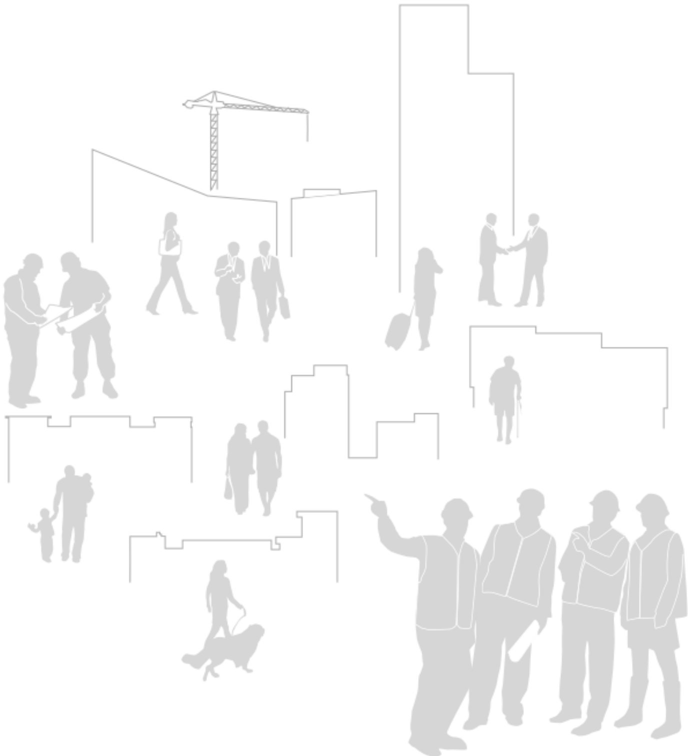
SEVENTH FRAMEWORK PROGRAMME

BUILDSMART

Energy efficient solutions ready for market



“Description of completed construction

May 2016

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Dissemination level	
X	PU = **Public**
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Document history			
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Summary

This deliverable provides the description of the final construction of the Buildsmart residential demo buildings:

- Skanska Residential Building, in the KKH area in Malmö
- Roth Residential Building in Hyllie, Malmö
- Residential building (G.V.) in Portugalete, Basque Country

The description is focused on:

- Description of the implemented final constructive solutions
- Graphic depiction of the final constructions
- Modifications introduced during the construction process on each demo building
- Description of the technical barriers found during the construction process and the solutions implemented to overcome them

Contents

Nomenclature

Symbols

U	U-value, thermal transmitance [W/(m^{2}K)]
λ	thermal conductivity, [W/mK]

Abbreviation

AHU	Air handling unit
CHP	Combined heat and power
DHW	Domestic hot water
DSH	Distributed space heating
DHM	District heating meter
EUM	Electricity utility meter
EXC	Excluded energy
GPRS	General packet radio service
GSM	Global system for mobile communications
HVAC	Heating, ventilation and air conditioning system
HW	Hot water
IAQ	Indoor air quality
IDHW	Individual domestic hot water
IE	Individual electricity
IR	Infrared radiation
LAN	Local area network
LC	Local climate
LED	Light-emitting diode
PIR	Polyisocyanurate

PLC	Programmable logic controller
PV	Photovoltaics
RES	Renewable energy sources

Swedish Construction glossary

Building elements

INSIDA	Inside
UTSIDA	Outside
MARK	Ground
SOCKEL	Base
BOSTAD	Dwelling
HISS	Lift
SCHAKT	Lift shaft
TRAPPHUS	Stair shaft

Partitions and closures

YTTERVÄGGAR	Exterior walls
BJÄLKLAG OVAN	Ceiling
KÄLLARGOLV	Basement floor
KÄLLARVÄGGAR	Basement walls
LOKAL	Local
MELLANBJÄLKLAG	Intermediate floors
MELLANVÄGGAR	Partitions
MILJÖRUM	Environmental rooms
PLATTA PÅ MARK	Ground floor

Contruction materials

ARMERAT BRUK/FLYTSPACKEL	Reinforced concrete / screed
BETONG	Concrete
CELLPLAST	Foam
DRÄN-ISOLERING	Drain-insulation
FIBERCEMENTSKIVA	Fiber Cement board
FINGERSPALT	Mortar
FUKTSKYDDSSKIKT	Moisture protection layer
GIPS	Plaster
HELBESLAGNING	Protection cover
ISOLERING	Insulation
LÄKT	Lath
LUFTSPALT	Air gap
MINERITSKIVA	Mineral insulation board
OORGANISK ARMERAD PUTS	Non-organic reinforced plaster
OORGANISK ARMERAD SOCKELPUTS	Non-organic reinforced base plaster

OSB-SKIVA	Osb
PLYWOOD	Plywood
RASPONT	Tongue and groove panel
REGEL	Beam
REGLAR/MINERALULLS-ISOLERING ÅNGSPÄRR	Mineral wool insulation vapor barrier
SKALMURSSKIVA	Mineral wool insulation board
SKIVA	Board
SKYDDSBESLAG	Protection coating
SNEDSÅGAD REGEL	Inclined beam
TAKBOARDSSKIVA FALLDILAR	Mineral wool roofing board
TÄTSKIKTSMATTA	Waterproof layer
TEGEL	Brick
TJOCKPUTSSKIVA	Thick plaster board
VINDSKYDDSSKIVA	Sheathing board
VKR STOMME	VKR profile
YTSKIKT	Surface finish

1 Introduction

The objective of the Buildsmart project is to demonstrate innovative and cost effective techniques and methods for constructing very low energy buildings in various climates.

Two countries, Sweden and Spain, participate in the project and represent different European climatic zones. The residential demo buildings described in this deliverable have allowed the demonstration of new and innovative techniques applied to the residential sector.

A systematic approach has been taken in the measures applied to reduce energy use and environmental impact of the demonstrated buildings. Techniques for creating airtight building envelopes have been combined with different kinds of energy efficient installations. Final constructions are characterized by:

- A very low total energy consumption
- Airtight, highly insulated envelopes in order to create a high air tightness and low energy losses
- Energy efficient installations to minimize energy use
- Heat recovery systems
- A high degree of renewable energy production either at the building or in the vicinity
- Close connections to surrounding infrastructures as energy systems optimizing energy use and reducing peak loads
- Waste management systems created for maximum recycling and energy recovery
- New combinations of existing and tested technologies to show cost effectiveness and a high replication potential.

In the following chapters an accurate description of the final construction of each of the demo buildings is provided. For each of the demo building specific subchapters have been included to describe the architectonic aspects and the systems finally deployed in the buildings.

Special attention is given to the description of the changes introduced in the construction phase of each building in relation to the solutions defined in the construction projects.

2 Skanska Residential Building, in the KKH area in Malmö

2.1. Introduction

This building is located in the KKH area in Malmö, within walking distance from the Central Station and the new City Tunnel station, between the old city center and the new modern district of the West Harbour. The gross floor area is 16,000 square meters, North building with 7,500 and South building with 8,500.

The northern building refers to 72 apartments and 5 facilities. The building has a broader base of five floors and a tower on top with thirteen floors and a basement and will be completed in April 2016.

The southern house relates to 86 apartments and 4 facilities. The house is projected as a building with three assembled buildings with five, eight and fourteen floors with a joint basement.

2.2. Thermal envelope

North building:

- 190 mm PIR insulation – λ-value 0.023W/mK
- Sandwich 120 mm concrete + PIR = λ-value 0.151 W/mK

Figure 1: Construction phase

Difficulties: Careful work with maintaining the air tightness of the insulation. Insulation can be easily damaged during transport and construction.

The design goal for air tightness was to meet the requirements of the position FEBY 12. The air tightness testing has been carried out in accordance with EN 13829 Dry-IT AB.

The average air density of four (5%) tested apartments was 0.28 $l/s/m^2$ when air leakage compared to the buildings envelope. Then the average air leakage compared to the total area encircling the building is 0.08 $l/s/m^2$.

South building:

- 200 mm cellular plastic Sandwich (λ 0.031), 50 mm mineral wool (λ 0.037)
- Sandwich 150 mm concrete + insulation = λ-value 0.114 W/mK

Figure 2: South mineral wool and cellular insulation

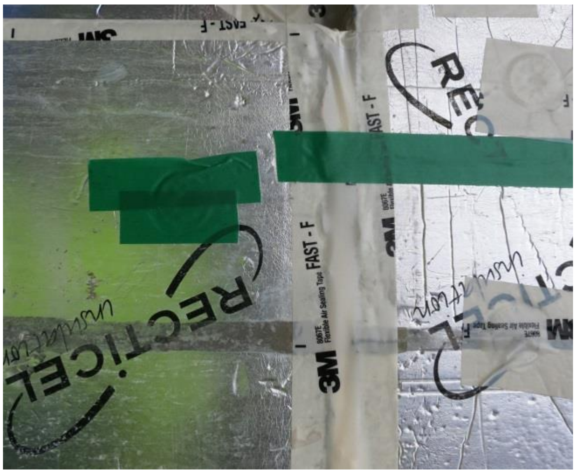
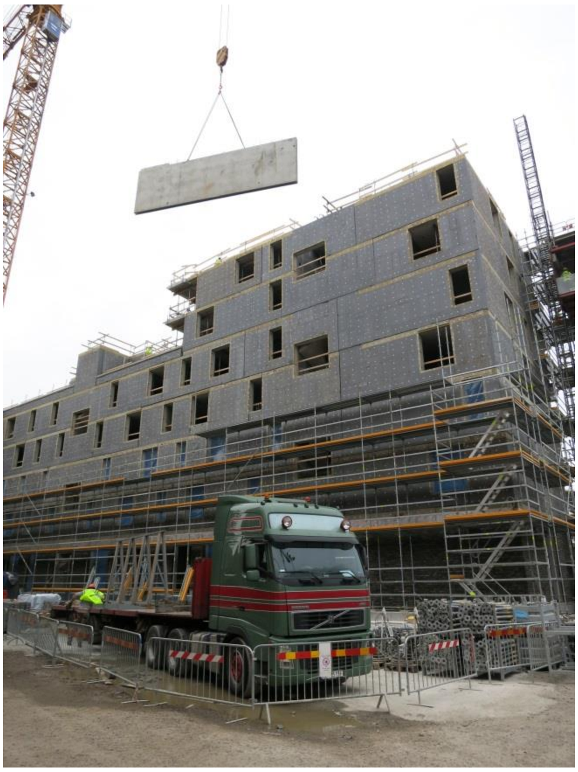
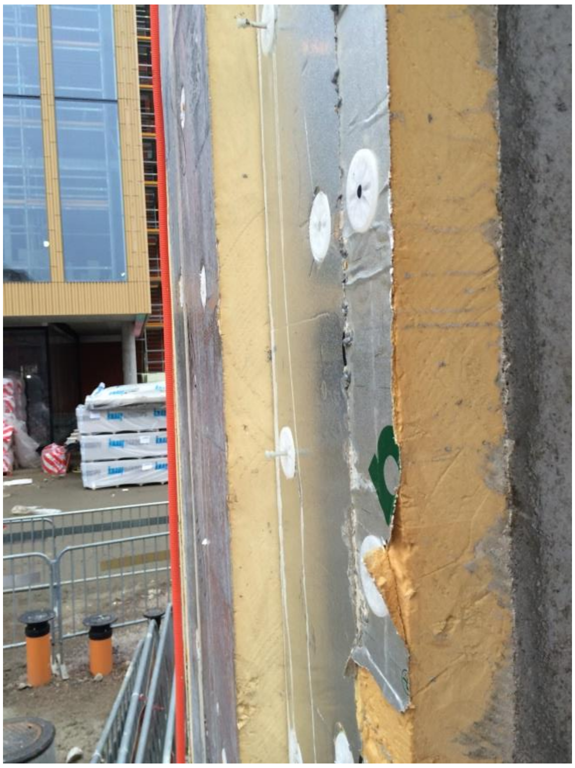


Figure 3: North PIR insulation





Air Pressure testing showed airtightness of the south building to 0.19 l / s/m².

Therefore, airtightness design goal is fulfilled since both buildings comply with the requirements of the position FEBY 12 (maximum air leakage of 0.30 l/s/m² compared to total area encircling the building at different pressure of 50Pa).

Listed leakage/difficulties for both building:

- Minor leakage between the balcony door and the light window in an apartment.
- Small leak at the floor angle to the balcony door.
- between the threshold and the "door leaf" at the balcony doors (three-door)
- At drywall in the entrance door to the stairwell.
- At pipe penetrations in the basement.
- Large leakage around the steel doors (entrance doors to the stairwells and basements).
- At the drywall in electricity shafts.
- between the frame and sash on the window's room

Internal air leakage was noted through the casing of the incoming water pipe.

Figure 4: leakage found in the incoming water, under balcony door and under window.

The found leakage areas were sealed, and the experience is used in the rest of the houses.

2.2.1. Facades

<u>North building</u>

Bricks (Concrete, PIR, Bricks,) 450 mm total thickness

Energy calculation for the specific facade element U-value 0.168 W/mK

<u>South building</u>

Plaster (Concrete, foam, mineral wool, Plaster) 460/430 total thickness

Energy calculation for the specific facade element U-value 0.144 W/mK

Figure 5: General view of the building

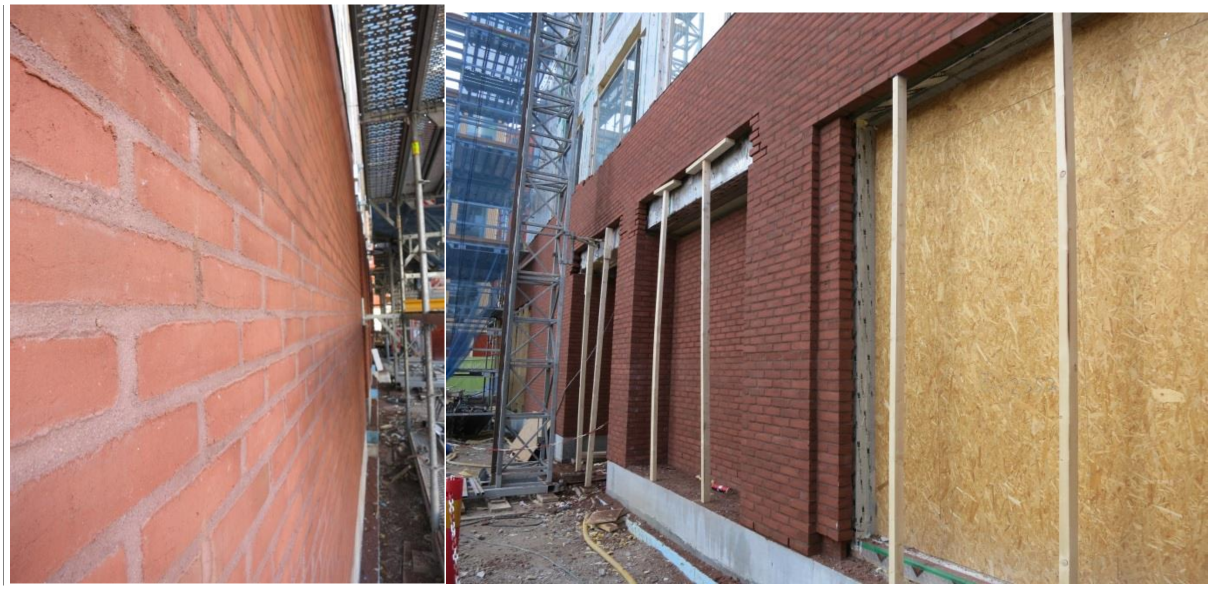


Figure 6: Facade execution

2.2.2. Glazing

Windows with U-value approximately 0.8 W/(m2K).

