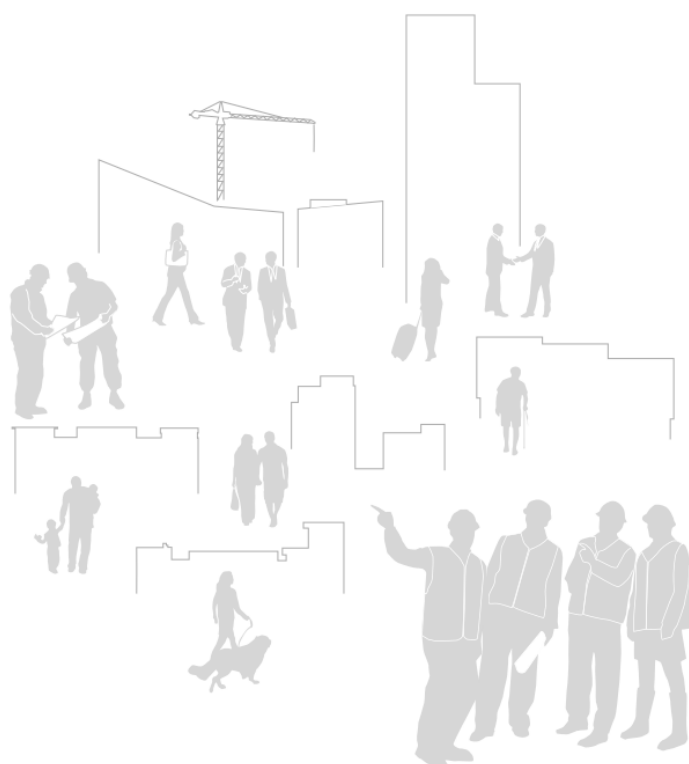




# BUILDSMART

Energy efficient solutions ready for market



## D2.7 “Experience exchange and knowledge transfer between demonstration projects”

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### Dissemination level

**X** PU = Public

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## Summary

This deliverable is focused on the Buildsmart non-residential demo buildings:

- Klipporna, the Skanska office building in the Hyllie area in Malmö
- Malmö Live hotel, the Skanska hotel in the KKH area in Malmö

It describes the innovative technical solutions implemented in the buildings and the technical barriers for these solutions dealt with during the construction phase. There is also an analysis for each of the solutions regarding their possible implementation in buildings in other climatic zones.

There is also a description on how knowledge and experience has been transferred between the development projects and a comparison on the solutions between the two buildings.

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

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## 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<sub>2</sub> 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 %, energy savings of 20 % and increased use of renewable energy with 20 %.

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 low-energy buildings.

A core task of the project is transfer of knowledge and experiences with techniques and methods between the different types of buildings. In this report, focus lies on the non-residential buildings: a hotel and an office building, both situated in Malmö. Since they are found in the same climatic zone, there has been no transfer or exchange to non-residential buildings in other climatic zones. This report will also give a comparison of different technologies. Knowledge transfer and experience exchange between residential buildings is 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 Assessment of implementation of innovative technologies

This report covers the non-residential buildings in the Buildsmart project: the office building Klipporna in Hyllie in Malmö developed by Skanska, and the hotel part of the Malmö Live project developed by Skanska in the central part of the city. Malmö Live also includes a conference center and a concert hall. Adjacent to this complex are two residential buildings that are also part of Buildsmart.

In this chapter, the technological solutions included in the two buildings are briefly described, as well as the technical barriers that were identified during the development of the projects. Also, there is an analysis on the relevance of transferring each solution to another climatic zone.

Since the buildings are developed in the same country by the same developer, some of the solutions are the same. For the same reason also the technical barriers are often similar.

### 2.1. Klipporna

Klipporna is mainly built for office purposes. Low energy use is at 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<sup>2</sup>/a or 62 kWh/m<sup>2</sup>/a in terms of primary energy. With the first phase (out of three) up and running the result confirms the calculations and shows an energy use of 62.6 kWh/m<sup>2</sup> (primary energy).

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

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.

The project is 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.

#### 2.1.1 Description

The most innovative technique implemented at Klipporna is the **Deep Green Cooling** installation that provides cooling for the indoor climate system. It is a Skanska patent. It consists of 70 bore holes that are each approximately 200 meters deep and connected to a closed cooling circuit supplying the buildings with renewable, locally produced chilled air.

The main components in the solution are 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. It 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.

The buildings are also equipped with high efficiency **heat recovery devices** providing sensible heat recovery efficiencies above 72 % (FTX-system). Finally, the air handling units have two extra pre-heating units of the outdoor air. In the first coil groundwater temperature is restored to normal level (during the cold season). In the second coil the return water is pre-cooled in the cooling beam system (when possible). This means that there are two extra steps of heat recovery beside the standard heat recovery unit.

Klipporna has a self-regulating **ventilation** system. The solution is based on having the pressure drop in the ducting system concentrated to the end of the ducting system, located to the supply air diffusers or cooling beams as supply air diffusers.

