ZERO ENERGY BUILDING

Best Practice Guide for Steel Applications in Zero Energy Building

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Part 1

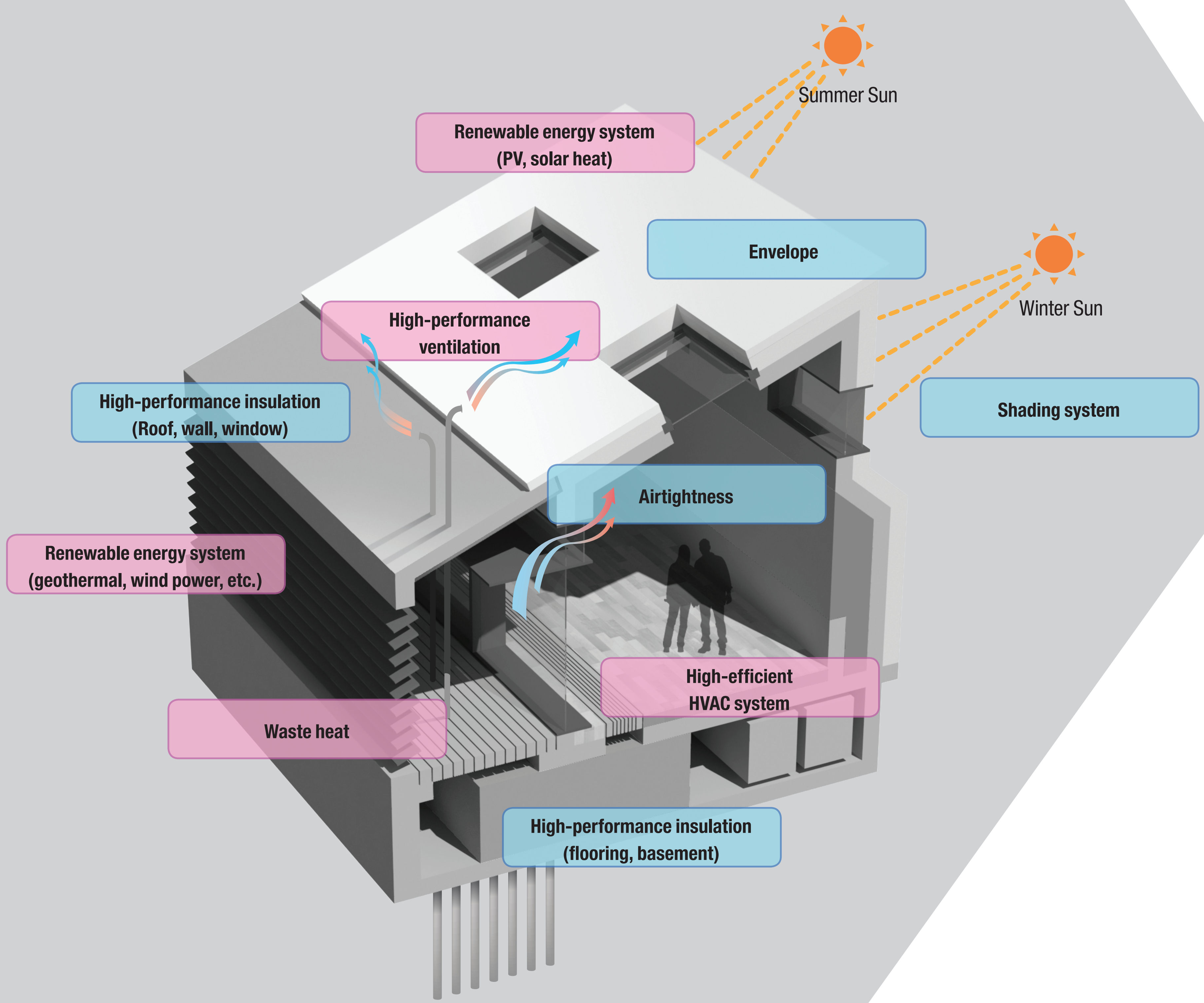
Best Practice Guide for Steel Applications in Zero Energy Building

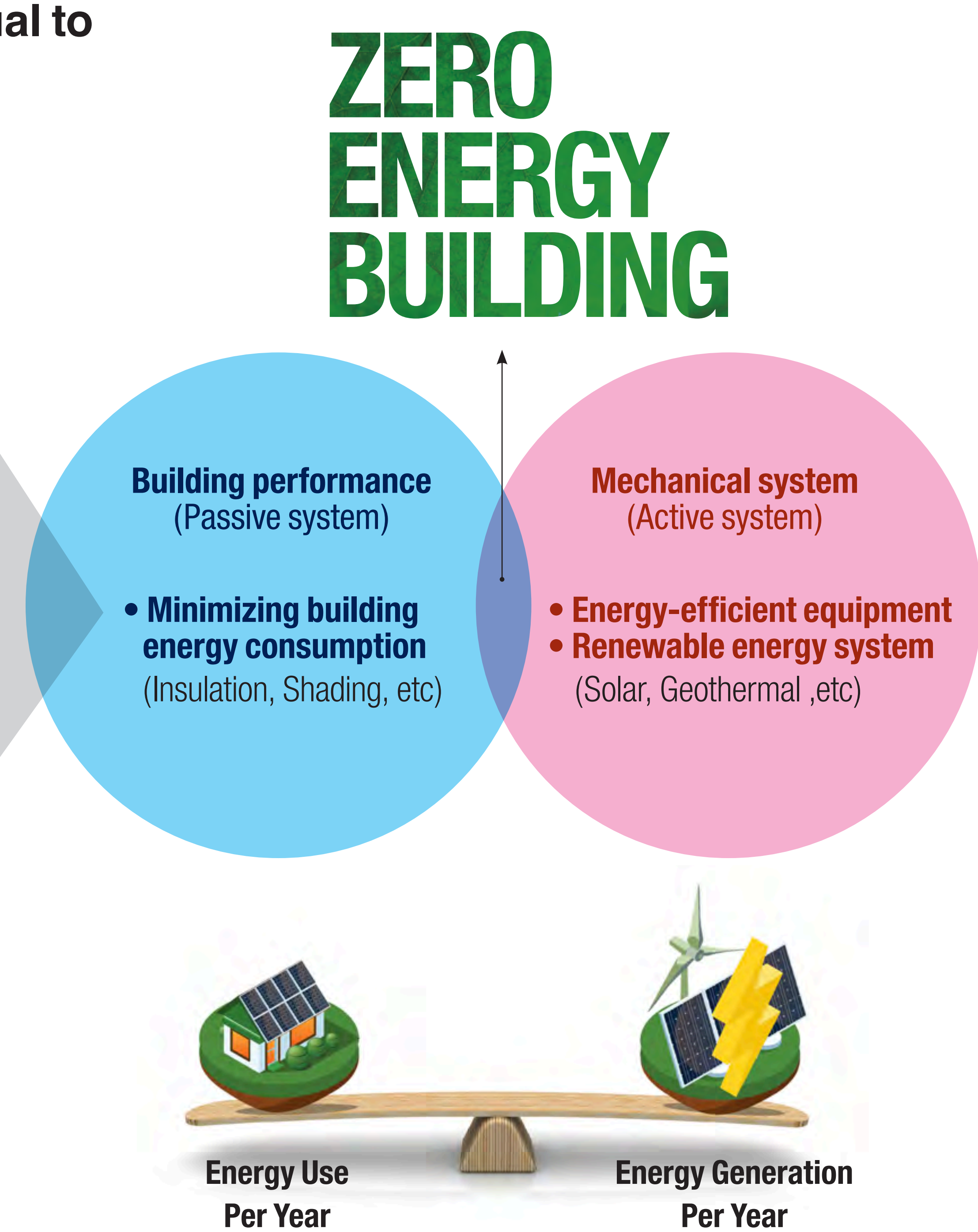
Best Practice Guide for Steel Applications in Zero Energy Building

Zero Energy Building →	Why we need ZEB? →	What is the benefit of ZEB? →	How steel contributes to ZEB →	Steel Applications in ZEB →	Energy Efficiency →	Thermal Conductivity →	Thermal Mass →	Airtightness →	Sustainability

Zero Energy Building

The total amount of energy used by the building on an annual basis is equal to the amount of renewable energy produced on the site.

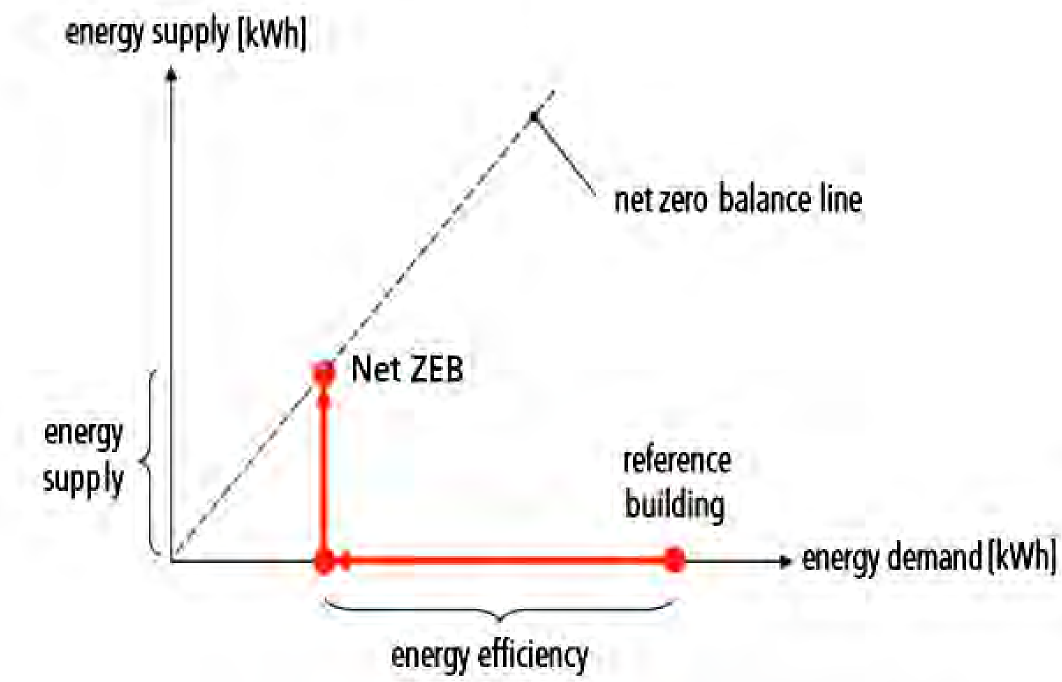




Definition of ZEB

An energy-efficient **building** where, on a **source energy** basis, the actual **annual delivered energy** is less than or equal to the on-site renewable **exported energy**.

Source : A Common Definition for Zero Energy Buildings, U.S. DOE, 2015

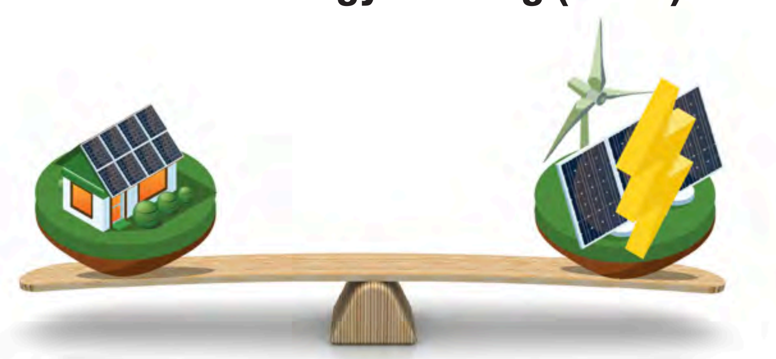


 Energy Use Per Year  Energy Generation Per Year

Nearly Zero Energy Building (nZEB)

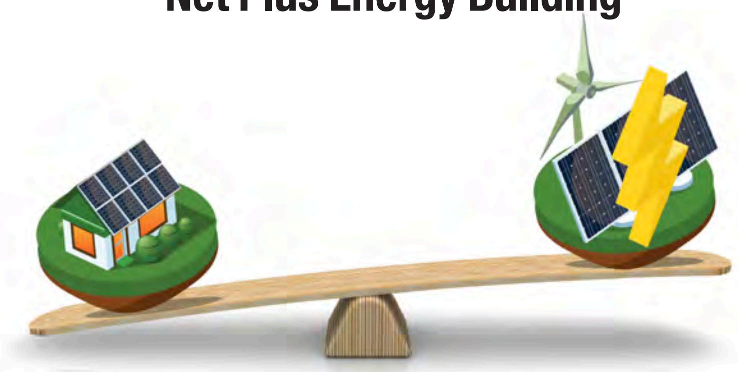
The nearly zero net energy required should be supplied from renewable energy sources, includ-ing those produced on-site or nearby.

Net Zero Energy Building (NZEB)



A building with greatly reduced energy needs from higher efficiency so that the energy required can be supplied with renewable technologies on site.