The ratio of glass to solid wall for each building is:

- North building: 36 %
- South building: 36,5 %

Noise reduction Rw up to 48dB, north building Skaala and in the south, Domlux, both 2+2 windows.

Figure 7: Detail of the one of the window of the building

Difficulties: it was a few manufacturers that could cope with the high technical demands; both noise reduction and high insulation.

2.2.3. Assemblies

Prefabricated concrete walls with the joist between are installed and molded on site.

Figure 8: assembly of the north building

Figure 9: floors with installations that are concreted on site

2.2.4. Roofs

North building is to be completed during April 2016. Roof terraces and sedum roofs.

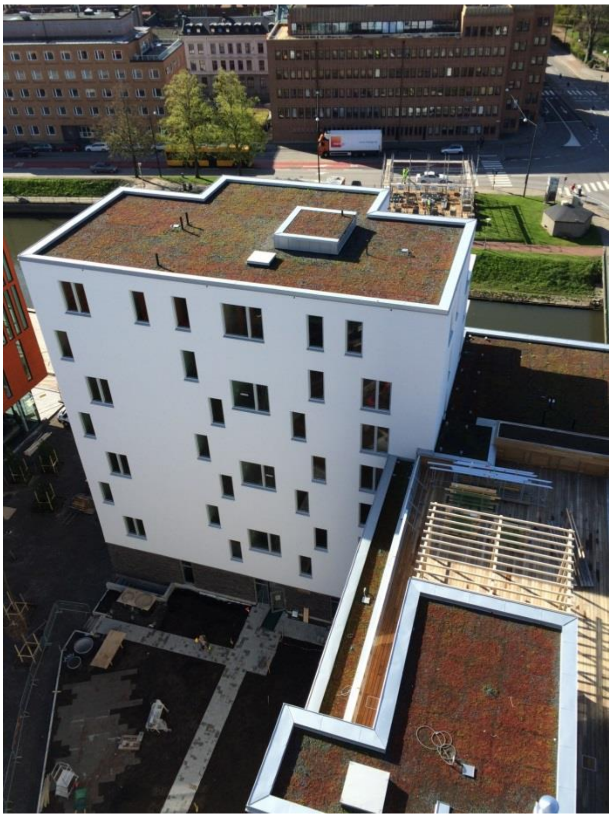
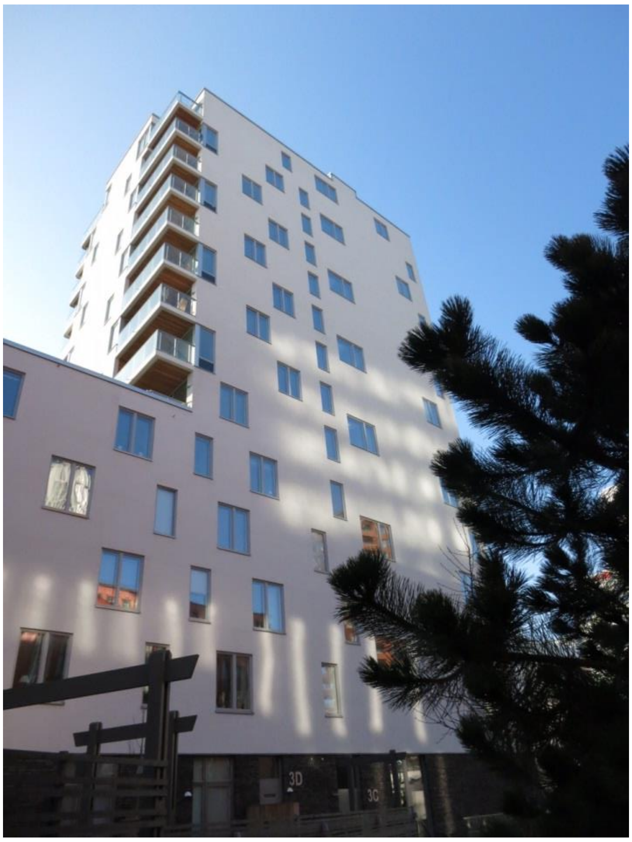


Figure 10: South building with sedum roof and terrace.

2.2.5. Final building

Figure 11: North building



2.3. Energy Technologies

2.3.1. Lighting and electric equipment

Lighting in the entrance hall, post room and elevator halls, is controlled through movement detection strategies implemented through the deployment of IR presence detectors. The basement and the garbage room are also included in the area covered by the presence detection based lighting control system. In order to reduce lighting electricity consumption LED lighting has been the prevalent technology.

In accordance with the followed sustainability criteria, all electric wires of the electric distribution system of the building are halogen free.

2.3.2. HVAC equipment

2.3.2.1. Heating. District heating

The building is connected through a heating substation to the district heating system of the city of Malmö.

The substation incorporates all the elements (heat exchangers, etc) and the integrated control necessary to supply the building with all the required services at the required conditions (radiator system, domestic hot water system and mechanical ventilation air pre-heating coils).

2.3.2.2. Ventilation - Heating system

The base heating of the apartments is solved with preheated ventilation to each apartment through air handling units equipped with heating coils. The ventilation is designed to heat the apartments to 21 degrees.

A conventional hot water radiator system allows the residents to regulate the heat delivery to each apartment to adjust the temperature to their specific comfort criteria. The radiator systems receive the hot water supply from the building substation located in the basement. This is due to Swedish regulation, the house can provide enough heat without this secondary system.

The mechanical ventilation system of the building is formed by AHUs and their supply and return duct networks. The AHUs are equipped with high efficiency heat recovery devices providing sensible heat recovery efficiencies above 80% (FTX-system).

At apartment level, intake air is supplied in living rooms and bedrooms, whereas exhaust air is evacuated from kitchen, bathrooms, toilets, closet and storage rooms.

The AHU-room of the northern building is located in the basement and the shafts placed on the stairwell positioned at key places to enable ventilation delivery to all the required zones. Two AHUs, have been installed, the first one dedicated to basements and stairwells, whereas the second one solves the ventilation of the apartments of the northern part of the building.

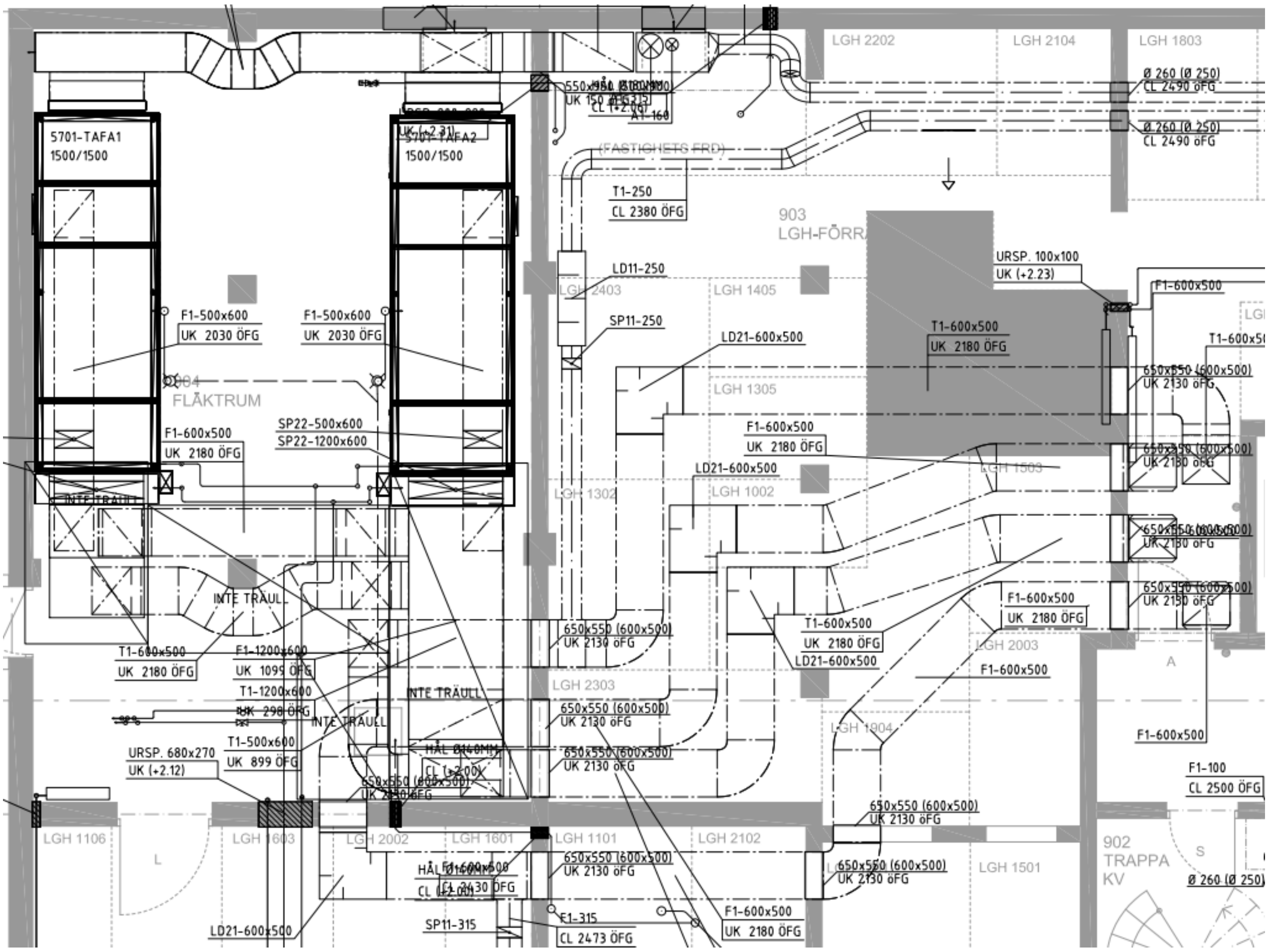


Figure 12: AHU-room in the basement of the North building

Figure 13: AHU-room in the basement of the South building

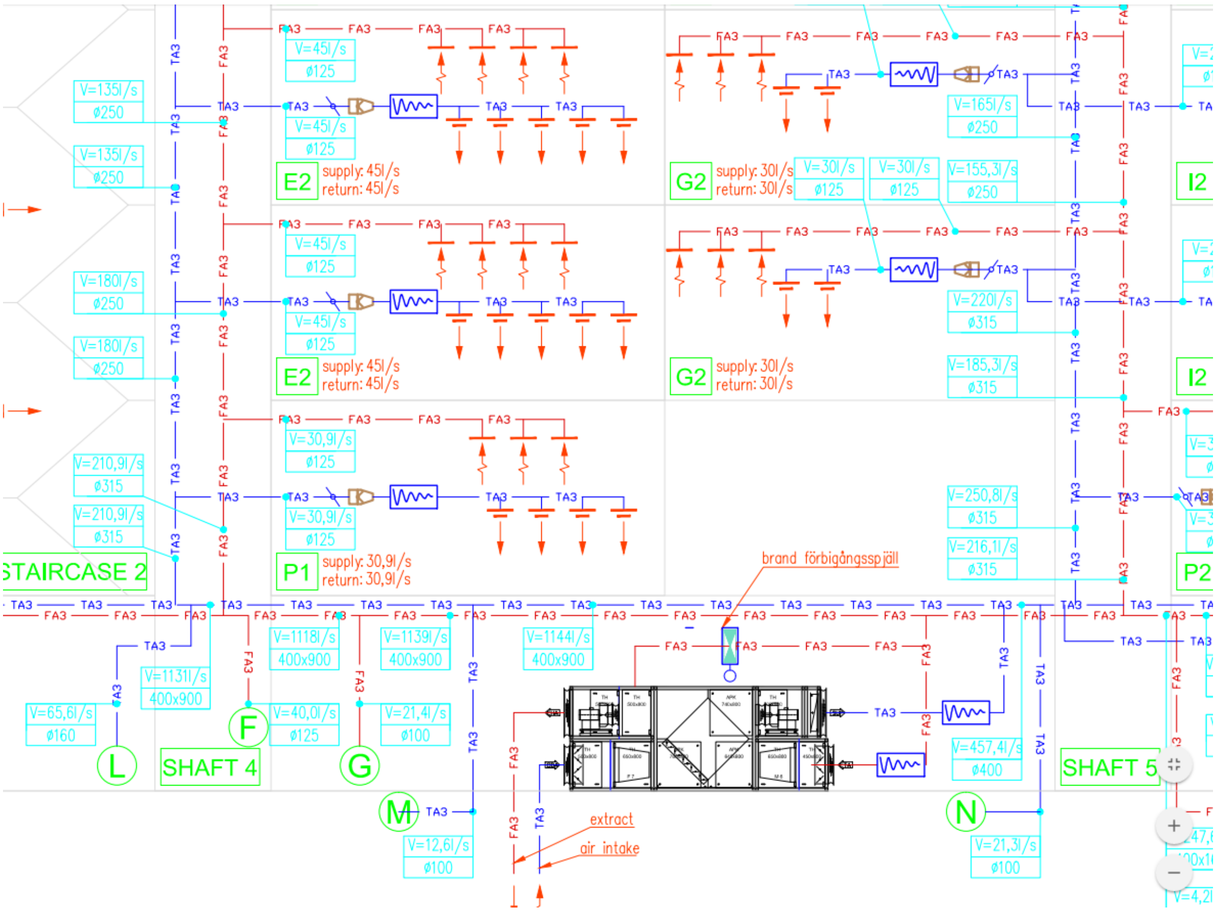


Figure 14: part of ventilation flow chart South building

The southern part of the building is equipped with two ventilation rooms located in the basement and a total number of four AHUs units. Fan room NR 1 provides ventilation/heating to the basement and the parts of the building with heights of eight floors and five floors. Fan room NR 2 serves the building part with a height of 14 floors. The North building has an AHU-room and according to the flow chart in the picture above, the one half of the building is served by each of the two AHUs.

Due to the limited dimensions of the ventilation rooms, difficulties were found when air conducts where designed and installed. Special effort was needed in order to design the definitive conducts' location and trajectories. The complexity of the system is appreciable in figure 14.

The AHUs include outdoor and exhaust air dampers, outside air filters (class F7), and exhaust air filters (class F6). In the following table, the main technical features are summarized:

AHU Ventilators (supply/exhaust)	Building	Manufacturer/size	Nominal flow (l/s)
TA1/FA1	Northern	Envistar Flex/300	1500/1500
TA2/FA2	Northern	Envistar Flex/300	1500/1500
TA1/FA1	Southern	Swegon Silver 10H	1040/1040
TA2/FA2	Southern	Swegon Silver 09H	820/820
TA3/FA3	Southern	Swegon Silver 12H	1600/1600

The monitoring of the ventilation system includes all the sensors and meters necessary to monitor all the relevant system status variables and apartment comfort and internal air quality parameters:

- Outdoor air inlet air flow rate to AHUs
- Exhaust air flow rate from AHUs
- AHU supply air temperature
- AHU exhaust air temperature
- Energy consumption of the heating coils of the AHUs
- Electricity consumption (CD) of the ventilators of AHUs (monthly)
- Outdoor temperature(LC1)
- CO_2 concentration value of the apartments (IAQ1, reported by four sensors, placed in different rooms of the apartment)
- Humidity and Inside Air Temperature (IAQ2)

The control and monitoring of the ventilation system is integrated into the central server through Modbus RTU communications protocol.

