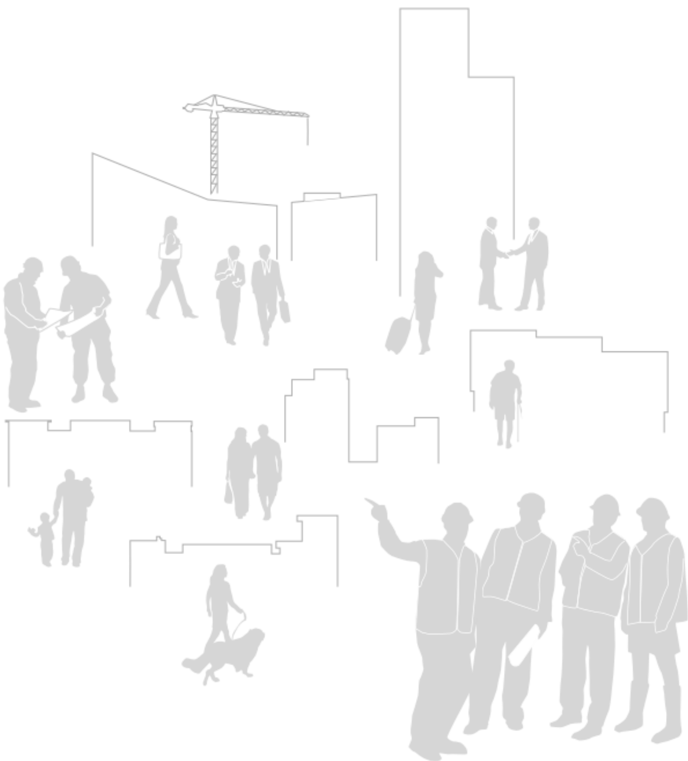
BUILDSMART

Energy efficient solutions ready for market



D2.6 “Description of constructed very low energy nonresidential building”

27 July 2016

Author(s): Kerstin Rubenson, City of Malmö; Åsa Johansson, Skanska; Behar Abdulah, Skanska

Dissemination level	
X	PU = **Public**
	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	2015-11-06	KR	First version (M 49)
1.1	2015-12-08	KR	Second version (M50)
2.0	2016-02-05	KR	Final version (M52)

Summary

This deliverable defines the main characteristics regarding energy efficiency of the Buildsmart non-residential demo buildings:

- Skanska Hotel Building, in the KKH area in Malmö
- Skanska Office Building, in the Hyllie area in Malmö

The three other non-residential demo buildings are withdrawn from the project.

The hotel and the office are constructed according to plan, and are now being fully used. The monitoring of the buildings is initiated, making it possible to assess the performance of the buildings during the upcoming year.

Contents

1 Introduction

Energy use in the construction and building sector is responsible for approximately 40 % of the entire energy use in the EU, and 36 % of the emissions of CO_2 throughout the union. In other words, this sector has an incredibly large impact on the environment and contributes massively to climate change. Energy performance of buildings will therefore be an important key factor to achieve the energy and climate targets set up by the European Commission for the year 2020: reduction of greenhouse gas emissions by 20 percent, energy savings of 20 percent and increased use of renewable energy with 20 percent.

The pattern in energy use varies regarding to the function of the building. Some use more electricity, some more heating or cooling. The energy use distribution over the day is also different in different types of buildings. Also, the restrictions and requirements differ. Therefore, in Buildsmart different types of buildings are constructed, in order to demonstrate and mainstream innovative and cost effective techniques and methods for different types of very low energy buildings. In this report, descriptions of construction of a hotel and an office building are included. Residential buildings are described in another report.

A systemic approach was taken during designing and construction of the demonstration buildings in order to reduce energy use and environmental impact. Techniques for air tight and insulating building envelopes were combined with different kinds of energy efficient installations. The buildings are characterized by:

- A total very low energy consumption
- Dense envelopes in order to create a high air tightness and low energy losses
- Energy efficient installations creating a minimized 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 technology to show cost effectiveness and a high potential for replication.

