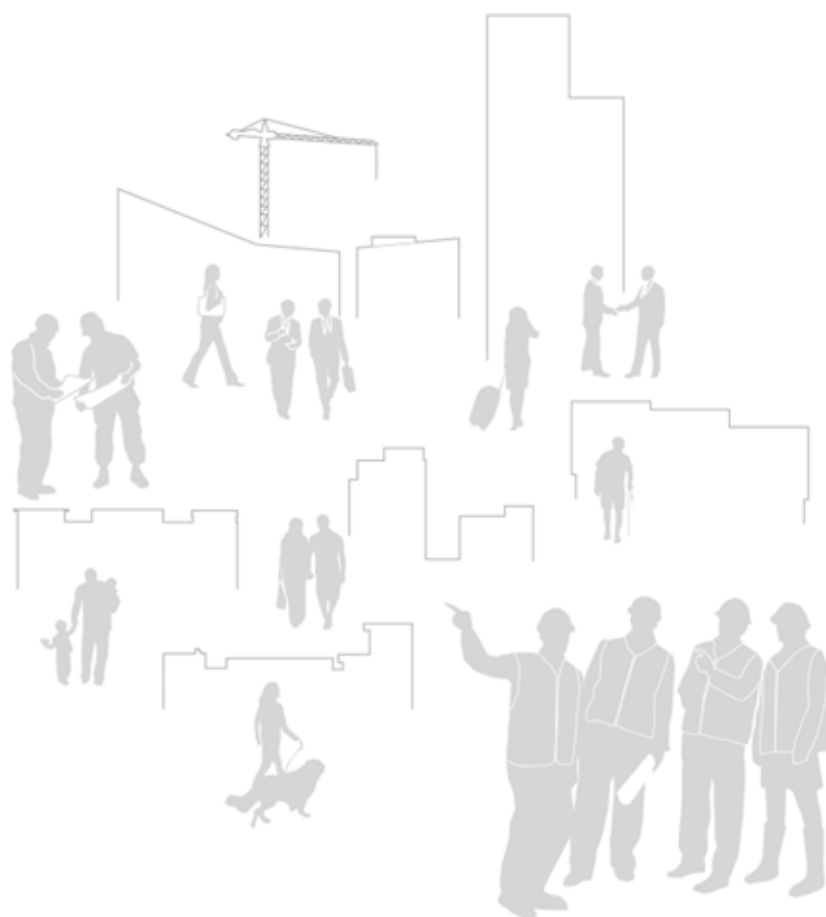




BUILDSMART

■ Energy efficient solutions ready for market ■



SYNTHESIS REPORT

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Malmö stad

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1. Background



All across Europe, construction companies are striving to create low-energy buildings. And all across Europe, property owners are striving to maintain a good energy performance. But how is it done? Part of the answer might be found in this brochure!

Here are presented five buildings constructed for low energy use, combined with training of end-users to ensure high energy performance in reality. The implemented measures and techniques are not out of reach for mainstream buildings; they are meant to show that almost any building can be a low-energy building.

A low energy use in the construction and building sector is a necessity if the 20-20-20 climate targets set up by the European Commission for the year 2020 are to be reached: 20 % reduction of greenhouse gas emissions, 20% energy savings and 20 % increased use of renewable energy. Energy use in this sector is responsible for approximately 40 % of the entire energy use in the EU, and 36 % of the emissions of CO₂ throughout the union. As of year 2021, there is also the near-zero energy requirement to be met by all new-constructed buildings within the EU. These targets are called EPBD II, and the measures and approaches tested in Buildsmart will be valuable as their implementation has the potential to be part of the roadmap towards these targets.

Buildsmart was a project that ran in Sweden, Spain and Ireland between 2011 and 2016. It was co-funded by the European Union funding program FP7 (Seventh framework program). The City of Malmö was lead partner, and the other partners were Codema, FCC, IVL, Roth Fastigheter, Skanska, Tecnalia and WSP.

In the project, the project partners FCC, Roth and Skanska constructed low-energy buildings: two residential projects in Sweden and one in Spain, and two non-residential projects (hotel and office) in Sweden. Project partner Codema was responsible for training of end-users in the buildings, when they were taken into use. Project partner IVL was responsible for the collecting and analysing of energy performance data from all the buildings. Project partner Tecnalia was the Spanish technical partner. Project partner WSP was responsible for the communication of the actions, progress and results from the project.