2.4. Control and monitoring system

In the following paragraphs, an overview of the architecture and the technical features of the defined control and monitoring system are provided, including a short description of its main components and the applied integration criteria.

2.4.1. Measurement and monitoring system

In the following lines the architecture, the included functionalities and the integration approach of the deployed system are described.

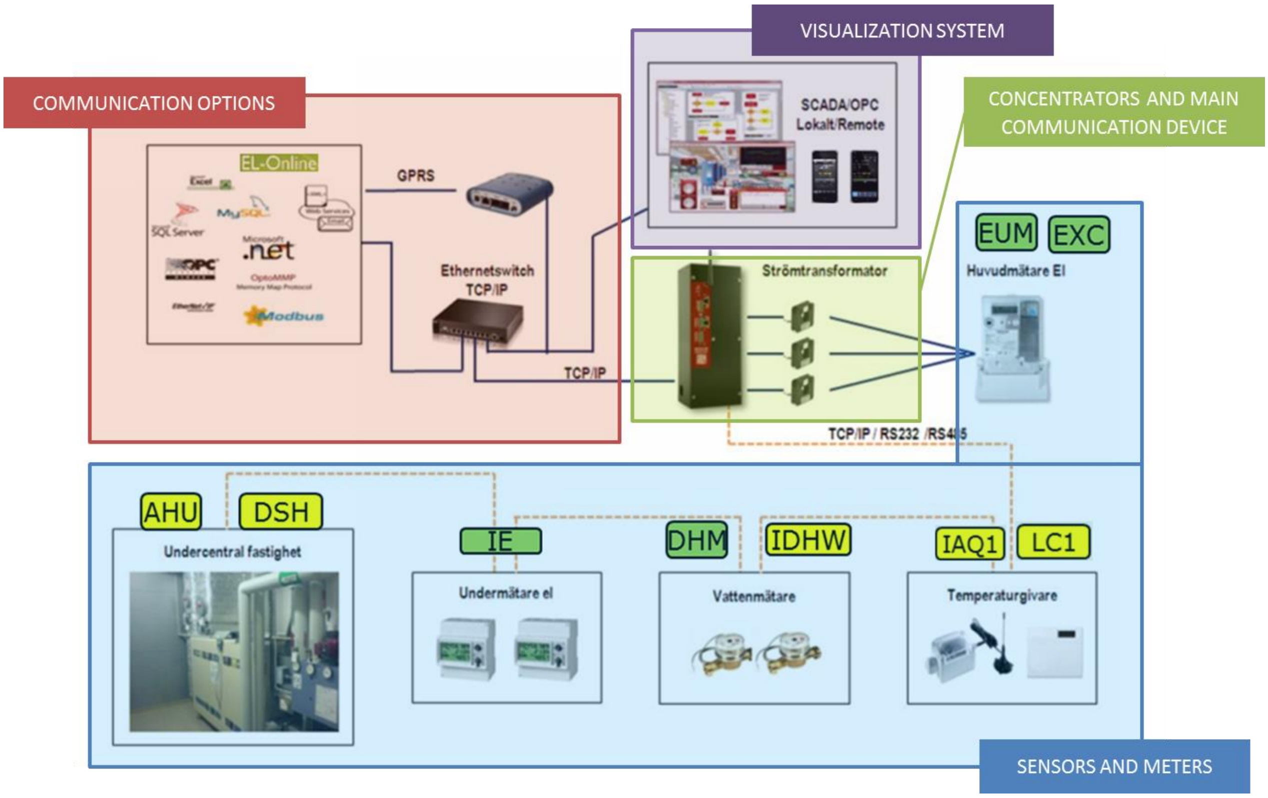


Figure 15: Explanation of diagram data points and meters, mod-bus system for the buildings.

The EL-Online system collects the information monitored by the deployed sensor and meter networks formed by remote sensors and meters focused on the monitoring of the electricity consumption of households, comfort, internal air quality, etc.

In the following table, sensors and meters included in figure 15 are explained:

AHU	Air Handling Unit data (Air flow rate, electricity use, heating and cooling supply and heat recovery data)
DSH	Distributed Space Heating
IE	Individual Electricity
DHM	District Heating Meter (Energy amount and temperature on supply and return flow rate)
IDHW	Individual Domestic Hot Water metering
IAQ1	Indoor Air Quality (Ventilation flow rate and indoor temperature)
LC1	Local Climate (air temperature)
EUM	Electricity Utility Meter
EXC	EXCluded energy (cannot be allocated to the building's energy use)

The data monitored by groups of sensors is collected through concentrators (OptoEMU-DR2) strategically deployed over the facility, and delivered to the main communication device, which sends the information to the central server (OptoEMU-SNR-3V). The OptoEMU-DR2 measures, displays and logs the voltage, current and power in real time from pulse input or serial from existing meter or PLC systems. The OptoEMU-SNR-3V

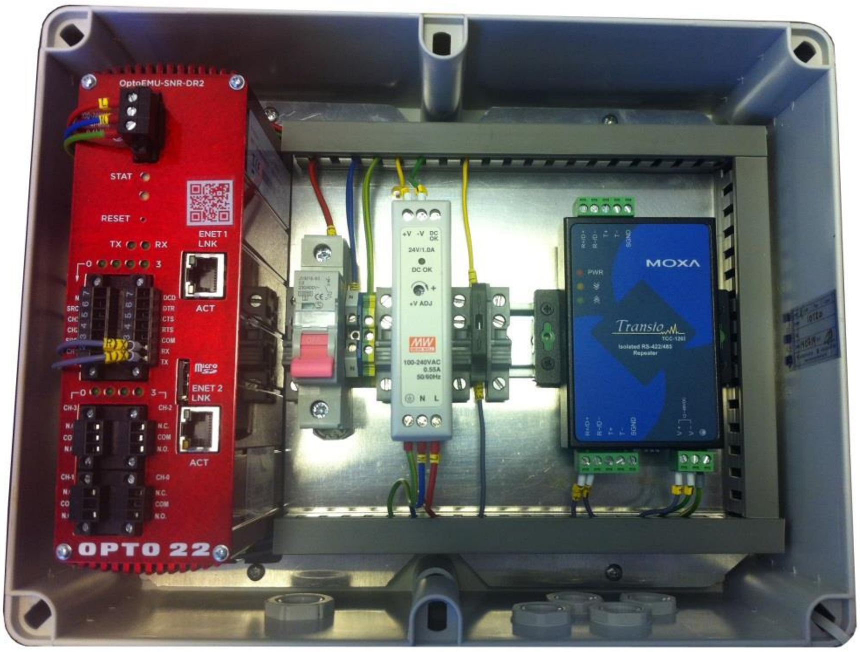


Figure 16: the enclosure used in the project, Opto 22.

The communication of the monitoring system and the central server, where all processing and data evaluation is performed, has been solved via the Internet. In any case, capabilities to connect via LAN, WiFi or GSM are available through specific modules added to the communication unit.

All the communications between different equipment, devices and sensors deployed all over the building is carried out through Mobus RTU (RS485), enabling an easy integration (no need of gateways to allow interoperability between different communications protocols).

The visualization module of the system is installed in a local computer deployed in the building. The Concerto database table has been used as the basis to develop an optimized output standard for easy reading and reporting.

Below a summary of the main advantages of the implemented system is given:

- **Simplicity:** Changes in the system parameters are performed via a centralized server through the Internet (No need to reprogramme controllers or PLCs locally)
- **Flexibility and interoperability:** This flexibility enabled more freedom to select providers as needed during the procurement process. Additionally, it makes it simple and easy to upgrade the system during the operation stage of the building.
- **Effectiveness:** The information communication box (Communicator) collects and sends all the data to the centralized server through the Internet. There the information can be processed, presented and supplied to external systems.
- OptoEMU is a flexible system that can communicate via cable, wireless or GPRS and where all software is free.

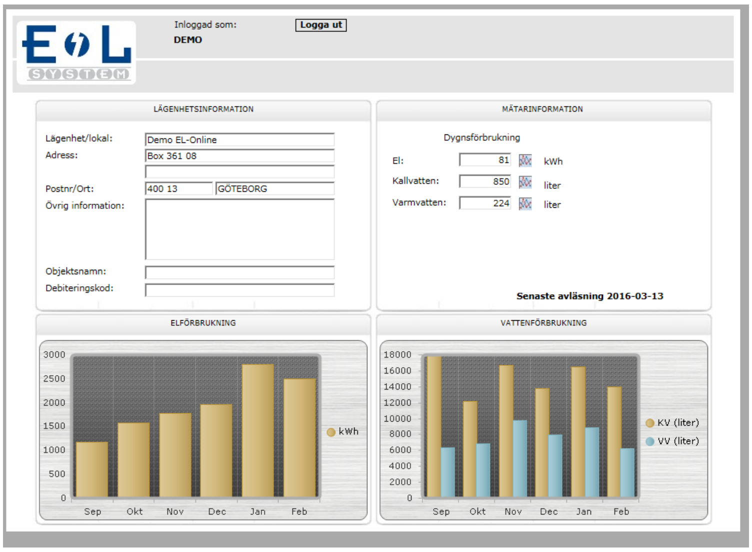


Figure 17: Each resident can log on and see the energy and water consumption for the specific apartment.

3. Roth Residential Building in Hyllie, Malmö

3.1. Introduction.

The building is located in the southern part of Malmö in an area called Hyllie. The area is specifically focused on solutions for the future urban environment. All areas are considered from a transportation, water, waste, energy etc perspective, to try to develop a sustainable area for the future. The Roth residential building is a good example of these sustainable solutions.

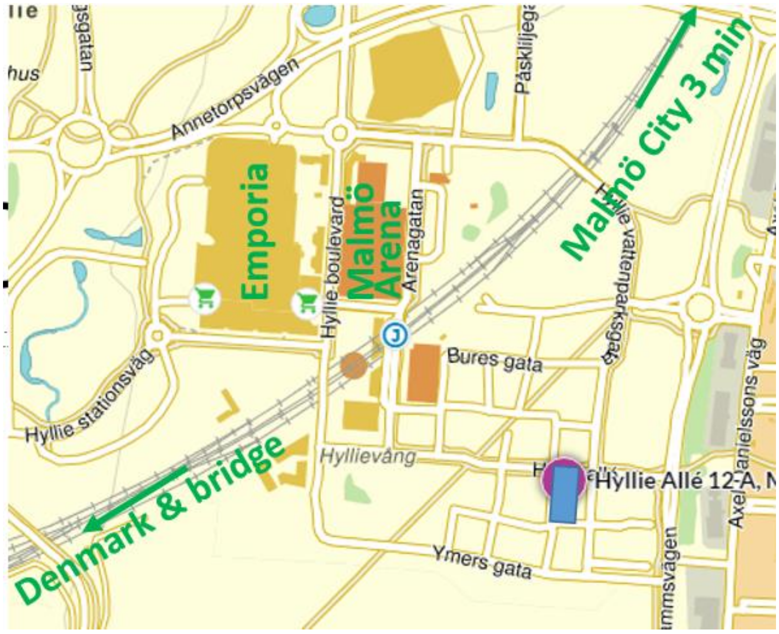


Figure 18: Location of the building

The project consists of 53 apartments and one office space.

Building area	5,466 m^2
Rented area apartments	3,461 m^2
Rented area office	74 m^2
1 room and kitchen	8 pcs
2 room and kitchen	31 pcs
3 room and kitchen	12 pcs
4 room and kitchen	2

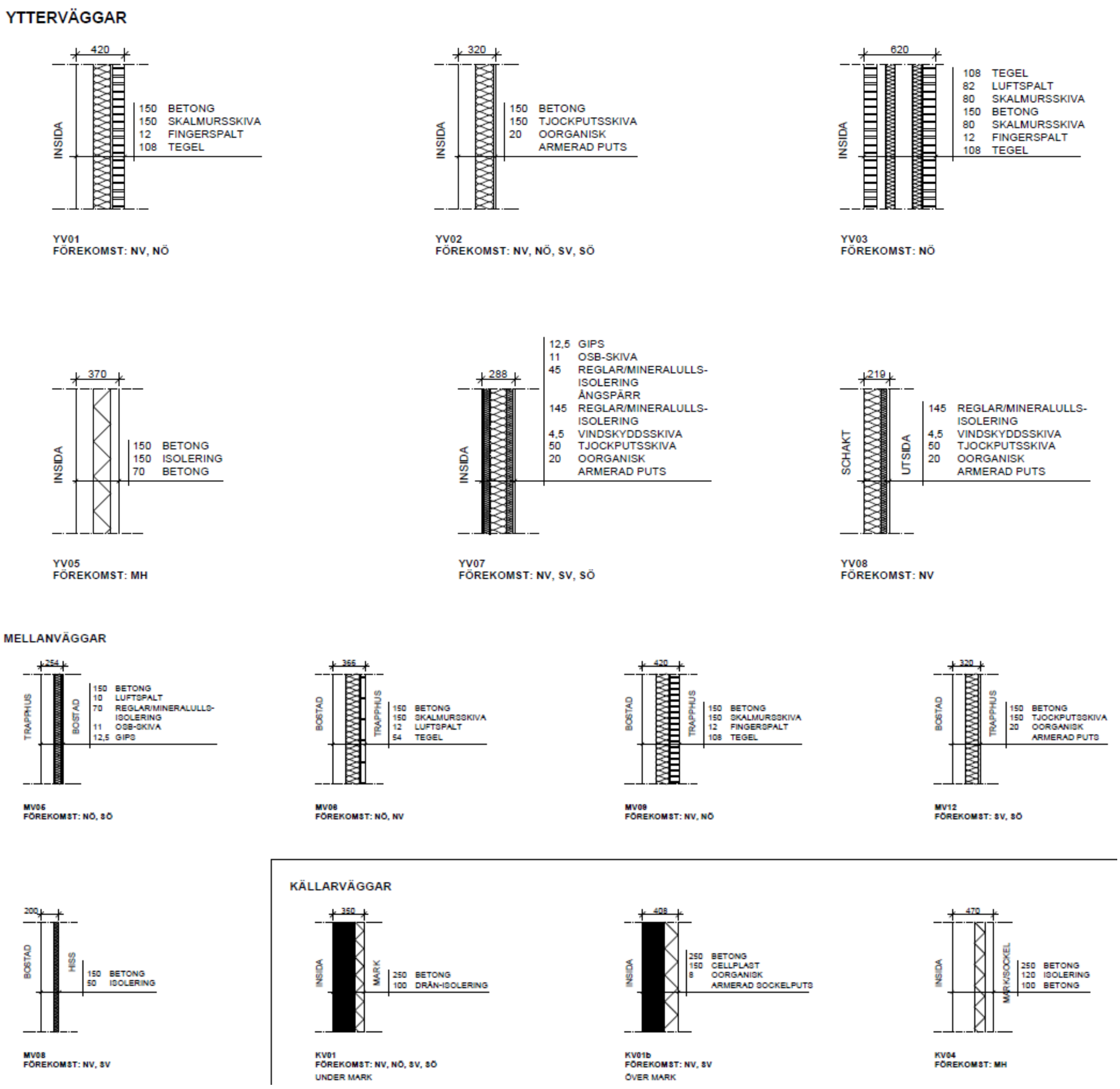
3.2. Thermal envelope

The high performance of the building is based on the minimization of the energy demand of the building, the use of highly efficient HVAC technologies and the integration of distributed generation systems.

In relation to the architectonic design, as described in D1.1, the high energy performance lies on several pillars, including:

- Very low infiltration level thanks to the tight envelope created by using concrete as the main constructive solution for the thermal envelope
- Special care during the building construction stage, in order to avoid thermal bridges and uncontrolled infiltration
- The optimized selection of windows technology to meet the insulation demands for low energy consumption buildings.