In a self-regulating ducting system the pressure drop relation between the ducts and the supply air diffusers is 20 Pa/100 Pa, compared to the relation 200 Pa/40 Pa that is common in a traditional system. The lower pressure drop leads to a lower energy demand.

The low pressure drop is possible to achieve if there are no sound attenuators in the ducts and if the duct diameter is constant along the shafts or the corridors on the office floors. For the high pressure drop in the supply air diffuser to be possible it has to be designed by the manufacturer for low noise, sound level.

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/m<sup>2</sup>K, 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.

In order to provide an optimized and coordinated operation of the technical systems at Klipporna, a **BEMS** (building energy management system) is implemented. It includes thermal comfort control, energy consumption optimization, indoor air quality and maintenance management. This will be further covered in deliverable D5.3 *Report on observed challenges and obstacles during development and installation of advanced ICT systems*.

### 2.1.2 Technical barriers

Below is a description of technical barriers, challenges and restrictions that have been present during the design and construction of Klipporna.

#### ***Deep Green Cooling (DGC)***

Whether to apply DGC techniques depends on a variety of specific conditions such as the geological characteristics in the specific area and the availability of district cooling. Test drilling for analyzing geological characteristics in geothermal energy storage areas include uncertainties. Despite extensive test drilling it is recommendable to plan ahead for possible difficulties and delays. Having boreholes positioned adjacent to the building body will facilitate the construction process, making it possible to complete founding work on time despite delays with borehole drilling.

The drilling issues have a direct impact on the budget for this measure. Deep Green Cooling is a large investment for which it is necessary that future purchasers and long-term owners of buildings value the technique highly.

#### ***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

The technique is well-established in Sweden and there is a well-functioning market with products. A general remark is that rotating heat exchangers are more energy efficient than flat-plate exchanger, but includes a risk of odor.

A balance has had to be reached between the level of energy efficiency and the quality and comfort demands from customers. There are difficulties controlling temperature in individual rooms (which is required in accordance with “BBR” - Swedish building regulations) solely with air-borne heating, due to comfort issues; high heating air flows could be needed at cold days, which could be experienced as uncomfortable.

#### ***Pre-fab walls***

Quality requirements of facade walls can often be reached easier with pre-fab products. The installation time on site is shorter and risks for rain infiltrating to the isolation layers is decreased.

#### ***Energy efficient windows***

It is difficult to reach a lower energy use with windows covering around half of the facade. It would have been possible to build a completely different, more energy efficient building, but there were restrictions regarding the façade from the municipality.

Large window areas are also complex concerning risks for high indoor temperatures in summer season, especially for tight concrete buildings. Possibility for external solar shading is a key question, and possibilities for cross-draft are preferable.

Windows with an average U value of 0.8 W/ (m<sup>2</sup>\*K) or lower is required in the Swedish FEBY passive building requirements (“FEBY, Kravspecifikation för nollenergihus, passivhus och minienergihus”). Since the purchasing market for 0.8 windows is considerably smaller than for e.g. 0.9, costs are significantly increased. The window requirement within FEBY has been described as inflexible, since even if the overall passive house energy requirements are managed anyway, 0.8 windows still has to be applied.



***Green roofs***

The challenge connected to the green roof installation is due to the relatively large slope of the roof. This is not suitable for green roofs since it could slide off. This is solved with a net covering the green roof parts.

**2.1.3 Non-technical benefits and challenges**

Skanska has a high environmental profile. Projects like Klipporna, as well as Malmö Live, are valuable to the company in the communication of that profile. Both to customers, competitors and other actors like municipalities. Therefore, all the implemented measures have the benefit of strengthening the Skanska trademark.

Also, the green profile of Klipporna attracts companies that have their own environmental goals. Since the number of environmentally-aware companies is growing, so is also the number of potential tenants for green office buildings like Klipporna.

One common challenge in low-energy buildings is the end-user behavior. In many cases more energy than calculated is used in terms of electricity for lighting and other appliances. This risk is partly reduced in Klipporna through the automated systems with e.g. presence detectors for lighting.

There are also some benefits and challenges related to individual installations:

***Deep green cooling***

There are always risks when implementing relatively new and untested techniques. But when you dare to try, and succeed, the gains from being a front-runner stretches from positive publicity to the upsides of owning your own solutions.

Deep Green Cooling is a large investment, mainly due to the drilling. For a company like Skanska, that develops buildings and then sell them, it is important that the market value the technique in line with the installation cost.

There is a risk that individual bore-holes collapse. This needs to be taken into account, for example through redundancy. In a situation with limited access to ground space this might be a constraint. In the Klipporna case all bore-holes were drilled outside the area planned for the actual construction, in order to reduce interference during the construction phase. If ground area is restricted, the holes could also be drilled under the building.