2. Klipporna Office Building in Hyllie, Malmö

2.1. General description

The design of the buildings is developed by the Danish architects Henning Larsen. As the name tells (the Swedish word Klipporna means The Rocks in English) the buildings are inspired to look like rocks, with leaning roofs and dramatic peaks on the top floor.

The buildings mainly consist of office floors. Low energy use is high priority both concerning the construction of the building and the information to the users of the building. The expected specific energy use was calculated to 58 kWh/m^2 and year or 62 kWh/m^2 and year in terms of primary energy. With the 1st phase (out of three) up and running the result confirms the calculations and shows an energy use of 62.6 kWh/m^2 (primary energy).

Energy used for cooling is usually large in office-buildings. Here cooling is delivered from the natural ground water beneath the buildings. To additionally reduce the need for cooling, the façades are designed with a characteristic window chamfer to prevent the sunlight to penetrate into the building.

Lighting inside often causes cooling needs, but in these buildings low energy lighting is used to lower the heat gained by lighting. The lighting on the office floors is controlled through sensors with movement- and daylight detection.

The ventilation system is of balanced form, with high heat recovery. The system uses energy efficient, low speed units for spreading the fresh air into the building.

The buildings are located just opposite a large public transport hub including Hyllie City tunnel station enabling transports to Malmö central station in 6 minutes and the international Copenhagen Airport in 12.

To further fulfill the sustainability vision, the project is pre-certified according to the highest level of LEED-certification – LEED Platinum. The project also has high standards when it comes to choosing sustainable and non-emitting building materials and creating a green and inviting environment surrounding the buildings.

2.2. Energy Technologies

2.2.1. Lighting and electric equipments

The lighting on the office floors is controlled by movement- and daylight detection through sensors. The basement and the facility management areas, WC, storage areas, staircases etc are also covered by the presence-detection lighting system. In order to reduce electricity consumption for lighting the prevalent technology is low energy and LED lighting.

To further reduce the impact of electricity usage at Klipporna, Skanska has signed a lease for electricity distribution with Sjisjka Wind Power Park in the north of Sweden. Skanska is co-partner of the park with 30 windmills producing 200 GWh/year. (See http://www.sjisjkavind.se/)

Spaces including switchgear and other electronic equipment are built to limit the electric and magnetic fields. All wirings and installations made out of plastic are halogen free.

2.2.2. HVAC (Heating, Ventilation and Air-Conditioning) equipment

2.2.2.1. District Heating

The buildings are connected to the district heating system of the city of Malmö. The district heating in Malmö is delivered from Öresundsverket which is a modern combined heat and power (CHP) facility that combines natural gas turbine, exhaust gas boiler and steam turbine. The use of advanced technologies provides a high electrical efficiency (58%) and the capability to extract and use, at full power, nearly 90 percent of the fuel´s energy during full production of heat.

The electricity produced by the CHP plant is injected on the grid while the heat production (as steam) is used to supply hot water to Malmö's district heating system. Natural gas is the used fuel which enables high efficiency and low emissions compared to other fossil fuels. In the long term, a progressive substitution of natural gas to biogas is planned which will further reduce carbon dioxide emissions.

The buildings are connected to the district heating system through a heating substation which supplies the buildings with all the required services at the required conditions (radiator system, domestic hot water system and mechanical ventilation air pre-heating coils).

2.2.2.2. Heating system

The system is designed to heat the office floors to 21.5 C°. The basement area is designed to have a lower temperature than the office floors: 10 C° in general, 15 C° for storage and 20 C° for changing rooms. The heating system consists of a conventional hot water radiator system which enables the tenants to regulate the heat delivery to adjust the temperature to their specific comfort criteria, within the range of 20-22 C°, in order to ensure high energy efficiency levels.