The following illustrations describe how the thermal envelope has been made in the various walls and floors & ceilings.



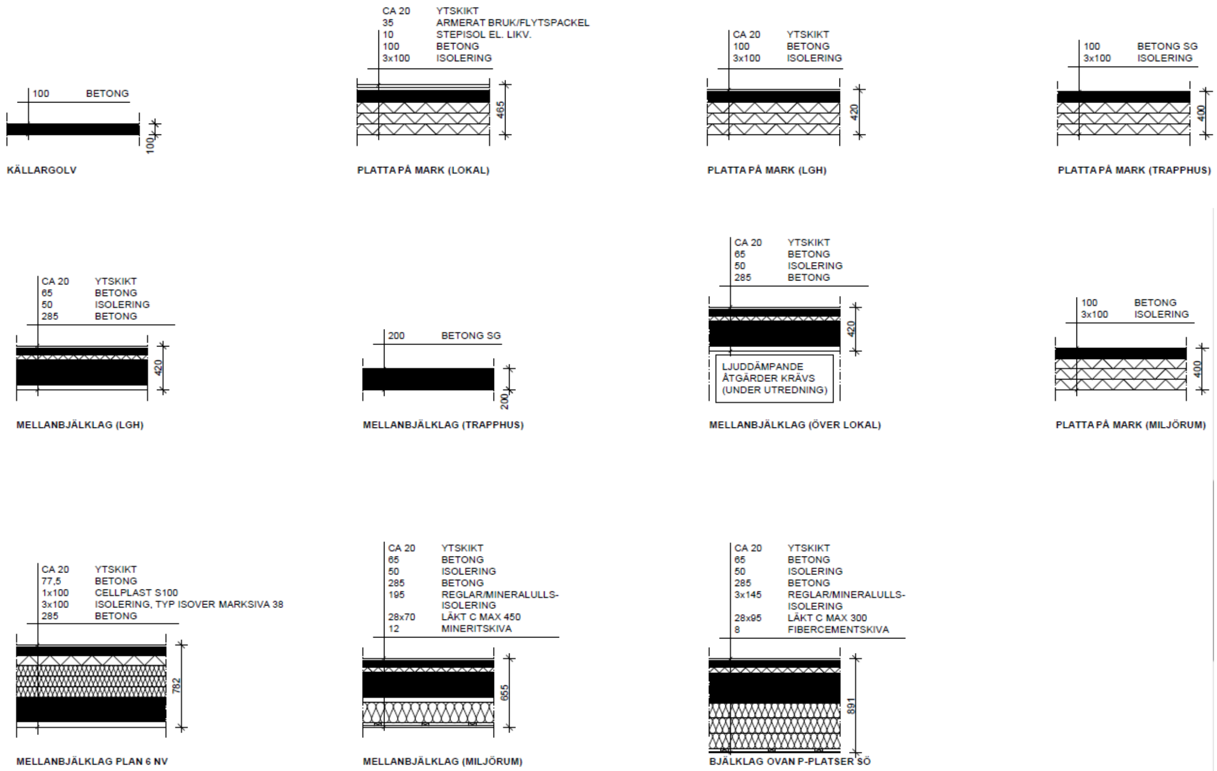


Figure 19: Construction sections (see Swedish construction glossary)

Keeping a tight envelope is essential to the energy performance of the building. Therefore 8 apartments have been tested for leakage after putting them under pressure. In all cases they have been seen as below the limit of 0.3 $l/s/m^2$ pressure being 50 Pa.

Figure 20: Prefabricated walls readymade with insulation. Middle part building.

During construction several questions had to be resolved. The most significant was how to mount the windows to avoid any thermal bridges. A solution was found where the window installation was made easier by placing in into the opening before the bricks or render were applied.

Figure 21: Windows installation before bricks/ render

Some prefabricated concrete walls came with the wrong sizes and holes in wrong places. This was fixed as they were found.

We had considerable amount of water inside the construction during rainy periods. This created the demand to pump water drastically more than planned.

3.2.1. Facades

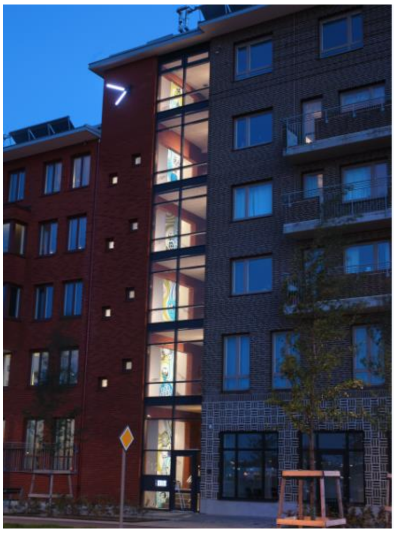
Figure 22: Concrete, render and brick façade

The building is a mixture between bricks, render and concrete. This gives life to the building bringing in a lot of variation. This is also one of the driving ideas behind the plan for this area.

Figure 23: Concrete facade, prefabricated

Figure 24: Concrete erected on site for render and brick buildings, to the left in picture

Figure 25: Some issues fixed at the end of the building period on the rendering.



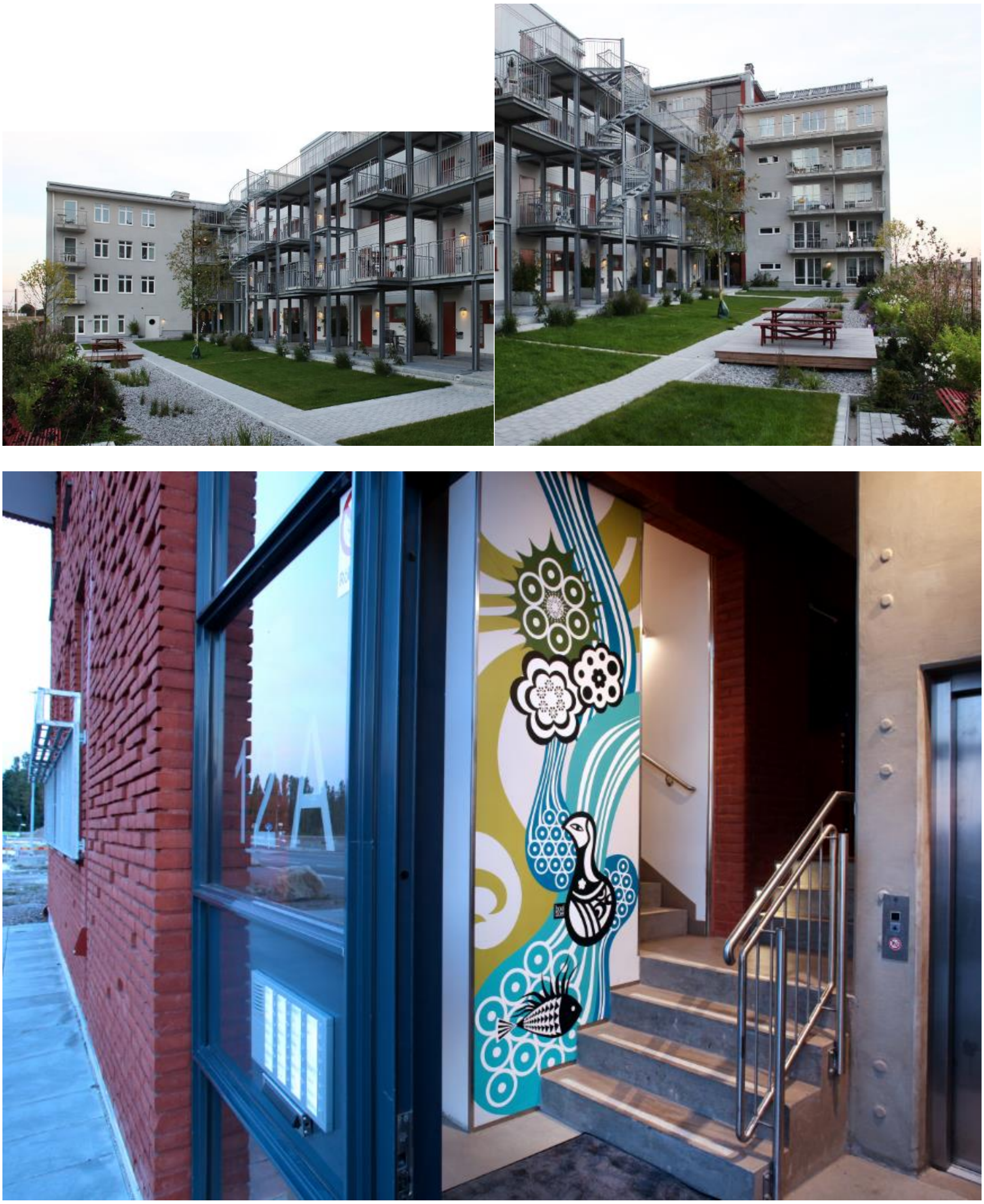


Figure 26: Pictures illustrating the finished facade in different places

3.2.2. Insulating material

Figure 27: Insulation before plaster is put onto the wall, picture to the right finished wall same place

Figure 28: Whole section insulation before plastering.

Figure 29: Insulation inside the bricks

Figure 30: Insulation is covered with a special steel net before plastering

Figure 31: Windows mounting in brick wall

3.2.3. Glazing

All glazing has been provided by Leiab AB. U values are set to lower than 1.2.

Openings represent 26% of the total area of the buildings' facades. Due to differences between the different buildings blocks, the ratio varies between facades. Below is a table with disaggregated windows ratios per building block and orientation.

	North	West	South	East	Building
North building	39%	24%	21%	7%	25%
Middle building	0%	51%	0%	27%	27%
South building	14%	29%	32%	21%	24%
Total building	25%	36%	21%	19%	26%

Noise reduction varies as follows depending on where they are mounted in the building:

- Rw/Rw+Ctr 35/30
- Rw/Rw+Ctr 42/37
- Rw/Rw+Ctr 43/38
- Rw/Rw+Ctr 46/41

Figure 32: Special Japanese inspired windows in the middle building, delivered in set pieces ready to be installed

Figure 33: Windows installed in prefabricated concrete walls

3.2.4. Assemblies

The project has to a large extent being erected on site with the exception of prefabricated walls in the middle building.

3.2.5. Roofs

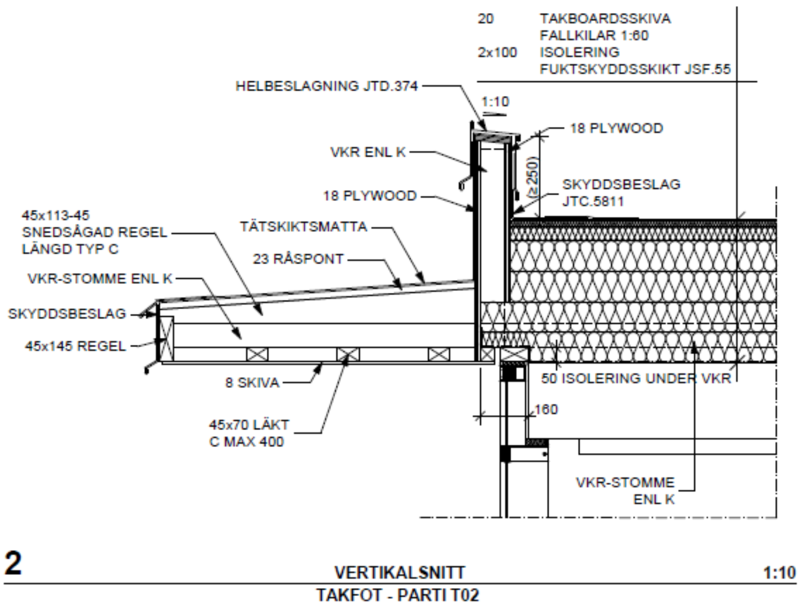


Figure 34: Special section showing the ending of the roof.

Figure 35: Standard roof cover

Figure 36: Some parts of roof is covered with grass in order to provide extra insulation & better water handling, while making the building look nice

3.3. Final building

See also the final facade pictures above. Below is a series of pictures from one apartment, 2 rooms and kitchen 62 m2.


Figure 37: Final apartments

3.4. Energy technologies

In the following sections, the description of the installations deployed on the building will be presented, including the HVAC systems, the lighting system, the solar thermal system and finally the energy monitoring system.

3.4.1. Lighting and electric equipment

The deployed lighting system is formed by low energy consumption LED type lamps (With the exception of some outdoor lights, based on high efficiency fluorescent technology lamps)

The control of the lighting system is based on strategies and control mechanisms that enable to provide artificial lighting only during the periods with actual demand (actual presence of people on the rooms), including:

- Lighting status control in common areas according to the presence of people, monitored through the deployment of movement detectors, mainly in the basement and garbage room.
- Stairway lighting status controlled by dedicated light sensors (switches).

3.4.2. HVAC equipment

Ventilation is provided by means of a mechanical ventilation system. See also ventilation below.

3.4.3. Heating

The building is equipped with a centralized heating and domestic hot water production system which supplies according to their specific needs heating hot water and domestic hot water to each apartment.

Heating is distributed through floor heating to get the highest efficiency. This system uses the thermal mass of the building to accumulate the heat and release it according to the existing thermal loads, providing the required comfort conditions only to the occupied zone of the heated rooms. The radiant emission mechanism makes it possible a very efficient energy delivery (avoidance of stratification, etc).

Furthermore, radiant floor systems can operate with low water supply temperatures (35-40 ºC) which can reduce the energy wasted from the pipe circuits on the distribution of the heating water.

The radiant floor is a key element of the demand side management functionalities provided by the smart control system. During special occasions it is possible to turn down or off the delivery of heating to the building without having a critical negative impact on the thermal comfort. The high thermal inertia of this heating system reduces the negative impact of a temporary lack of energy delivery on the comfort level of the apartments.

Figure 38: Floor heating system

At apartment level, all rooms have independent heating circuits and can be controlled separately with specific thermostats. It is also possible to control the settings of each room through a specially designed app running on an IPOD touch available in all apartments.

Termostat schema

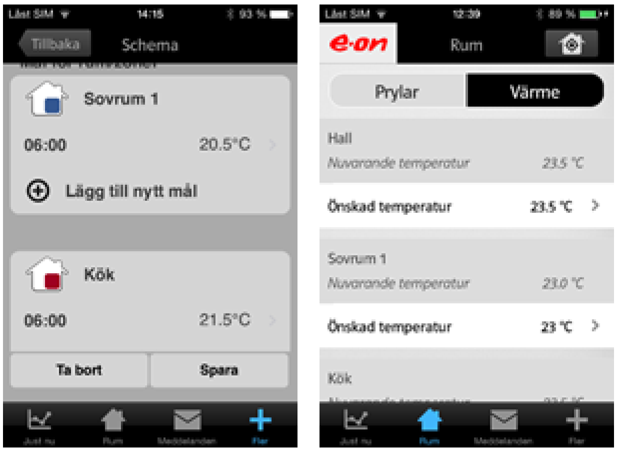


Figure 39: The app supports different temperatures for all rooms in the apartment, withn around 2 degrees. It is also possible to see current temperature at all times through this program.

Apart from comfort condition adjustment and monitoring functionalities, the app provides real time data on water (cold and warm) and electricity consumption. The connection to EON´s central pricing system allows the user also to follow the evolution of energy consumption cost according to the instantaneous evolution of market price. See control and monitoring below.

