# Part 2

## Best Practice Cases

# Häe University of Applied Sciences (HAMK)

**Overview**

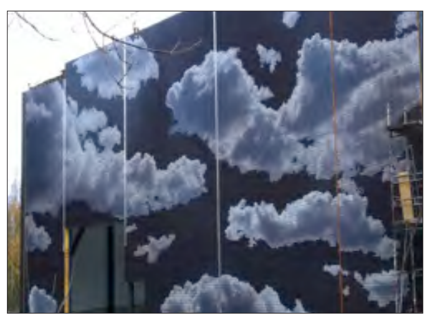
· Location: Häeenlinna
· Completion Date: 2015
· Building Type: Commercial / Industrial

**Featured Tech.**

· Building envelopment
· Radiant profile
· Energy pile
· Solar heat collector
· BIPV

**Team/Owner Details**

· Architect: Ruukki Construction
Heating, cooling and ventilation
· system: Ruukki Construction
· Renewable heating energy system:
Ruukki Construction



## Nearly Zero-energy Building in Häe University of Applied Sciences (HAMK)

Finland's first nearly-zero "Big -Box" type one-story building (nZEB) was designed for commercial, logistical and industrial uses with the purpose of cost effectiveness and utilisation of renewable energy sources during the life cycle. In particular this project addressed the co-operation with different parties toward a common target.

## Building envelope

The building shell of the wall and roof has a significant role in its energy efficiency. Thus, the outer walls are constructed of a sandwich panel system with ultra-airtight panels and sealing air leaks between the panels, plinth, roof, windows and doors. The sandwich panels consists of a glass-wool insulation in between two thin steel sheets. The insulation thickness of both wall and corner panels is 230 mm, with U-value 0.16 W/m²K. The building roof incorporates a new type of prefabricated PIR roof elements with U-value 0.12 W/m²K. The entire building airtight status contributes to substantial savings in the heating energy demand. Total building airtightness was measured as $q_{50}$ = 0.76 m³/hm² (amount of air leak per envelopment area in the pressure condition of 50 Pa). With this level, it was estimated that the building heating energy demand can be 28% lower than that with minimum airtightness of $q_{50}$ = 4.0 m³/hm² (Finnish energy regulations) using the building emulator.

## Heating, cooling and ventilation systems

A new type of radiation-based heating and cooling profiles was developed and installed in the building. The panels are placed on the surface, suspended on the ceiling as shown in Figure 1. The radiation panels provide either cooling or heating to the room depending on the season and the desired indoor temperature. Radiant panels work with a low temperature difference to the ambient air, allowing the heat pump to efficiently perform. The radiant system also helps to lower the temperature variations between floors, thereby gaining thermal comfort and higher productivity at work.

Fig.1 Ruukki radiant panel and installation

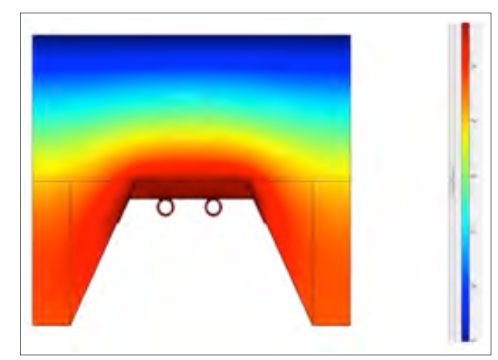


Fig.2 Ruukki radiant panel integrated into the roof panel

**Source** : Jyrki Kesti (Ruukki Construction)

Fig.3 Heat collector pipes installed in the floor slab piles

Heating and cooling performance of the new product were studied by Finland's leading building services consulting firm, Granlund, using Comsol Multiphysics program. The properties of the product such as material, color, tube diameters and geometry were optimized to achieve high performance. It was observed that the radiant system takes about 76 % of the total heat output and the total heating power was 77 W/m with average fluid temperature of 45 ℃. In the cooling mode, the cooling power was 31 W/m with average fluid temperature of 16.5 ℃. Temperature distribution of the system in the heating mode is illustrated in Figure 2.

The new type of indoor heating and cooling system can also contribute to energy saving compared to air heating systems. With this system, the ventilation does not consider room heating to calculate required airflow to building. The mechanical ventilation with heat recovery system can keep up to 80% energy.

## Renewable heating energy system

Geothermal energy is utilized for building heating and cooling. Total 60 Ruukki Construction energy piles with diameter of 115 mm and 11 m in length are placed in the foundation to use the geothermal energy for the building. Steel foundation piles are used for the energy pile system. Uponor double U-heat-collecting pipes (25 mm) were installed in the piles, connecting pipes to the heat pump with heat-transfer liquid. Figure 3 shows the heat collector pipes installed in the floor slab piles. Furthermore, two conventional heat wells of 200 m in depth were built for heating and free cooling. The heat pump capacity is 32 kW.
A total of 24 m² of Ruukki Classic solar collectors were installed on the building roof. The Classic solar system is fully integrated with the roof, as shown in Figure 4. Solar collectors accumulate thermal energy from the sun and deliver it to the soil through the energy piles. The soil is charged whenever heating energy is available even in January, due to the very low ground temperature level.

Fig.4 Roof-integrated solar heat collectors

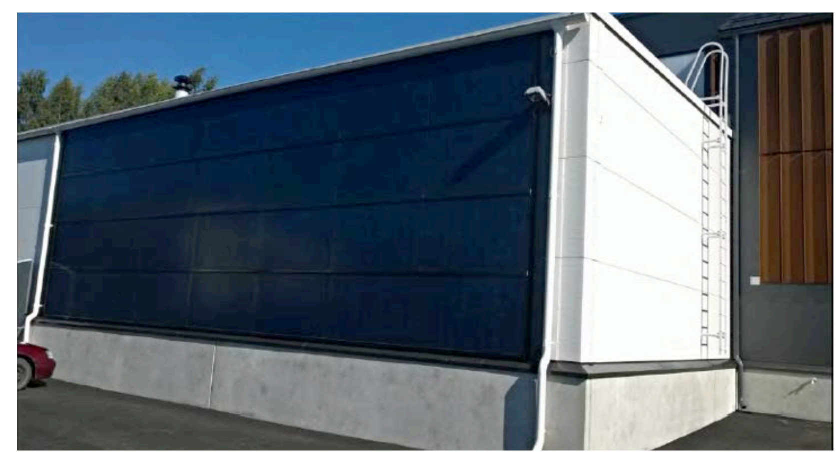


Fig.5 Building-integrated solar PV panel installed on the southern facade

## Building Integrated Solar Energy Solution

Wall-mounted, vertical panels utilizes solar power for energy generation. Ruukki Construction on-wall solar panels installed on building southern façade can generate electricity from the sun lights. A total of 61 m² PV (Photovoltaic) panels with total peak power of 10 kW are incorporated in the wall (see Figure 5). Total electricity of 7 MWh/year can be produced from the system. Due to lower solar angle at Finnish latitude, the on-wall system is relatively effective.