Net Plus Energy Building



An incredibly efficient energy performing building, which generates more renewable energy than its annual needs

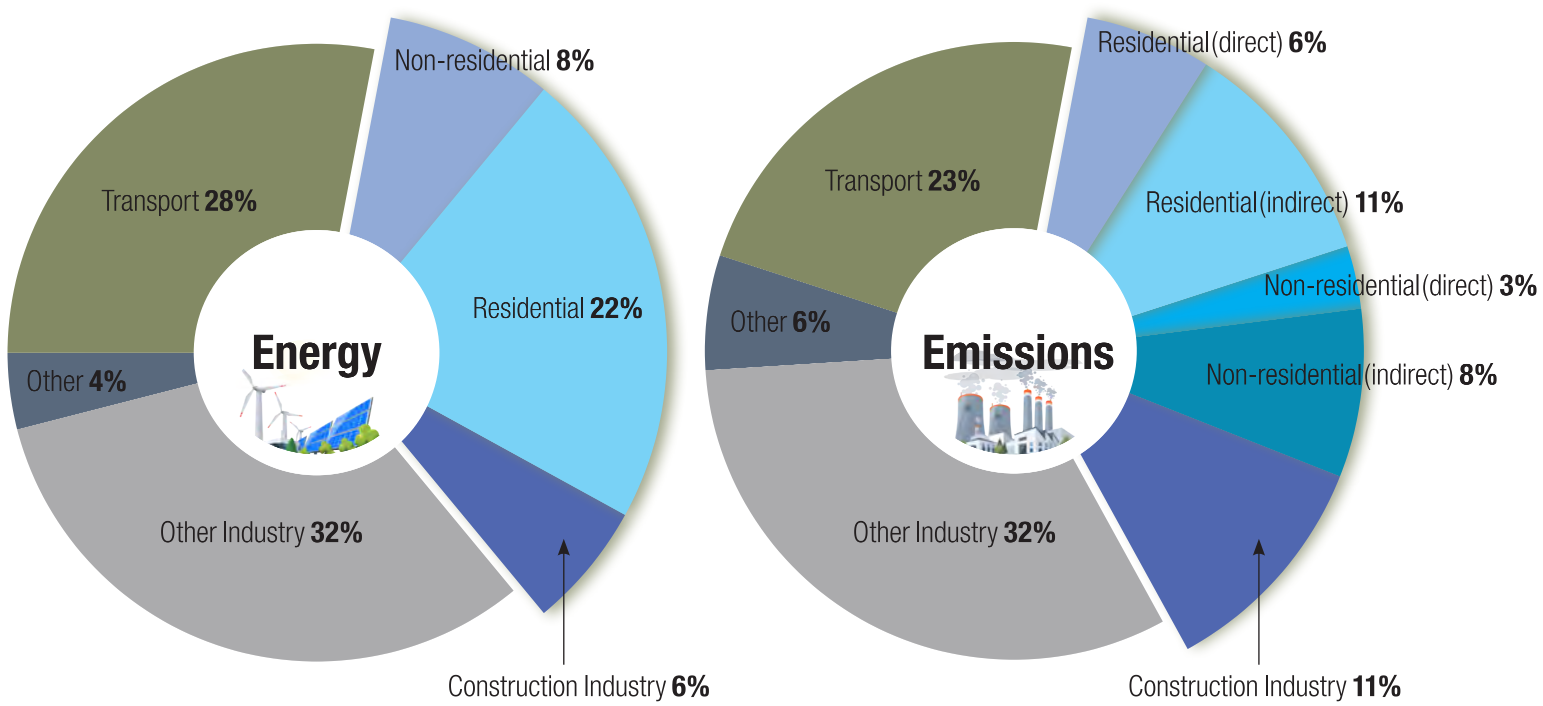
Source : Defining Nearly Zero Energy Buildings in the UAE,2017 Zero Energy Buildings: A Critical Look at the Definition, NREL, 2006
Source : ZEMUSIC, Design Guide for steel intensive nearly-zero energy office buildings WP6.4

Why we need ZEB?

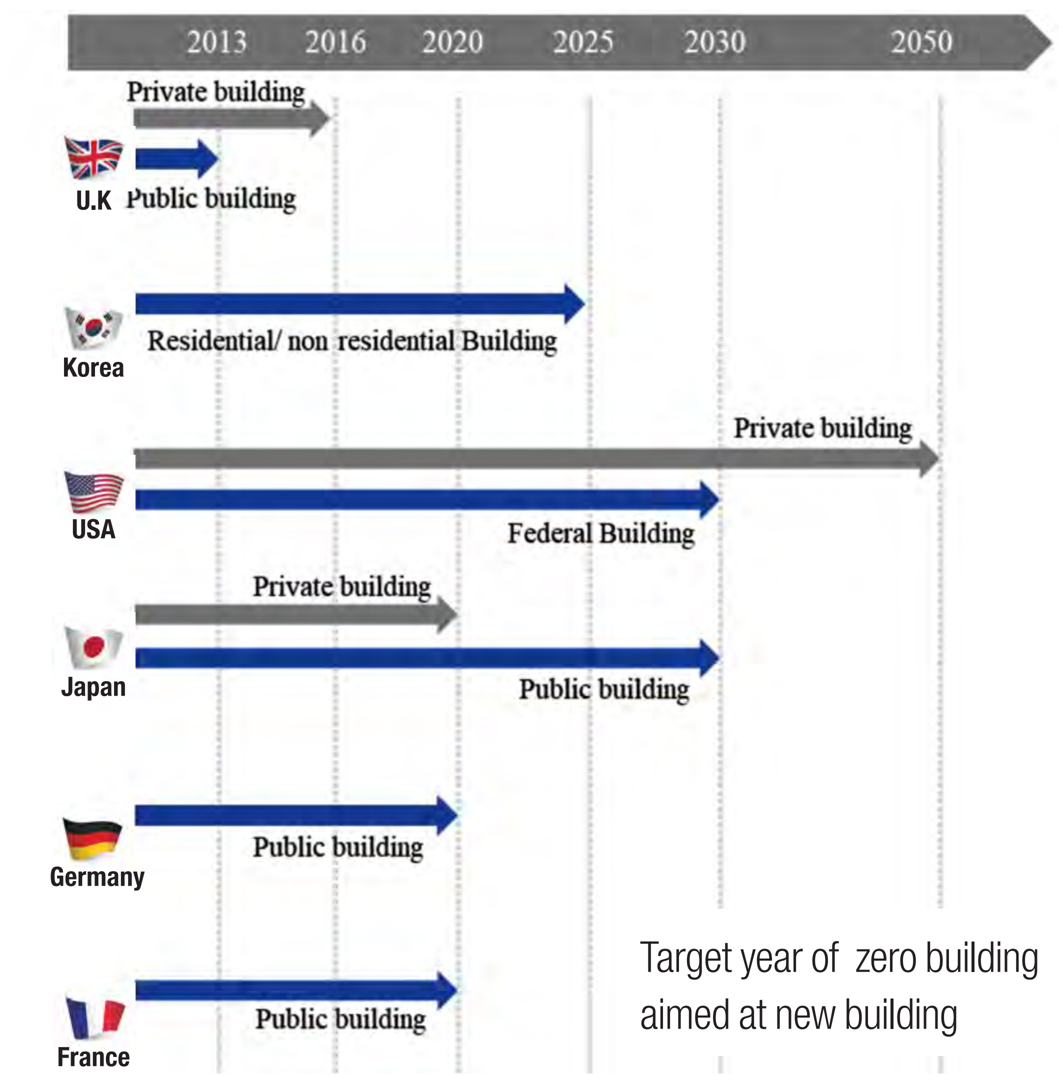
The buildings and construction sector has a key role in the fight against climate change.

36% of final energy use **39%** of energy-process related emissions

Global share of buildings and construction final energy and emissions, 2017



Roadmap to move toward ZEB



According to a study by Grand View Research, **the global ZEB market** is expected to reach **$78.8** billion by 2025.

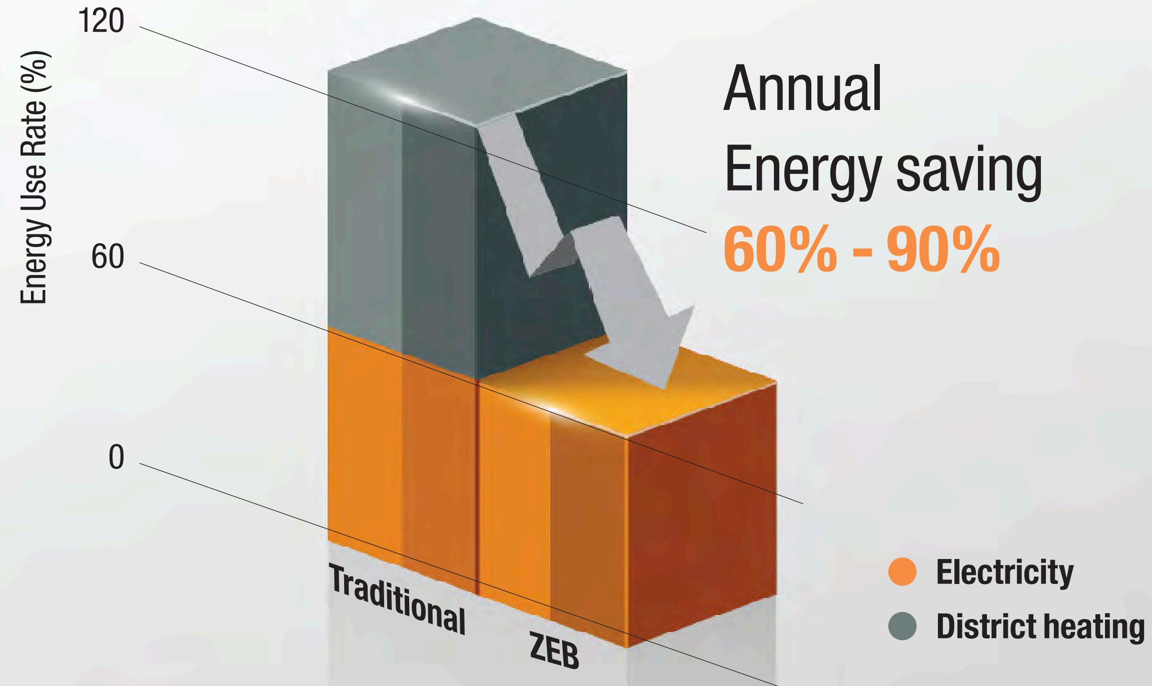
Sources : Derived from IEA (2018a), World Energy Statistics and Balances 2018, **www.iea.org/statistics** and IEA Energy Technology Perspectives buildings model, **www.iea.org/buildings.**
https://www.grandviewresearch.com/industry-analysis/net-zero-energy-buildings-nzebs-market

Sources : Green Energy Technology Insight 2017 vol.8 no.5

What is the benefit of ZEB?

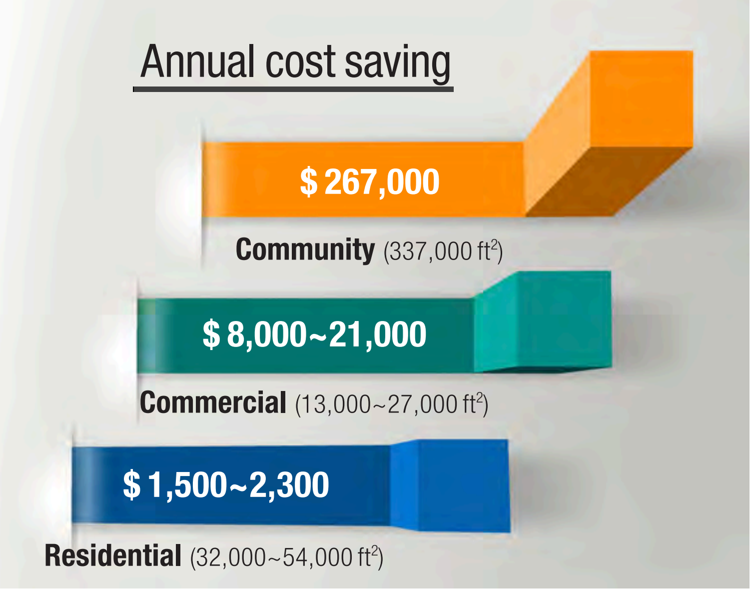
The buildings and construction sector consumes nearly **40%** of total fossil fuel energy. ZEB can contribute to energy & cost savings and CO_2 reduction.

Energy saving

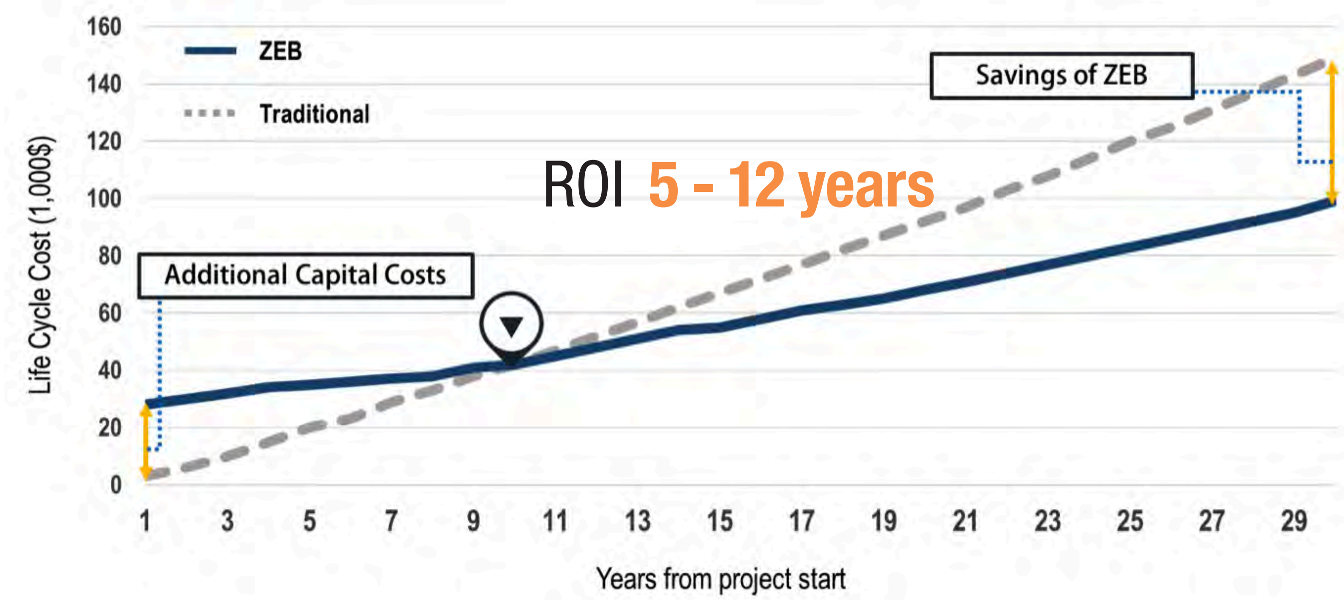


Source : Feasibility studies of energy retrofits – case studies of Nearly Zero-Energy Building renovation, Riikka Holopainen, 2016

Cost saving



Return of investment



* This calculation is based on the assumption of new buildings located in Vermont, USA. The financial factors such as SBA loan, local incentive and tax credit, have been considered in saving the cost of new buildings. See reference for details.

