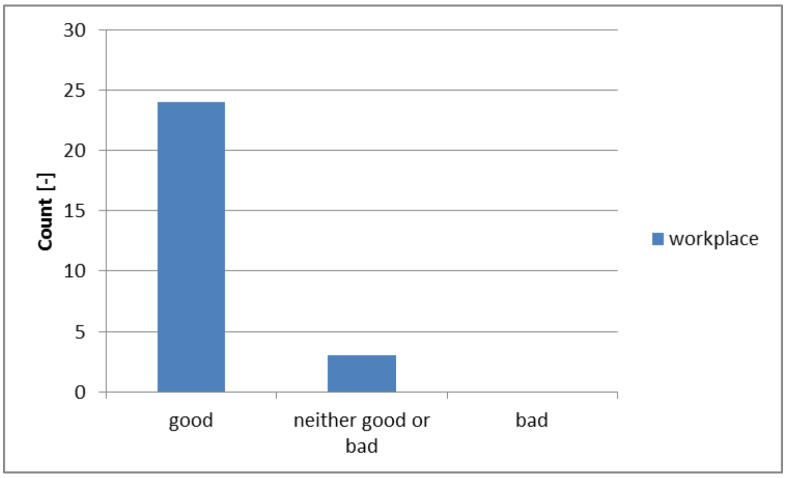


Figure 38 Air quality, for non-residential buildings.

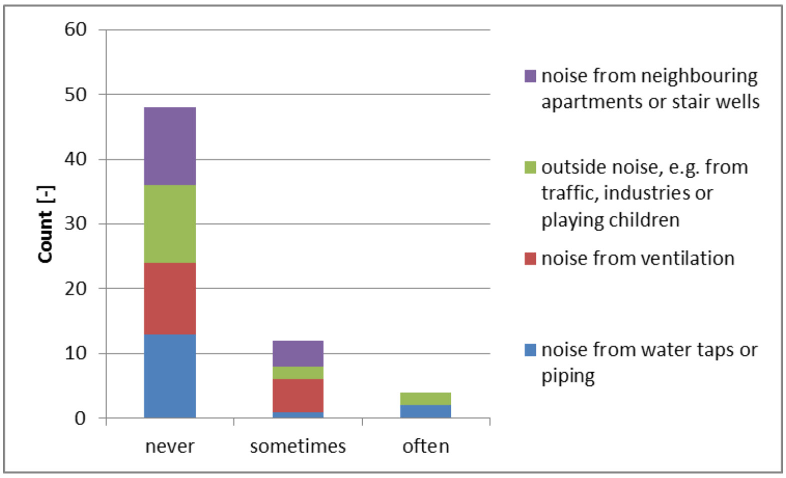


Figure 39 Noise, for residential buildings.

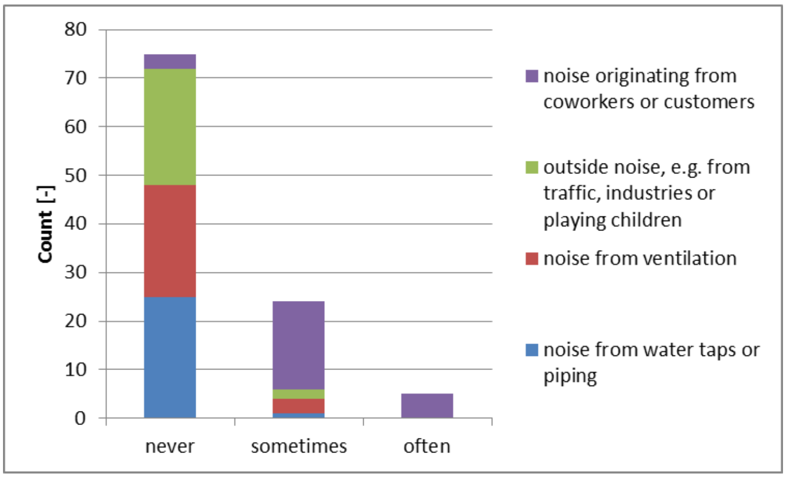


Figure 40 Noise, for non-residential buildings.