## Energy-saving/$CO_2$ emission

Delivered energy of each case is compared in Figure 6. The result shows that it is possible to cover more than half of total energy uses by smart building design and systems. The annual energy production of the building-integrated solar PV panels is approximately 7000 kWh/a. Thus, the need for delivered energy can be decreased by approximately 5 kWh/m², which account for over 10 % of decrease in a primary energy use.

## Economic Feasibility Study

As driven in Figure 7, the nearly zero-energy solution is economically feasible with a 9-year payback period. Also, it should be noted that the actual extra investments for the nZEB solution are only about 2% of the total construction costs.

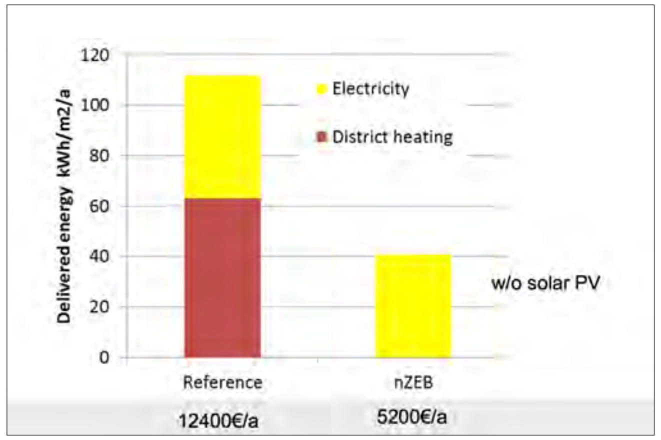



Fig.6 Comparison of delivered energies of the reference case and nZEB case

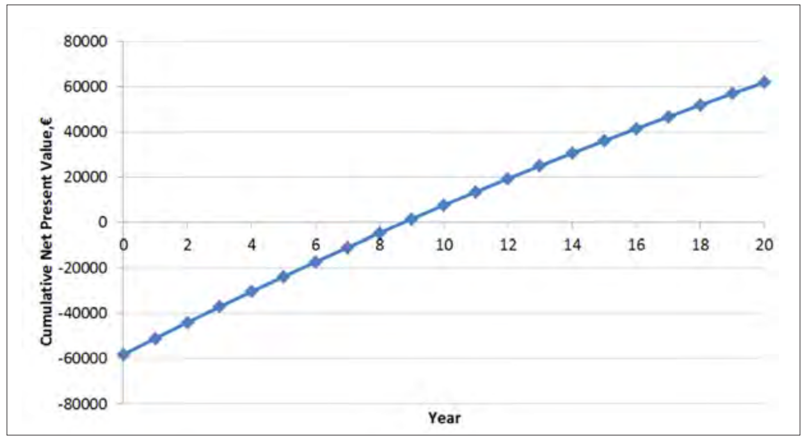



Fig.7 Net present value for the nearly zero-energy building compared to the reference building

# POSCO Green Building

**Overview**

- · Location: Incheon, Korea
- · Completion Date: 2013
- · Building Type: Office/Residential

**Featured Tech.**

- · BIPV
- · Fuel cell
- · Prefabricated exterior wall
- · BEMS
- · Super Strength PHC (Pretensioned High Sterngth Concrete)

**Team/Owner Details**

- · Architect : POSCO A&C
- · C Inspection company : Plan A Architectural Firm
- · Contractor : POSCO E&C
- · Owner : Yonsei University

## Future-Oriented and Environment-friendly Architecture POSCO Green Building

POSCO completed 'POSCO Green Building' construction, a future-oriented and environmental-friendly building with energy reduction technologies, located on the Yonsei University International Campus in Incheon, South Korea. The POSCO Green Building, which was completed in 1 year and 2 months after starting construction consists of offices (5 floors, B1~4F, total square of 5571m$^2$), joint housing building of 5 units (3 floors), 4 modular home units and a PR exhibition hall. The POSCO Green Building was carried out as part of the Ministry of Land, Infrastructure and Transport R&D project, research on spreading green technology to market demand-based new buildings which aims to increase the construction of domestic green buildings, while abiding by environmentally-friendly and low energy methods during the entire process.

## Green Technology

More than 100 green technologies including solar power, geothermal air-conditioning and heating, vacuum outer-insulation, and ICT (Information Communication Technology) were applied to the building, optimizing energy performance and saving energy usage from 30 to 100% compared to existing buildings. Further, this environmental-friendly building can generate approximately 35% of the required building energy using the renewable energy sources on site. Building materials developed by POSCO that can reduce energy were used. On the frontside of the building, a steel curtain wall, which boasts the best domestic insulation performance, was installed. Its insulation effect is twice more than existing aluminum curtain walls, and external vacuum insulation was applied to the exterior walls to increase heat capacity. In addition, self-cleaning steel plates were applied to the building exterior to maintain a clean appearance and remove pollutants via rainwater. This steel plate has a 30% longer life-span than that of regular steel plates. High corrosion-resistant alloy gilt steel plates were used in the facilities to save rainwater, and high manganese steel that can reduce vibration was experimentally applied to the sound-blocking floor to solve noise between floors. Further, a Building Energy Management System (BEMS) controls air-conditioning, and OLED lighting automatically by analyzing the production-delivery-consumption process of energy and sensing temperature differences caused by sunlight. BEMS was applied to improve energy efficiency and allow intelligent energy management.

## 7 Proprietary Technologies applied to POSCO Green Building

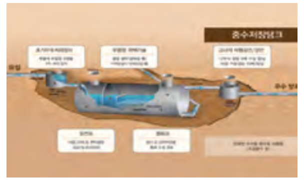
**Reuse steel structure**

Environmental-friendly architectural technique with vibration control damper mounted on column beam joints, which can control damage to structural materials that may arise from earthquake or internal force.