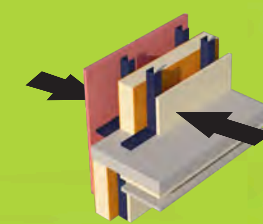
Source : Making the Financial Case for Net Zero Buildings, AIA Northeast Sustainable Energy Association (2015)

How steel contributes to ZEB

The steel construction can reduce energy consumption and gas emissions.

01 Thinner Walls

Steel wall can be thinner than other walls to reach the same target value for insulation.



02 Light weight

Lightweight steel components enables ease of construction and diverse functionalities such as automatic ventilation systems

03 Off-site production

Steel structures are built off-site under quality controlled, highly regulated and safe factory conditions.

04 Various systems

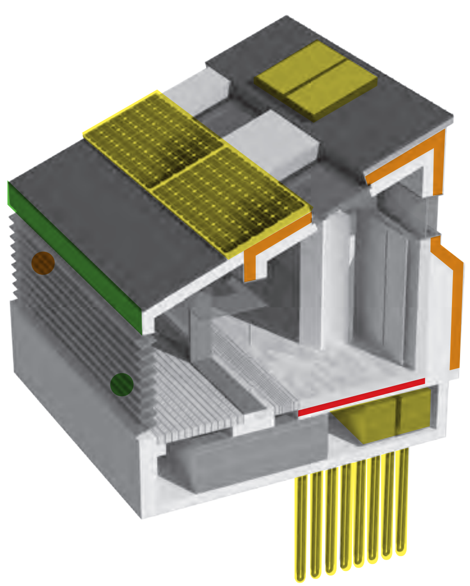
The radiant properties of steel make possible various types of heating systems for diverse building components

05 Non-organic

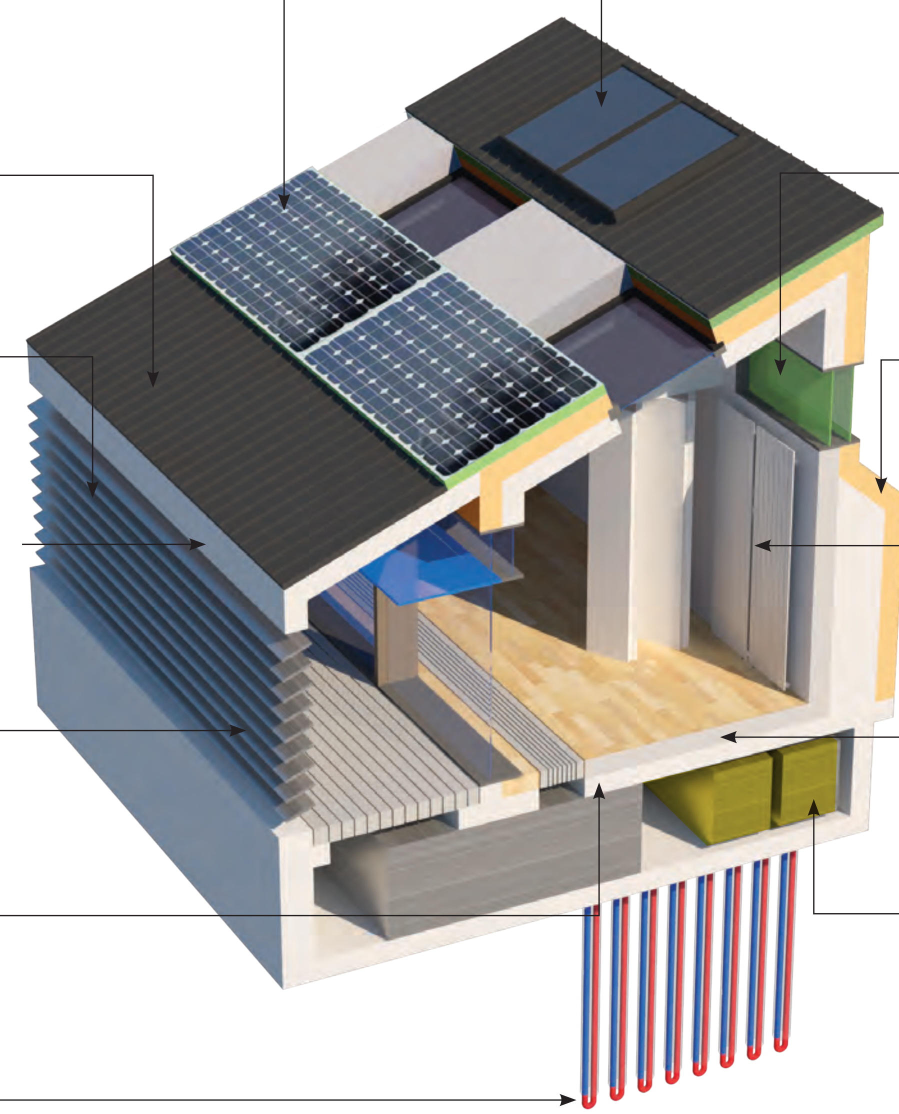
Steel is a permanent material that can be infinitely recycled without loss of quality

Steel application in ZEB

5 categories for the efficient steel application in ZEB



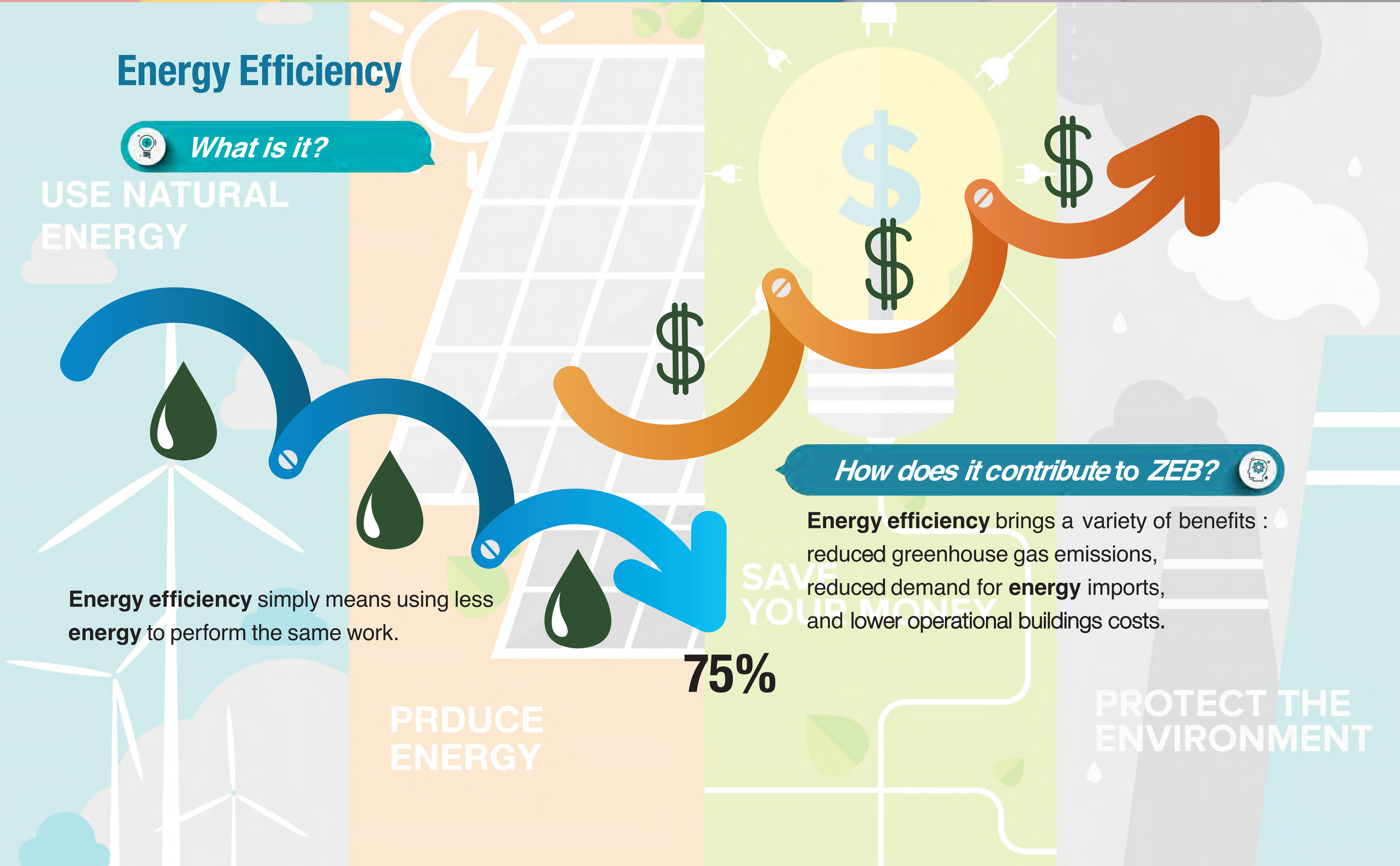
- Energy Efficiency
- Thermal Conductivity
- Thermal Mass
- Airtightness
- Sustainability



Energy Efficiency

What is it?

Energy efficiency simply means using less **energy** to perform the same work.



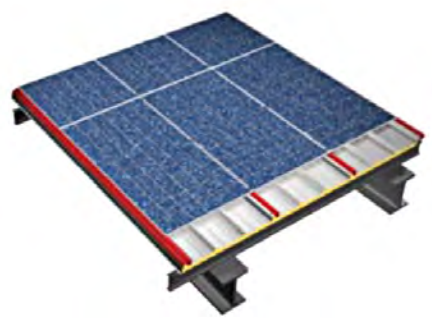
How does it contribute to ZEB?

Energy efficiency brings a variety of benefits : reduced greenhouse gas emissions, reduced demand for **energy** imports, and lower operational buildings costs.

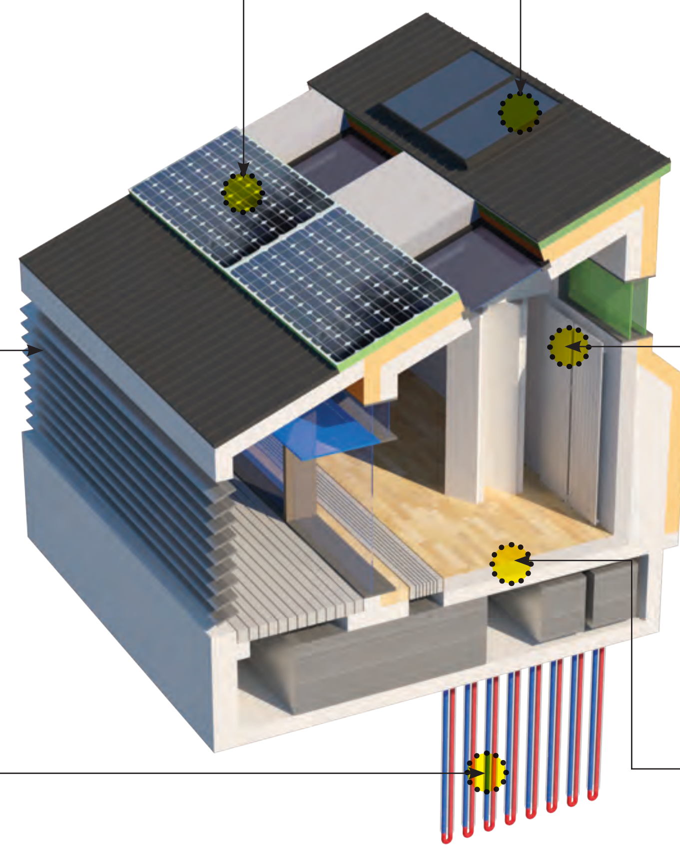
Energy Efficiency

Steel is energy efficient. It is an excellent building material for transferring or collecting energy.

Buliding Integrated PV Panel System



Steel can make PV the best building exterior material with high performance.



Roof Integrated Solar Heat Collector

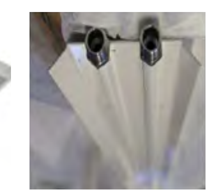
Steel is an essential material in solar heat collectors. System Efficiency : Up to 80% (Average efficiency 40~50%)

Light Shelf & Reflective Panel

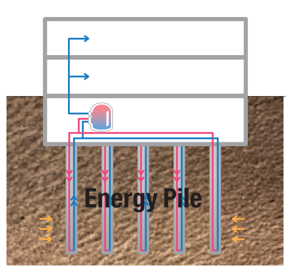
Steel ceiling panels can reduce lighting energy up to 12% with above 85% reflectance.