***Self-regulating ventilation***

The self-regulating ventilation comes with some benefits. Firstly, it is easy to install since a smaller duct dimension is used than in a traditional ducting system. When in use, it is also easier to make changes locally, without demand for rebalancing of dampers in the ducting system. Finally, since the self-regulating system uses a lower air flow, the experience of draft caused by ventilation is much lower than in other offices.

***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

When choosing an ESX heat recovery system, there are some trade-offs that have to be made. Firstly, there are two techniques to choose between: rotating or flat-plate heat exchanger. While the

rotating exchanger is more energy efficient, it is also more vulnerable due to its moving parts. There is also a risk of odor, having a negative effect on the tenants' comfort.

The trade-off between energy efficiency and comfort is also relevant when deciding for the heat exchanger technique at all. While it is highly effective, and can reduce the need for bought energy drastically, it is difficult to regulate the temperature in individual rooms with only a system for air-borne heating. Increased need for heating will also lead to increased air flow, something that can be perceived as uncomfortable.

### ***Pre-fab walls***

Well-insulated and air tight walls leads to a more even indoors temperature and less draft. Mechanical ventilation is necessary, and if properly installed that will lead to improved air quality.

There are also benefits already in the planning and construction phases. Quality requirements on facade walls can often be reached easier with pre-fab products. The installation time on site is shorter and the risk of rain infiltrating the insulation is decreased.

### ***Green roofs***

The non-technical benefits from green roofs are multiple. They promote biodiversity, have a noise-dampening effect and purify the air from particles. For the tenants, the green roof can be a nice place to spend a break or a meeting, if the roof is planned accordingly.

At Klipporna, the roofs have a fairly steep decline. Therefore there was the extra challenge with the risk of the green roof to slide off. The roof is secured with nets, and this can show as a good example that green roofs can be installed also on non-flat roofs.

## **2.1.4 Analysis of installed technologies**

Following is an analysis of the possibility to implement the above described solutions at Klipporna in buildings in other climate zones.

### ***Deep green cooling (DGC)***

For a deep green cooling installation to work properly, there are a few conditions that need to be met. These are related to annual mean temperature, type of ground and energy system. There are also some requirements on the need for cooling demand and ventilation rate.

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

#### Annual mean temperature

The main condition is that the temperature difference between the annual mean ground temperature and the indoor design temperature (summertime) is not smaller than 10 K. At the same time, the ground temperature is normally increased by 1.5 K every 100 meters below ground surface, compared to mean outdoor temperature. Therefore the mean temperature in the ground, with bore-hole length of approx. 200 meter, is approx. 3 K higher than the annual

mean outdoor temperature. This means that the higher the outdoor temperature, the lower is the possibility to have a well-functioning DGC installation.

In the colder climate zones the presence of snow during winter is a factor. The snow will have an impact on the ground temperature, approx. 1.2 – 1.3 K per 100 days of snow in Sweden.

Finally, in cities the mean temperature in the ground could be higher due to the urbanization. For example, in a location in the City of Stockholm the mean temperature in the ground is 2 K higher than it should have been outside of the city.

Annual mean outdoor temperatures	
City	Temperature
Paris	+11.6°C
Berlin	+9.7°C
Malmö	+8.0°C
Stockholm	+6.6 °C
Helsinki	+5.0°C

#### Type of ground

The type of ground where the installation is planned has some impact on the performance of the installation. Even though it is not exactly related to climatic zone, it is still relevant for potential investors.

First of all, drilling down to the bed rock is necessary. 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.

#### Building design

The chilled water circuits have to be designed for a much higher temperature level than in a traditional building. This can be done regardless of climatic zone.

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

Some of these requirements are more difficult to meet in warmer climatic zones, namely the two related to cooling demand of the building. Therefore, in those areas it is even more important to connect the DGC installation to buildings with high energy performance.

#### 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
<b>Cooling coil for charging storage, °C</b>		
Outdoor Air	0	+7
Chilled brine (KB3)	+9	+2
<b>Cooling coil for air, °C</b>		
Supply Air	+27 /50% RH	+20
Chilled water (KB1)	+17	+23
<b>Chilled beams, °C</b>		
Chilled water (KB1)	+17	+23
Chilled beam water (KB2)	+20	+23
<b>Cooling coil for process, °C</b>		
Chilled water (KB1)	+17	+23 (or less)

#### ***Energy storage for DGC***

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. This could be done during wintertime by charging the storage either with 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.

In climatic zones where there is no winter season in this sense, the DGC installation will not work, since it is dependent on the annual mean ground temperature being at least 10 degrees lower than the required indoors temperature. This could to some extent be taken care of through a higher requested indoor temperature, but that flexibility is limited.

There are a few requirements or recommendations regarding the bore holes and the storage. For some of them the climatic zone has implications for the performance and choices made before installation:

- 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 K when charging

- Storage circuit water temperature difference between supply and return 6 K when cooling

There are also requirements regarding the charging of the storage:

- Charging should be done when the mean outdoors temperature is low enough.
- 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.