**Source** : Posco Green Building

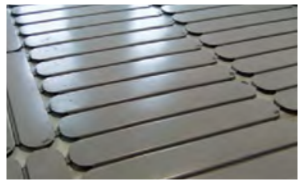
**Seismic control steel damper**
A damper made of steel materials can control the damage from earthquake by absorbing the earthquake mechanical energy instead of building structure.

**POSCO Steel Curtain Wall**
Steel curtain wall surpasses other metallic curtain wall with the insulation performance and strength. Workability and cooling/heating effects are maximized when applied to elevation design.



**Storage Tank**
Storage tank is developed to prevent flood and reuse rainwater by using corrugated steel pipe and plate with high resistance to bending load when compared with general steel plate.

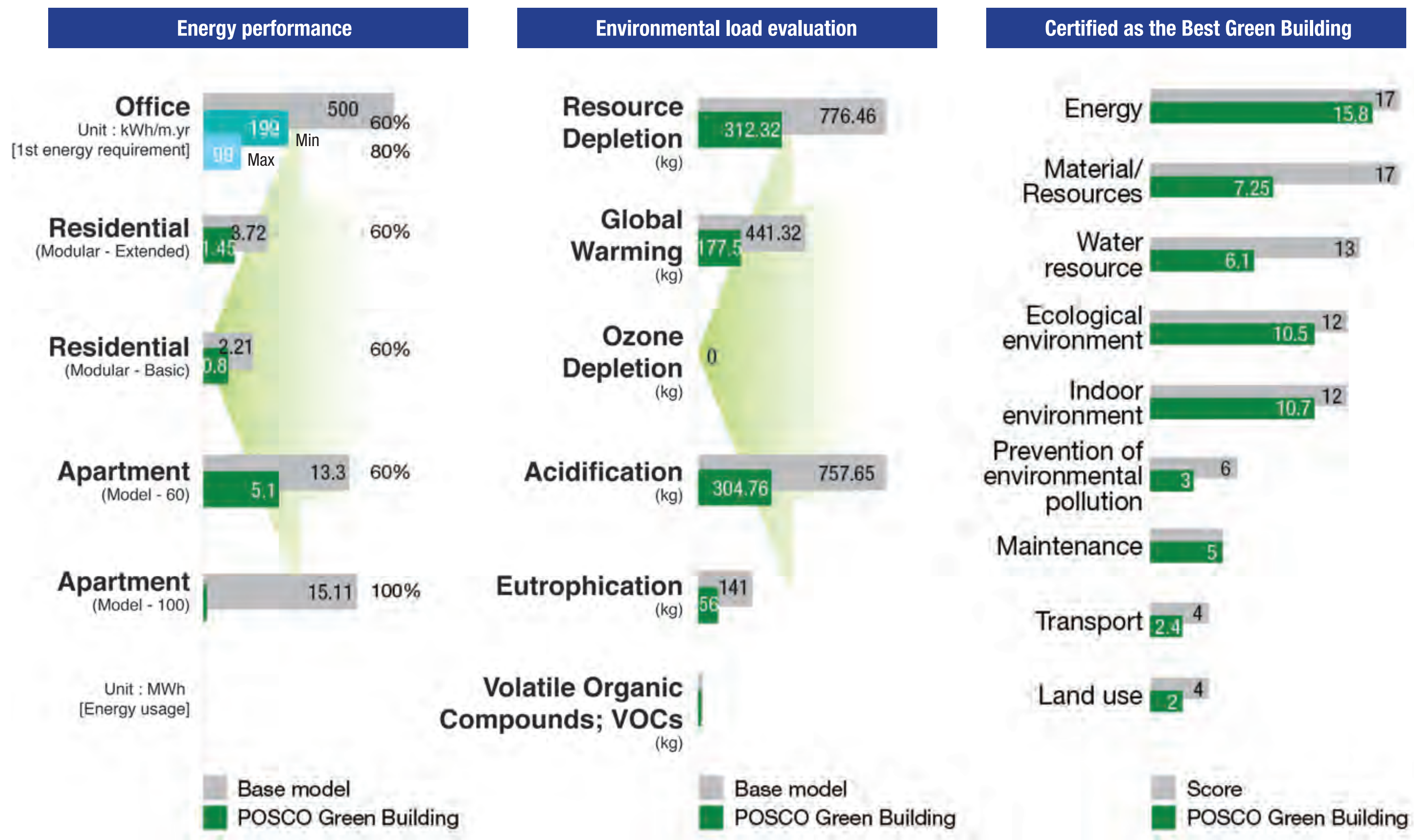
**Prefabricated exterior wall system**
As the system can be assembled on site with the panel modules produced in the factory, it can reduce construction period as well as save construction cost.



**Floor structure with high manganese steel for reducing impact sound**
New type of high manganese steel structure is characterized with vibration reduction, which is applied to Ondol floor of the Green Building  apartment section to reduce interlayer noise.

**Energy Pile**
With heat exchange pipe installed into the steel tube foundation pile, it reduces early-stage construction cost and saves $CO_2$ emissions up to 35% using environmental-friendly geothermal heat energy.

**Comparison of POSCO Green Building with base model**



# Kitakyushu Dormitory

**Overview**

- Location: Kitakyushu, Japan
- Completion Date: 2012
- Building Type: Residential/Dormitory

**Featured Tech.**

- Building design
- Energy pile
- Solar heat collector
- BEMS

**Team/Owner Details**

- Business Owner : NIPPON STEEL & SUMIKIN ENGINEERING CO.
- Producer : Makoto Takahashi
- Director : Katsunori Seo
- Designer: Hitoshi Etoh et al.

## NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD. [Kitakyushu Dormitory]

At the Kyoto Protocol (COP3), Japan announced to reduce $CO_2$ emissions and other greenhouse gases. However, energy-related $CO_2$ emissions are still increasing as a result of higher energy consumption. It is required to apply energy saving techniques to office buildings.

The NS Ene-Pile Ground Thermal Energy System utilizes the NS Eco-Piles, which are one type of foundation piles with the rotating press-in method, as a round heat exchanger. The NS Ene-Pile are used for the whole thermal energy utilization along with the NS Eco-Piles.
By utilizing the hollow section of the NS Eco-Pile, it can dramatically reduce the initial investment cost of ground heat exchangers. The NS Eco-Piles are relatively low cost if it is installed only for the heat exchangers. In the construction process of the NS Ene-Pile, it works for ground excavation and building underground structure simultaneously. Thus, the underground space can be built in a very short time at reasonable costs. It compensates the limitation of the conventional method. The effectiveness of the ground thermal energy is higher even when applying the NS Ene-Pile to the underground heat storage tank.