3.4.4. Cooling

Cooling demand has been avoided by the application of passive design strategies, which enable to minimize solar gains, and to take advantage of the free cooling possibilities provided by the mechanical ventilation system whose air intake duct is coupled to a heat exchanger with the ground.

3.4.5. Mechanical ventilation

The building incorporates a mechanical ventilation system to provide fresh air to apartments.

The FTX ventilation system reuses warm air coming from all the apartments through a heat exchanger. During the cold season some extra heating is required. This comes from the district heating making sure that the distributed air is at least 21 degrees warm.

Totally 1,600 litres per second is catering for the full demand of all apartments.

The new air inlet and exhaust air outlet are located in the garden and take place through large scale ventilation ducts. This system provides a key contribution to the energy efficiency of the building, thanks to the availability of heat recovery of the exhaust air, and the preheating and free cooling functionalities obtained taking advantage of the steady temperature of the ground (15 ºC) all over the year.

Figure 40: FTX ventilation system

3.4.6. Natural ventilation

Besides the installed HVAC system, the relative position of the windows inside the apartments allows to benefit from cross ventilation technique. Users should open the windows in order to create internal air cross flows, when weather conditions are adequate. Thus, energy consumption related with mechanical ventilation could be reduced by using natural ventilation.

3.4.7. Renewable Energy Sources (RES)

A solar thermal system to produce domestic hot water has been deployed in the flat roof of the building. Totally 62 m^2 of collector field have been installed on the north part of the building ´s roof.

Figure 41: Thermal panels

3.4.7.1. Solar thermal system

The solar collection field formed by 36 flat plate solar collectors (Euronom EXOSOL OPC 15) and has been installed on the roof of the north building, south oriented and with the optimum slope to provide the maximum efficiency and total hot water production.

The total collection area of the solar field is of 62 m^2 (2.5 m^2 of useful collection area per collector)

The solar hot water storage system consists of 6 vertical tanks, located in the basement, with a unitary capacity of 1,000 l. The integration of the storage enables to decouple solar production from DHW demand.

According to the foreseen production, this system will provide the energy required to meet 30% of the total yearly energy consumption associated to the domestic hot water preparation.

3.5. Control and monitoring system

A smart metering system has been deployed on the building including smart grid connection to the electric distribution grid of EON. The availability and implementation of demand side management strategies is one of the most innovative aspects of this building.

The smart metering system provides real time usage data on electricity consumption, hot and cold water together with heating to enable control decisions focused on saving when possible. Consumption data are provided in terms of kWhs and cost.

Figure 42: Consumption figures are availble in the app on the IPOD. Several views can be selected, current usage, weekly, monthly and yearly.

Control functionalities are provided by the installed BASTEC system integrated with the central systems of EON, to enable demand side management strategies. The Bastec system uses Modbus as communications protocol.

In the following lines a summary of the functionalities supported by the system is given:

- Communication with the smart grid system for information, control and reporting.
- Prioritization and handling of loads and groups of loads (demand side management. peak shaving performed by E.ON)
- Measurements and reporting of energy data to the smart grid system.
- Visualization of relevant information to and from the smart grid system in dynamic flowchart pictures.

- Logging of data for relevant signals to and from the smart grid system.
- Alarms when communication is lost within the building system.

4. Residential Building in Portugalete, Basque Country

4.1. Introduction

The building is located in the neighborhood of Repélega in the town of Portugalete and has been constructed by the regional Basque Government for social housing purposes specifically oriented to low-income people.

The plot where it has been built has a total area of 2,154 m^2, distributed as follows:

- Residential land area: 609 m^2
- Public Green area: 1,426 m^2
- Pavement: 119 m^2

The plot is rectangular with its longer side aligned with Juan de la Cosa street (Figure 43). The topography is an inclined plane with an approximate slope of 10% from West to East.

Figure 43: Location of the building

In order to adapt to the existing slope of the street (about 6 meters) the building is formed by three blocks of 5 floors. Each of these blocks has 10 dwellings, 2 per floor, and two additional adapted 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 (figure 44)

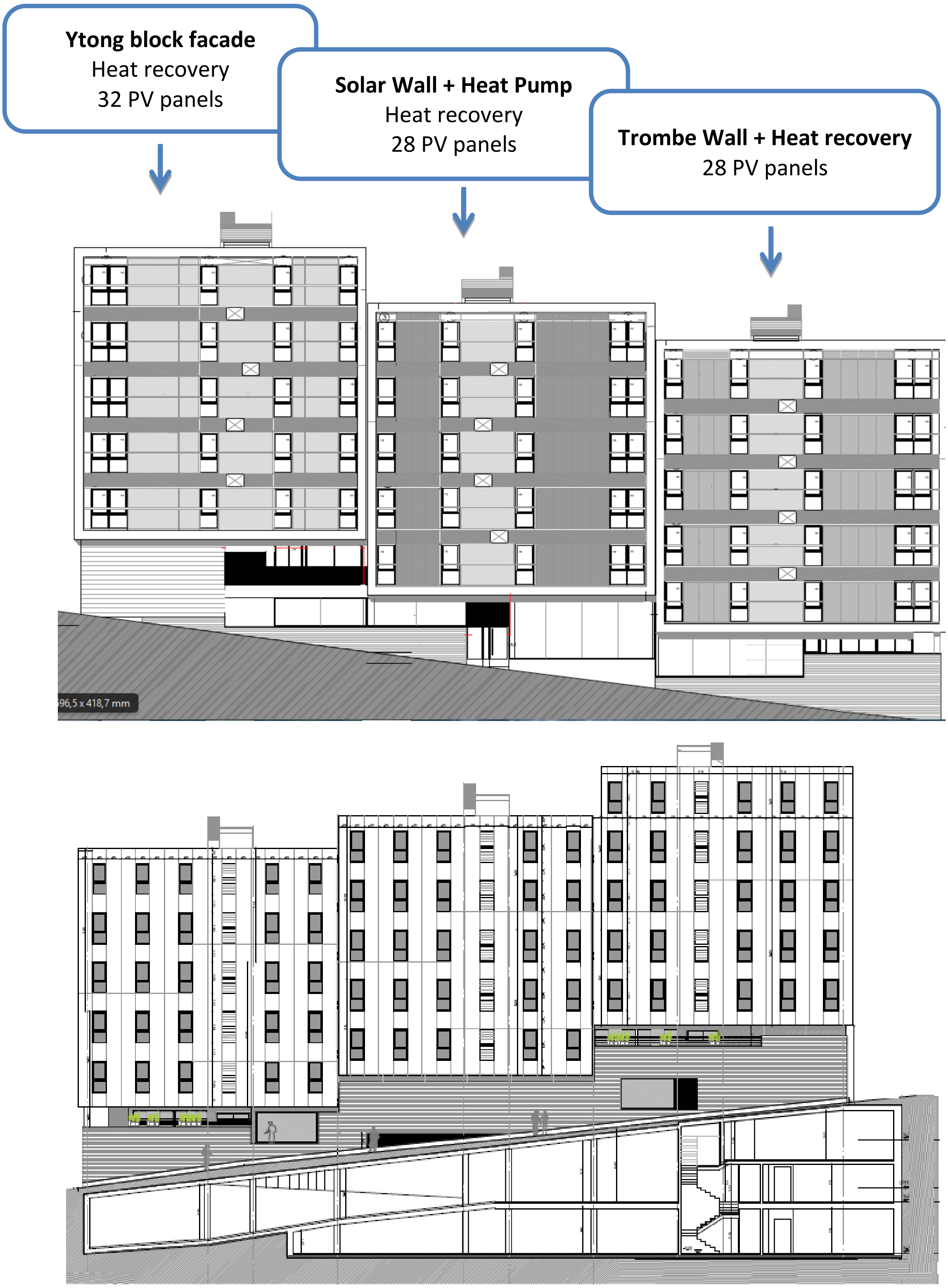


Figure 44: Building south facade and high performance solution deployment (above), and north facade (below)

All the dwellings have a similar configuration where the living room, kitchen and drying space face to south, bedrooms face to north and bathrooms are located in interior spaces (figure 45).

There are different dwelling types, depending on the existing number of bedrooms:

- 16 two-bedroom apartments with net floor area of 57.42 m^2
- 14 three-bedroom apartments with net floor area of 86.24 m^2.
- 2 two-bedroom adapted apartments with net floor area of 88.39 m^2.

The project also includes:

- 32 storage rooms
- 34 parking spaces (two of them adapted)

Figure 45: Distribution of the dwellings

The energy efficient design concept of the building is based on a minimized energy demand (heating and cooling) optimized system technologies and integration criteria, the deployment of onsite electricity production Technologies and on an advanced control and monitoring platform to ensure optimum operation of all the systems of the building.

4.1.1. "Free Energy" concept

"Free energy" concept is one of the innovations that are included in the project. There are several factors that have promoted the definition and implementation of this concept.

On the one hand, due to the profile of the expected tenants for the social housing apartments (low-income people) it was believed that it was necessary to find and implement innovative approaches that could contribute to provide satisfactory comfort conditions to tenants with an affordable cost.

The implementation of such approaches is facilitated by the low energy demand of the building achieved through its optimized design, the deployment of active façade solutions and the availability of onsite free renewable electricity production provided by a PV plant. The climatic conditions existing on the area of Portugalete are ideal for the deployment of active façade solutions and PV systems and, as a consequence, those technologies were incorporated to the design of the building.

This boundary condition combination has allowed the definition of the "free energy" concept that consists on the delivery of a free heat supply to the dwellings of the building, without any fossil fuel consumption.

The operation of the “Free Energy” concept is detailed at the end of this section.

4.2. Thermal envelope

The low heating demand is assured by the combined effect of a highly insulated envelope and the heat provided by active facade elements. The design of the building also aims to minimize its environmental impact by using materials with low embodied energy and low environmental toxicity wherever possible.

The thermal envelope is made of lightweight materials, glazing and metal panels.

4.2.1. Facades

The facade of the building is formed by active facades in its south face, and in the rest of the orientations the selected constructive solution consists on an Ytong block facade

4.2.1.1. Ytong ceramic block solution

The Ytong block facade is composed of the following material layers (from outside to inside):

- Sandwich panel with 5 cm of Polyurethane
- 5 cm of rock wool
- Ytong block
- Plasterboard.

Figure 46: Detail of the Ytong facade

4.2.1.2. Active facades

One of the objectives of the Buildsmart project is to spread the use of energy-efficient and commercially available but still infrequently used strategies and technologies in the residential sector. With such purpose, Buildsmart project contemplates the installation of three different systems on South facade, one different solution per block, with the aim of studying the behavior of such systems under the same conditions, climate and environment and comparing their performance. Two of the systems that configure the South facade are two different options of active facades.

In general, an active facade is an envelope that allows to collect, transfer and store large amount of solar energy in form of heat used for various purposes in buildings, enabling multiple functions including shielding, thermal collection, mitigation to the extreme weather conditions, etc.

In particular, the active facades used in Buildsmart project use the solar radiation to preheat ventilation air; in such a way that energy consumption for space heating decreases and indoor comfort conditions improves.

Used active facades are double skin envelopes that incorporate a solar thermal absorber into its structure and allow external or internal air to flow inside the cavity located between the layers. This cavity is ventilated mechanically or naturally and generally managed by control mechanisms. Active facades are designed to maximize the absorption of solar radiation and to transfer these heat gains to the air in the cavity increasing its temperature.

4.2.1.2.1. Trombe wall

The trombe wall, with a continuous air gap from the first floor to the roof, is deployed on the southern facade of the lowest block of the building. It is coupled to the ventilation system, which acts as distribution mechanisms of the collected energy. The trombe wall is divided in two sections, one of 2.5 meters and the other of nearly 4 meters wide. Both are located in the same place relative to the dwellings, between the kitchen and the living room (figure 47).

Figure 47: Trombe Wall position

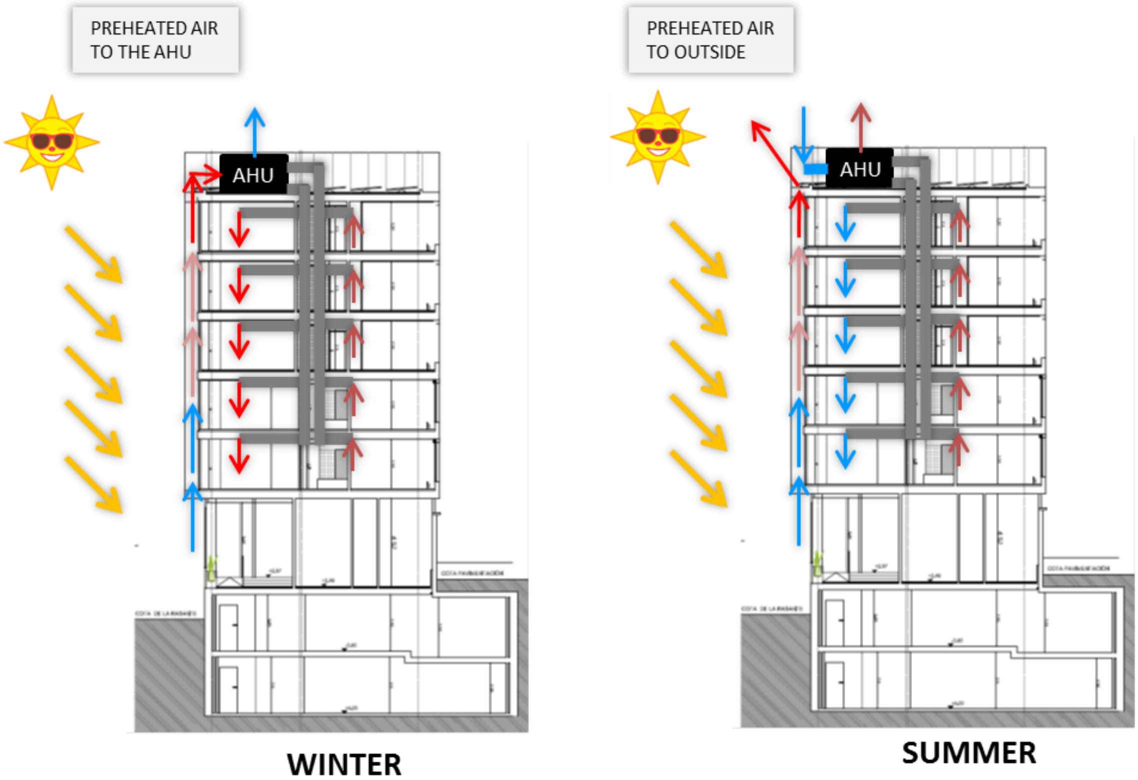


Figure 48: Trombe Wall operational principle (left winter mode and right summer mode)

The outlet of the trombe wall on the roof of the building is connected to the ducts that enable the delivery of the hot air produced by the trombe wall to the AHU of this block. The connection allows taking the hot air leaving the air cavity of both sections of the trombe wall and to deliver it to the AHU (figure 49).