### ***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

This technology is well-established in Sweden, and uses the fact that the outgoing air is warmer than the incoming air. Thus, is used as a highly effective way to recover heat. The technology as such is possible to use anywhere where there is a heating demand.

In climatic zones where there is instead a higher need for cooling, the technology could be used the other way around. That means that when the outgoing air is cooler than the incoming, the excess heat from the incoming air could be transferred to the outgoing air. In that way, the cold in the outgoing air is “recovered”.

In both alternatives, the impact on the need for other sources for temperature adjustment depends on the outdoor temperature compared to the outgoing air.

### ***Pre-fab walls***

This technology has in itself no limitations that are related to climatic zone. Naturally, the specifications of the wall could vary between different zones. Also, it is important to notice that an air-tight building envelope requires sufficient building ventilation in order to provide a good indoors climate.

### ***Energy efficient windows***

This technology has in itself no limitations that are related to climatic zone. They can be used also in warmer climates, where there is a demand to keep the warm out. But it is relevant to take deep consideration when designing the building, since size and placement of windows are always relevant from an indoors temperature perspective. Ill-designed window placement will increase the need for cooling. It is also important to notice that, just like with the walls, an air-tight building envelope requires sufficient ventilation in order to provide a good indoors climate.

### ***Green roofs***

This technology has in itself no limitations that are related to climatic zone. The types of plants that can be used and the potential need for maintenance will vary, though.

### 2.1.5 Lessons learned

Reaching a low energy use in the constructed building was a very important factor when it was designed. During the construction phase, the energy issue was kept in mind in each small decision, and there were no compromises regardless of cost etc. This led to decisions e.g. on the cooling and ventilation systems, what windows to install, lighting, and design of window chamfers. This is identified as the main success factor in receiving a building with very good energy performance, even better than projected for.

Other lessons learned include:

- In order to reach a low-energy building, there are restrictions on what is possible to do with the architecture.
- The restrictions regarding facades, from the municipality, have an impact on what energy performance that is possible to reach.
- Large window areas require external solar shading and/or possibilities for cross-draft in order to minimize the risk for too high indoor temperatures.

## 2.2. Malmö Live Hotel

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 25<sup>th</sup> floor is a bar/restaurant. HVAC rooms are placed in the basement, on the 13<sup>th</sup> floor and on the 24<sup>th</sup> 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<sup>2</sup>/a, which translates to 47 kWh/m<sup>2</sup>/a 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.

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.

### 2.2.1 Description

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 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, the geothermal plant takes cold 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 buildings are also equipped with high efficiency **heat recovery devices** providing sensible heat recovery efficiencies above 72 % (FTX-system).

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.

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. Approximately 500 m<sup>2</sup> of solar panels are mounted on the roof of Malmö Live. The panels produce electricity which goes out to the 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.

In order to provide an optimized and coordinated operation of the technical systems at the hotel, a **BEMS** (building energy management system) is implemented. It includes thermal comfort control, energy consumption optimization and indoor air quality and maintenance management. This will be further covered in deliverable D5.3 *Report on observed challenges and obstacles during development and installation of advanced ICT systems*.

### 2.2.2 Technical barriers

Below is a description of technical barriers, challenges and restrictions that have been present during the design and construction of Malmö Live.

In general, Skanska needed to make a lot of adjustments during the construction process. Since they were building on their own (Skanska was also the contractor) it was easier to do all these changes, compared to having an external contractor.

During the Malmö Live project it also became obvious that all the requirements needed to reach when constructing a low-energy building will have implications for the architecture.

Another remark is that when the energy goals are based on final energy, it is almost necessary to choose a heat pump solution instead of connecting the building to the district heating grid. In a city where such a grid exists, this could be viewed as a sub-optimization if a broader perspective is applied.

***Geothermal reversible heat pump for heating, domestic hot water (DHW) and cooling***

The heat pumps are used for heating and DHW. Free cooling is used as far as possible, complemented with cooling by storing heat geothermally. Stored heat can subsequently be utilized during the heating season.

Geothermal heat pump facilities are well-established in Sweden and available on the market, but the system solution as a whole for Malmö Live Hotel is innovative and the products applied are not standard products.

***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

The technique is well-established in Sweden and there is a well-functioning market with products. A general remark is that rotating heat exchangers are more energy efficient than flat-plate exchanger, but includes a risk of odor.

A balance has had to be reached between the level of energy efficiency and the quality and comfort demands from customers. There are difficulties controlling temperature in individual rooms (which is required in accordance with “BBR” - Swedish building regulations) solely with air-borne heating, due to comfort issues; high heating air flows could be needed at cold days, which could be experienced as uncomfortable.

***Energy efficient windows***

It is difficult to reach a lower energy use with as much as 50 % windows in the facade. It would have been possible to build a completely different, more energy efficient building, but there were restrictions regarding the façade from the municipality.