## System Summary

The project building utilized a solar collector for domestic hot water and heat pump systems with ground and air source for heating and cooling. Ground heat pump systems used 68 piles with double U-tube as a ground heat exchanger. They can extract geothermal energy from underground, satisfying high seismic resistance with lower soil waste. The pile length was 15 m which is short enough not to get to the groundwater located in deeper area. Thus, air-source heat pump systems are utilized as base systems for heating and cooling to meet total building demand.
Using geothermal energy, 6% of heating and cooling energy costs could be saved compared to conventional system. The cooling SCOP and the heating SCOP were 5.0 and 3.7, respectively.
Compared to the gas water heater, approximately 57% of $CO_2$ emissions can be reduced. It was found that the payback period could be shortened by five years based on the simple calculation of higher initial cost, with a lower operational cost.

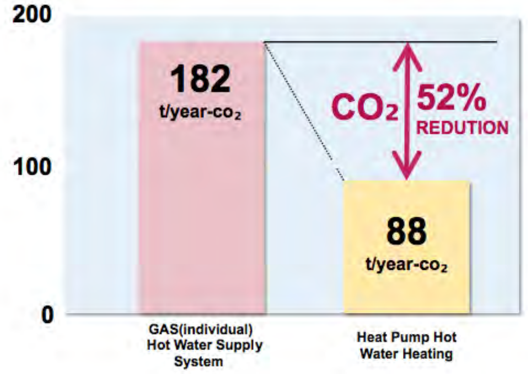



Fig.1 Energy and $CO_2$ reduction of the solar heating system
Smart heat pump system