2. The Buildings

The Buildsmart project includes five different development projects placed in two different countries, and climatic zones. Three of the projects are mainly residential, one is a hotel and one is an office complex.

In each of the buildings, a number of energy-efficient solutions are installed and implemented. The thought-through combination of measurements assures that the result is truly low-energy buildings. Also, it is important to make sure that the design of the solutions and systems make a smooth operation process possible. Otherwise, all the good installations might underperform due to improper operation.



2.1 Skanska residential buildings

Between the old city centre and the new district in Western Harbour, and very close to the central station, Skanska has developed two residential buildings. They are called Sopranen and Tenoren. After completion they were sold as housing association apartments, and are now owned by the inhabitants.

Installations:

Both Tenoren and Sopranen are constructed with well-insulated thermal envelopes with high air tightness. But that is reached in partly different ways. The walls of Tenoren consist of pre-fabricated sandwich concrete elements insulated with PIR and have a total thickness of 450 millimetres. Sopranen has standard concrete walls insulated with mineral wool, and have a thickness of 460 millimetres.

In both buildings, the windows are composed of 2+2 layers of glass with an average U-value of approximately 0.8 W/m²K. The concrete roofs are well insulated and partly covered with sedum. Tenoren has 200 millimetres PIR insulation and Sopranen has 400 millimetres of foam.

The main heating source for the apartments is the ventilation system. Both the incoming and outgoing air is forced and the incoming air is preheated by the outgoing, through a highly efficient heat recovery device. With a heat recovery potential of 80 %, the system is designed to heat the apartments to 21 degrees. The system is called FTX which stands for forced in- and outgoing ventilation combined with heat recovery.

On top of the ventilation heating system, a conventional hot water radiator system is connected to the city-wide district heating system. This is due to Swedish regulations; the house can provide enough heat without this secondary system.



Facts Sopranen (southern building):

Net floor area: 8298 m²
Apartments: 86
Facilities: 4
Stories: 5/8/14
Moving in: summer 2015

Technical specifications Sopranen

U-value facade: 0.14 W/m²K
U-value roof: 0.10 W/m²K
U-value floor: 0.26 W/m²K
U-value windows: 0.80 W/m²K
Energy performance: 57.6 kWh/m²
Space heating: 28.9 kWh/m²

Facts Tenoren (northern building):

Net floor area: 7186 m²
Apartments: 72
Facilities: 5
Stories: 5/13
Moving in: summer 2016

Technical specifications Tenoren

U-value facade: 0.15 W/m²K
U-value roof: 0.14 W/m²K
U-value floor: 0.26 W/m²K
U-value windows: 0.80 W/m²K
Energy performance: 47.0 kWh/m²
Space heating: 13.9 kWh/m²

2.2 Basque Government residential building

In the neighbourhood of Repélega in the town of Portugalete, the regional Basque Government has developed a residential building. It is meant for social housing, specifically oriented to low-income people.

The building is constructed in a steep slope, with a height difference of approximately 6 meters. Therefore, the building is formed by three blocks consisting of 5 floors each. On each building, different façade constructions have been tested.

Facts Basque:

Gross floor area: 2302 m²

Apartments: 32

Stories: 5/5/5

Moving in: summer 2016

Technical specifications Portugalete (simulation)

U-value facade: 0.14 W/m²K

U-value roof: 0.10 W/m²K

U-value floor: 0.26 W/m²K

U-value windows: 0.80 W/m²K

Energy performance: 57.6 kWh/m²

Space heating: 28.9 kWh/m²



Installations:

In order to really test what type of construction is the best, and most cost-effective, three different types of wall constructions are used. To the south, one part of the building has a trombe wall and another part a so called solar wall. In the other directions, the façade consist of Ytong blocks insulated with rock wool and polyurethane.

The lowest building is constructed with a trombe wall. It has an air gap all the way from the bottom floor to the roof, where the air heated from the sun will flow upwards. The heat will be fed into the heat recovery system since the wall is connected to the ventilation system. The pre-heated air is then distributed inside the house through that system. When heating is not needed, the system can exhaust the excess heat in order to avoid overheating risk.