Large window areas are also complex concerning risks for high indoor temperatures in summer season, especially for tight concrete buildings. Possibility for external solar shading is a key question, and possibilities for cross-draft are preferable.

Windows with an average U value of 0.8 W/ (m<sup>2</sup>\*K) or lower is required in the Swedish FEBY passive building requirements (“FEBY, Kravspecifikation för nollenergihus, passivhus och minienergihus”). Since the purchasing market for 0.8 windows is considerably smaller than for e.g. 0.9, costs are significantly increased. Some companies were not even familiar with the required products. The window requirement within FEBY has been described as inflexible, since even if the overall passive house energy requirements are managed anyway, 0.8 windows still has to be applied.

***Pre-fab walls***

Quality requirements of facade walls can often be reached easier with pre-fab products. The installation time on site is shorter and risks for rain infiltrating to the isolation layers is decreased.

***PIR (polyisocyanurat) insulation, hard foam insulation material***

The PIR insulation is relatively new in Sweden, so there are a limited number of examples to look at. But despite that, there have not been any major technical barriers reported.

***Green roofs***

No specific barriers for the green roofs at Malmö Live are reported. In general, the type of greenery that is planned to grow on the roof gives restrictions for the construction of the building. For larger plants like bushes and trees a lot of soil is needed, making the green roof heavy and a strong roof



construction is necessary. If there is an ambition to create a place for insects and birds, thought has to be put into the mix of plants, and a high degree of biodiversity is preferable.

### 2.2.3 Non-technical benefits and challenges

Skanska has a high environmental profile. Projects like Malmö Live, as well as Klipporna, are valuable to the company in the communication of that profile. Both to customers, competitors and other actors like municipalities. Therefore, all the implemented measures have the benefit of strengthening the Skanska trademark.

One common challenge in low-energy buildings is the end-user behavior. In many cases more energy than calculated is used in terms of electricity for lighting and other appliances. This challenge is maybe even more relevant in the Malmö Live hotel. Partly since it is a hotel, and therefore it is difficult to create incentives to the end-users. They only spend one or a few nights and will not be affected by e.g. an energy bill. Their main concern is comfort, and therefore that is also the main concern of the hotel owner.

Added to this is the fact that the hotel was sold to the operator before all systems were fully adjusted and optimized. With the main focus being comfort, the measured energy performance data was initially well above the predicted values. It is also a general risk when a building is sold, that the buyer does not share the same environmental values.

In addition to these above-mentioned general benefits and challenges, there are also a few related to individual installations:

#### ***Geothermal reversible heat pump for heating, domestic hot water (DHW) and cooling***

The heat pump technique as such is well-established in Sweden, but the system solution as a whole for Malmö Live Hotel is innovative and the products applied are not standard products. This could lead to a higher cost, and there is always an increased risk associated with non-standard solutions.

Compared to some other heating systems, a heat pump is generally low-maintenance, meaning that there are low operating costs apart from the cost for energy. Since a heat pump is a reversed air conditioner, the same system can be used for both heating and cooling, if there is a need.

There was a plan for a solar thermal installation. But since the solar thermal gain would be decreasing the effect from the geothermal plant it was deemed unprofitable for the project. This shows that even if it is possible to install various types of renewable energy, it is important to calculate the effects of the installation in order to find the optimal set of installations.

#### ***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

When choosing an ESX heat recovery system, there are some trade-offs that have to be made. Firstly, there are two techniques to choose between: rotating or flat-plate heat exchanger. While the rotating exchanger is more energy efficient, it is also more vulnerable due to its moving parts. There is also a risk of odor, having a negative effect on the tenants' comfort.

The trade-off between energy efficiency and comfort is also relevant when deciding for the heat exchanger technique at all. While it is highly effective, and can reduce the need for bought energy

drastically, it is difficult to regulate the temperature in individual rooms with only a system for air-borne heating. Increased need for heating will also lead to increased air flow, something that can be perceived as uncomfortable.

The entire system needs to be balanced and adjusted. There have been issues with some corridors, where the temperature has been too high. This is looked into when the entire system is balanced.

#### ***Pre-fab walls***

Well-insulated and air tight walls leads to a more even indoors temperature and less draft. Mechanical ventilation is necessary, and if properly installed that will lead to improved air quality.

There are also benefits already in the planning and construction phases. Quality requirements on facade walls can often be reached easier with pre-fab products. The installation time on site is shorter and the risk of rain infiltrating the insulation is decreased.

#### ***Green roofs***

The non-technical benefits from green roofs are multiple. They promote biodiversity with habitats for birds and other species, they limit the storm water run-off, they have a noise-dampening effect, and they purify the air from particles. For the tenants, the green roof can be a nice place to spend a break or a meeting, if the roof is planned accordingly. The green roofs also have a positive impact on the building's energy use. Rainwater that is stored in the roof evaporates in the sun and results in further reduced cooling needs for the buildings.