**Source** : Nippon Steel & Sumitomo Engineering

## Smart heat pump system

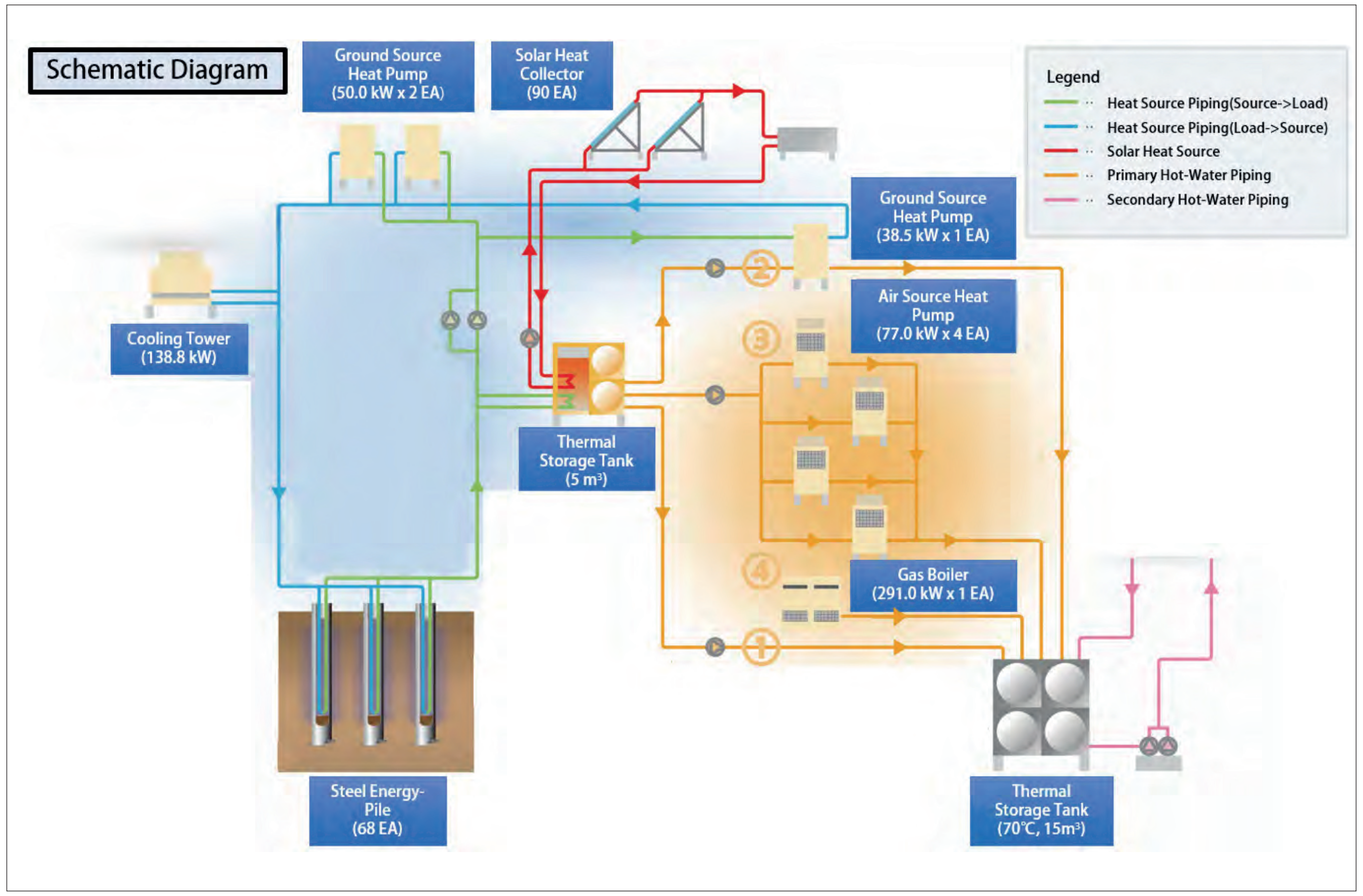



Fig.2 System summary

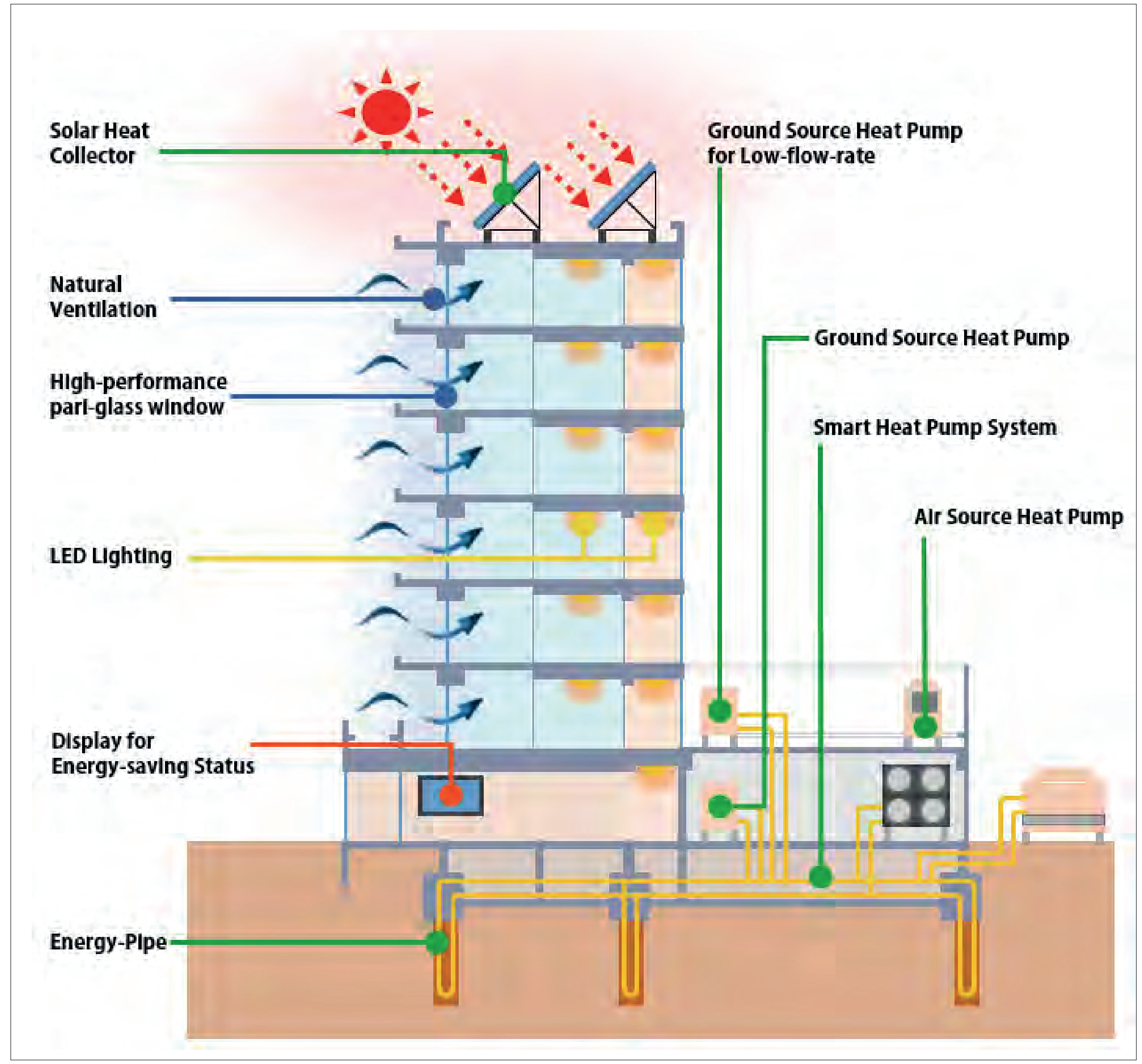



Fig.3 Schematic diagram

Fig.3 Pile head after penetrating steel pipe pile (after attaching curing lid)

Fig.4 Insertion into U-tube pile started (with curing cover and weight at tip)

Fig.5 Remove U-tube of pile head in specified direction

Fig.6 Remove U-tube from footing in specified direction

# K-Rauta Lahti

**Overview**

· Location: Lahti, K-Rauta
· Completion Date: 2008
· Building Type: Commercial

**Featured Tech.**

· Building envelopment
· LED
· Natural ventilation
· Energy pile
· PV panel

**Team/Owner Details**

· Steel frame and building envelope: Ruukki Construction
· Energy piles: Ruukki Construction

## Improving life cycle efficiency in one-story commercial buildings (K-Rauta Lahti)

Latest researches on building energy efficiency have been conducted on both residential and office buildings. There is a lack of research on total energy performance analysis for commercial one-story buildings. Innovative techniques with the new concept have significant potential that can save large amounts of heating, cooling energy as well as lighting energy. The developed solutions are cost effective and efficient enough to be ramped up in a very limited timescale and large geographic area. Some of the identified technical solutions in development include:

1. Using foundation piles that support the buildings as ground heat harvesters.
2. Integrating solar photovoltaic panels directly into the exterior wall structures.
3. Using highly isolative translucent panels to maximize natural light without compromising commercial aspects.
4. Providing natural ventilation with exterior wall performing a hybrid heat recovery systems.

The combined effects of solutions drive towards more realistic way, taking the entire building type into a new level in energy efficiency. The best way to achieve a successful energy efficiency of EU one-story commercial building stock is to have a solid and viable business plan.

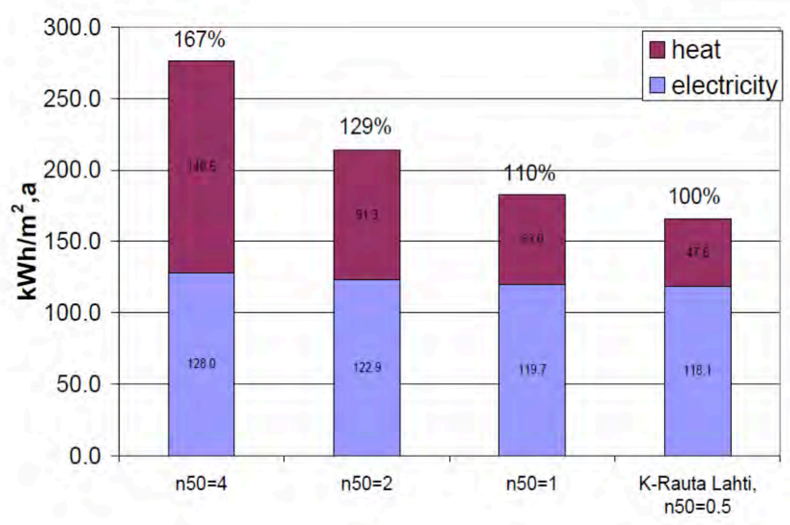



Fig.1 Effect of airtightness on energy consumption of the single-story store building