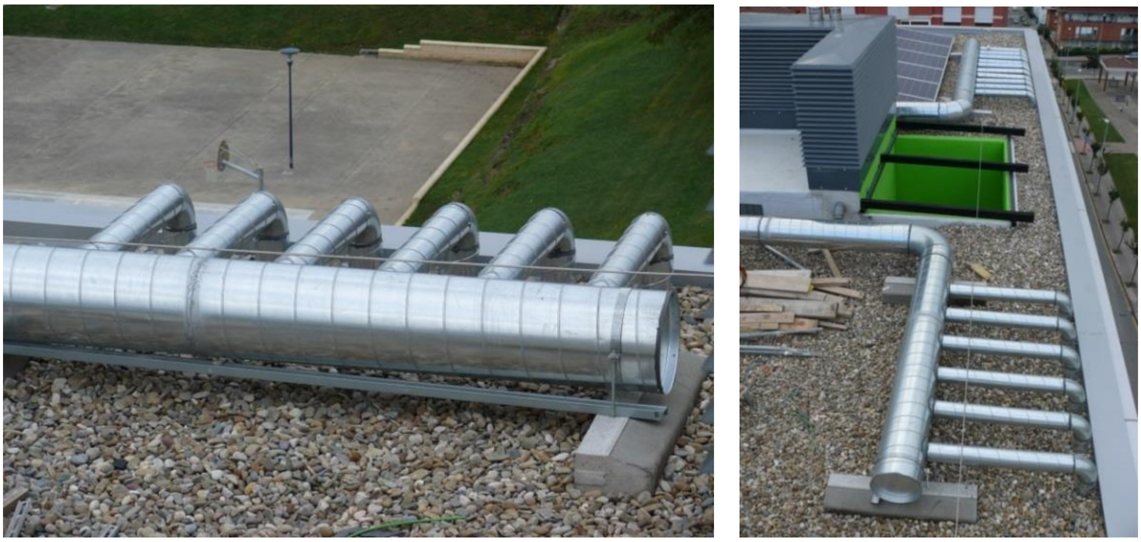


Figure 49: Exhaust system placed on the roof

With this method the air is pre-heated by the effect of the Trombe wall and is introduced into the heat recovery system, whenever necessary in order to reduce energy demand. The production of the trombe wall is exclusively connected to the ventilation system of the lowest block of the building. The position of the ventilation equipment and ducts through which air flows is displayed in Figure 50.

Figure 50: HR Ventilation system with hot air inlet of Trombe Wall

When heating is not needed, the system can exhaust the hot air produced by the trombe wall, in order to reject the collected energy and avoid overheating risk. This is possible through dedicated dampers located at the inlet of the heat recovery device that enable the delivery of the preheated air to the AHU or to exhaust it, according to the presence or lack of heating demand. Figure 51 displays the position of the exhaust damper for the trombe wall air flow and its actuator.

Figure 51: Damper and damper actuator to enable the Trombe Wall air rejection

4.2.1.2.2. Solar Wall

As previously stated, there is an active facade called Solar Wall in the south facade of the central block of the buildings (figure 52).

It consists on a black colored perforated sheet of metal that allows the inlet of exterior air into the air gap, where the air is heated through the collected solar energy. There are 2 different sections of Solar Wall on the facade, the first one of 2.5 meters wide (left side) and the second one of around 4 meters wide (right side).

Figure 52: Solar Wall active façade solution

The air preheated by the solar wall is used as heat source of the air to water high performance heat pump deployed on the roof of the central block. The temperature increase provided by the solar wall to the air used by the heat pump as energy source, will allow very high mean seasonal performance values for the heat pump.

The air flow preheated by the solar wall is delivered to the heat pump through a specifically deployed duct network, including a variable air flow rate fan to facilitate air circulation through ducts (figure 53).

When the building presents heating demand to be covered by the heat pump, the preheated air production of the solar wall will be delivered to the heat pump, which will generate the hot water necessary to heat the building through the existing radiant floor heating system with very high performance values. The operational principle of the solar wall system is shown in figure 54.

Figure 53: Chutes on the roof, extracting hot air from the Solar Wall air gap

Below the operational principle of the solar wall solution is summarized (Figure 51):

- Air enters the cavity of the solar wall
- Air is heated with collected solar irradiation
- Heated air is delivered to the air to water heat pump and produced hot water is sent to the heating plant of the building
- Finally hot water is distributed over the building and required energy delivered by the radiant floor system.

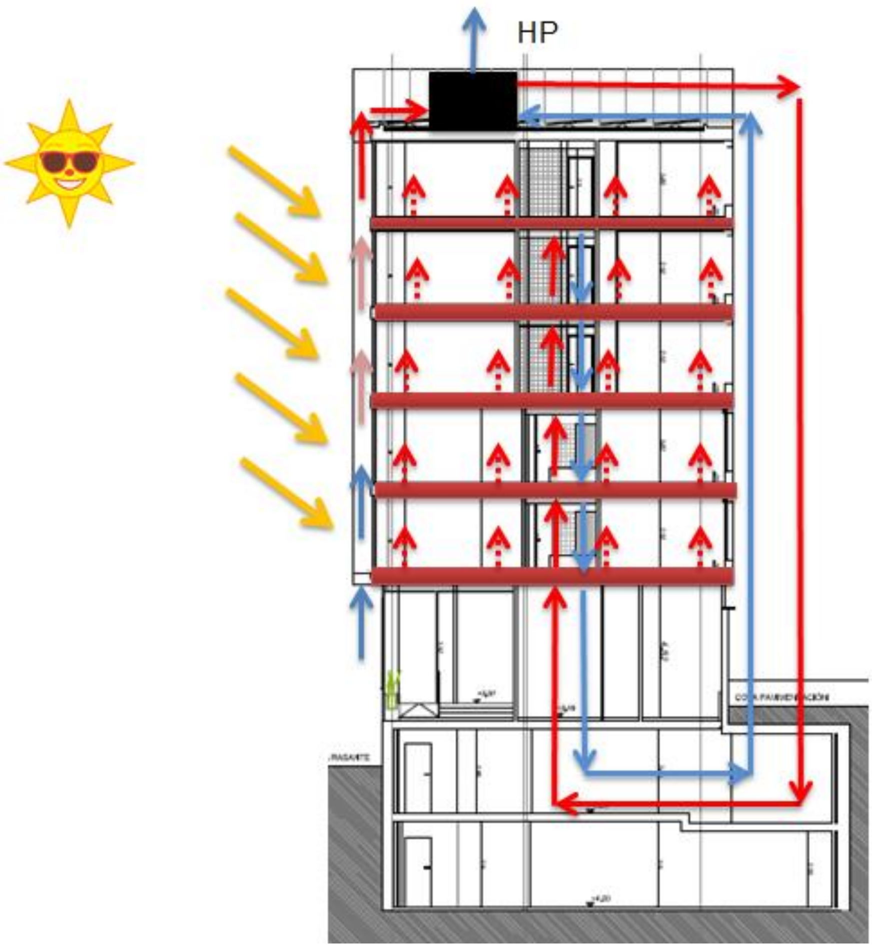


Figure 54: Bioclimatic Solar Wall system operational principle

However, when heating or DHW production is not required, the heat pump and variable air volume fan will be deactivated. In this circumstance, the preheated air produced by the solar wall is exhausted though the mechanized damper located between the duct and the heat pump (figure 55).

Figure 55: Integration of the solar wall and the heat pump

4.2.2. Windows

Selected windows are double-paned, air-filled windows (4/12/6) with low-emissivity (low-e) coating. They have a U-value of 1.6 W/m2K.

Windows represent 3.61% of total building facades' area. East and West facades are totally opaque. The ratio of glass to solid wall in South façade is 4,1% while in North facade the window/wall ratio is slightly lower, 3.5%.

4.2.3. Roofs

The solution selected for the roof of the building is an externally (8 cm of Polystyrene) insulated conventional flat roof.

4.2.4. Final building

Figure 56: South facades

Figure 57: North facades

4.2.5. HVAC system

4.2.5.1. Heating and DHW production system

4.2.5.1.1. Plant overview

The heating and DHW production plant deployed on the building to meet its energy demand is formed by a CHP unit, a high performance air to water heat pump and a condensing boiler. Additionally the heating plant includes a storage subsystem formed by a storage tank coupled to the CHP unit and a second tank for DHW storage.

In order to maximize its operating hours the CHP unit will be given priority for DHW production, whereas the heat pump will be the leading heating generator whenever, the electricity production provided by the photovoltaic system can cover the consumption of the heat pump.

If the production of the PV system is not enough to cover 100% of the electricity consumption of the heat pump, the control system of the building will set the CHP unit or the heat pump as the leading heating generator of the heating plant, depending on the expected heat pump performance. This will ultimately be function of the outlet temperature of the preheated air flow produced by the solar wall.

If the existing heating request cannot be met by the leading generator of the heating plant (the heat pump or the CHP unit depending on the availability of local PV production and the air outlet temperature of the solar wall), then the rest of the generators will start sequentially until the heating energy request is met. For heating production the condensing boiler will be the last generator of the operational sequence.

On the other hand, if the energy request necessary for DHW production cannot be meet by the CHP unit, then the condensing boiler will act as backup system and complete the production of the plant necessary meet the existing request.

In order to ensure the highest performance values for the heat pump, in principle, this equipment will not be used for DHW production purposes. However, during periods of low heating demand and high PV production, if the electricity production exceeds the consumption of the heat pump for heating the remaining electricity production and heat pump capacity could be used for DHW preheating (to 40 /45 ºC).

As already stated, the emission subsystem of the building consists on a radiant floor heating system that will allow the operation of the heat pump with low supply water temperature values (35-45 °C). This along with the temperatures of the preheated air flow used as heat source by the heat pump will enable to maximize its mean seasonal performance value. The scheme of the thermal facilities of the building is shown in the figure 58. The main components of the system are:

- The High performance air to water heat pump
- The CHP unit and its storage tank
- The condensing boiler
- The DHW storage tank and the DHW production heat exchangers
- The heat exchanger for energy delivery to the low temperature system from the storage tank coupled to the CHP unit.
- The variable and constant volume pumps deployed on the different hydraulic circuits to produce water circulation.

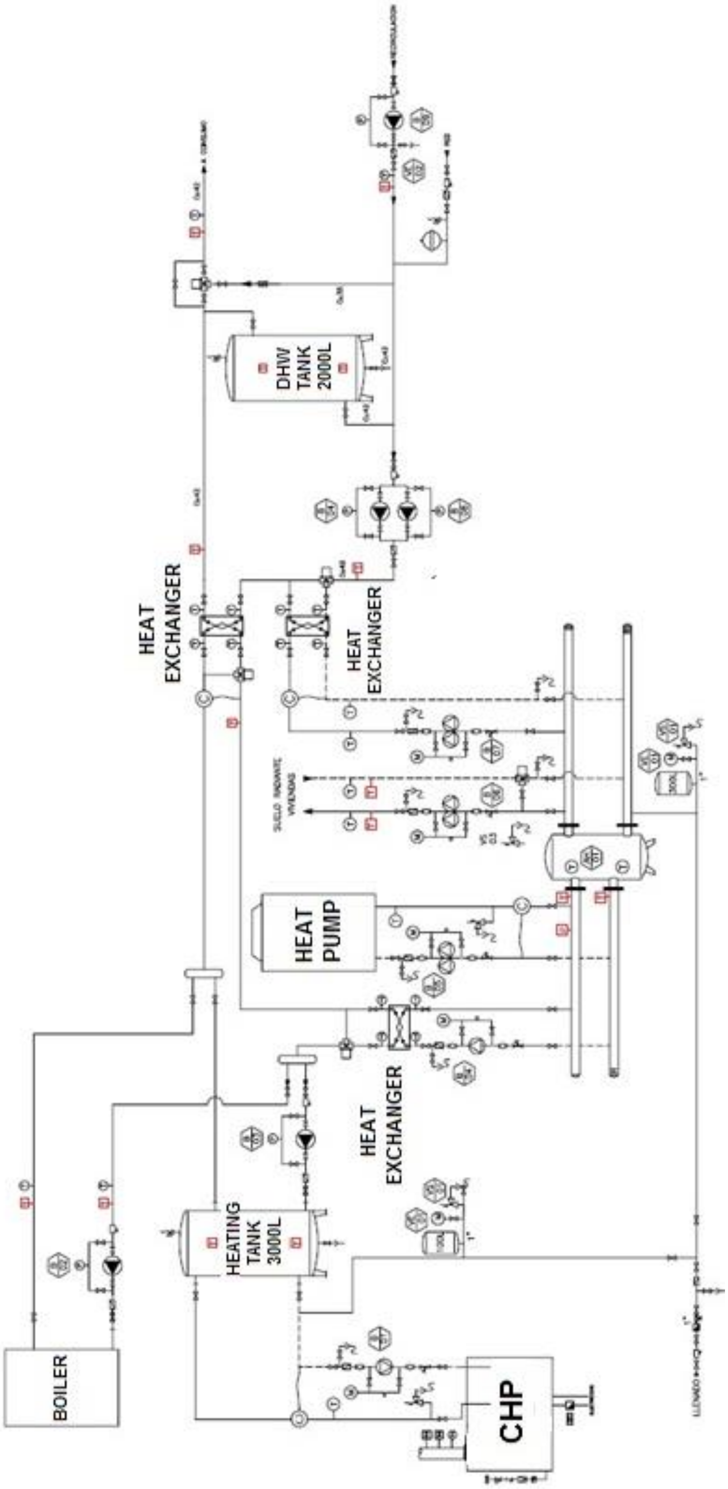


Figure 58: Scheme of thermal facilities of the building

4.2.5.1.2. Heat Pump

As already stated the deployment of an air to water heat pump will play a key role in the implemented high performance heating and DHW production plant. More specifically, the installed unit is a Mitsubishi Electric, model CAHV-P500YA-HPB, with the following technical specifications (figure 59).

Figure 59: Heat pump model CAHV-P500YA-HPB of Mitsubishi Electric

MODEL: CAHV-P500YA-HPB	
Power	45 kW
Electrical consumption	12.5 kW
COP	3.49
Outlet water	+25/+70 °C
Exterior air	-20/+40 °C
Air flow	7.5-15 m^3/h

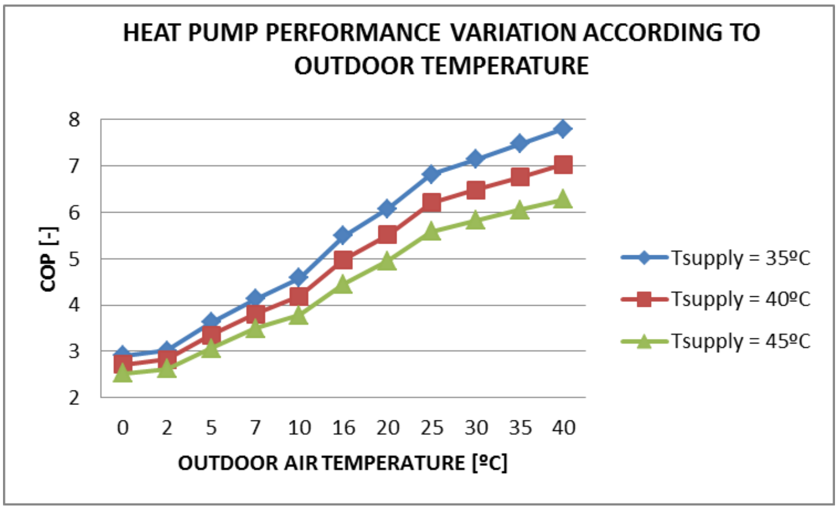


Figure 60: Heat pump performance variation

4.2.5.1.3. CHP

The CHP unit will produce hot water for heating and DHW production and additionally will complement the onsite electricity production provided by the PV system deployed on the roof of the building. A SENERTEC DACH 5.5 model micro-CHP unit has been selected (Figure 61).