2.2.2.3. Ventilation

Klipporna has a self-regulating ventilation system. The solution is simply based on having the pressure drop in the ducting system concentrated to the end of the ducting system. The pressure drop is located to the supply air diffusers or cooling beams as supply air diffusers. Traditionally the pressure drop relation in a ducting system between the ducts including dampers/sound attenuators and the supply air diffusers is 200 Pa/40 Pa.

In a self-regulating ducting system the pressure drop relation between the ducts and the supply air diffusers is 20 Pa/100 Pa, a final pressure drop. The low pressure drop in the ducts is possible to achieve while there are no dampers/sound attenuators in the ducts and while the duct dimensions are not reduced in diameter along the shafts or along the corridors on the office floors. The high pressure drop in the supply air diffuser is possible to achieve if the component is designed by the manufacturer for low noise, sound level.

Self-regulation ventilation enables changes to be easily made locally, without demand for rebalancing of dampers in the ducting system. It is also easy to install since smaller duct dimension is used than in a traditionally designed ducting system.

Energy efficiency is increased when using self-regulating ventilation due to the lower power demand caused by the lower total pressure drop over the ventilation ducting system (120 Pa compared to traditional 240 Pa).

The ducting system on the office floors is designed for maximum 3 m/s. Even if the air flow is reduced along the duct the dimension shall not be reduced. To keep the duct dimension constant on the floor will enable same static pressure in the duct independent on where on the duct the pressure is measured.

The ducting in the shafts is designed for maximum 5 m/s. Even if the air flow is reduced along the duct the dimension shall not be reduced. Connection ducts between shaft duct and the corridor ducts shall be made with no sharp bends that causes pressure drop, maximum 20 Pa. Keeping the pressure drop in the ducting system low gives flexibility for future changes of air flows on the office floor during construction and after finalizing of construction.

The AHUs are located on the two top floors of the buildings and are equipped with high efficiency heat recovery devices providing sensible heat recovery efficiencies above 72 % (FTX-system). The AHUs also have two extra pre-heating units of the outdoor air. The first step is a coil to restore the groundwater temperature to its normal level (during the cold season), the second coil is to pre-cool the return water in the cooling beam system (when possible). This means that there are two extra steps of heat recovery beside the normal heat recovery unit.

The first two buildings (phase 1 and 2) have two AHUs each, with separate intake chambers and ventilation shafts adjacent to the stairwells. The third building is equipped with one AHU.

The AHUs are Eurovent certified and CE labeled and include outdoor and exhaust air dampers, outside air filters (class F7), and exhaust air filters (class F6).

2.2.2.4. Cooling

Deep Green Cooling is designed to provide cooling for the indoor climate system for heating, ventilation and air conditioning (HVAC) but could also be used for cooling of processes as computers, servers etc.

The system at Klipporna is based on 70 bore holes approx. 200 m deep connected to a closed cooling circuit supplying the buildings with renewable, locally produced chilled air.

The main component in the solution is the self-regulating cooling system in the building which operates with chilled water temperatures at room temperature level, and the ground storage which operates with chilled water temperatures at normal ground temperature level.

The solution can cover the entire annual cooling demand of a building without usage of chillers, if the conditions described below are fulfilled. The solution is simple and robust since it is operated by traditional circulation pumps instead of by compressors.

The ground is cooling the building in the summertime. Wintertime the temperature in the ground is restored by outdoor ambient temperature. Preferably the heat stored in the ground during summer can be used to preheat the incoming ventilation air in the winter, while at the same time the storage is cooled down by the ventilation air.

Annual mean temperatures

The main condition is that the temperature difference between the annual mean ground temperature and the indoor design temperature (summertime) is not lower than 10 degrees C.

Normally, the ground temperature is increased by 1.5^{o}C every 100 meters below ground surface and therefore the mean temperature in the ground, with bore hole length of approx. 200 meter, is approx. 1.5^{o}C higher than the annual mean outdoor temperature. Also the presence of snow during winter will have impact of the ground temperature, approx. 1.2 – 1.3^{o}C per 100 days of snow in Sweden. In cities the mean temperature in the ground could be higher due to the urbanization (in a location in the City of Stockholm the mean temperature in the ground is 2^{o}C higher than it should have been outside of the city).