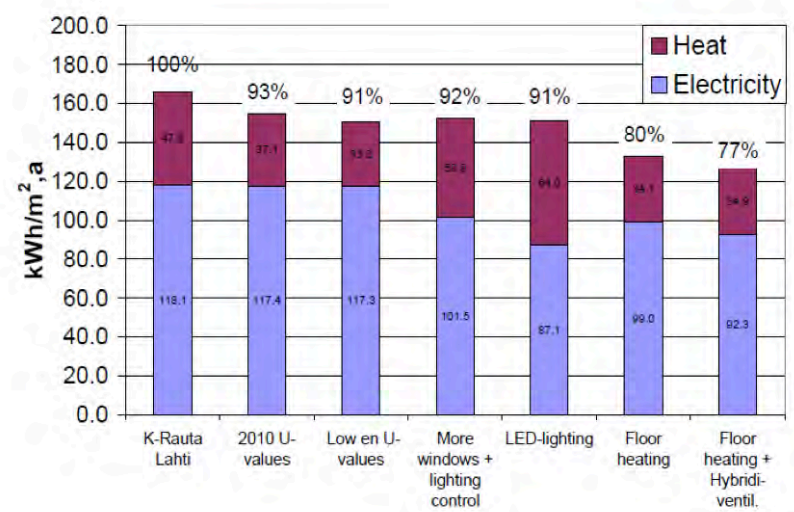



Fig.2 New technical improvements for energy demand reduction

**Source** : Jyrki Kesti and Petteri Lautso (Ruukki Construction)

## New solutions in energy reduction

Figure 1 indicates that the airtightness has a great influence on the heating energy under the Finnish climate. Building heating energy with airtightness of n50 = 0.5 1/h is about half of that having airtightness of n50 = 2.0 1/h. On top of that, alternative approaches were explored for the potential in energy demand reduction. Technical improvements from the original building were studied and the results are shown in Figure 2.

1. Better U-values in envelope with Finnish energy efficiency regulations in 2010.
2. Low-energy U-values (walls: 0.12 W/m²K, roof: 0.08 W/m²K, floor: 0.12 W/m²K, windows: 0.7 W/m²K, door: 0.5 W/m²K).
3. Band window 118 m x 4.5 m to the south facade + Day light control.
4. LED lighting (50 lm/W).
5. Water-based floor heating + Ventilation with constant air flow during opening hours.
6. Additional natural ventilation in store area during summer season.

If the building envelope had better heat insulation, the total energy consumption would be 7% lower than that of the original building. It means the changes of Finnish regulations in 2010 are reasonable, even for large enclosure buildings.

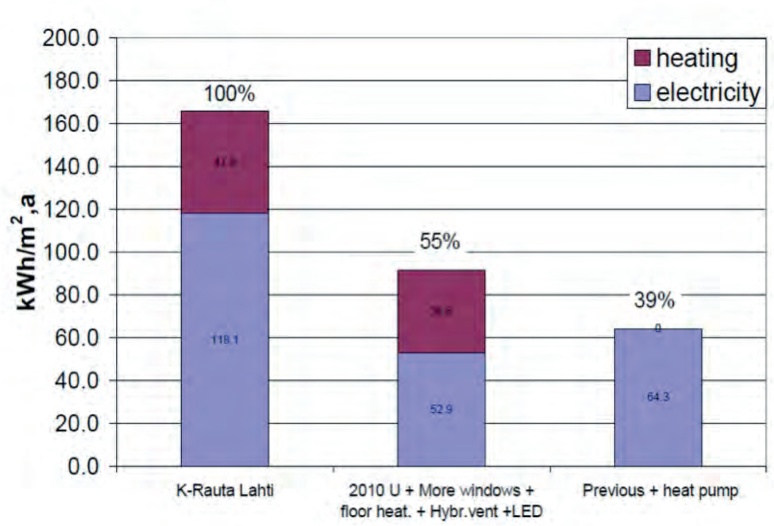



Fig.3 Combination of new technical improvements for energy demand reduction

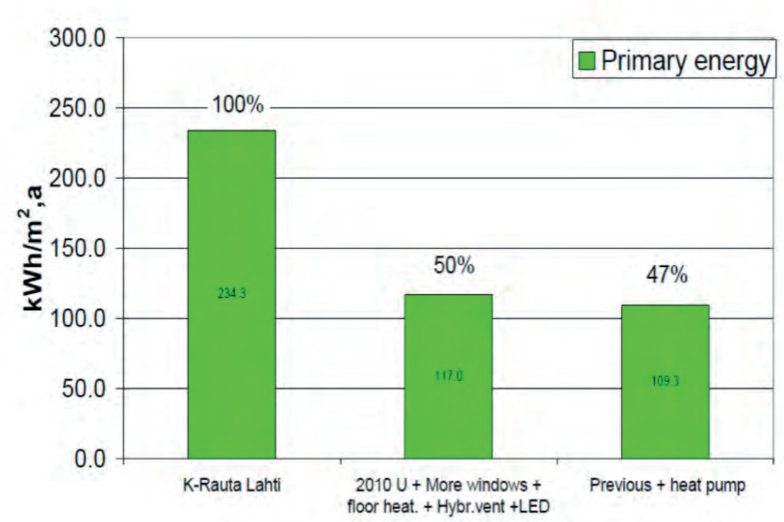



Fig.4. Primary energy consumption for different cases

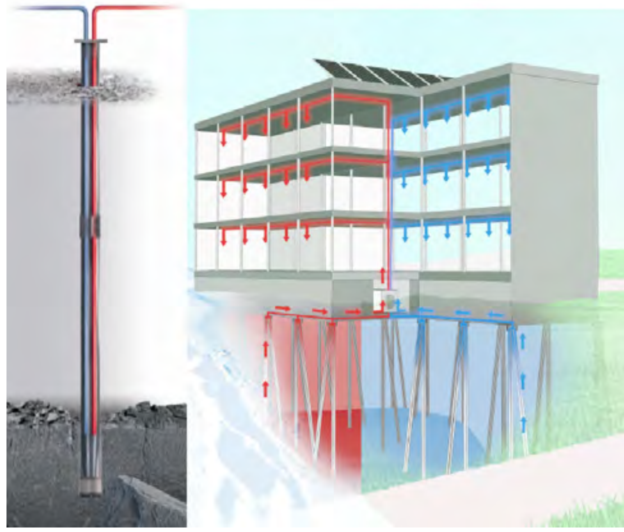


Fig.5 Energy piles

Fig.6 Building integrated solar-PV (Ruukki)