Radiant Panel System

Steel radiant panel meets both thermal comfort and energy saving.



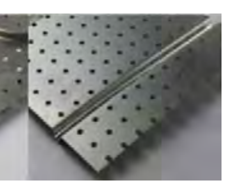
Energy Pile System



Steel pile is utilized as ground heat exchanger.
It is used for both structural stability and energy production. Energy Production : Steel Energy Pile 80 W/m (Ordinary GHX 45W/m)

Radiant Floor Heating System

Radiant floor heating system made from steel can supply heat into a room efficiently by saving 15% of energy use.



Source : ArcelorMittal, POSCO, Tata Steel Europe, Ruukki Construction

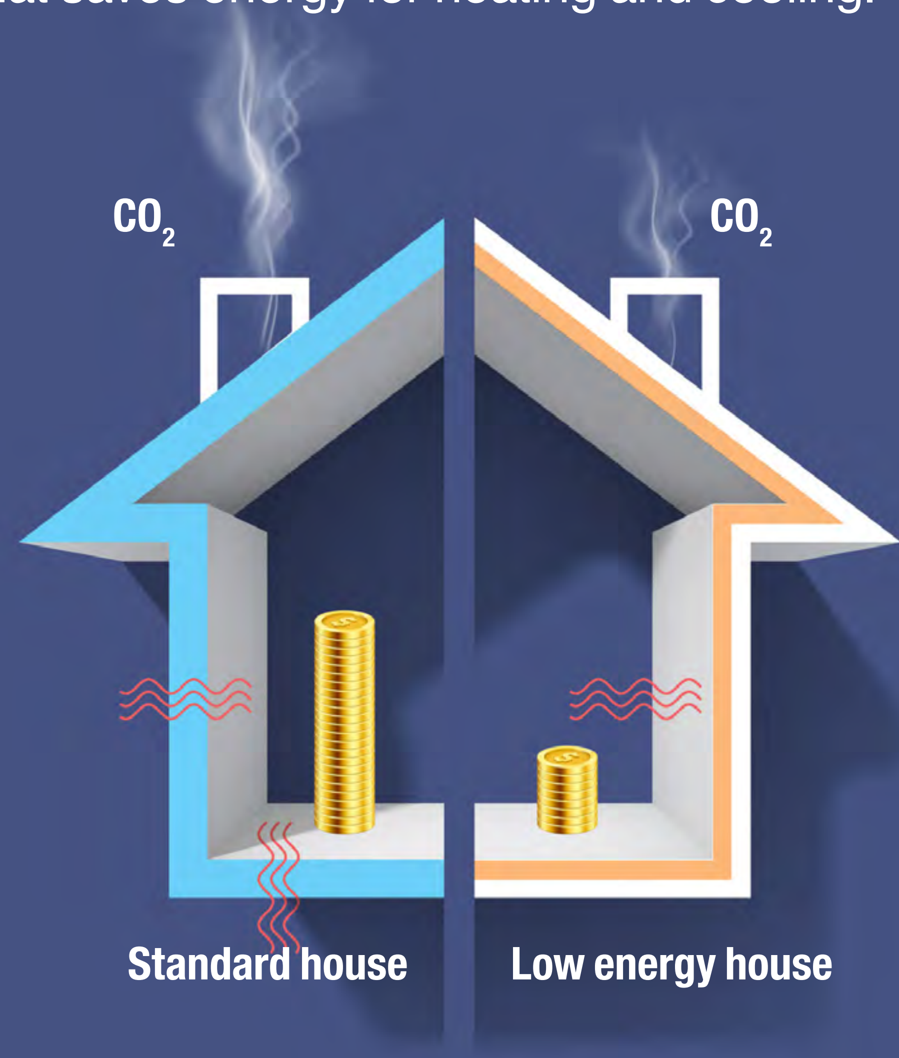
Thermal Conductivity

What is it?

The thermal conductivity of a material is a measure of its ability to conduct heat.

How does it contribute to ZEB?

The material of **low thermal conductivity** could be good for **insulation**.
That saves energy for heating and cooling.

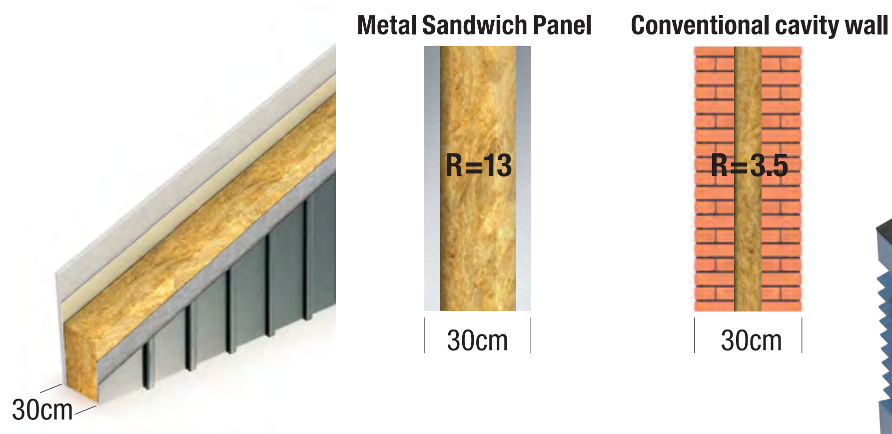


Thermal Conductivity

Steel enhances thermal resistance in combination with other materials.

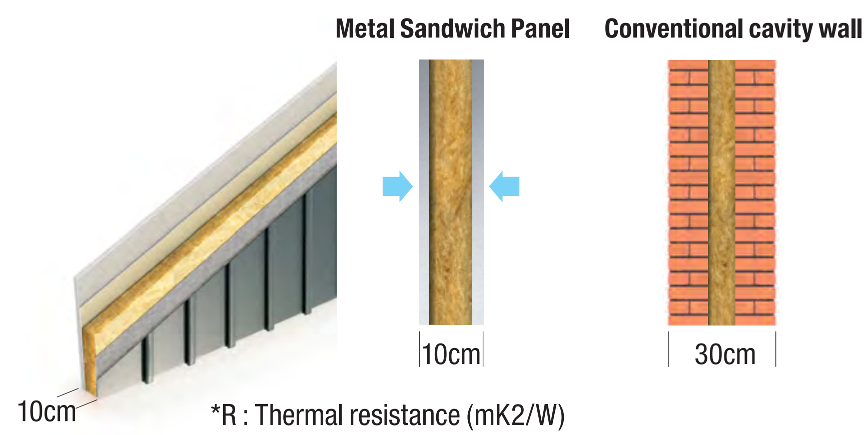
High-Insulated Steel Wall

Metal sandwich panel has higher insulation value (R) than conventional cavity wall under the same conditions for wall thickness.

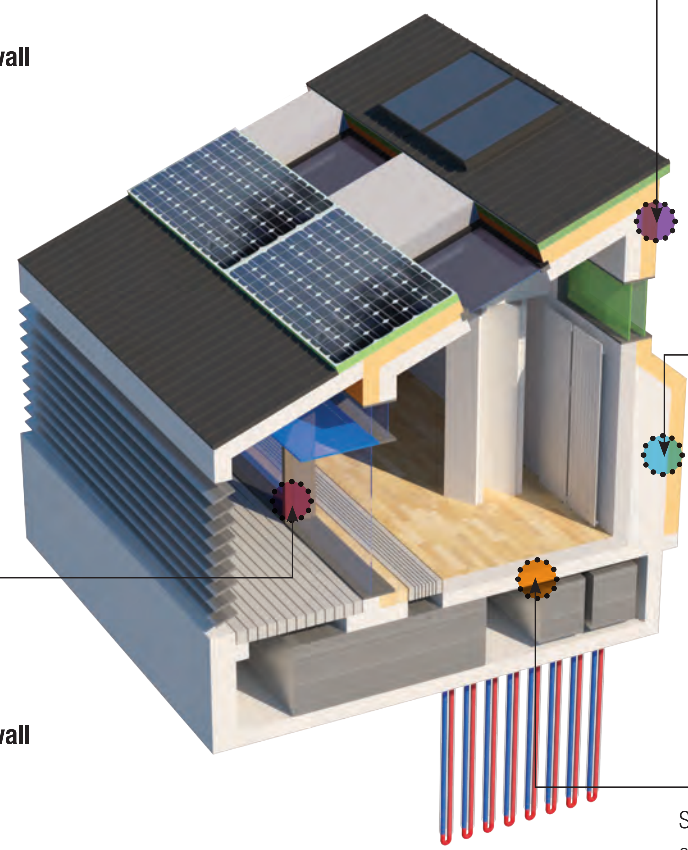


Thinner Steel Wall

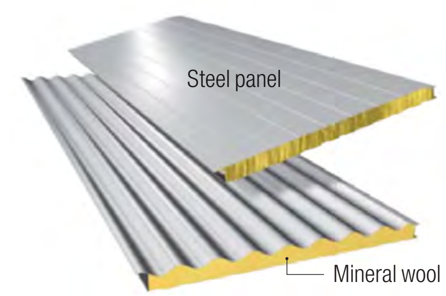
Metal sandwich panel can be thinner than conventional cavity wall under the same conditions of thermal resistance.



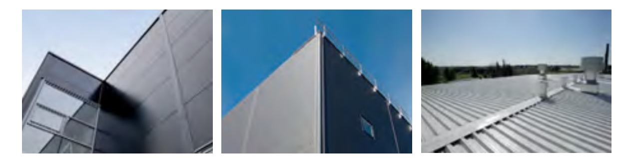
*R : Thermal resistance (mK2/W)



Steel with MW(Mineral Wool)



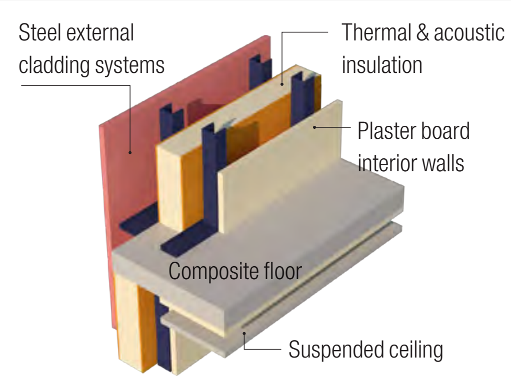
Steel with mineral wool facilitates lightweight, durable and fast construction.



Steel with PU(Polyurethane) / PIR(Polyisocyanurate)

Steel in combination with other special materials has great thermal and fire properties and it is visually appealing.

Thermally efficient steel-based design



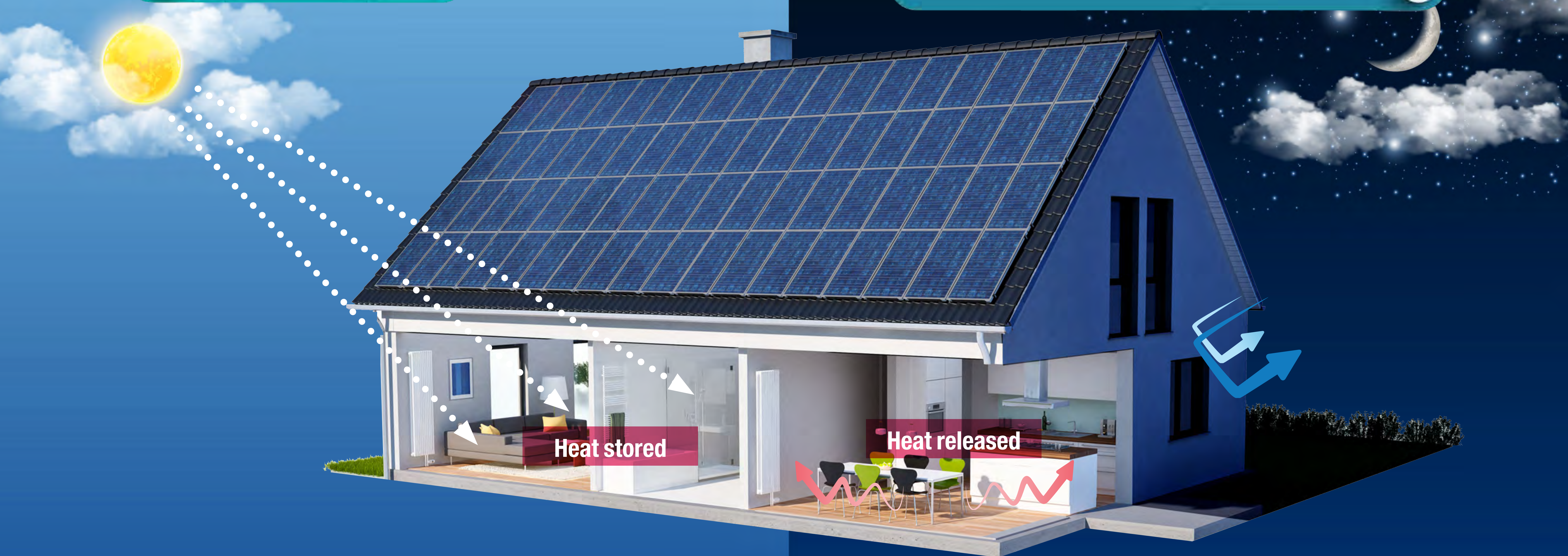
A good steel-based design with effective external insulation drastically reduces building energy consumption.

Source : Sandwich Panels - ArcelorMittal, POSCO, Ruukki

Thermal Mass

What is it?

How does it contribute to ZEB?



Thermal mass is the ability of a material to absorb and store heat energy.