How a person reacts to the indoor environment is influenced by many factors. It is seldom possible to distinguish the psychological and physiological factors [24].The possibility to influence the situation is important to the human experience and well-being. If the residents, for example, can open their windows to improve air quality or lower the temperature affects the experience of the indoor climate positively. This applies regardless of whether the measure will lead to an improvement or worsening of the climate [25].

5 References

[1] European commission, “Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. On resource efficiency opportunities in the building sector”, COM(2014) 445 final, Brussels, 1/7-2014.

[2] European commission, “Europe 2020: A strategy for smart, sustainable and inclusive growth“, COM(2010) 2020 final.

[3] EPDB II, "om byggnaders energiprestanda (omarbetning)", Europaparlamentets och rådets direktiv 2010/31/EU, 19/5-2010, Europeiska unionens officiella tidning 18/6-2010, L 153/13-35.

[4] Jacob Lindblom, Ivana Kildsgaard, Johanna Andersson, Víctor Sánchez Zabala and Joe Hayden, “D5.2. Specification of the monitoring systems for two building types”, Report “BuildSmart – Energy efficient solutions read for the market”, 7th framework programme, 2012.

[5] Roland Zinkernagel (Ed.), “BuildSmart – energy efficient solutions ready for the market”, Annex I – “Description of Work”, 7th energy programme, 2011-10-28.

[6] http://www.skanska.se/sv/projekt/projekt/?pid=7365, 2016-11-21

[7] http://byggfakta.today/vilket-hus-blir-arets-basta-bostad-103987/nyhet.html, 2016-11-21

[8] https://www.malmokongressbyra.se/svenska_thoraxmotet/konferensanlaggning, 2016-11-25

[9] http://www.skanska.se/sv/projekt/projekt/?pid=8721, 2016-12-05

[10] Chair of Sustainable Management of Housing & Real Estate (ÖÖW), Institute for Technology Assessment and Systems Analysis (ITAS), French-German Institute for Environmental Research (DFIU), Renewable Energies Program (EE), Building Science Group (FBTA), “Evaluation of (Smart) Solutions –Guidebook for Assessment Part I –Methodology, CONCERTO Premium, Karlsruhe Institute of Technology, Karlsruhe, Germany, November 2013.

[11] http://smartcities-infosystem.eu/concerto/concerto-archive, 2016-10-31.

[12] Carolina Lijenström, Tove Malmqvist, Martin Erlandsson, Johanna Fredén, Ida Adolfsson och Gustav Larsson, ”Byggproduktionens miljöpåverkan i förhållande till driften. Livscykelberäkning av klimatpåverkan och energianvändning av ett nyproducerat flerbostadshus i beting med lågenergiprofil”, IVL Rapport C32, ISBN 978-91-7595-218-5.

[13] Gunnel Forslund, Jan Forslund, ”Bästa inneklimat till lägsta energikostnad.”, AB Svensk byggtjänst, 2016, ISBN 978-91-7333-768-7.

[14] Boverkets Författningssamling BFS 2014:3 BBR 21, 2014-06-17.

[15] Ingela Qvirist (red), “Utvecklingsprojekt brukarrelaterad energianvändning. Räkna på brukarbeteendet- klimatet är bortisolerat”, s. 18, Lågan – för energieffektiva byggnader, www.laganbygg.se

[16] Carolina Faraguna, “D5.4. Individual reports on the monitoring results. Residential building – Finn.”

[17] Carolina Faraguna, “D5.4. Individual reports on the monitoring results. Residential building – Sopranen.

[18] Carolina Faraguna, “D5.4. Individual reports on the monitoring results. Residential building – Tenoren.”

[19] Carolina Faraguna, “D5.4. Individual reports on the monitoring results. Non-residential – hotel Malmö Live.”

[20] Carolina Faraguna, “D5.4. Individual reports on the monitoring results. Non-residential – Klipporna.”

[21] Jenny Gode, Fredrik Martinsson, Linus Hagberg, Andreas Öman, Jonas Höglund, David Palm ”Miljöfaktaboken 2011. Estimated emission factors for fuels, electricity, heat and transport in Sweden”, VÄRMEFORSK Service AB, 2011, ISSN 1653-1248.

[22] Camilla Mörn, Rasmus Andersson, Ida Adolfsson, Victor Sanchez Zabala and Olga Macías “D5.3. Observed challenges and obstacles during development, installation, and operational stages of advanced ICT Systems.”