The middle building is constructed with a solar wall, also with an air gap behind the facade. The façade consists of a black perforated metal sheet that allows the inlet of exterior air into the air gap, where the air is heated by the sun. The heat is then fed into an air-to-water heat pump. The resulting temperature increase will allow very high mean seasonal performance values for the heat pump.

In times when there is no demand for heating or hot water in the building, the heat pump will be deactivated and the preheated air exhausted through a dedicated opening.

The energy system in the building consists of a CHP unit, an air-to-water heat pump, a condensing boiler, storage tanks and photovoltaics.

The purpose of the CHP unit is to produce heat, domestic hot water and electricity. It has first priority when it comes to hot water, and will only produce heat if the heat pump cannot meet the need.

The heat pump is mainly meant for heating. It will be in use when the electricity provided by the photovoltaic system is enough. Under certain circumstances the heat pump will also be used for preheating of domestic hot water. This happens if the electricity from the photovoltaics exceeds the need for generating enough heat in the heat pump, namely when the heating demand is low.

The condensing boiler is the back-up generator of the heating plant, deployed to complete the peak output power of the plant.

The thermal storage subsystem is formed by two different tanks. The first one has a capacity of 2 m³ and is part of the DHW production system. The second one is coupled to the CHP unit and has a capacity of 3 m³.



2.3 Roth residential building

Facts:

Net floor area: 4575 m²
Apartments: 53
Facilities: 1
Stories: 3/4/5/6
Moving in: fall 2013

Technical specifications Roth:

U-value windows: 0.80-1.2 W/m²K
Energy performance: 66.0 kWh/m²
Space heating: 32.0 kWh/m²

In the new-development district Hyllie, meant to be the most climate-smart district in the Öresund region, the small real-estate company Roth Fastigheter has developed a residential building in three sections. They are now acting as the land lord for the inhabitants in the rental apartments.



Installations:

The building is designed and built with the ambition to reach a high energy performance. This is based on a minimization of energy demand, use of highly efficient HVAC technologies and integration of distributed generation systems.

The building is constructed with heavy frames and an air-tight envelope. Thermal bridges are avoided and the infiltration levels are low. In order to minimize heat leakage through windows, traditionally a weak part of the building, there were restraints on window size and consideration was taken to placement of windows in the design phase. The windows have U-values below 1.2. One experience made was that there are some challenges with overheating during the summer. This problem might be reduced in the future when surrounding buildings are constructed that provide some additional shading.

On the middle part of the building there is a green roof, leading to better roof insulation. In the north house there is also solar thermal heating. They are oriented south and have the optimal slope in order to provide the maximum efficiency and total hot water production. The installation contains 36 flat plate solar collectors with a total collection area of 62 m². When there is excess heat, that heat is stored in a storage system consisting with a total capacity of 6000 litres. This decreases the demand for bought energy for domestic hot water. However, the efficiency of the solar thermal collectors was lower than anticipated, despite correct installation and orientation.

The building is connected to the Malmö district heating network. The need for added heating is low though, due to the integrated system for heating and ventilation called FTX, which stands for forced in- and outgoing ventilation combined with heat recovery. The system is also heat exchanging with the ground,

taking advantage of the steady temperature of 15 °C throughout the year, enabling to preheat the air during winter and to cool it during summer. This system, in combination with the passive design of the building, removes the need for cooling.

Heating is distributed to the apartments via floor heating. This is a key element of the demand side management functionalities installed in the building. Since the thermal mass of the building accumulates any superfluous heat and releases it when there is a thermal load it is possible to turn down or off the heating delivery without significant temperature decrease.



2.4 Malmö Live hotel

Facts Malmö Live:

Net area: 20 042 m²
Stories: 25
Height: 85 m
Rooms: 444
Restaurants: 2
Inauguration: spring 2015

Technical specifications Malmö Live:

U-value facade: 0.10 W/m²K
U-value roof: 0.08 W/m²K
U-value floor: 0.10 W/m²K
U-value windows: 0.80 W/m²K
Energy performance: 65 kWh/m²
Renewable energy: 68 kWh/m²

In the same area as Sopranen and Tenoren, between the old city centre and the new district in Western Harbour, Skanska has developed the Malmö Live complex, which is in part a hotel. The building also includes a congress facility and a concert hall. The hotel is now owned and run by a hotel chain with high environmental concern.