## Natural ventilation

The biggest influence on the energy demand was heating system changes. Water-based floor heating system can save 20% energy compared to the original air-heating system. It is mainly achieved by lower electrical demand for ventilation blowers. Utilizing natural ventilation during summer can provide potential energy savings. It is possible to integrate different types of openings to the wall . Also, a variety of architectural designs can be adapted to the facades.
For the next step, the combined effect of single solution can create substantial energy saving potential. Total energy saving, with respect to the original building, can be up to 45% by applying 2010 U-values to building envelope, more windows, LED lighting , day light control and water-based floor heating system. Even, utilizing the geothermal energy can maximize the energy saving with lower net energy transfer. Figure 3 highlights the combined effect for energy demand reduction. It was observed that floor heating with ground heat is very efficient since the floor heating requires low temperatures which is well aligned with the ground heat pump system.
Incorporating the ground heat pump system can reduce the total net energy transfer up to 39% of the original energy demand. Since the coefficient of performance (COP) for ground heat pump is above 3 in Finnish environmental conditions, the primary energy consumption is expected to be lower. Comparison result of primary energy consumptions in different cases is shown in Figure 4. Ground energy can also be utilized as a free cooling at a very low cost (i.e by circulating cooled liquid in the floor embedded pipes only with circulation pump).

## Energy piles

After the steel piles are installed, heat exchanger pipes will be placed into the empty steel piles (length typically over 15 m) and connected to the ground heat pump located in the building. In order to provide enough heat transfer from the ground to the heat exchanger pipes, the steel piles are concreted. The system installed in the building provides both heating and cooling with higher efficiency. Such that, the heat balance of the soil can be stabilized in a long run. Compared to the traditional ground heat systems, the prominent advantage of this system is cost saving for drilling the heat wells.

## Targeting zero energy building with solar-PV solution

One of typical building characteristics is having large solid surfaces on the walls and the roof. The surfaces can be effectively utilized for building integrated photovoltaic systems. With the development of PV technology, it becomes economically feasible and easily applicable to commonplace construction. For instance, well-designed building integrated photovoltaic system is illustrated in Figure 6.

# Swansea Active Office / Active Classroom

**Overview**

- · Location: Swansea, UK
- · Completion Date: 2016(Classroom), 2018(Office)
- · Building Type: Educational/Office

**Featured Tech.**

- · PVT system
- · BIPV
- · Heat Pump
- · Solar roof
- · Modular steel frame

**Team/Owner Details**

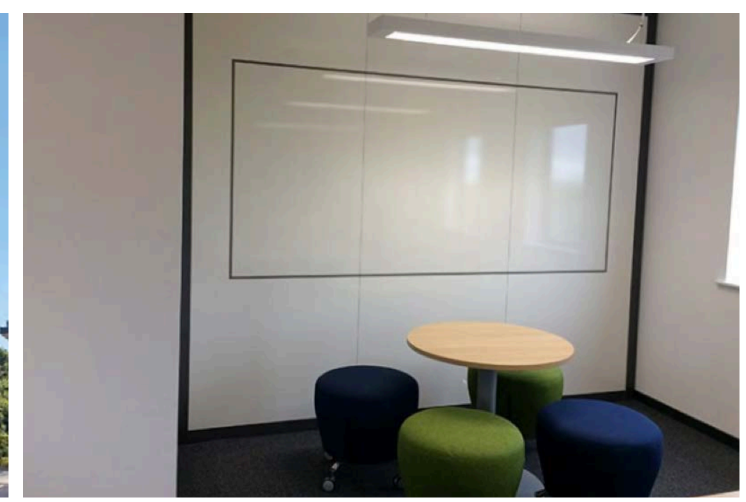
- · Architect & Main contractor: SPECIFIC
- · System manufacturer: Tata Steel
- · Owner: Swansea University

## The UK's first Plus Energy Office Buildings in Swansea

The Active Office and the Active Classroom at Swansea University's Bay Campus are designed to be net plus energy buildings. These can generate more energy by renewable energy systems than the energy they use during a year. The Active Office was completed in 2018 as a two-story building and the Active Classroom was completed in 2016 as a single-story building.

## Main Challenge

This project aimed to satisfy the conditions of net plus energy buildings and transfer systems from 'passive' into 'active' using fascinating technologies and integrated systems. The Active Office is the first plus energy office in the UK. This building has a lot of innovative technologies that enable it to generate, store and release solar energy. Also, it has the solar roof system and a wall-mounted photovoltaic-thermal (PVT) system simultaneously generating electrical energy 2.4kWp and thermal energy 9.6kWp. The generated energy works together with battery and heat storage in one combined system. Electricity generated by the 22kWp PV system can be stored in a 100kW lithium-ion phosphate battery system. In this building, a smart controller was equipped to optimally use a water-based thermal storage (2 kiloliters) with occupancy-weather forecasting information. It meets energy demand for the next day, allowing time-shifting of electric heating demand. The Active Classroom also has renewable energy systems such as BIPV attached in the roof and windows, battery storage, a new resistive underfloor heating system, and solar thermal heat generation. The two Active buildings were designed to share energy. Tata Steel worked as a main partner and provided some sponsorship towards this project. The products externally include Colorcoat Renew SC® transpired solar collector, Trisobuild® plank profile walls, and Colorcoat Urban® as a roof system providing the substrate for BIPVCo's integrated photovoltaic modules. Moreover, Tata Steel supplied Coretinium® for internal walls; and Colorcoat Prisma® was also used as the base for the floor heating system designed and manufactured by SPECIFIC. According to reference based on performance data, the building can produce 1.5 times the amount of energy it consumes over an annual period.



**Source** : Joanna Clarke (SPECIFIC's architect), Tata steel construction

# House of Tomorrow Today (HoTT)

**Overview**

· Location: Heeze-Leende, Netherlands
· Completion Date: June 2014
· Building Type: Single family home

**Featured Tech.**

· Energy surplus house
· Cold-formed steel frame
· PCM
· Home automation system

**Team/Owner Details**

· Owner/User: Prof. Dr. Jos Lichtenberg
· Design and Engineering: KAW Architects, Lichtenberg Consultancy, CFP Engineering
· Smart Building Process: An Archi, ZBO and subcontractors

## Net Plus Energy Building for Single Family

The House of Tomorrow Today (HoTT) is an experimental house, built in the municipality of Heeze-Leende (Sterksel) in the Netherlands. It was realized according to relatively new sustainable visions like Smart Building and Active House, but with mostly new, available technology. The project was finished in 2014 and next it was subsequently subjected to demonstration and research.