[23] Camilla Mörn, Rasmus Andersson, Ida Adolfsson, Elizabeth Rodríguez Rodríguez, Nuria Gallego Salvador, “D4.3. Exploitation and market deployment plan after project is finished.”

[24] Johnny Kellner och Göran Stålbom. ”Byggande och miljö – Om hälsa, välbefinnande och hållbar utveckling”, Byggförlaget, 2001. ISBN 91-7988-208-0.

[25] Ragnar Hjertén, Ingemar Mattson och Helena Westholm, ”Som man bygger får man ventilera. Om arkitektur och inomhusklimat”, Arkus, 1996.

Appendix A Questions for interviews

Questionnaire:	**1**
Phase:	**Planning and design phase**
Target group:	**Project team and property owner**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Which were the driving forces (price, energy performance, market availability, company rules, maintenance etc.) for the final selection of building design elements and technical systems solutions? Construction and technical systems included are listed below. Choose appropriate for interviewee.

- Building envelop
- Installations - heating system
- Installations - cooling system
- Installations - ventilation system
- Installations – DHW
- Installations - renewable energy
- Installations - non-renewable local energy
- Installations - lighting systems
- Installations - Building Automation System (BAS, BMS, BEMS, etc.)
- Measurement systems and measuring equipment

To what extent did the property owner / you to participate in decision regarding the choice of construction elements and technical systems?

How much have energy targets and simulations guided the choice of construction elements and technical systems?

Have you considered alternative solutions for the construction and technical systems? If yes, why did you choose not to go ahead with these solutions?

Could anything have been done better regarding design and energy performance?

Have you been involved in developing the strategy for measuring and monitoring the building's energy performance?

Who is responsible for monitoring and evaluation of the building's energy performance?

Do you have any plan / checklist / template for how the building's energy performance will be evaluated?

Do you plan to follow up on the building’s energy performance in the future, i.e. after the project has finished?

Questionnaire: **2**

Phase: **Construction Phase**

Target group: **Project team and entrepreneur**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Have there been any problems with the installation of the planned technical systems? If yes, please state the problem and what has been done to fix it. Technical systems included are listed below. Choose appropriate for interviewee.

- Building envelope
- Installations - heating system
- Installations - cooling system
- Installations - ventilation system
- Installations – DHW
- Installations - renewable energy
- Installations - non-renewable local energy
- Installations - lighting systems
- Installations - Building Automation System (BAS, BMS, BEMS, etc.)
- Measurement systems and measuring equipment

Have there been any problems with the purchase of the technical systems?

Were there any obstacles for implementing the options you defined in the design stage?

Have there been any significant changes to the structural building system or the building envelope?

Has the air tightness of building envelope been measured?

Are you satisfied with the outcome so far?

Is there anything that could have been done differently or better?

How has the cooperation worked in the project during the construction phase? Is there something different compared to other projects?

Do you have other experiences from the project's construction phase that you can share?

Questionnaire: **3**

Phase: **Construction Phase**

Target group: **Property owner**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Were there any obstacles for implementing the options you defined in the design stage?

Did high cost have an influence on your choices and lead to compromises in your efforts to achieve the wanted energy performance?

Have there been any significant changes to the structural building system or the building envelope?

Have there been any problems with the purchase or installation of the planned technical systems (facilities and systems)?

Are you satisfied with the outcome so far?

Is there anything that could have been done differently or better?

How has the cooperation worked in the project during the construction phase? Is there something different compared to other projects?

Do you have other experiences from the project's construction phase that you can share?

Questionnaire: **4**

Phase: **Commissioning**

Target group: **Project team and contractor**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Have the technical systems worked as intended?

Have you conducted any system adjustments, improvements and/or changes?

Have there been any problems during commissioning of the planned technical systems? If yes, please state the problem and what has been done to fix it.

Have the monitoring systems worked as intended?

Have you conducted any adjustments, improvements and/or changes to the monitoring system?

Has the owner of the building received training or instructions regarding the future use, monitoring and further development of the installed systems?

Questionnaire: **5**

Phase: **Operation**

Target group: **Contractor**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Have the technical systems worked as intended?

Have you conducted any system adjustments, improvements and/or changes?

Have the systems malfunctioned?

Do you have any suggestions for improvements?

Have the monitoring systems worked as intended?