MODEL: DACHS 5.5	
Electricity power	5,5 kW
Thermal power	14,8 kW
Gas consumption	2,1 m³/h
Dimensions (W x L x H)	72 x 107 x 100 cm
Weight	530 kg
Sound level	52-56 dB

Figure 61: CHP and its technical specifications

4.2.5.1.4. Condensing boiler

The condensing boiler is the last generator of the heating plant of the building, deployed to complete the peak output power of the plant, and managed to act as the backup generator of the plant. Therefore, it will operate only during peak load periods.

For this purpose a BAXI, BIOS PLUS 110F model unit (figure 62) with a rated heat output of 102 kW has been selected.

MODEL: BIOS PLUS 110F	
Rated heat output	102 kW
Electricity consumption	320 W
Weight	320 kg

Figure 62: Condensing boiler model and its specifications

4.2.5.1.5. Thermal storage

As already stated, the thermal storage subsystem is formed by two different tanks deployed in the heating plant room of the building. The first one, a Coditer S.L CGTR-2000 model (grey), has a capacity of 2 m^3 and is part of the DHW production system. The second one (red) is coupled to the CHP unit and has a capacity of 3 m^3 (SH-AC 3000 D.S1763 model). This tank will enable to maximize the operational hours of the CHP unit.

The storage tanks are shown in the figure 63.

Figure 63: Thermal storage tanks for heating (left) and DHW (right)

4.2.5.1.6. Other relevant components

The heat transfer between the different hydraulic circuits of the generation subsystem and the distribution subsystem of the building is enabled through heat exchangers specifically deployed in the heating plant room of the building (figure 64). These heat exchangers enable:

- DHW production using the energy provided by the CHP storage tank and the condensing boiler.
- DHW preheating using energy delivered by the heat pump.
- Heating production using the energy stored in the CHP storage tank.

Figure 64: Plate heat exchanger

Finally, it is necessary to mention, that in order to ensure the energy efficiency of the system, the critical pumps of the heating plant and of the distribution subsystem will operate according to variable flow rate strategies (figure 65).

The operational strategy will enable the critical hydraulic circuits to operate with optimum temperature difference values for the complete range of existing thermal loads. It will minimize the pumps' electricity consumption.

Figure 65: Installed variable mass flow rate pumps

4.2.5.2. Ventilation system

Each of the 3 blocks of the building has its own ventilation system formed by an AHU with heat recovery and the corresponding supply and return duct networks to distribute the ventilation air necessary to maintain satisfactory levels of internal air quality inside the building. The heat recovery device deployed for each of the three blocks is an Alder DFE-2000 G4 model. Its technical characteristics are shown in figure 66:

MODEL: DFE + 2000 G4 (885209)	
Nominal airflow	2000 m^3/h
Nominal efficiency	90 %
Supply	1 x 230 W
Weight	281 kg

Figure 66: Technical properties of the heat recovery device

4.2.6. Renewable energy sources

There are 88 photovoltaic panels (figure 67) placed along the three different roofs of the building. Their main technical features are shown in the following table:

MODEL: ELIFRANCE EL60255	
ELECTRICAL DATA AT STC	
Maximum Power (Pmax)	255 Wp
Voltage at Maximum Power (Vmpp)	30.58 V
Current at Maximum Power (Impp)	8.34 A
Open Circuit Voltage (Voc)	38.14 V
Short Circuit Voltage (Isc)	8.89 V
Panel Efficiency	15.42 %
MATERIAL DATA	
Panel Dimension (H/W/D)	1,655 x 999 x 35 mm
Weight	19 kg
Cell Type	Polycrystalline

The peak electric output of the complete solar field is approximately of 22 kW. The produced electricity is consumed onsite to supply the required electricity to the following equipment:

- Heat pump.
- Dwelling ventilation system.
- Parking floor ventilation systems.
- Pumps of the heating and DHW production system.
- Elevators
- Lighting of the common areas (entrance, storage rooms, etc).

Figure 67: PV panels distributed on the different roofs of the building

4.2.7. "Free Energy" concept operation

As mentioned before, described construction solutions and energy systems in previous sections allow supplying free heat to the dwellings of the building, without any fossil fuel consumption. Therefore, tenants could maintain satisfactory comfort conditions with low cost.

On sunny days with high level of solar irradiation availability, the solar wall active facade can provide a satisfactory temperature increase to the preheated air flow used as heat source of the heat pump. As a consequence, the heat pump will operate with very high performance values and low electricity consumption.

At the same time the high availability of solar irradiation will enable high values of local electricity production that in many cases will allow covering 100% of the electricity consumption of the heat pump with the production of the PV plant.

Therefore, whenever the temperature of the preheated air produced by the solar wall is above the established setpoint value (in order to ensure high efficiency values for heat pump operation), and the production of the PV plant can cover the electricity consumption of the heat pump, the heat plant will operate, to supply free heating to the dwellings at no cost for tenants (figure 68). The setpoint temperature to be provided by the heating system of the building operating under the free energy mode is set to 21 ºC. All the residents will have the same priority to access to the free energy heat delivery.

Obviously, the scope of the free energy concept will only cover heat pump operation, and therefore, if the power output of the heat pump is not enough to cover the demand of the building and the contribution of any of the other generators running on natural gas is necessary, the cost of their operation will not be included inside the "free energy concept".

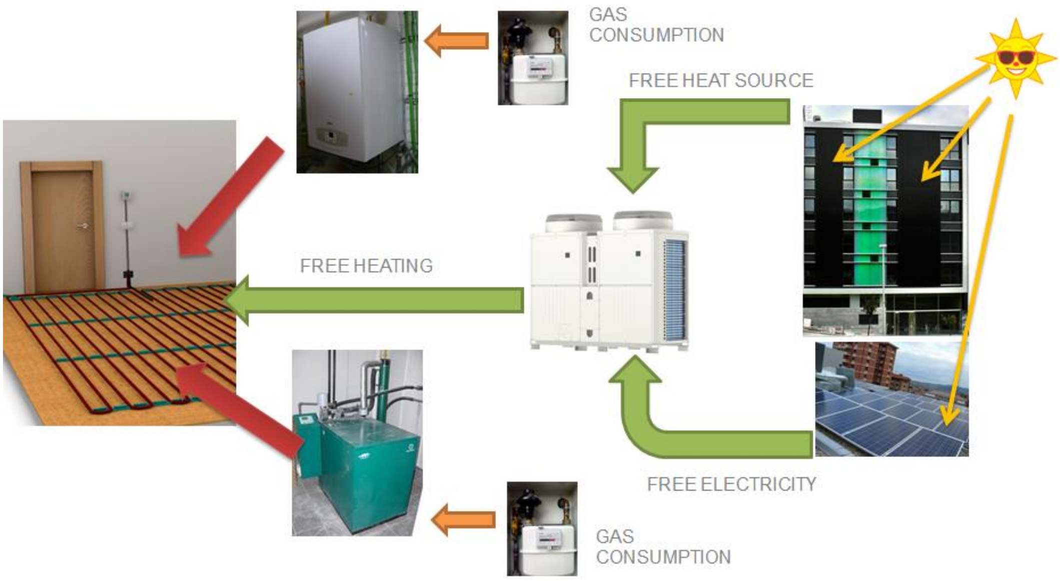


Figure 68: Different options of heating the dwellings

The free energy mode will remain active whenever the following conditions are satisfied:

- Air temperature pre heated up to established set point (21 ºC)
- Internal temperature of the dwellings <21 ° C

The defined free energy heating mode will contribute to ensure a minimum comfort level for all the tenants of the building, and will avoid the presence of dwellings with unacceptably low comfort conditions that could generate envelope pathologies (thermal bridges, condensation problems, etc) and, additionally, behave as cold spots or heat sinks that would affect negatively to the comfort conditions and the cost associated to the heating of surrounding dwellings.

When the existing boundary conditions are not compatible with the activation of the free energy mode (cloudy days, etc), the heating system of the building will operate according to the conventional operating mode. The cost of the heating system operating according to the conventional mode will generate a monthly fee that tenants will have to pay.

Additionally, tenants will be allowed to increase the comfort level set for the free "energy mode" (21 ºC) through their thermostats located in the living room of their dwellings, but the energy necessary to cover this additional comfort will not be included inside the boundaries of the free energy operational mode, and as a consequence will have a cost for tenants.

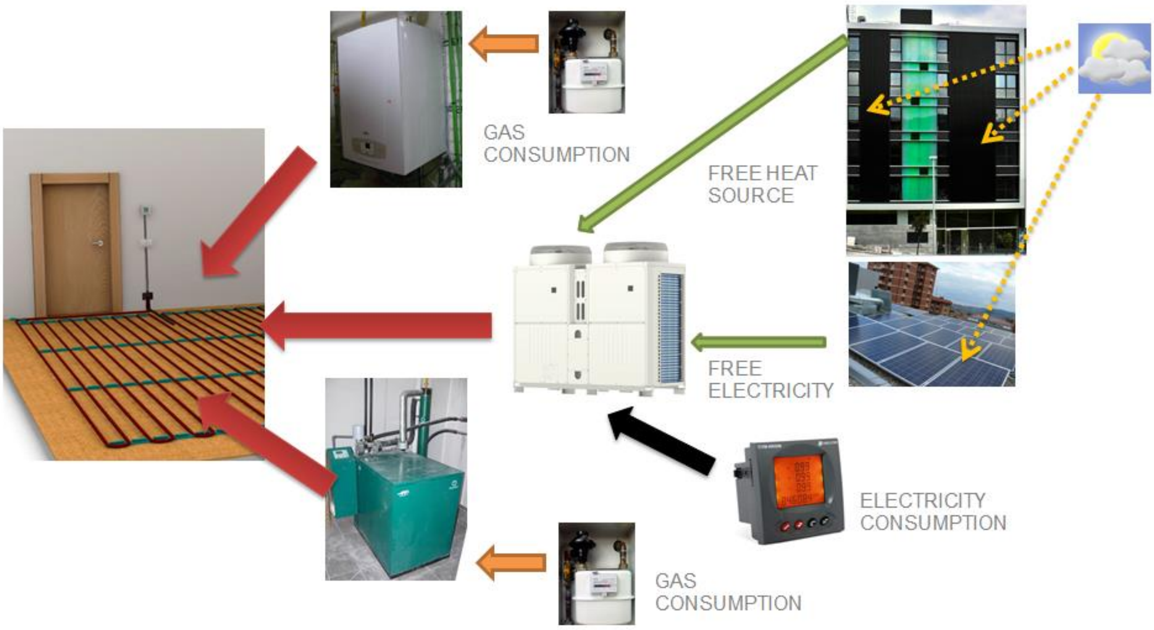


Figure 69: Conventional heating delivery mode

4.2.8. Control and monitoring platform

An advanced control and monitoring system has been deployed, in order to enable the operation of all the integrated systems according to their designed strategies and to provide monitoring and optimization functionalities. The platform is formed by a dedicated sensor network, a dedicated actuator network, a meter network and control hardware and software.

This platform will permanently supervise the operation of all the systems (setpoints and active operational modes) according to the evolution of internal and external boundary conditions, and will read the values collected by the dedicated sensor and meter networks and write them in the data base, according to the set time stamp and data structure (15 minutes).

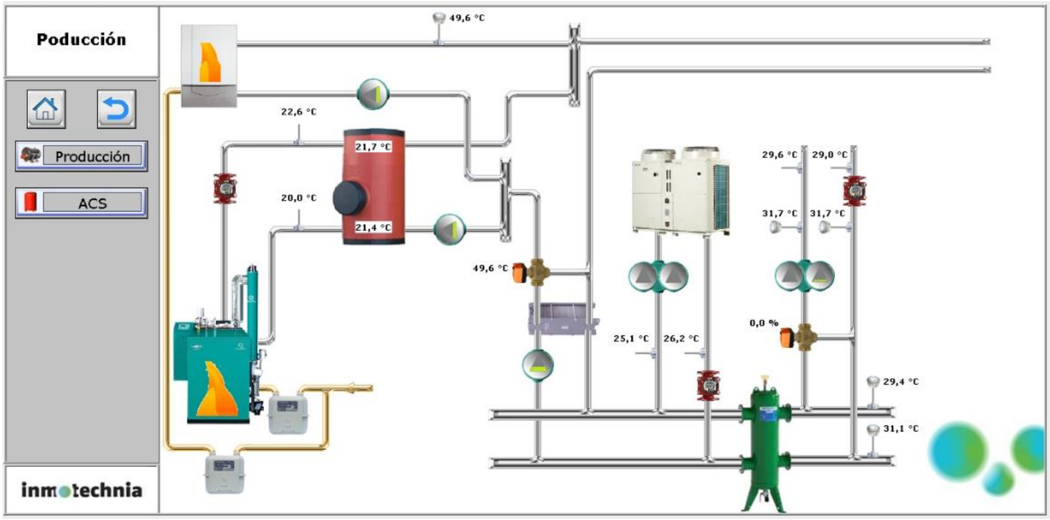


Figure 70: Monitoring platform's interface

4.2.8.1. Control system

The control cabinet with the automation server, all the necessary field controllers and the input/output cards required to integrate the existing sensor and actuator networks is deployed in the heating plant room. All the data are read and all the commands are sent from the central cabinet of the control and monitoring system. The interior of the control cabinet is displayed in the figure 71.

Figure 71: central control cabinet with the automation server and field controllers

Figure 72: Visualization screen integrated in the central control cabinet

The networks that are connected to the central cabinet are integrated according to the following criteria (infrastructure and communications protocols):

- Field controller integration through a dedicated Bus (ModBus)
- Heat plant meter network integration through a dedicated Bus (ModBus)
- Electric meter network integration through a dedicated Bus (ModBus)
- Apartment level heat meter integration through a dedicated Bus (MBUS)
- Roof field controller integration through Ethernet

In the following figure the most relevant hardware integrated on the system is displayed:

Figure 73: Hardware integrated in the monitoring system

4.2.8.2. Monitoring system

The monitoring system monitors the evolution over time of the values of the variables that have an impact on the final performance of the building, including climatic conditions, thermal comfort and the operation of all the sub-systems/systems of the building.

In the picture the scope of the monitoring system is summarized:

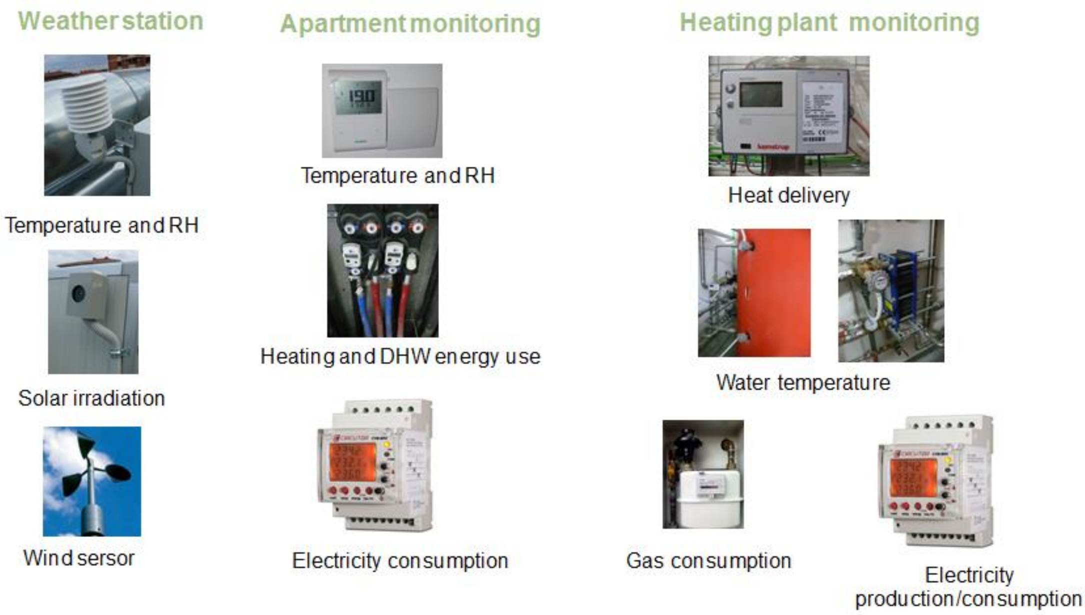


Figure 74: Scope of the monitoring system

Dwelling level monitoring includes thermal comfort (indoor temperature and relative humidity), heating energy use, hot water consumption and the electricity consumption. The scope of the dwelling level monitoring system is displayed in Figure 75.