## Main Challenge

HoTT is based on both the Smart Building and Active House vision. It was the very first newly built Active House in the Netherlands. The main structure is comprised of a cold-formed steel frame combined with large prefabricated double shelled and lightweight dry wall, floor and roof elements. For the outer walls, roof and ground level floor, the thermal transmittance (U-value) is 0.15 W/m$^2$K. Thermal bridges are eliminated by an additional outside layer of insulation material, covering the entire exterior surfaces. Insulation of windows/glazing is enhanced partly with high performance double and triple glazing, and partly with solar controlled and insulating spacers. The U values for windows are in the range of 0.7-0,9 W/m$^2$K. The south-facing roof, with a 20-degree pitch, is covered with 94 m$^2$ of PV panels, providing 15,000 kWh each year. In addition, six solar collectors have been installed for the production of hot tap water. The PV energy production covers the heating and cooling demands, domestic energy use of electrical devices and lighting, and also provides energy for an electric vehicle charging station. The heating and cooling demand is supplied by means of an air to water heat pump that feeds a floor heating/cooling system, as well as a number of active convectors.

The house is ventilated by a hybrid system. Most of the time, ventilation occurs via a $CO_2$ controlled natural air supply and mechanical extraction, obtaining a high-level indoor climate in terms of clean air and an extremely low $CO_2$ concentration in the range of 450-700 ppm, and in the cold periods with a balanced ventilation with heat recovery. During summer months, the house takes advantage of the prevailing south-westerly winds, offering night ventilation by opening, some of the 19 roof windows, creating a chimney effect above the atrium in the centre of the house.

A 1.2 m wide zone, named Aorta, crossing the total centre of the house, provides the main distribution of services, like sewerage pipes, air ducts, cable bundles, etc. The channel is being covered by a new developed ceramic suspended floor system prototype allowing full access to the services. The house is equipped with a KNX based home automation system in order to be able to operate various components, including hybrid natural ventilation system, sunscreens, and automated roof windows.

The research and development in the frame of HoTT is manifold and can be categorized in the following topics:

· realization (process analysis),
· health/comfort in use
· energy control
· sustainable building technology

**Source** : Prof. Jan Hensen (Eindhoven University of Technology), J Lichtenberg, Slimbouwen (2006)

## Experiences and next generation

After roughly five years in use, the HoTT project has achieved an energy surplus. The house generates 15,000 kWh annually, in addition the energy for hot water through solar collectors. For domestic use, 3,000 kWh is needed, for supplementation on hot water 1,000 kWh (MAX), 3,000 kWh for heating and 2,000 kWh for cooling. That results in a surplus of 6,000 kWh, which covers the use of the electric vehicle for some 30,000 to 40,000 kilometers travel annually.
Since the house is a rather lightweight house with a significant number of roof windows, the behaviour is that on a day of greater than 35°C, the indoor temperature without cooling would raise up to 32-33 °C. As a result, the floor cooling system is essential. With active cooling and PV generated energy, on such extremely hot days, the indoor temperature remains on below 27 °C. Together with night ventilation and an outdoor night time temperature dropping below 18 °C, morning indoor temperatures on such days is reduced to <22 °C. Subsequent to a period of extreme hot weather, the indoor temperature will return to a normal comfort level of 20-21 °C within just one night.

In HoTT 2.0 even more attention will be paid to the reduction of entering heat through such measures as reducing internal heat production, introducing additional mass or PCM in walls, equipping the moderately sunlit windows with sunshades, adding a double skin ventilated roof (parasol roof) and burglar-proof night ventilation also in the facades, as well as new operating software for shading and ventilation. Figure 1 shows the result of a sustainability assessment with  a common software tool (GRP Building). The GRP stands "Green Performance of Real estate".

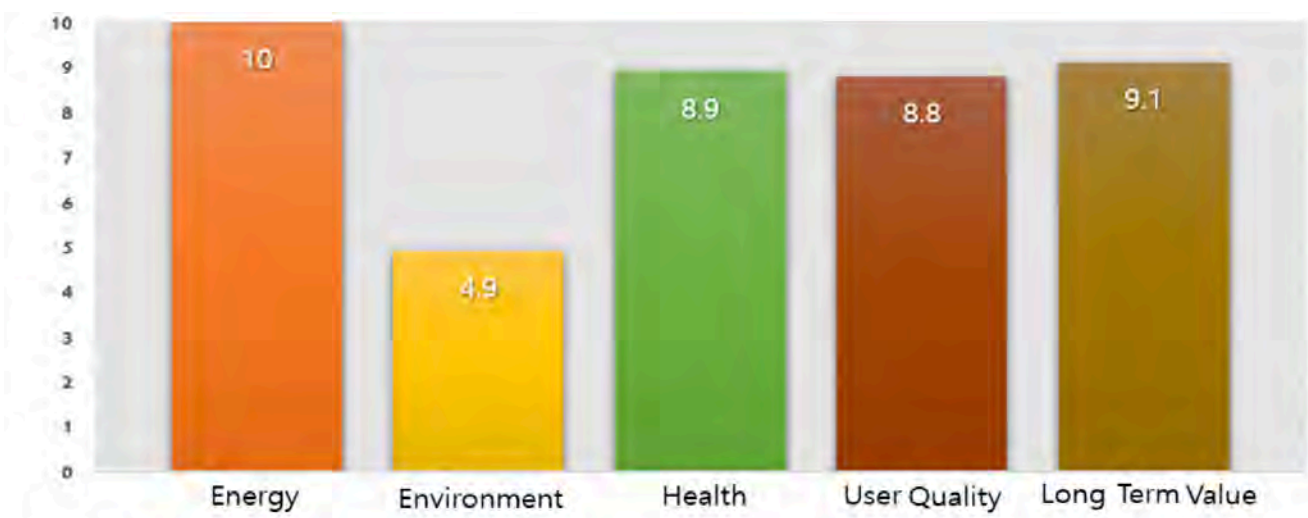



Fig.1 Result of a sustainability assessment with a (for the Dutch housing market) comman software tool named GPR Building