Annual mean outdoor temperatures	
City	**Temperature**
Copenhagen	+8.5^{o}C
Malmö	+8.0^{o}C
Gothenburg	+7.9^{o}C
Stockholm	+6.6 ^{o}C
Helsinki	+5.0^{o}C

Ground conditions

The type of rock in the ground affects to some extent the heat transfer between the pipes in the bore hole and the rock, but not dramatically. The absence or presence of ground water flow in the rock does not affect the function while the rock storage is maintained in the normal ground temperature level.

Size of project

The size of the storage, or the building, is not critical while the storage operates at normal ground temperature and therefore there are no losses from the storage that affects the performance.

Building design

The chilled water circuits have to be designed for a much higher temperature level than in a traditional building.

General building requirements

The general building performance requirements on which the here described solution is based, can be summarized as:

- Cooling peak demand for HVAC approx. 25 W/m^2 LOA (lettable area)
- Cooling annual demand 35 kWh/m^2 LOA (lettable area); approx. 25 kWh/m^2 LOA for HVAC and approx. 10 kWh/m^2 LOA for process
- Ventilation air flow rate 1.5 l/s m^2 LOA
- Running hours approx. 3400 hours/year (13h/5d)
- Water-based cooling system by using self-regulating cooling beams

Specific building requirements (cooling related)

Ventilation air speed is 1.0 m/s through cooling coils in the air handling unit.

Specific building requirements		
	Indoors	**Outdoors**
Cooling coil for charging storage, °C		
Outdoor Air	0	+7
Chilled brine (KB3)	+9	+2
Cooling coil for air, °C		
Supply Air	+27 /50% RH	+20
Chilled water (KB1)	+17	+23
Chilled beams, °C		
Chilled water (KB1)	+17	+23
Chilled beam water (KB2)	+20	+23
Cooling coil for process, °C		
Chilled water (KB1)	+17	+23 (or less)

2.2.3. Renewable Energy Sources (RES)

2.2.3.1. Geothermal

See chapter **2.2.2.4 Cooling** for more information regarding *Deep Green Cooling*.

2.2.4. Energy storage (for Deep Green Cooling)

The cooling load extracted from the ground during cooling phase in the summer has to be restored into the storage during winter. Otherwise the ground temperature will increase from year to year, and finally exceed the limit where it will not be possible to cover the cooling demand.

In wintertime the storage could be charged by the incoming outdoor air for ventilation of the building, by surface cooling (heating of pavements) and/or by use of outdoor-placed glycol dry cooler etc.

A cost effective depth of a bore hole is approx. 180 - 200 meters and the effective length could be approximated to 170 meters (below ground water level). The size of the storage is a multiple of this. The distance between the boreholes should be at least 6 meters. If there is a shortage of area for placing the bore holes in the ground at the surface, the bore holes could be angled relative each other keeping in mind the minimum average distance of 6 meters at 100 meters' depth.

- bore hole diameter 115 mm.
- bore hole depth approx 170 m
- bore hole distance min 6 m
- U-tube dimension 40 mm PEM hose with tube wall thickness of 2,4 mm (PN8).
- design power output 50 W/m per bore hole
- storage circuit water flow per U-tube 0,3 l/s
- storage circuit water temperature difference between supply and return 7 ^{o}C when charging
- storage circuit water temperature difference between supply and return 6 ^{o}C when cooling

Heat exchanger for storage charging, ^{o}C	In	Out
Chilled brine (KB3)	+2	+9
Storage circuit (KB0)	+10	+3

Heat exchanger for storage output, ^{o}C	In	Out
Storage circuit (KB0)	+16	+22
Chilled water (KB1)	+23	+17

Charging (of storage):