The integration of the field devices (sensors and meters) has been carried out through a wired communications infrastructure in order to simplify the platform and maximize its reliability (no battery failures, no black spots with deficient connectivity, etc). Additionally, this design allowed optimizing the cost of the system.

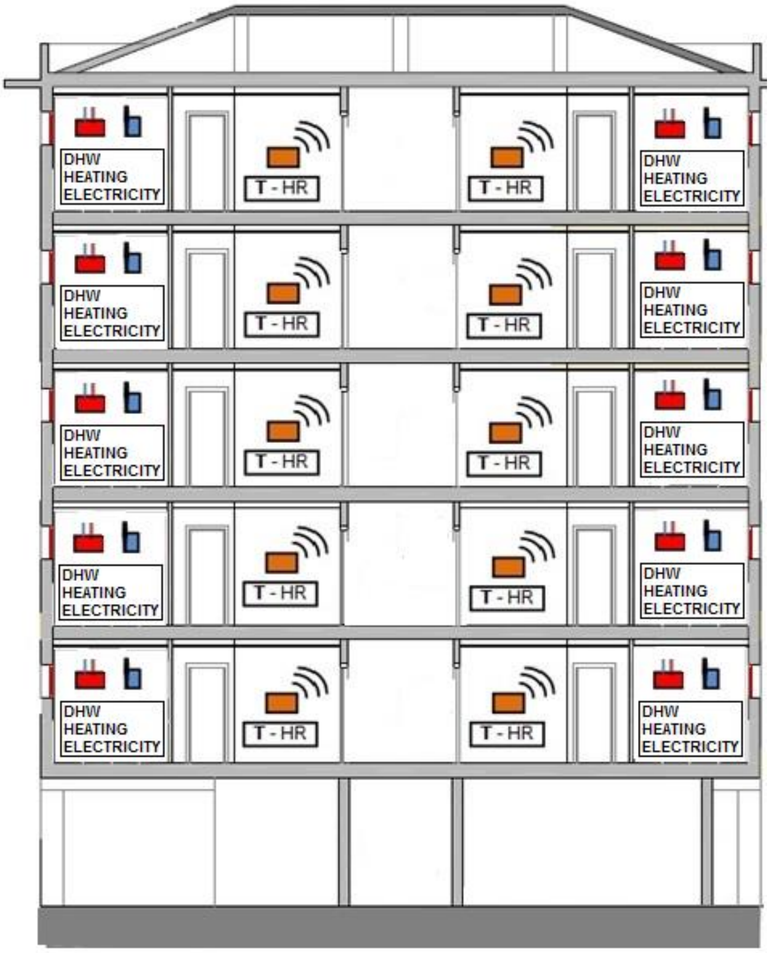


Figure 75: Dwelling level Monitoring scope

Dwelling interior temperature [°C] and relative humidity [%] are measured with a single multipurpose sensor installed in the living room of each dwelling (figure 76).

Figure 76: Temperature and relative humidity sensor

The heating and domestic hot water consumption of each dwelling is metered through a dedicated energy meter deployed in the utility ducts (figure 77)

Figure 77: Energy meter deployment inside utility ducts

On the other hand, and in order to measure the electric consumption of each dwelling, dedicated electricity meters have been installed in the electric cabinet deployed in the main entrance of the building (figure 78).

Figure 78: Electricity meters of the dwellings

On the other hand, the specific climatic conditions on the building site are monitored by a meteorological station deployed on the roof of the building. The following climatic variables are continuously monitored.

- Outdoors air dry bulb temperature (figure 79)
- Humidity
- Wind speed
- Wind direction

Figure 79: Exterior temperature and humidity sensor

Regarding the control and monitoring of the operational variables of the subsystems/systems of the building, the scope of the existing platform includes the active facades (trombe wall and solar wall), the ventilation system, and the generation and distribution subsystems of the heating and DHW production system of the building:

In the following lines, a summarized description of the components deployed to control and monitor these subsystems/systems is provided:

- Active facades: The same variables are controlled and monitored in the case of the Trombe wall and in the case of the Solar Wall:
    - Air flow in the air cavity
    - Temperature of the air
    - Control of the existing dampers to exploit or reject the preheated hot air flow produced by the active facades (figure 51)
- Ventilation system: All the necessary air temperature and flow rate sensors have been deployed to monitor the conditions of intake air, return air and exhaust air of each of the AHUs of the ventilation system.
- Generation subsystem: All the sensors and meters necessary to evaluate the performance of each of the heat generators of the heating plant and to perform energy balances at all the relevant points of the generation sub-system have been deployed.
- Heat Pumps

  - Heat production (heat meter)
  - Electricity consumption (electric meter)
- CHP
  - Produced heat (heat meter)
  - Produced electricity (electric meter)
  - Gas consumption (gas meter)
- Condensing Boiler
  - Produced heat (supply temperature, return temperature, water flow)
  - Gas consumption (gas meter)
- DHW production heat exchanger (energized by the CHP storage tank and the condensing boiler)
  - Delivered heat (heat meter)
- DHW preheating heat exchanger (energized by the low temperature load side manifold)
  - Delivered heat (heat meter)
- Heating distribution subsystem
  - Delivered heat (heat meter)
- DHW distribution subsystem
  - Delivered heat (heat meter)
- CHP storage tank
  - Water temperature at the bottom of the tank (temperature sensor)
  - Water temperature at the top of the tank (temperature sensor)
- DHW production/storage tank
  - Water temperature at the bottom of the tank (temperature sensor)
  - Water temperature at the top of the tank (temperature sensor)

The MULTICAL® 602 heat meter has been the selected equipment for heat metering purposes (figure 80). It is used typically in water-based HVAC systems with temperatures ranging from 2°C to 180°C for heat and from 2°C to 50°C for cooling. The heat meter is formed by a ULTRAFLOW® 54 water flow meter, and two temperature sensors.

Figure 80: Energy calculator device

The deployment of the heat meter of the heating and DHW distribution hydraulic circuits is displayed in the next figure (figure 81).

Figure 81: Heat meters deployed on the heating and DHW distribution hydraulic circuits

In the following picture the main specifications of the water temperature sensor used all over the heating and DHW production system are summarized. The used temperature sensor is the TREND TB/TB/S model (figure 82).

SPECIFICATIONS

Sensing element	:Thermistor 10 kΩ at 25 °C
Thermistor accuracy	
-10 °C to +40 °C	:±0.43 °C (14 °F to +104 °F, ±0.77 °F)
- 30 °C to +50 °C	:±0.59 °C (-22 °F to +122 °F, ±1.06 °F)
- 30 °C to +100 °C	:±1.11 °C (-22 °F to +212 °F, ±2.0 °F)
- 30 °C to +110 °C	:±1.28 °C (-22 °F to +230 °F, ±2.30 °F)
Ambient limits	
box	:-40 °C to +50 °C (-40 °F to +122 °F)
/TC probe	:-40 °C to +100 °C (-40 °F to +212 °F)
/TI probe	:-40 °C to +110 °C (-40 °F to +230 °F)
Humidity	:0 to 95 %RH
Measurement ranges	
/TO	:-30 °C to +50 °C (-22 °F to +122 °F)
/TC	:-30 °C to +100 °C (-22 °F to +212 °F)
/TI	:-30 °C to +110 °C (-22 °F to +230 °F)
Cable entry	:M20 conduit with M16 cable gland
Connections	:1 part screw terminals for 0.5 to 2.5 mm² cross section (20 to 14 AWG) cable
Pockets	:Pressure tested to 7 bar
Dimensions	
/TC	:57 mm (2.24") x 117 mm (4.61") max diameter, cable 2 m (6'6")
/TO	:57 mm (2.24") x 102 mm (4.02") max diameter
/TI	:(box)57 mm (2.24") x 105 mm (4.13"), /S probe 150 mm (5.91") x 6 mm (0.24") /L probe 400 mm (15.75") x 6 mm (0.24")
Material	
Enclosure	:Impact resistant ABS
/TI, /TO probes	:Brass
/TC probe	:Plated copper
POC/SS/6	:pocket, 316 stainless steel/silver solder
POC/B/6	:pocket, brass/silver solder
Environmental Protection	:IP67 (NEMA6)

Figure 82: Temperature sensor and its specifications

The figure below shows the mounting positions of the water temperature sensors installed in the CHP storage tank and the DHW production and storage tank (figure 83).

Figure 83: Temperature sensors installed in the thermal storage tanks

In the following pictures the mounting position of some of the water temperature sensors integrated on the heating and DHW production and distribution sub-systems are displayed, including the sensors on the hydraulic circuits of the plate heat exchangers (figure 84), and the sensors of the heating distribution hydraulic circuit (figure 85).

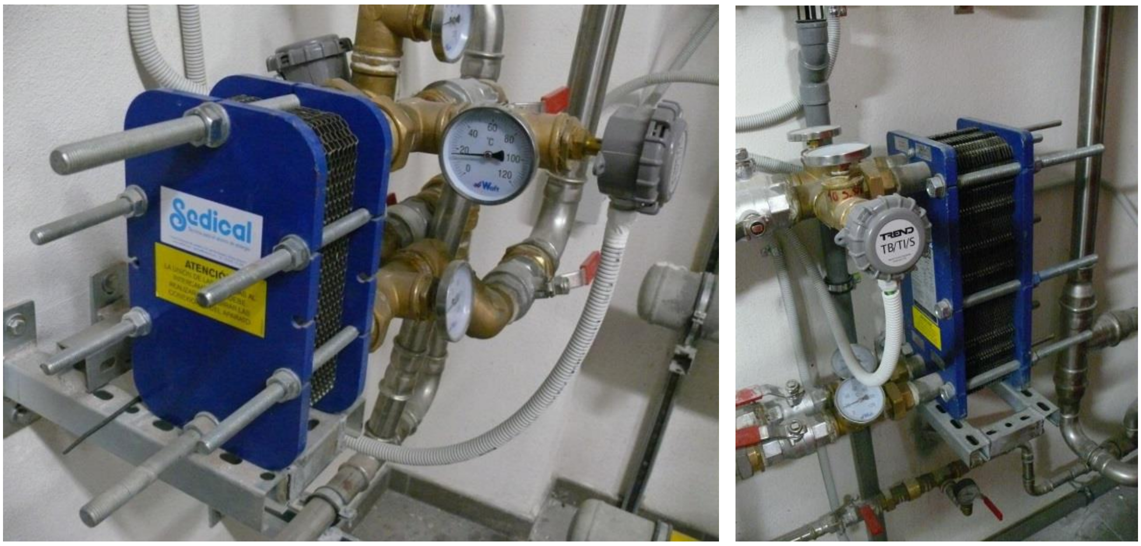


Figure 84: Temperature sensor installed in the plate heat exchangers

Figure 85: Temperature sensor in the heating distribution hydraulic circuit

4.2.9. Visualization system.

One of the main objectives of the project is to develop procedures to promote an energy efficient behavior of building occupants. Visualization technologies that can supply accurate real time information about the existing comfort conditions and the energy consumption and cost necessary to deliver them, is considered the best strategy to give the opportunity to users of optimizing their use of energy.

Each dwelling incorporates a thermostat (field controller) that the dwelling occupant can use to adjust the desired thermal comfort profiles (setpoint temperatures and heating availability schedules on a daily, weekly or seasonal basis), and a visualization screen that displays real time energy consumption figures.

The thermostat (SIEMENS RDE100.1 mo/ figure 86) is placed in the living room and enables the definition of different heating programs on a daily, weekly or seasonal basis.

Figure 86: Dwelling thermostat

In order to enable monitored data visualization to the user, a digital screen has been installed in the living room of each dwelling, below the thermostat. The selected visualization screen is the Energy System Energy Neo 2 model (figure 87).

MODEL: ENERGY NEO 2	
TECHNICAL SPECIFICATIONS	
Screen dimension	TFT-LCD 7”
Resolution	1024 x 600 pixels
Internal memory	8 GB
Ram Memory	1 GB
Processor	Quad Core ARM Cortex A7 1.3 GHz
MATERIAL DATA	
Display Dimension (H/W/D)	191 x 110 x 11 mm
Weight	265 g
Cell Type	Polycrystalline

Figure 87: Visualization screen technical specifications

The visualization devices provide many functionalities and visualization screens such as:

- The dwelling energy use visualization screen including the information about the instantaneous values of the comfort variables (temperature and relative humidity), the heating, DHW and electricity energy use and the remaining monthly heating credit value.
- Building level performance visualization screen including information (performance indicators and trend charts) about the onsite electricity production (PV panels and CHP), the average consumption of the residents in heating and domestic hot water, the electrical consumption of the elevators, and the lighting consumption of the common area of the building (entrance, etc)

The final assembly of the visualization screen below the thermostat and the temperature sensor is shown in the figure 88.

Figure 88: Final assembly of the information system

4.3. Overcome difficulties and barriers.

Portugalete demo building was designed aiming to reach high level of energy efficiency including high efficient solutions not very used normally in construction in Spain. Apart from the technical solutions differing from the traditional construction systems, innovative concepts are included in the project relating with the management of the building and social participation. Due to this innovative profile, some difficulties and barriers were found during different project stages. These are described bellow.

4.3.1. Building envelope

First of all, in general and comparing with traditional constructions, some technical difficulties were found when installing prefabricated elements and active solutions on the facade. In order to ensure a correct execution of the building special resources and specialized workforce were required.

Regarding active facades, at the beginning of the project a different solution was proposed. An active façade system called Intelligas was selected at first. However, some difficulties appeared regarding profitability of the solution, maintenance and water risk problems and other. Therefore this solution had to be rejected and it was necessary to look for another solution to install instead of it. Finally, ”solarwall” was selected as alternative active façade.

During the ejection of the envelope, special effort was made to ensure the tightness of the building and a correct integration of the different solutions.

Another critical point was the connection of the active facades to the energy systems. Due to some different reason including costs and available space in the dwellings, ventilation heat recovery system was forced to be centralized instead of individual systems. Therefore, the planned use of the heat gains derived from the active facades had to be changed to be used with the central system. Revisions of the air conducts had to be made.

4.3.2. Energy systems

One of the main barriers that had to be overcome in the Project was related to the generation systems. At the beginning of the project two cogeneration units were planned besides the PV collectors. However, Spanish regulations regarding electricity production and exploitation became very restrictive in such a way that the solution had risk not to be profitable enough. Therefore, one of the planned CHP units was replaced by a heat pump. This heat pump could use generated electricity by the other CHP unit and the PV system, so that self-consumption strategy was implemented.

Other critical point was to ensure a correct connection of all energy systems and establish required control channels and strategies.

4.3.3. Building use

The difficulties may continue during the first stages of the building use. Due to the special features and innovative solutions integrated in the building some problems may appear with the tenants and the correct use of the building. In order to reduce these difficulties, special training is planned addressed to the tenants.

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