Has the monitoring strategy changed during the operational phase?

Have you and/or others in your organization received information and training on how to use the technical systems?

Questionnaire:	**6**
Phase:	**Operation**
Target group:	**Property owner**

What is your role in the project?

How does your decision-making process work and how much influence do you have in it?

Have the technical systems worked as intended?

Have you conducted any system adjustments, improvements and / or changes?

Have the systems malfunctioned?

Have you and/or others in your organization received training and information on how to use the installed technical systems?

With the focus on energy performance; how has the cooperation between the project team and the contractor worked?

Will you recommend the chosen solution for future projects?

Do you have any suggestions for improvements?

Is there a solution (that would improve the energy performance) that could not be used in this project that you would like to see in future projects?

Is there anything you think is relevant and important to the building's performance, which has not been discussed or implemented in this project?

What are your energy targets? Will you use the same goals, or are you going to modify them in future projects?

Have you been involved in developing the strategy for measuring and monitoring the building's energy performance?

Is the responsibility for monitoring and evaluation of the building's energy performance clearly defined?

Have you and/or others in your organization received information and training on how to use the monitoring systems?

Do you feel that you have got the correct / relevant information from the project group, the developer and the contractor regarding your responsibilities and how to evaluate the energy performance of the building?

Do you plan to follow up on the building’s energy performance in the future, i.e. after the project has finished?

Is there any particular knowledge gained during this project that you will take with you and utilize in future projects?

Appendix B Questionnaire for residential building

Background Questions

How big is your apartment?

1 bedroom apartment □

2 rooms apartment □

3 rooms apartment □

4 rooms apartment □

5 rooms apartment □

6 rooms apartment □

7 rooms apartment or larger □

On what floor is your apartment on?

Ground floor □

1st floor □

2nd floor □

3rd floor □

4th floor □

How many people, including yourself, live in the apartment?

__ adults

__ children aged 0 – 6 years

__ children aged 7 – 17 years

How old are you?

24 or younger □

25-34 years □

35-44 years □

45-54 years □

55-64 years □

65 or older □

How long have you lived in the apartment?

less than 1 year □

more than 1 year □

THERMAL CLIMATE

How do you rate the temperature in the rooms of the apartment during the winter?

	too cold	neutral	too warm
kitchen	◻	◻	◻
bedroom	◻	◻	◻
living room	◻	◻	◻
bath room	◻	◻	◻

How do you rate the temperature in the rooms of the apartment during the summer?

	too cold	neutral	too warm
kitchen	◻	◻	◻
bedroom	◻	◻	◻
living room	◻	◻	◻
bath room	◻	◻	◻

Do you think that the heating system in the apartment allows you to influence the temperature?

no ◻

yes ◻

Do you think the temperature, in the apartment, varies due to changes in the outdoor temperature?

◻ No, rarely or never

◻ Yes sometimes

◻	Yes, often

Do you think your apartment has ...?

	no	yes	no opinion
cold floors	◻	◻	◻
cold walls	◻	◻	◻

Are you troubled by draft in any room? Please check the boxes that apply. Several boxes can be checked.

	not troubled	troubled by draft at				
	by draft	floor	door	window	balcony door	valve
kitchen	◻	◻	◻	◻	◻	◻
bedroom	◻	◻	◻	◻	◻	◻
living room	◻	◻	◻	◻	◻	◻
bath room	◻	◻	◻	◻	◻	◻

Overall, how do you assess the thermal comfort in your apartment during the ...?

	good	neither good or bad	bad
summer	◻	◻	◻
winter	◻	◻	◻

AIR QUALITY

How do you feel that the air is in your apartment?

Is the air dry or humid?

dry	neither	humid
☐	☐	☐

Is the air clean or dusty?

clean	neither	dusty
☐	☐	☐

Is the air fresh or stale?

fresh	neither	stale
☐	☐	☐

Highlight to what extent you agree with the following statements.

	disagree	partly agree	agree	no opinion
condensation appear on windows by cooking	☐	☐	☐	☐
it takes long time for towels to dry in the bathroom	☐	☐	☐	☐
condensation appears in between windows	☐	☐	☐	☐
condensation appears on the inside of windows	☐	☐	☐	☐

Own cooking smells spread in the apartment	□	□	□	□
I can smell cooking smells from neighbouring apartments or stairwells	□	□	□	□
I smell odours from the neighbouring apartments or stairwells	□	□	□	□
I am bothered by odours from the outside	□	□	□	□

Do you feel you can influence the air quality in the apartment with the ventilation system?