The Malmö Live complex is certified according to the highest level of LEED-certification – LEED Platinum. The building is also certified to the highest level of the city of Malmö's "Miljöbyggprogram syd", which emphasizes energy performance, preservation of wildlife etc.

Installations:

The proportion of windows is high, potentially leading to an ill-performing thermal envelope. This is handled through an upgrade in the choice of insulation material, to PIR and graphite EPS. The envelope also has high air tightness. The roofs are covered with sedum that among other things has an energy-reducing effect. All of this, together with 3-glazed windows with a U-value of 0.5, creates a well-insulated building.



Malmö Live, where the hotel is one part, has a system for heating and cooling consisting of a geothermal plant combined with heat pumps. Waste heat from the chillers for the refrigerating rooms for the hotel kitchen is also used. This system caters for the entire need for thermal energy, both heating and cooling.

The geothermal plant consists of 75 holes each drilled to a depth of 270 meters. During the cold season the heat pumps extract heat from the deep holes and deliver it into the building. That also cools down the holes and the bedrock.



During the warm season the process is reversed: free cooling is transferred from the holes into the building, and the bedrock is gradually warmed before the cold season. Each of the parts of Malmö Live is served separately, and the system is co-owned by the building owners.

Part of the electricity demand for the heat pumps and other facilities is covered by photovoltaic panels mounted on the roof of Malmö Live. The approximately 500 m² gives an installed efficiency of 69 kW and an expected energy production of approximately 70 000 kWh/year.





2.5 Klipporna office building

In the new-development district Hyllie, meant to be the most climate-smart district in the Öresund region, Skanska has developed an office complex called Klipporna. It was developed as three separate buildings in three different phases. Skanska has sold the property, but rents part of it.

Klipporna is certified to platinum in the LEED energy rating system, the highest level in the certification system.

Installations:

The thermal envelope is well insulated and air tight. The walls and floors are prefabricated concrete, insulated with cellular plastic to a total thickness of 575 respective 750 millimetres. The roofs have a 400 millimetres thick layer of mineral wool insulation. The top layer of the roof consists of sedum, creating a green roof that adds to the insulation effect. The windows are triple glazed with a U-value of 0.9. The window openings are chamfered and thus provide shading, resulting in a reduced need for cooling.

At Klipporna, Skanska have implemented Deep Green Cooling, their award-winning innovative system for indoors cooling. It requires almost no electricity for the circulation and is thus an energy-efficient way to cool the offices. This is combined with a self-regulating ventilation system with heat recovery.

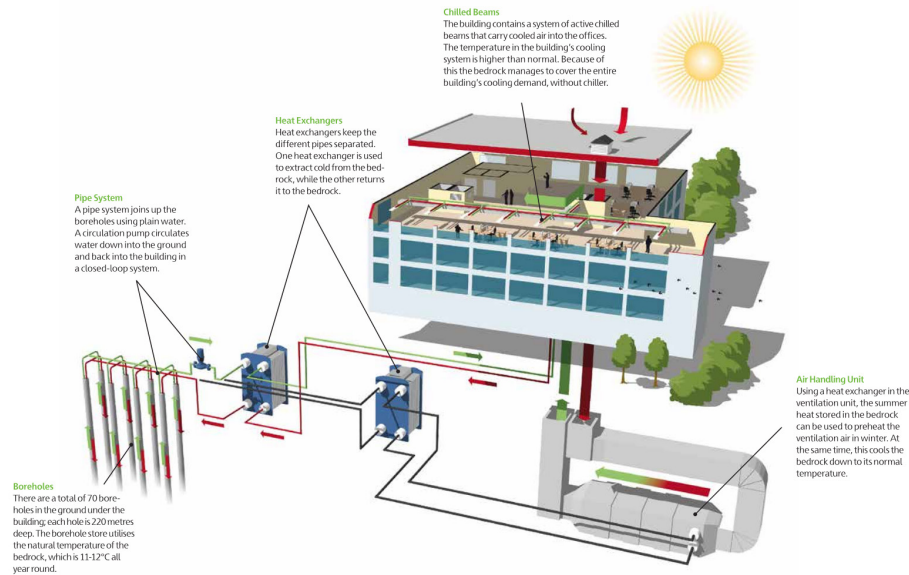
The Deep Green Cooling uses the temperature 200 meters into the earth to cool the air in the building. From the drilled holes a closed cooling circuit supplies the buildings with chilled air. A self-regulating cooling system in the building operates with chilled water temperatures at room temperature level. A ground storage operates with chilled water temperatures at normal ground temperature level. In this way, the ground is heated before the heating season. It is then possible to preheat the incoming ventilation air in the winter.