- Charging start by date[1]. Charging is allowed between 15 October and 15 March.
- On/off motor valve for charging heat exchanger in storage circuit (KB0) is working in parallel with Air Handling Unit. If at least one AHU is in operation during charging period the on/off valve is fully open, otherwise it is closed.
- Temperature in storage circuit (KB0), out from charging heat exchanger in to storage, is kept at constant +5° C, controlled by variable speed (flow) of circulation pump in chilled brine (KB3).
- Freeze protection by closing all pumps in chilled brine circuit (KB3) when temperature in storage circuit out from charging heat exchanger (KB0) is below +2° C.
- Circulation pump in storage circuit (KB0) is working continuously, see below.

2.2.5. Building envelope

The building envelope is constructed of pre-fabricated thick concrete walls and floors, insulated with cellular plastic, resulting in an airtight building envelope. The windows are triple-glazed with a U-value of 0.9 W/m2K, and the window openings are designed to provide sun shading, for reduced cooling need. The roof consists of a supporting steel frame, corrugated steel sheets and mineral wool insulation. It is covered with sedum, creating a green roof as to promote biodiversity, give a noise dampening effect and purify the air from particles and capture acid deposition.

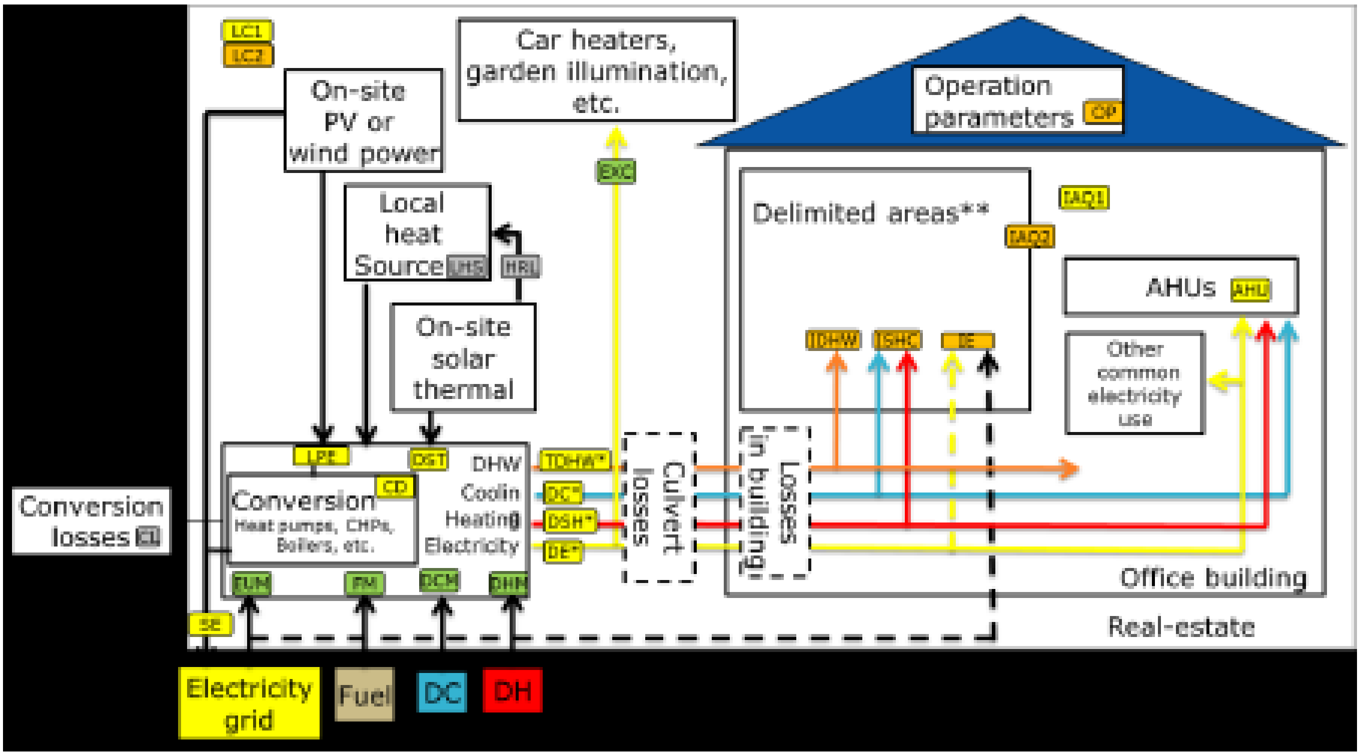
2.3. ICT/BEMS

Below is a schematic picture of the BEMS system in the building. The metering points are colour coded according to to the following:

- Green points represent basic metering requirements in Sweden.
- Yellow points represent additional metering points needed to meet the goals within the frame of the BuildSmart project.
- Orange points represent advanced metering options that can provide information for a more detailed analysis of the building's energy performance.

More information on this system, such as a description of the individual metering points, is found in Deliverable 5.2: Monitoring systems for two buidling types – residential and office buidlings.

[1] By using date instead of outdoor temperature several starts and stops are avoided. By initiating the charging late in the autumn, instead of starting every hour that the storage temperature is higher than the outdoor temperature, hours of operation with high power demand for circulation pumps at low charging cooling power is avoided.



*If applicable and if not measured indirectly by subtraction of other meter data
**Delimited areas are physically separated areas such as separate floors or delimited areas rented to separate tenants

Below is a table over the kinds of energy flows that are measured in the building:

	Energy meter description	Measured energy use
Electricity utility meter	Utility meter A1A, A1B, A1C and A1D	Bought energy, Electricity utility meter
Fuel utility meter		
District cooling utility meter	Electricity for the Deep Green Cooling-pumps 5500-P1A/B and 5505-P1.	This electricity use is also included in the distributed electricity
District heating utility meter	From energy supplier Eon (VMM)	
Sold electricity		
Solar thermal		
Locally produced electricity		
Heat for domestic hot water use	Utility meter 5201_VMM1	
Distributed cooling	(Utility meter 5500-KMM1)	Locally produced renewable (geothermal) cooling system called Deep Green cooling. Not included in the total energy usage.
Distributed space heating	Utility meter 5601-VMM2, 5603-VMM1	
Distributed electricity	Utility meter A1A and A1D	Elevators, sprinkler, telecom, AHU, pumps
User electricity	Utility meter A1B and A1C	User electricity includes restaurant.
Excluded electricity		
Electricity for heating in AHU or other local heater		
Water volume for domestic hot water	Utility meter 5201-VMM1	
EXAMPLE	**Distributed space cooling: Data from utility meter (the only cooling source which is only used for space cooling).**	**Heat for domestic hot water use: Losses from hot water tank is included (approx. 2000 kWh/year according to product data).**

3. Malmö Live Hotel, Malmö

3.1. General description

The design of the buildings is developed by the Danish architects Schmidt Hammer Lassen. The hotel is an integrated part of the larger complex Malmö Live, which consists of a congress facility and a concert hall.

The building consists of two floors with entrance and office areas, as well as a restaurant in two floors. The hotels' 444 rooms are on floors 3 to 24, and the 25th floor is a bar/restaurant. HVAC rooms are placed in the basement, on the 13th floor and on the 24th floor to serve the hotel, and on top of the congress hall to serve the lower kitchen and restaurant. Low energy use was an important factor in the design and the calculated specific energy use is 31 kWh/m^2 and year, which translates to 47 kWh/m^2 and year in terms of primary energy. No verification of the use is yet presented, and start-up of the geothermal energy plant and stabilizing the geothermal temperatures will generate slightly higher numbers initially.

In hotels, as in offices, the cooling load is fairly large. In Malmö Live the cooling load is roughly equal to the heating and hot water loads combined. Therefore the geothermal energy solution is suitable, since the production of heat during the cooler months produces cooling to be used during the warmer months and vice versa.