#### ***PIR (polyisocyanurat) insulation, hard foam insulation material***

Due to the large windows, and therefore the high aluminium ratio in the walls, the insulation is upgraded to PIR and Graphite EPS. This gives a better U-value than conventional EPS/XPS insulation, and also better fire resistance.

#### ***Windows***

The windows have a U-value of 0.5 W/m<sup>2</sup>K, which is very low. There were problems with thermal bridges, though, but the system was adjusted in order to come to terms with that. Even though there are no real complaints from the guests, there are a few very large windows with a lot of solar gain.

### **2.2.4 Analysis of installed technologies**

Following is an analysis of the possibility to implement the above described solutions at Malmö Live in buildings in other climate zones.

#### ***Geothermal reversible heat pump for heating, domestic hot water (DHW) and cooling***

This technology is well-established in Sweden and could be used anywhere where there is a need for heating or cooling. On the other hand, the quality of the ground is important from an economic perspective, since it is necessary to drill down to a certain depth of the bed rock.

#### ***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

This technology is well-established in Sweden, and uses the fact that the outgoing air is warmer than the incoming air. Thus, is used as a highly effective way to recover heat. The technology as such is possible to use anywhere where there is a heating demand.

In climatic zones where there is instead a higher need for cooling, the technology could be used the other way around. That means that when the outgoing air is cooler than the incoming, the heat from the incoming air could be transferred to the outgoing air. In that way, the cold in the outgoing air is “recovered”.

In both alternatives, the impact on the need for other sources for temperature adjustment depends on the outdoor temperature compared to the outgoing air.

### ***Energy efficient windows***

This technology has in itself no limitations that are related to climatic zone. They can be used also in warmer climates, where there is a demand to keep the warm out. But it is relevant to take deep consideration when designing the building, since size and placement of windows are always relevant from an indoors temperature perspective. It is also important to notice that, just like with the walls, an air-tight building envelope requires sufficient ventilation in order to provide a good indoors climate.

### ***Pre-fab walls***

This technology has in itself no limitations that are related to climatic zone. Naturally, the specifications of the wall could vary between different zones. Also, it is important to notice that an air-tight building envelope requires sufficient building ventilation in order to provide a good indoors climate.

### ***PIR (polyisocyanurat) insulation, hard foam insulation material***

This technology has in itself no limitations that are related to climatic zone. The thickness of the insulation layer should be adjusted to the specific climatic zone, keeping in mind that insulation also maintain a cooler indoors temperature in areas with a warmer climate. During design and construction it is important to notice that an air-tight building envelope requires sufficient ventilation in order to provide a good indoors climate.

### ***Green roofs***

This technology has in itself no limitations that are related to climatic zone. The types of plants that can be used and the potential need for maintenance will vary, though.

### ***PV panels***

The PV panel technology is already well-established around the world. Since they produce electricity from sun light, they are most valuable in areas where the highest energy demand occurs during the sunny part of the year or day, for example in areas where there is a high need for cooling during summer. In that sense, PV panels are more adequate in warmer (sunnier) climatic zones than southern Sweden. But they can be profitable even in colder climate.

With the development of battery technology, this is becoming less valid, though. There are battery technologies that could serve as a short- or medium-term storage for electricity, making it possible to use the electricity during the peak load of the day or week. Still, seasonal storing capacity is limited.

### 2.2.5 Lessons learned

The building was designed as to reach passive house standard, thus reaching a low energy use in the constructed building was an important factor when it was designed. Also generation of renewable energy was included, but the plan for a solar thermal installation had to be discarded. Since the solar thermal gain from that installation would be decreasing the effect from the geothermal plant it was deemed unprofitable for the project. This shows that even if it is possible to install various types of renewable energy, it is important to calculate the effects of the installation in order to find the optimal set of installations.

Other lessons learned include:

- A lot of adjustments had to be done during the construction. Since Skanska was their own contractor, that was manageable in a way that would not have been possible with an external contractor. All actors were included from the beginning and made the whole concept together. The earlier you involve constructors into the design phase, the more you have the ability to make changes.
- Having boreholes positioned adjacent to the building body will facilitate the construction process, making it possible to complete founding work on time despite delays with borehole drilling.
- When the energy goals are based on final energy, it is almost necessary to choose a heat pump solution instead of connecting the building to the district heating grid. In a city where such a grid exists, this could be viewed as a sub-optimization if a broader perspective is applied.
- Skanska used common technique but tried also to develop new things. It is generally harder to sell new technology to residential owners.
- LCC-tools should be used more.
- Difficult to separate measuring data in a building where there are multiple functions and owners.

### 3 Exchange of implementation experiences and knowledge

The transfer of knowledge and experiences of techniques and methods between different buildings is important in order to promote energy-efficient construction. In that way, problems might be avoided and challenges decreased to a minimum.

When exchanging knowledge and experience it is important to understand that a technique or measurement that is performing well in one building might not perform equally good, or at all, under other preconditions. That can be preconditions regarding economy, financial instruments, policy regulations and social factors among other things. In this report, focus lies on the climatic preconditions.