Facts:

Gross floor area: 27 801 m²
 Lettable area: 17 877 m²
 Stories: 7
 Moving in: summer 2014

Technical specifications Klipporna:

U-value facade: 0.17 W/m²K
 U-value roof: 0.09 W/m²K
 U-value floor: 0.30 W/m²K
 U-value windows: 0.90 W/m²K
 Energy performance: 50.4 kWh/m²



This solution can cover the entire annual cooling demand of a building without usage of chillers, if the required conditions are fulfilled. These conditions are described in chapter 6, Transferrability of project results.

The ventilation system is self-regulating, based on concentrating the inevitable pressure drop to the end of the ducting system, the supply air diffusers. This requires a low pressure drop along the ducts. To achieve this, the static pressure is kept constant since the duct diameter is constant, and the ducts have no dampers. In this self-regulating system less energy is used compared to a traditional system since the total pressure drop is lower.

The heat in the outgoing air is recovered through a heat exchanger (FTX system). There are also two extra pre-heating units of the outdoor air: firstly a coil to restore the groundwater temperature to its normal level (during the cold season), secondly a coil to pre-cool the return water in the cooling beam system (when possible).



3. End-user training

All the buildings in Buildsmart are designed and constructed as to have high energy performance when they are taken into use. But that does not necessarily mean that the actual energy performance is high once the tenants have moved in. That also depends on the tenants' behaviour. Therefore, an important part of Buildsmart has been to teach the end-users how to minimize their energy use.

The end-user training method and material has been developed by Codema. They ran a first, successful, implementation at the Dublin City Council's headquarters. But it was also obvious that the method and material had to be adjusted before implementing it in the Buildsmart buildings. Thus, this was done for each of the buildings.

The entire concept is called "Think energy". In Dublin, it rested on three mayor pillars: a staff survey on energy awareness, an interactive online space for communication (Think Energy Hub), and a year-long campaign directed at the employees, containing for example energy saving events.

During the year that the Think Energy campaign ran, the energy use in the building was reduced by 13%.

There is no way of knowing, though, how much that can be attributed to the campaign.

In the evaluation it became clear that it is important to include also aspects of the non-working part of the employees' lives in such a campaign, in order to make the message stick. Also the roles of so called Energy Ambassadors are important. These are members of staff that either have a direct influence on energy use, Energy Change Makers, or a personal interest in the energy reduction issue, Energy Change Supporters.

The next step was to implement the concept in the Buildsmart demo buildings. Four generic documents were created to support this; these can also be used by other property owners to create their own adjusted Think Energy campaigns. There are examples for implementation in residential buildings, hotels and commercial/public buildings. The four documents are:

- 1. Think Energy - Step-by-Step Behavioural Change Training Programme**
- 2. Think Energy - How to develop the Think Energy Online Hub**
- 3. Think Energy - Energy Ambassador Support Manual**
- 4. Think Energy - Training Guide to Energy Efficiency**

When the buildings were completed and taken into use, Codema helped the other project partners with the end-user training. They delivered End-User Training Specifications for each demo site, and after that visited each of the sites and delivered a Train the Trainer session.

Apart from the training delivered by Codema, there were also other initiatives in order to inspire the end-users to be energy efficient. At the Roth building, the

property owner delivered information and training to all tenants so that they would get full usefulness of the smart home applications in the apartments.

Also in the three Skanska buildings, the end-users were engaged in order to secure the buildings being as energy efficient as possible. At the Klipporna, the companies renting office space were instructed on the specifics of the building. At Sopranen and Tenoren, the individuals buying apartments received training at two occasions before moving in. At the Malmö Live hotel, the company owning and operating the hotel was instructed as well as the personnel actually using the equipment and meeting the customers.

4. Monitoring

The construction partners in Buildsmart have a high interest in knowing if their buildings perform as good in reality as in theory. Therefore, all the buildings in Buildsmart have been monitored after they were taken into use. Sensors and meters monitor air quality, temperature, air flow and other relevant parameters.