The hotel has a large proportion of windows in the façade, which raises the cooling demand in the rooms, and also raises the heating demand during the colder months. Therefore there is a booking system for the hotel that decreases the temperature set points for the room is unbooked and the temperature set points tightens when the room is booked and the guest is about to check in. Lighting inside often causes cooling needs, but low energy lighting is used to lower the heat gained by lighting.

The ventilation system is centrally tempered and provided to a fan-coil in the room which then adjusts the room temperature to the desired temperature. The central air handling units have a heat recovery of more than 85%.

The hotel is situated close to Malmö Central station, so public transportation by train is on the doorstep, and 20 minutes by train from Copenhagen airport.

The whole Malmö Live complex is about to get the platinum certification in the LEED energy rating system. The building is also certified to the highest level of the city of Malmö's "Miljöbyggprogram syd", which emphasizes on the energy, preservation of wildlife etc.

3.2. Energy Technologies

3.2.1. Lighting and electric equipment

All lighting is LED-lighting and in the hotel rooms lights are only able to be turned on when the key card is inserted in the activation slot. The lighting in the corridors is motion- and daylight-sensor controlled. Any confined spaces such as waste rooms and storage areas are motion sensor controlled.

3.2.2. HVAC (Heating, Ventilation and Air-Conditioning) equipment

3.2.2.1. Geothermal plant

Malmö Live has its own heating and cooling plant, which is not connected to the district heating and cooling systems in Malmö. The drilled holes, 75 holes that are 270 meters deep, function as heat exchangers for the media that serves the heat pumps in the plant room. During the cold season when the building needs heat, the heat pumps generate heat to the buildings and cooling to the geothermal drilled holes. This makes the bedrock gradually cool down during the cold season. When the warmer season begins, and the building needs cooling, the geothermal plant uses free cooling from the drilled holes until the bedrock has warmed up. When the water from the drilled holes is too warm to use as free cooling, the heat pumps start to produce cooling water for the buildings. The heat pumps will heat up the bedrock to serve the plant during the heating season. Hot water production will always be running and provide cooling for the bedrock all of the year. The geothermal plant is connected to serve each of the buildings separately, and is co-owned by the building owners. Connected to the geothermal plant are the PV-panels on the roof of the concert hall, and the waste heat from the chillers for the refrigerating rooms for the hotel kitchen.

3.2.2.2. Heating system

The system is designed to heat the hotel to 20°C. This is partly done by the central air handling units and partly by the fan coil units in each room, so the guests can adjust the temperature individually. For some rooms with large window areas, the rooms are complemented by a radiator. The administrative areas, basement areas and storages are heated by radiators. All heating is run on a hot water system throughout the building.

3.2.2.3. Ventilation

The ventilation system is a conventional ventilation system with connected fan coils in the guest rooms for individual adjustment. The supply air is treated in the central air handling units, to supply an even temperature to the building, so that temperature set points can be met throughout the hotel.

The AHUs are Eurovent certified and CE labeled and include outdoor and exhaust air dampers, outside air filters and exhaust air filters (class F7).

3.2.2.4. Cooling

The cooling of the hotel is run on free cooling from the geothermal plant for as long as possible. The cooling system cools the air in the central air handling units, and in the fan coil units in the guest rooms.

3.2.3. Renewable Energy Sources (RES)

3.2.3.1. Geothermal

Malmö Live is heated and cooled with a geothermal plant using heat pumps. The system takes advantage of the bedrock's high capacity to store thermal energy. In summertime, it is cold enough to cool the building, and in wintertime it is warm enough to heat the building. See chapter 3**.2.2.1 Geothermal plant** for more information on the system.

3.2.3.2. Photo-voltaics

Approximately 500 m^2 of solar panels are mounted on the roof of Malmö Live. The panels produce electricity which goes out to electricity system of the building, which reduces the amount of bought energy and covers a part of the energy demand of the geothermal energy heat pumps. The installed efficiency is 69 kW and the expected energy production is approximately 70 000 kWh/year.