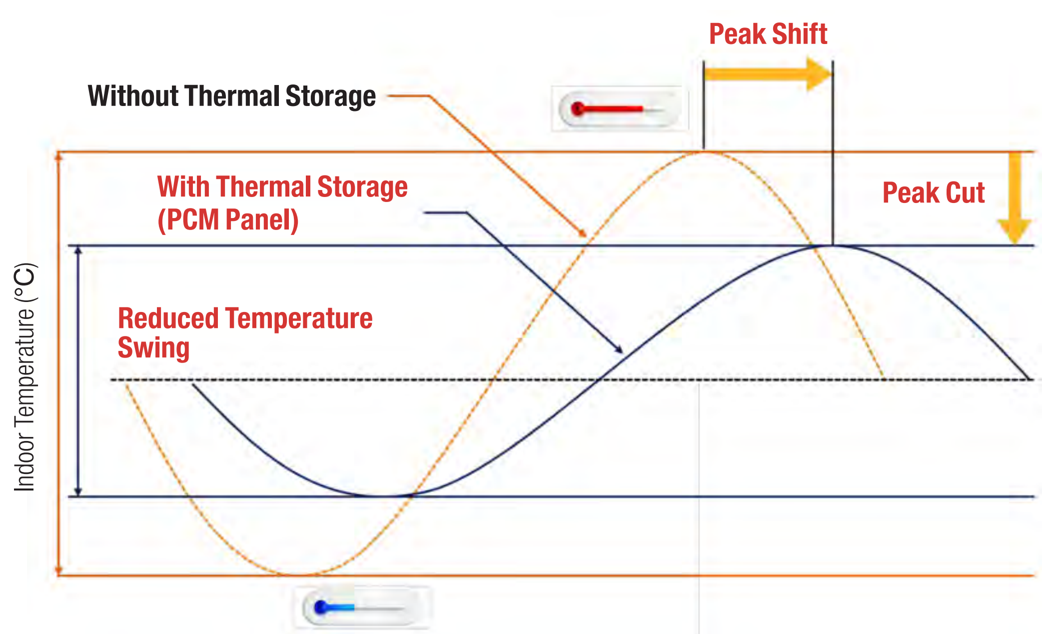
Thermal mass can play an important role in reducing energy use in heating and cooling systems.

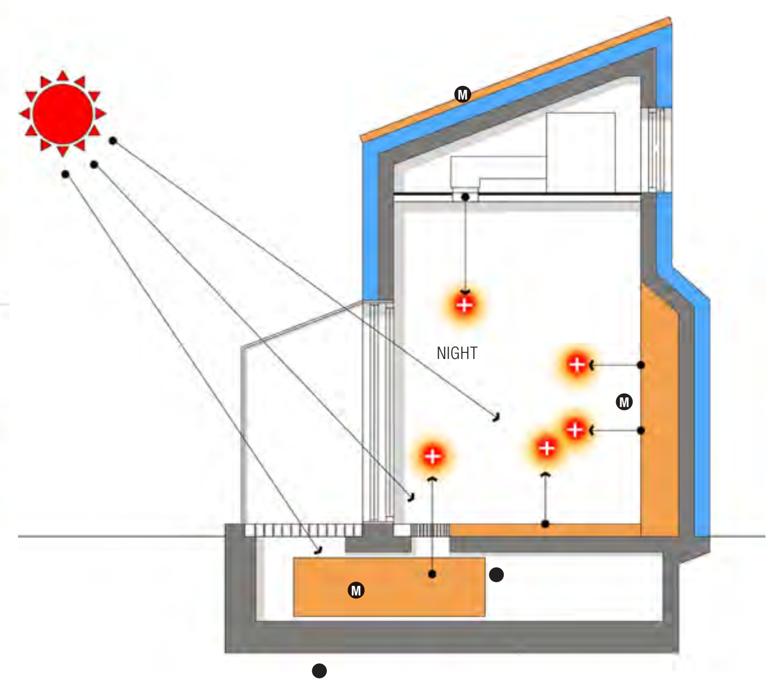
Thermal Mass

Steel is used in **energy storage systems**.

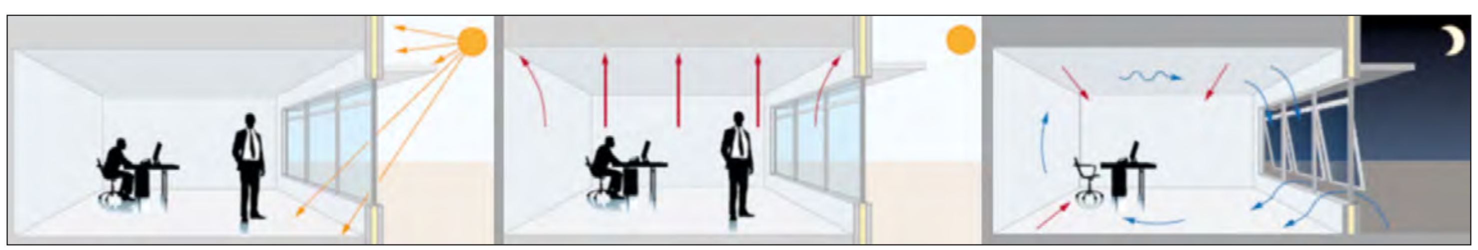
Steel can **quickly** store and release heat when needed.

Merit of energy storage system





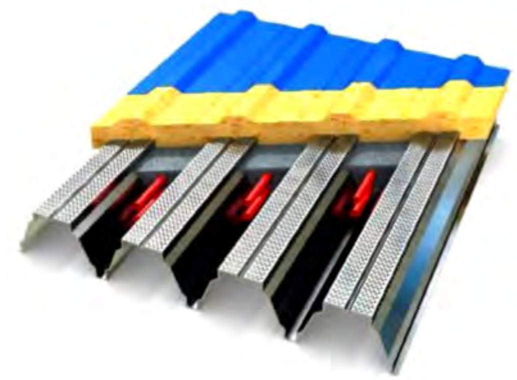
Thermal storage system can store heat at daytime and release it at nighttime.

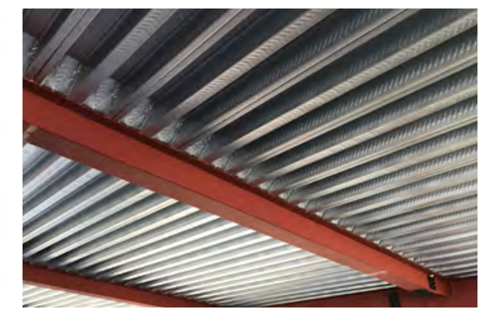


Source : Ruukki, ZIMUSIC

Radiant ceiling embedded in a PCM(Phase Change Material) layer

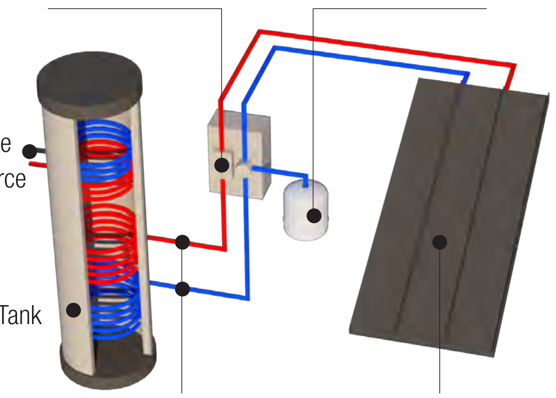
Steel panel with PCM can efficiently maintain indoor temperature.





Thermal Storage Tank

Steel is the most useful material for thermal storage tanks.



Airtightness

What is it?

Airtightness is the fundamental building property of the resistance to air leakage.

How does it contribute to ZEB?

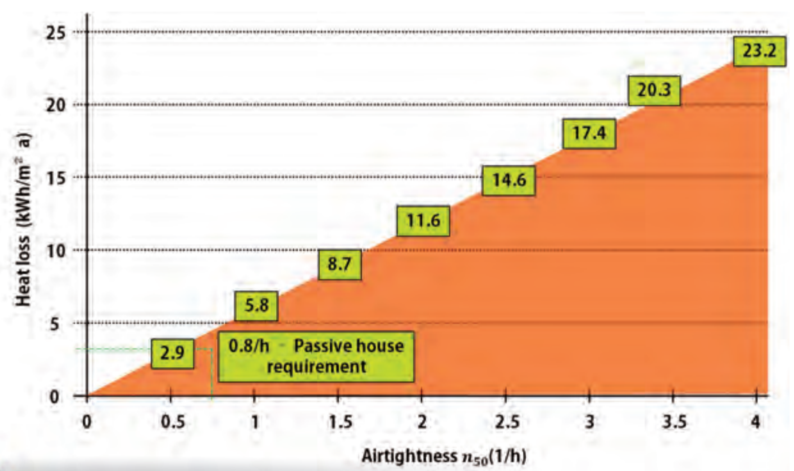
An airtight building has lower heating bills, better performing ventilation and increased thermal comfort.

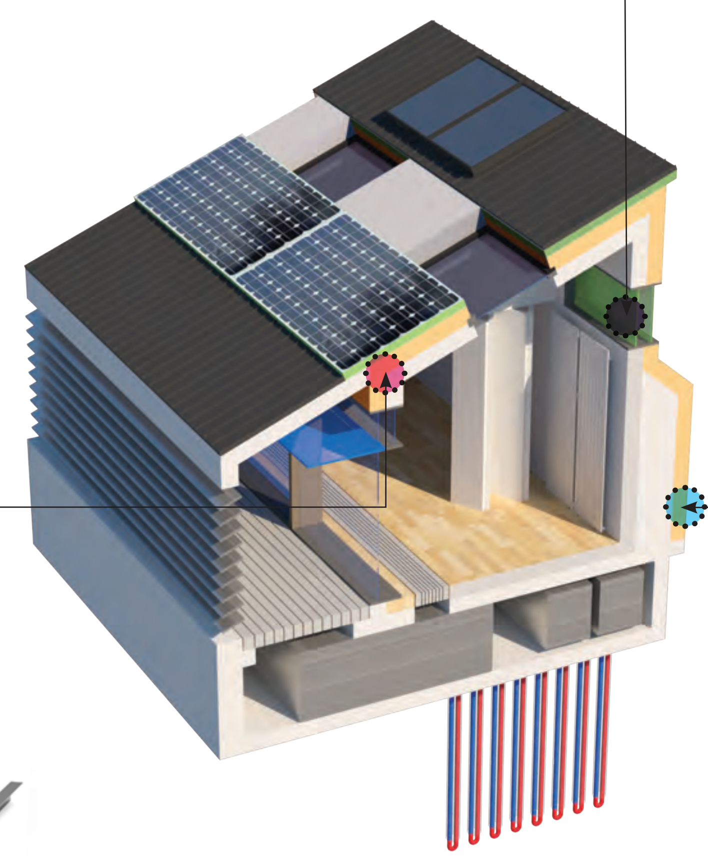
Airtightness

Steel can be easily formed into various geometries to improve airtightness

Airtightness vs Heat Loss

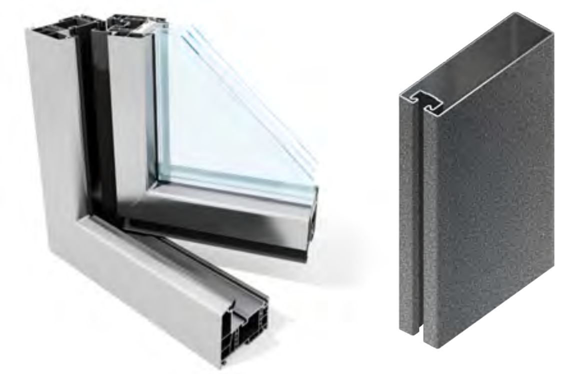
Airtight buildings can reduce energy for heating and cooling. Through envelopment techs with steel, building airtightness can be improved up to 70% compared to standard building.





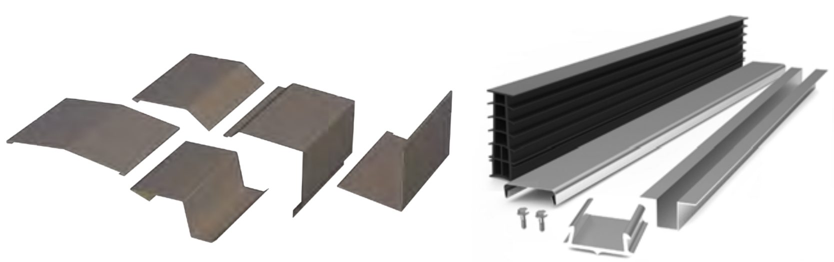
Metal Window System

Steel window can easily be formed into various geometries to improve airtightness



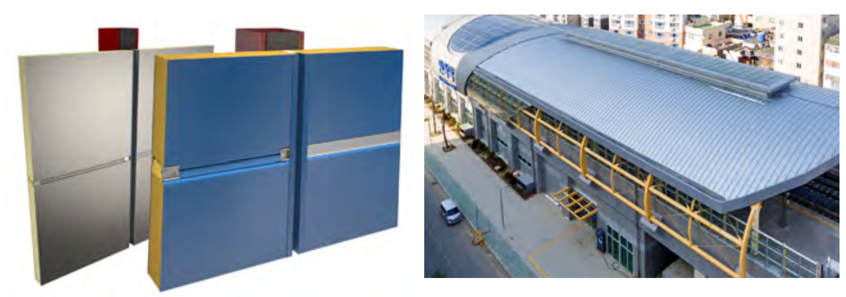
Highly Airtight Sealant

Steel can reduce heating cost and improve thermal comfort by improving building airtightness



Metal Sandwich Panel System

Metal sandwich panels are some of the most airtight structures



Sustainability

What is it?