This chapter covers the knowledge transfer and experience exchange between the non-residential buildings in the project: a hotel and an office building. They are both situated in Malmö, so there has been no transfer or exchange to non-residential buildings in other climatic zones. Knowledge transfer and experience exchange between residential buildings is described in another report.

Since the buildings are developed in the same country by the same developer some of the solutions are the same, and thus there is no need for knowledge transfer. Exchange of experiences could still be relevant, though. Another factor is that the buildings are built for completely different purposes and thus varying needs from an energy perspective. This means that the possibility to transfer knowledge and to exchange experience is somewhat limited. It also to some extent reduces the need for such exchange, since the varying preconditions could mean that certain experiences are not relevant in another setting.

#### 3.1 Between buildings in the same climatic zone

Even though the functions of the buildings differ, several technologies and work methods has been discussed and evaluated between Malmö Live and Klipporna throughout the project. Examples of technologies where exchange of implementation experiences and knowledges has occurred are as follows.

- Deep Green Cooling compared to geothermal plant
- Air tightness in the building envelope
- Installation systems

##### ***Deep Green Cooling compared to geothermal plant***

Malmö Live and Klipporna have chosen different solutions to generate heating and cooling in their buildings, because the demand for heating is higher in the hotel building compared to an office building. As a result Malmö Live have chosen a geothermal reversible heat pump, in contrast to Klipporna that uses the Deep green cooling system. However, the systems show similarities which has been discussed. The drilling is executed in the same bed-rock and therefore both projects used the same drilling method, the Wassara method. In addition building material, such as hoses, collectors, joints, BMS etc. are other subjects that have been evaluated in the projects.

***Air tightness in the building envelope***

The air tightness of a building's envelope is essential for the energy balance calculation. One of the main obstacles to achieving high air tightness is air leakage between different building materials. The projects have discussed different solutions where applicable, for example fixed windows and seals between prefabricated elements.

***HVAC systems***

In order to achieve an efficient HVAC system it is important that the systems transport the energy from the source (cooling/heating) with low energy losses. The ratio between bought energy and energy delivered into the building has been studied and is a commonly used parameter used as a decision support. Experiences regarding air-velocity in the system, methods for high energy exchanges, efficient air handling units, shapes and dimensions of ventilation pipes have been shared and discussed throughout the project.

## **3.2 Comparison of different technologies**

For the systems that generate heating and cooling to the buildings, Skanska has chosen different solutions. This is partly due to the differing needs that the buildings have, considering their differing functions. Also, Skanska wanted to implement their own newly developed solution for cooling, the so-called Deep green cooling. It is standard practice not to introduce the same untested technique at two projects simultaneously.

For most types of installations, Skanska has chosen similar or identical technologies in the two buildings. Those are technologies that are standard in Sweden, at least when it comes to low-energy buildings. It is difficult to reach high energy performance without heat recovery ventilation, well insulated walls and windows with a low U-value. Both buildings also have green roofs. This is not necessary from an energy efficiency point of view, but is often included in buildings with high sustainability profile, since it promotes green elements in areas where that would otherwise be lacking.

### **3.2.1 Differing installations**

***Deep Green Cooling (DGC)***

The innovative Deep Green Cooling installation implemented at Klipporna is most suitable for buildings where there is a high cooling demand, such as an office. It is tested in some other buildings in Sweden, and also in Poland.

The difference between DGC and a more traditional cooling installation is that the DGC does not use chillers, but instead takes advantage of the free cooling that can be extracted from the bed rock approximately 200 meters down. Since this could cover the entire cooling need for a building, the energy savings potentials are good: up to 30% of the annual energy need could be reduced, compared to using a standard installation.

***Geothermal reversible heat pump for heating, domestic hot water (DHW) and cooling***

The geothermal heat pump solution installed at Malmö Live could also have been used at Klipporna. It is a well-developed and established technology in Sweden with relatively reliable function and performance that can be calculated in advance. But Skanska wanted to implement their own-developed DGC technology for cooling, and then the geothermal heat pump would be obsolete.

***PV-panels***

PV panels are installed at Malmö Live, but not at Klipporna. There is no alternative electricity-generating installation at Klipporna, instead Skanska has made an investment in a wind park in the northern part of Sweden.

There is no strictly technical reason not to install photo-voltaics at Klipporna, or anywhere in Malmö. Even though the panels generate electricity at periods when the need for electricity is at its lowest – during daytime and in the summer – most buildings use at least some electricity during these times. And for an office building like Klipporna, there is a high demand for electricity during day time almost the year round, stemming from work-related demand such as computers and lighting as well as from cooling need.

The reasons for not installing photo-voltaics are more often non-technical. It could be due to business economics reasons, where the demanded pay-back time is too short for the solar panels to be taken into consideration. It could also be due to restrictions set up by the city regarding i.e. allowed height of construction or aesthetical values decided on for the area in the city planning process.