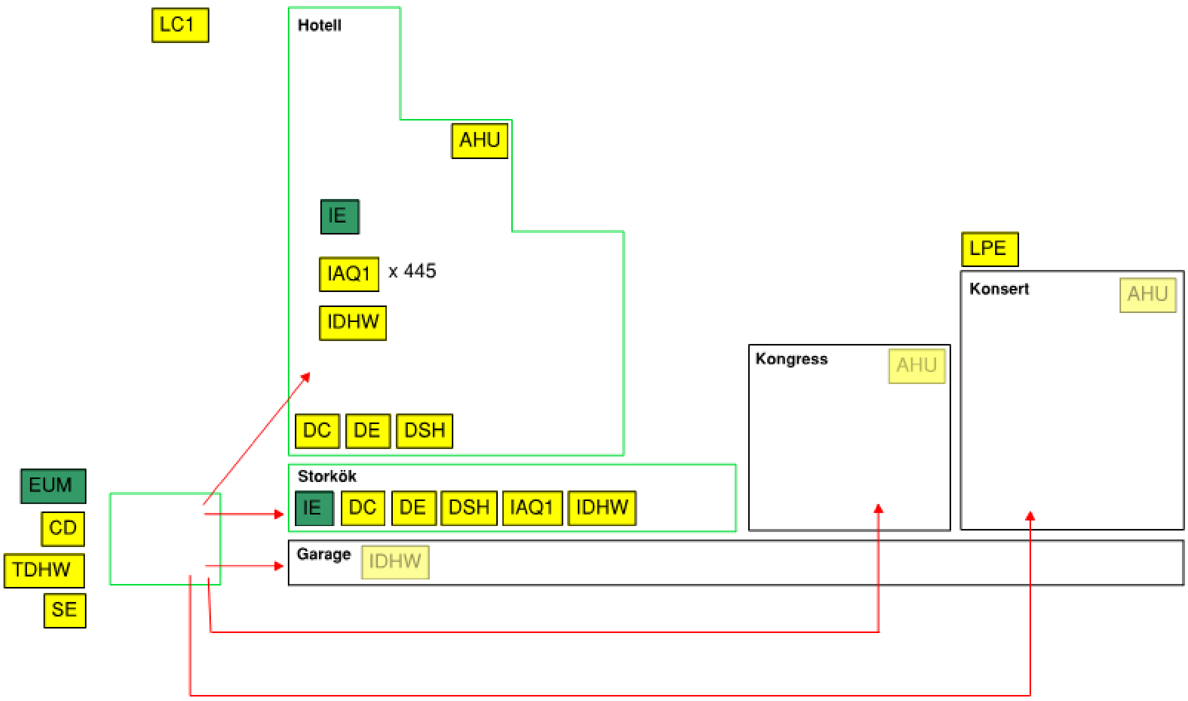
3.2.4. Other energy measures

3.2.4.1. Building envelope

The building envelope is constructed of prefabricated facades consisting of a conventional curtain wall aluminum frame. Due to the large windows and therefore the high aluminum ratio in the walls, the insulation is upgraded to PIR and Graphite EPS, with better U-value than conventional EPS/XPS, and also better fire resistance. The windows are 3-glass panes with a U-value of 0.5. The roofs of the hotel are green roofs to limit the storm water run-off from the site and also provide habitats for birds and other species.

3.3. ICT/BEMS

The Hotel building will be measured on different levels in order to achieve as accurate energy measures as possible. The data will be collected and sent over to IVL for further research.



4. Conclusions

The two non-residential buildings described in this report were both designed with high ambitions regarding energy performance and sustainability criteria. They are both about to get certified with LEED Platinum, the highest rank in the LEED system, administrated by Green Building Council, showing that these ambitions were not lowered during the construction phase. For both projects, the techniques chosen have proven successful, both individually and in combination. The monitoring will verify their reliability in the longer run.

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