Sustainability means living within the resources of the planet without damaging the environment.

How does it contribute to ZEB?

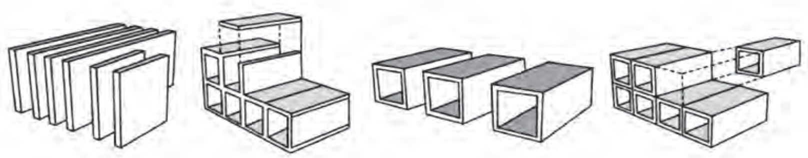
Sustainable building increases construction productivity, conserves the natural environment and contributes to energy and resource savings.

Sustainability

Steel is the most eco-friendly and sustainable building material and makes ZEB possible.

Prefabrication

Prefabrication guarantees construction speed and quality.



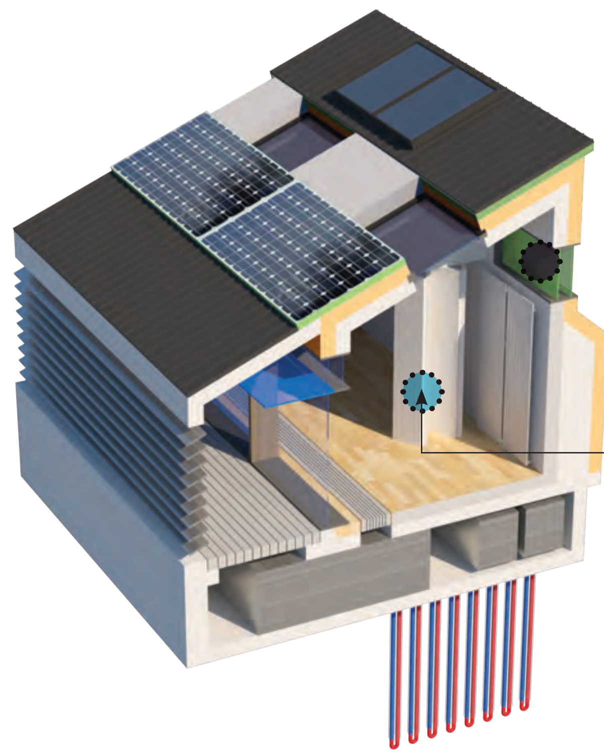
2 Dimension

3 Dimension

Modular

Modular steel systems increase airtightness and minimize thermal bridge effect.

Modules Containers Cabins



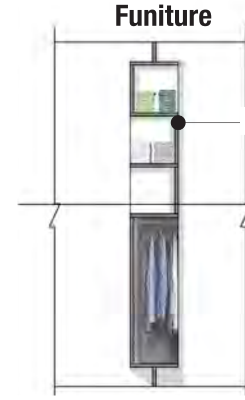
Reuse

Steel can be reused in the same or higher quality without reprocessing. This saves gas emissions.

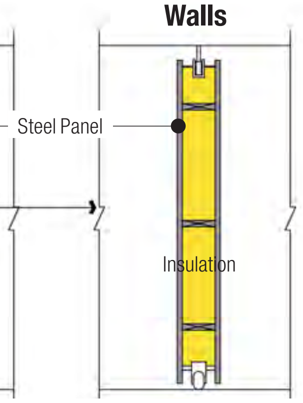
Flexibility

Steel makes flexible design possible for ZEB.

Movable System Funiture



Movable Steel Walls



Flexible Steel Louvre Window system

Source : ArcelorMittal, POSCO, SCI, Fokker 7 Building ;Schiphol Airport

Terminology

Airtightness : Resistance against air leakage through unintentional openings

BEMS : Building energy management system

BIPV : Building integrated photovoltaic system

Energy Pile : A pile used as ground heat exchanger in geothermal system

HEMS : Home energy management system

HVAC : Heating, ventilation and air-conditioning

LCA : Life cycle assessment

LCC : Life cycle cost

nZEB : Nearly zero energy building

NZEB : Net zero energy building

PCM : Phase change matarial

PV : Photovoltaic

U-value : Rate of transfer of heat through a structure [W/m²K]

ZEB : Zero energy building

Best Practice Guide for Steel Applications in Zero Energy Building
Project Team

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Woo-zoo Shin (Think) : South Korea, Illustration Company

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 profi es 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

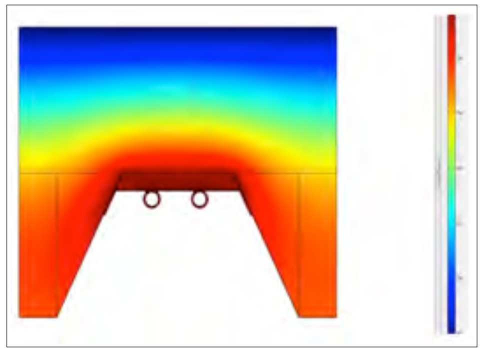


Fig.2 Ruukki radiant panel integrated into the roof panel

Source : Jyrki Kesti (Ruukki Construction)

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

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 flo r 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.

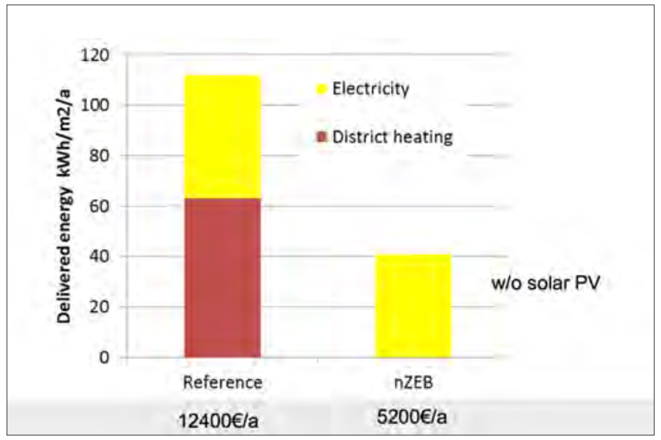


Fig.6 Comparison of delivered energies of the reference case and nZEB case

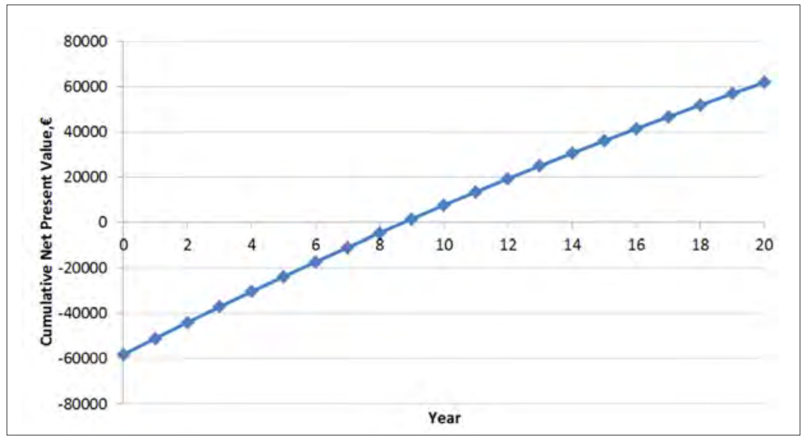


Fig.7 Net present value for the nearly zero-energy building compared to the reference building

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

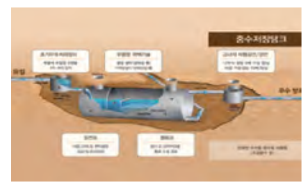
Reuse steel structure

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

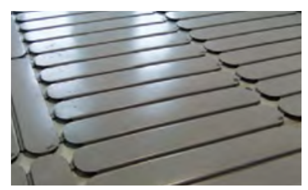
Seismic control steel damper
A damper made of steel materials can control the damage from earthquake by absorbing the earthquake mechanical energy instead of building structure.

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.

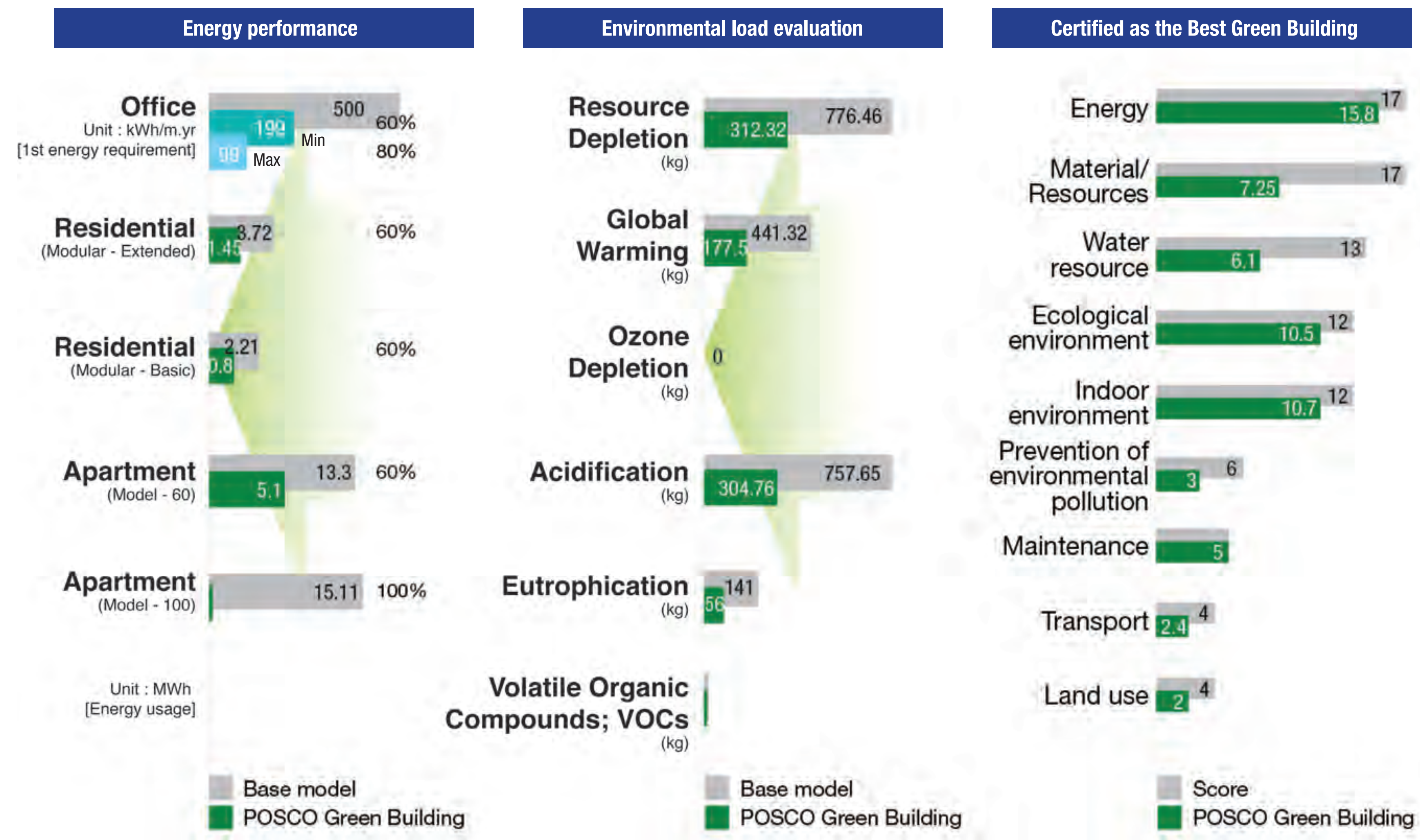
Prefabricated exterior wall system
As the system can be assembled on site with the panel modules produced in the factory, it can reduce construction period as well as save construction cost.



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.