***Pre-fabricated walls and insulation***

Both Klipporna and Malmö Live are constructed with pre-fabricated walls. The experience is that quality requirements on facade walls often can be reached easier with pre-fab products. The installation time on site is also shorter and the risk for rain infiltrating to the isolation layers is decreased.

The choice of type of pre-fabricated wall is mainly related to the design of the building. It depends on factors such as size and placement of the windows and what type of façade that is wanted.

For the two projects, different choices have been done for the materials. At Klipporna, a concrete frame is combined with a thick layer of the conventional cellular plastic for insulation.

At Malmö Live the pre-fabricated building envelope is constructed of a conventional curtain wall aluminum frame. The plan was to insulate with cellular plastic, just as at Klipporna. But due to the large windows and therefore the high aluminum ratio in the walls, the insulation was upgraded to PIR and Graphite EPS, with better U-value than conventional EPS/XPS, and also better fire resistance.

The PIR layer should have the same insulating performance as a standard material of double thickness. It is relatively new in Sweden, and the exact performance under Swedish conditions is not yet certain.

### 3.2.2 Similar installations

#### ***ESX heat recovery system (exhaust air pre-heating intake air), and air-borne heating***

A ventilation system with forced in- and outgoing air is common in Sweden, especially in newer buildings. Often it is connected to a heat exchanger, recovering the heat from the outgoing air. This reduces the need for heating in the building, and could basically remove the need for a heating system, if installed correctly.

In Sweden there are strict regulations on ventilation, in order to secure a high quality of the indoors air. But this also leads to a higher heating demand, since the heated air is ventilated out after a relatively short time. Therefore, the heat recovery aspect of this system is very important when it comes to energy performance.

The FTX system is a passive one, relying on the thermodynamic principle of temperature equalization. It cannot be constructed in a variety of ways and a comparison of the installations in two different buildings will not show much variation. A general remark, though, is that rotating heat exchangers are more energy efficient than flat-plate exchangers, but they include a risk of odor. Since the rotating alternative introduces a moving part in the construction, it also has a higher level of maintenance and increased risk of failing.

#### ***Energy efficient windows***

The windows are a weak part of the façade when it comes to energy performance. A lot of energy is leaking through glazed areas.

As described above (chapter 2.1.2) the Swedish requirements on passive houses requires a U-value of maximum  $0.8 \text{ W}/(\text{m}^2\cdot\text{K})$ , and this sets the framework when designing low-energy buildings. A U-value below 0.8 is often not considered cost effective, with the effect that most windows in this type of houses having precisely  $0.8 \text{ W}/(\text{m}^2\cdot\text{K})$ . This also means that there is really no difference between the technologies in the two Buildsmart demo buildings.

Theoretically, if there was a difference in U-value between the buildings it would imply that the one with the lower value was leaking less energy per square meter of glazed area. A similar effect, but much stronger, would be reached with a decreased glazed area, since walls always have lower U-value than the glass. The reason for not doing this is either functional (daylight is needed and wanted) or aesthetical, or both.

A common observation is that the 0.9 windows are more of a standard option with the suppliers. Therefore, the variety of models is higher for those windows, and the costs are also lower.

#### ***Green roofs***

The installation of green roofs has limited implication on the energy performance of the building. It could have an insulating effect, and it has also proven to increase the efficiency of photo-voltaics, if they are placed over the green roof. But the installation of a green roof is often more of a statement measurement, showing the sustainability profile of the building.

A green roof could be designed in many different ways, and have a large variety of plants. The combined weight of the earth and the plants is a restricting factor though, since the entire building



construction needs to be adjusted in order to be able to carry the weight. The most common solution is to have the major part covered with sedum, and that is also the case on both Klipporna and Malmö Live. This also requires an absolute minimum of maintenance (preferably none), but does not promote biodiversity as much as a more varied roof.

At Klipporna, there have been some problems since the roofs have an incline. This means that there is a risk for the green roof to fall off. It has been secured with a net. At Malmö Live, there are flat roofs and this is not an issue.

## 4 Conclusions

Some internal knowledge transfer and experience exchange within Buildsmart between non-residential buildings would probably have happened also outside the project, since the two buildings are developed by the same company in the same city. But Buildsmart has provided an arena where the involved units of Skanska have met and discussed regularly, and that has been valuable. On this arena there have also been relevant discussions with the developers of residential buildings.

Both of the development projects have seen some technical barriers during the implementation and construction. None of them have had such a dignity that they have severely delayed or altered the buildings.

Most of the implemented technologies are possible to transfer to other climatic zones. It is not always to transfer the solution exactly as it is implemented, but alterations could be needed due to climatic reasons. There could also be other needs for altering, such as policy regulations, financial factors etc. The only implemented technique that is not possible to transfer to any climatic zone is the Deep green cooling at Klipporna. The reason is that the solution is based on a temperature difference of at least 10 degrees between required indoors temperature and mean ground temperature. This is not possible to achieve in all climates.



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