Most of the buildings have been in use for more than one year, and it is possible to compare actual and simulated performance. In most cases, the actual energy use is higher than the simulated value. There are a few possible explanations for this. Firstly, more energy is used during the first year of operation in order to dry out the structure. Secondly, many systems for heating, cooling and ventilation take some time to fine-tune so that they perform ideally. With this taken into consideration, it is more relevant to evaluate actual energy performance from the second or third year of operation.

Building	Simulated performance (kWh/(m ² , yr)	Actual performance (kWh/(m ² , yr)	Discrepancy (kWh/(m ² , yr)	Years of operation
Skanska Sopranen	53	57.6	-4.6	~1
Basque	64,8	62,3	2,5	<1
Roth	60	66	-6	>1
Malmö Live hotel	38	65	-27	>1
Klipporna	59	50.4	8.6	>1

5. Transferability of project results

In each of the Buildsmart demonstration sites, a combination of installations has been implemented in order to show the possibility of constructing truly energy efficient buildings in a cost-effective way. It is not possible to reach this effectiveness without implementing several measures, but they do not have to be implemented in the exact combination that is tested within Buildsmart.

Most of the techniques implemented within Buildsmart can be used in other climatic zones and on other types of buildings, individually or combined, with little or no adjustment. This is valid for the following techniques:

Geothermal reversible heat pump

Could be used anywhere where there is a need for heating or cooling. 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.

Energy efficient windows

This technology can be used both to keep the warmth inside and outside. Size and placement of windows are relevant for the indoors temperature. And an air-tight building envelope requires sufficient ventilation in order to provide a good indoors climate.

Trombe wall and Solar wall

Both these types of walls can be used in any climatic zone and type of building. Since the system is based on heating from the sun, it is less adequate in regions with little sunshine during the colder parts of the year, though.

Pre-fab walls

There are no limitations related to climatic zone or function. Naturally, the specifications of the wall could vary. And an air-tight building envelope requires sufficient building ventilation in order to provide a good indoors climate.

PIR (polyisocyanurat) insulation, hard foam insulation material

The thickness of the insulation layer should be adjusted to the specific climatic zone; insulation also maintain a cooler indoors temperature in areas with a warmer climate. An air-tight building envelope requires sufficient ventilation in order to provide a good indoors climate.

PV panels

The PV panel technology is already well-established around the world. They are more adequate in warmer (sunnier) climatic zones but they can be profitable even in colder climate, especially on a building with high electricity demand in the summer season.

PV panels

The PV panel technology is already well-established around the world. They are more adequate in warmer (sunnier) climatic zones but they can be profitable even in colder climate, especially on a building with high electricity demand in the summer season.

Heat recovery and air-borne heating

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 to transfer heat from the incoming air to the outgoing. In that way, the cold in the outgoing air is “recovered”.

Use of ICT

The buildings have made use of different ICT solutions (such as smart metering, controls, visualisation of energy demand). A number of technical and financial barriers have been identified. These range from procurement related barriers (compatibility between different suppliers), the complexity of the systems in order to be able to guarantee a comfortable indoor environment, barriers for individual metering, questions of how to communicate complex energy systems to the users, to financial barriers, such as the balance between necessary investments and energy saving potential or the fair distribution of energy costs amongst building occupants.

There is also one technique that is truly dependent on the climatic zone: the Deep green cooling system at Klipporna.

Deep green cooling (DGC)

For a deep green cooling installation to work properly, there are a few conditions that need to be met. Some of these 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. The conditions are:

Annual mean temperature. The temperature difference between the indoor design temperature (summertime) and the annual mean ground temperature must not be lower than 10 degrees 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.

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.

Specific building requirements (cooling related). Ventilation air speed is 1.0 m/s through cooling coils in the air handling unit.

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/m² LOA (lettable area)
- Cooling annual demand 35 kWh/m² LOA (lettable area); approx. 25 kWh/m² LOA for HVAC and approx. 10 kWh/m² LOA for process
- Ventilation air flow rate 1.5 l/s m² LOA
- Running hours approx. 3400 hours/year (13h/5d)
- Water-based cooling system by using self-regulating cooling beams

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www.malmo.se/buildsmart



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SKANSKA



ROTH