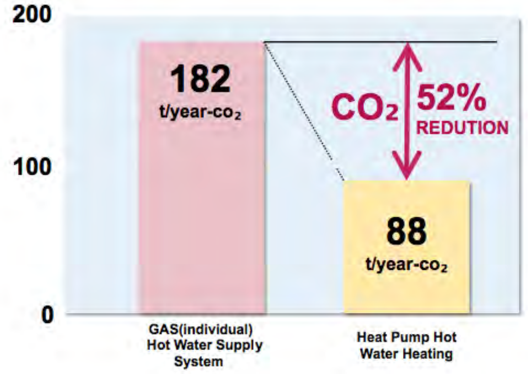


Fig.1 Energy and CO_2 reduction of the solar heating system
Smart heat pump system

Source : Nippon Steel & Sumitomo Engineering

Smart heat pump system

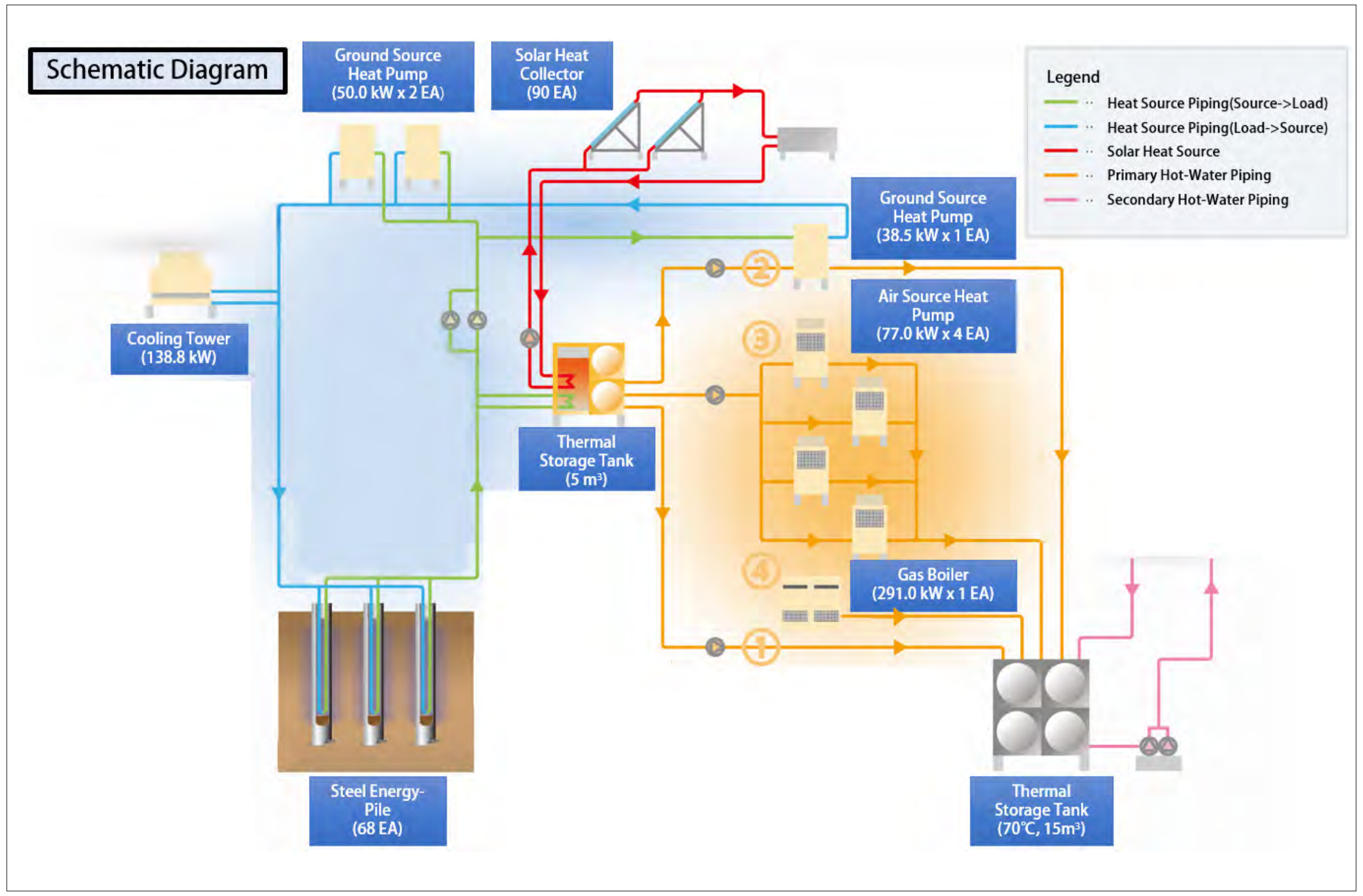


Fig.2 System summary

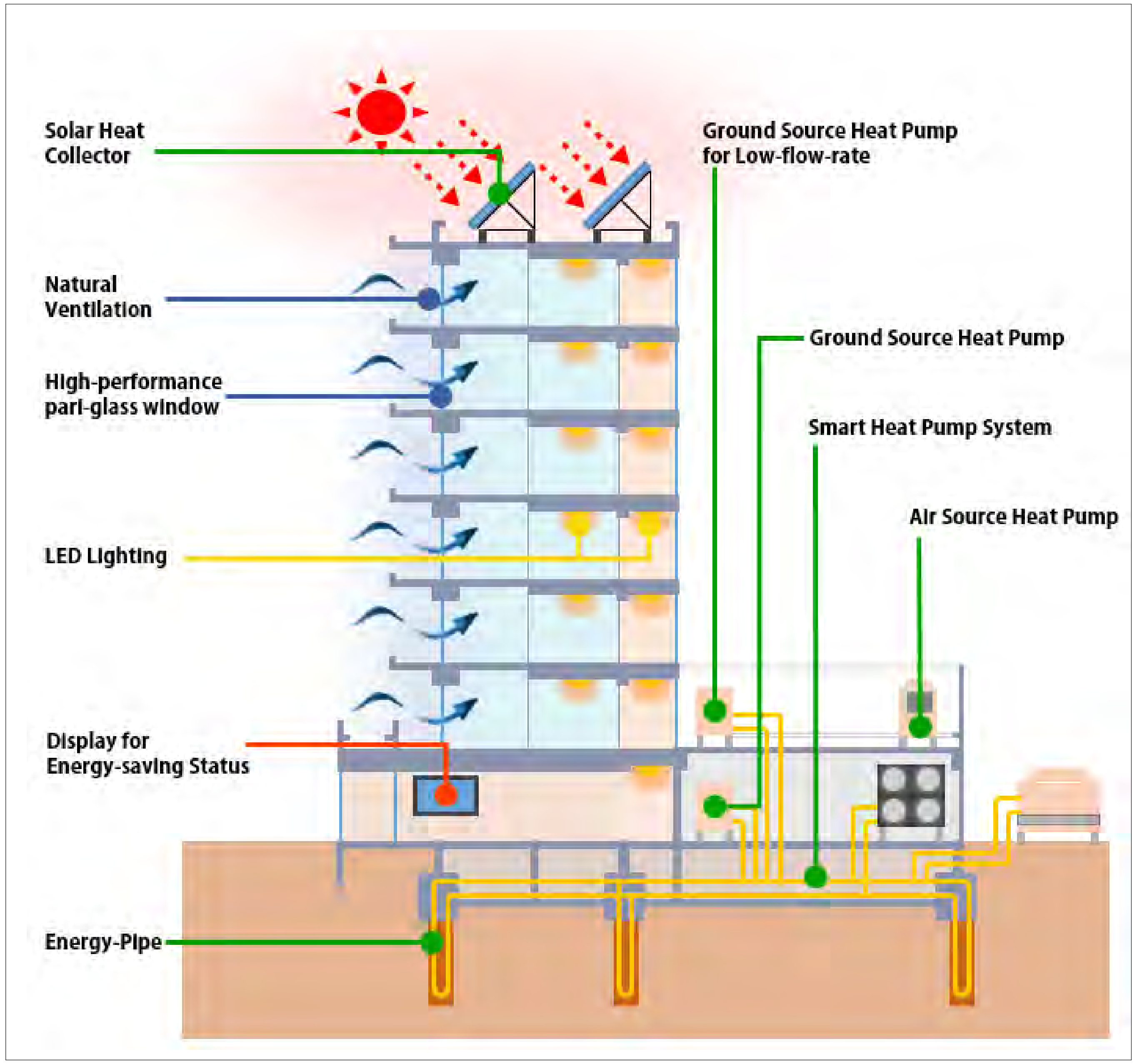


Fig.3 Schematic diagram

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 directio

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

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 efficienc . 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.

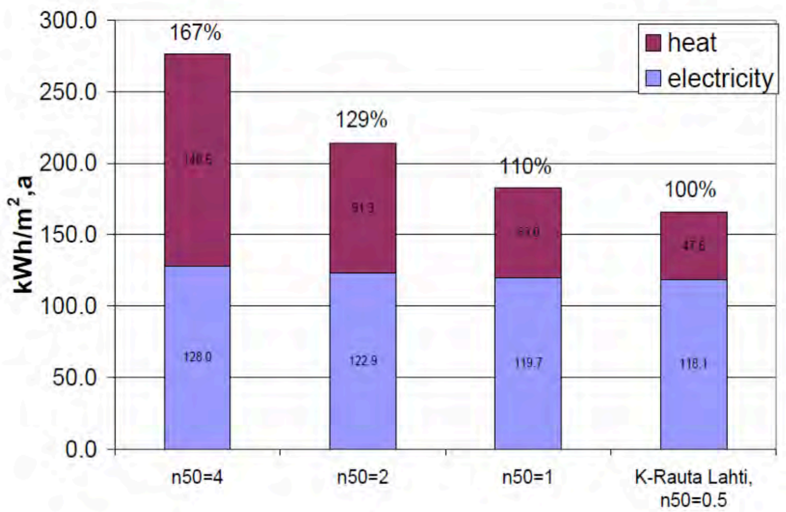


Fig.1 Effect of airtightness on energy consumption of the single-story store building

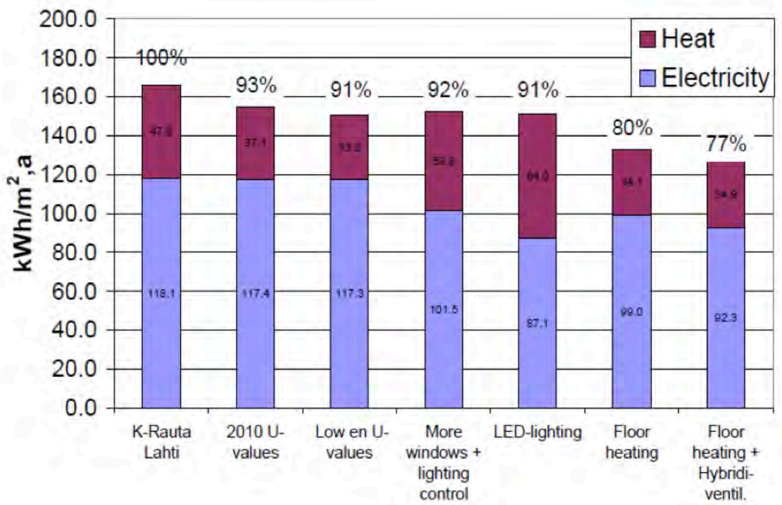


Fig.2 New technical improvements for energy demand reduction

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.

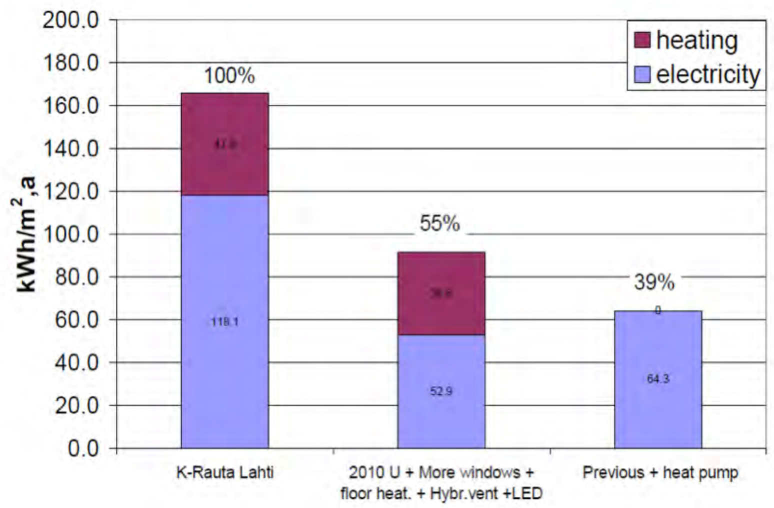


Fig.3 Combination of new technical improvements for energy demand reduction

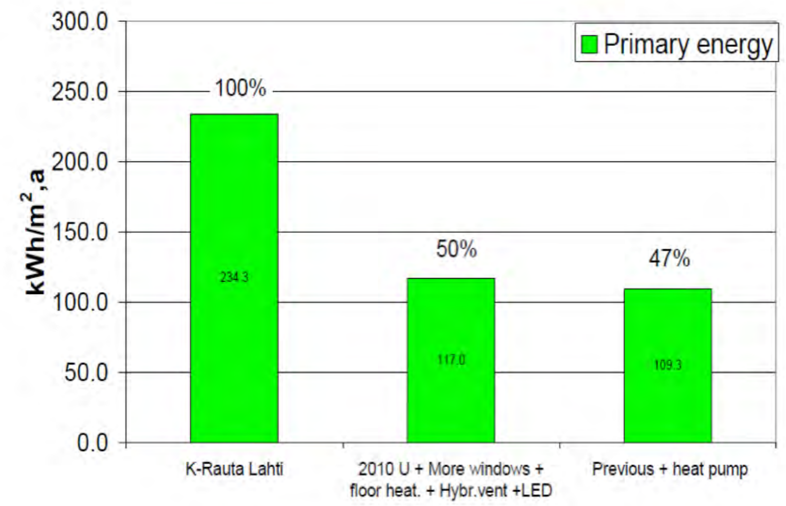


Fig.4. Primary energy consumption for different cases

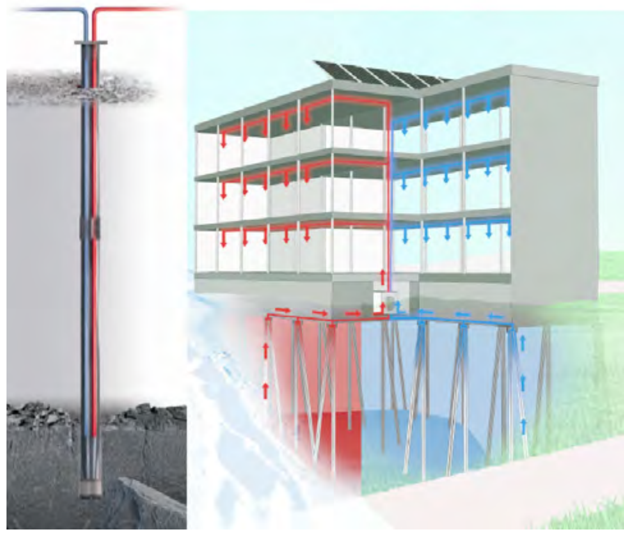


Fig.5 Energy piles

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 Offi e 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 profi e 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 floo , the thermal transmittance (U-value) is 0.15 W/m^2K. 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^2K. 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 eating/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 ears 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 umber 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 ooling 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”.