□	yes
□	no

How often do you clean .....?

	every month	1/half year	1/year	not done
exhaust air unit in the kitchen	□	□	□	□
grease filter in the cooker hood /fan	□	□	□	□
exhaust air unit in bathroom	□	□	□	□

How often do you air the apartment during the heating season (i.e. september - april)?

daily/almost every day	□
approximately once a week	□
about once a month	□
rarely or never	□

How do you air?

window is open all day / night	◻
open window a few hours	◻
cross draft in a few minutes	◻

Overall, how would you rate the air quality in your apartment?

	good	neither good or bad	bad
kitchen	◻	◻	◻
bedroom	◻	◻	◻
living room	◻	◻	◻
bath room	◻	◻	◻

NOISE AND LIGHT

Are you bothered by disturbing noise in your apartment?

	never	sometimes	often
noise from water taps or piping	□	□	□
noise from ventilation	□	□	□
outside noise, e.g. from traffic, industries or playing children	□	□	□
noise from neighbouring apartments or stair wells	□	□	□

Do you feel that your apartment is quiet or noisy?

quiet	neither quiet or noisy	noisy
□	□	□

Do you think your apartment is light or dark?

too light	just right	too dark
□	□	□

Do you think you get enough sunlight in the apartment during the ....?

	too much	enough	too little
winter	□	□	□
summer	□	□	□

Appendix C Questionnaire for non-residential building

BACKGROUND QUESTIONS

Do you have a fixed workplace?

yes ◻

no ◻

If you have a fixed workplace, on what floor is your work place located?

Ground floor ◻

1st floor ◻

2nd floor ◻

3rd floor ◻

4th floor ◻

5th floor ◻

6th floor or higher ◻

How old are you?

24 or younger ◻

25-34 years ◻

35-44 years ◻

45-54 years ◻

55-64 years ◻

65 or older ◻

For how long have you been working in the building?

less than 1 year □

more than 1 year □

THERMAL CLIMATE

How do rate the temperature at your work place during the …?

	cold	just right	hot
summer	◻	◻	◻
winter	◻	◻	◻

Do you think that the heating system in the building allows you to influence the temperature?

yes ◻

no ◻

Do you find that the temperature at your work place varies due to temperature changes outside?

◻ no, seldom or never

◻ yes sometimes

◻ yes, often

Are you troubled by draft?

yes ◻

no ◻

If you are troubled by draft, please specify the origin. Multiple boxes can be checked.

troubled by draft at window	□
troubled by draft at floor	□
troubled by draft at valve	□

Overall, how do you assess the thermal comfort at your work place during the ...?

	good	neither good or bad	bad
summer	□	□	□
winter	□	□	□

AIR QUALITY

How do you feel that the air is at your work place?

Is the air dry or humid?

dry	neither	humid
☐	☐	☐

Is the air clean or dusty?

clean	neither	dusty
☐	☐	☐

Is the air fresh or stale?

fresh	neither	stale
☐	☐	☐

Overall, how would you rate the air quality at your work place

good	neither good or bad	bad
☐	☐	☐

NOISE AND LIGHT

Are you troubled by disturbing noise at your work space?

	never	sometimes	often
noise from water taps or piping	□	□	□
noise from ventilation	□	□	□
outside noise, e.g. from traffic,	□	□	□
industries or playing children	□	□	□
originating from coworkers or customers	□	□	□

Do you find your work place quiet or noisy

quiet	neither quiet or noisy	noisy
□	□	□

Do you find your work place light or dark?

too light	moderately/just right	too dark
□	□	□

Do you think you get enough sunlight at your work place during the ....?

	too much	enough	too little
winter	□	□	□
summer	□	□	□

BUILDSMART

Energy efficient solutions ready for market

www.buildsmart-energy.eu

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no ENER/FP7/285091/BUILDSMART

Malmö stad SKANSKA ROTH ivl WSP EUSKO JAURLARITZA GOBIERNO VASCO tecnalia Inspiring Business FCC codema Dublin's Energy Agency