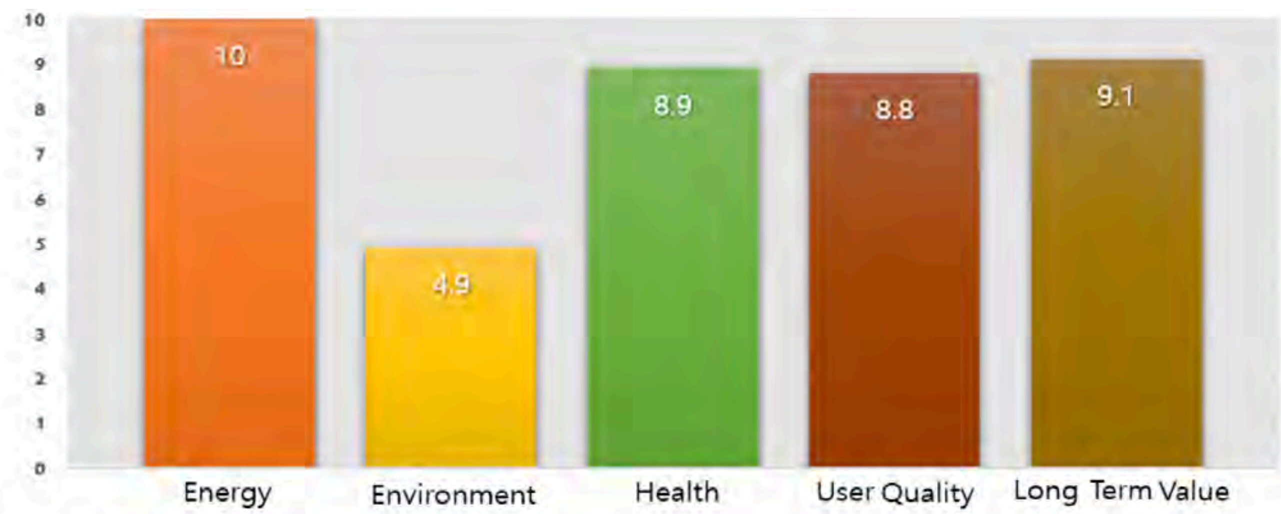


Fig.1 Result of a sustainability assessment with a (for the Dutch housing market) comman software tool named GPR Building

Part 3

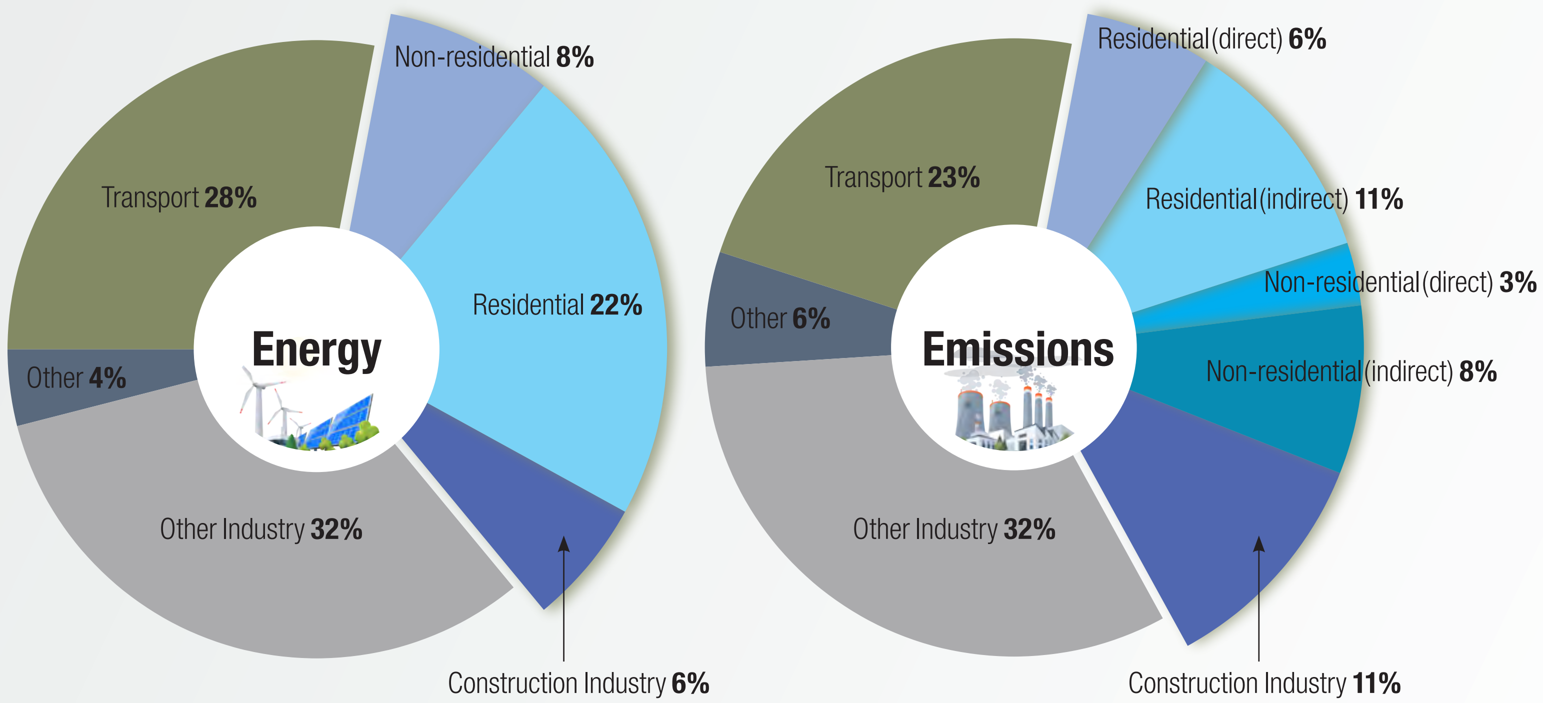
Fact Sheet

Why we need ZEB…?

Energy and emissions in the buildings and construction sector

Recent trends in energy consumption and energy-related carbon emissions for the global buildings and construction sector are varied, with increasing energy use but limited growth in buildings-related emissions. Building construction and operations accounted for 36% of global final ene gy use and 39% of energy-related carbon dioxide (CO_2) emissions in 2017. The buildings and construction sector therefore has the largest share of energy and emissions, even when excluding construction-related energy use for transport associated with moving building materials to construction sites.

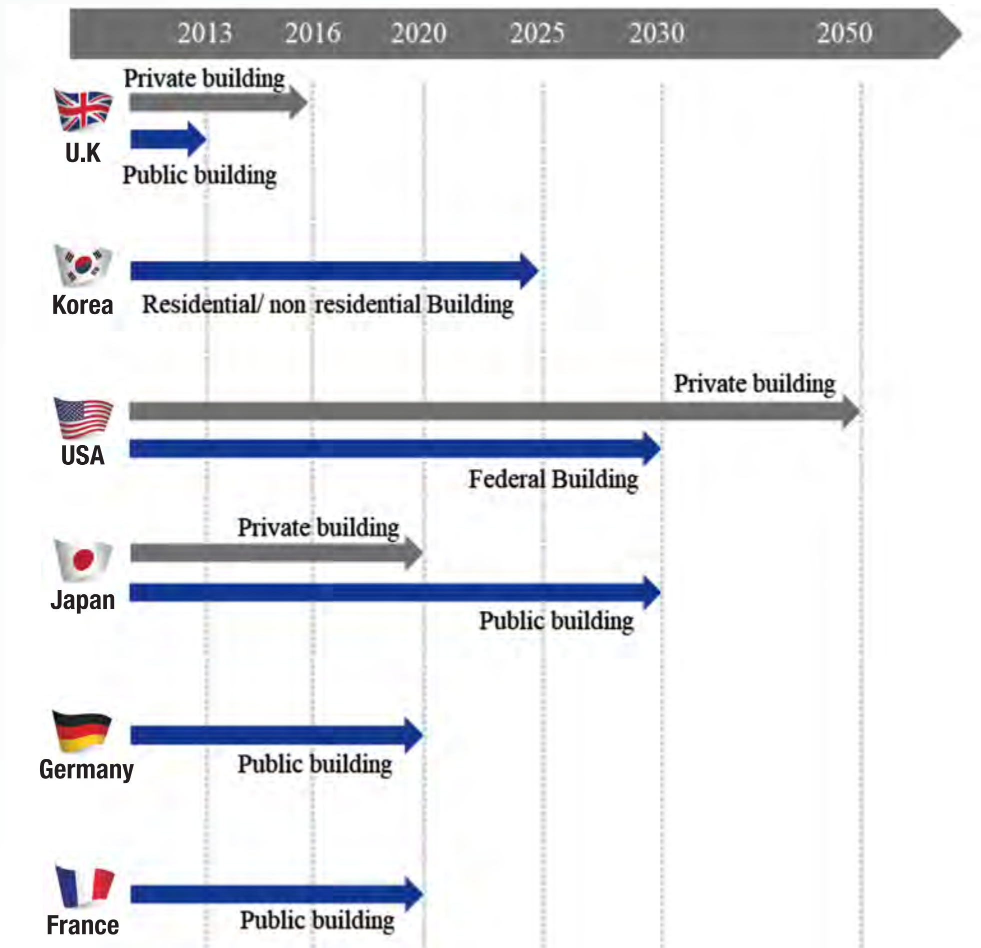
Global share of buildings and construction final energy and emissions, 2017



36% of final energy use

39% of energy-process related emissions

Roadmap to move toward ZEB

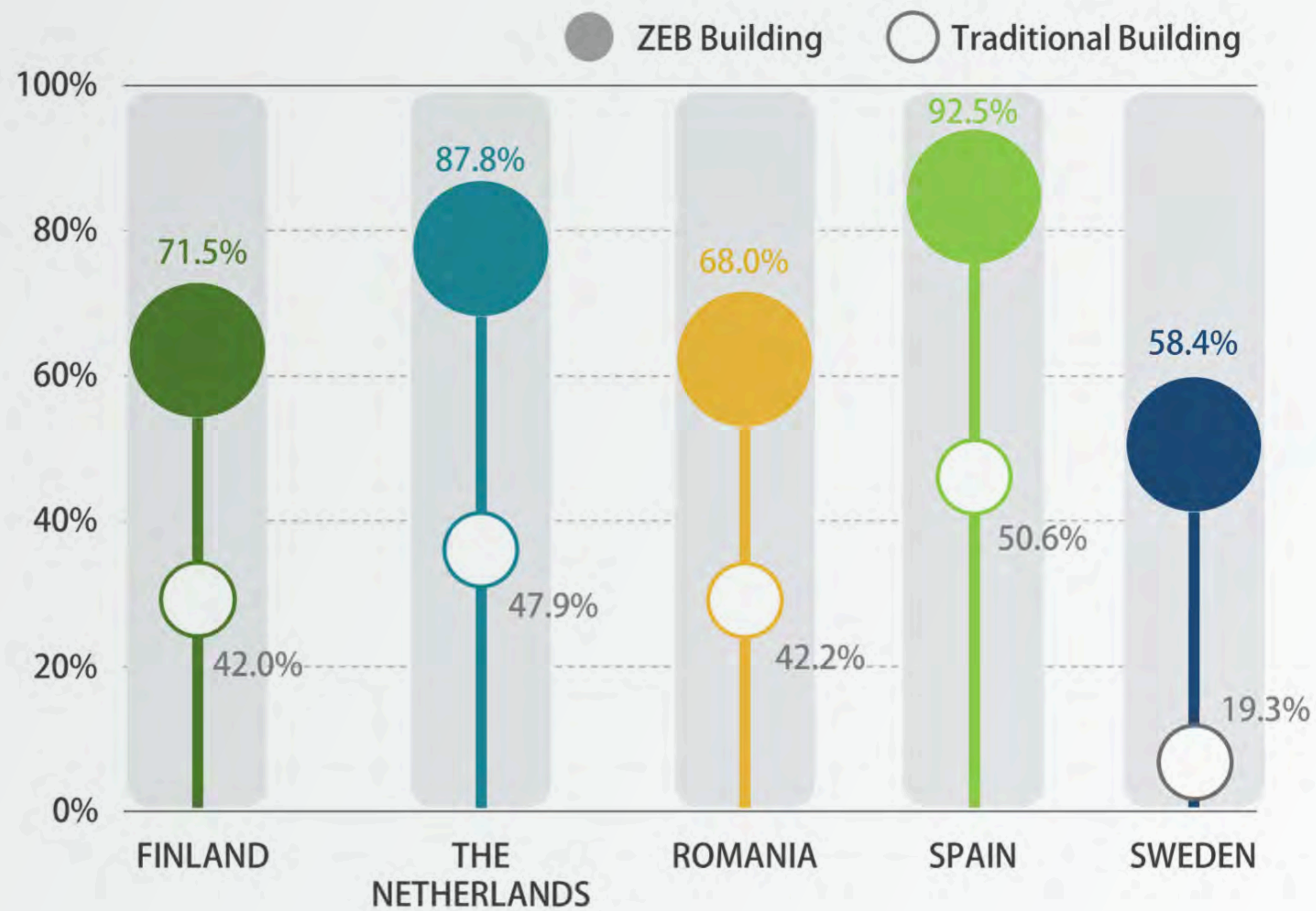


Source : Green Energy Technology Insight 2017 Vol.8, No.5

Source : Derived from IEA (2018a), World Energy Statistics and Balances 2018, www.iea.org/statistics and IEA Energy Technology Perspectives Buildings Model, www.iea.org/buildings. https://www.grandviewresearch.com/industry-analysis/net-zero-energy-buildings-nzebs-market

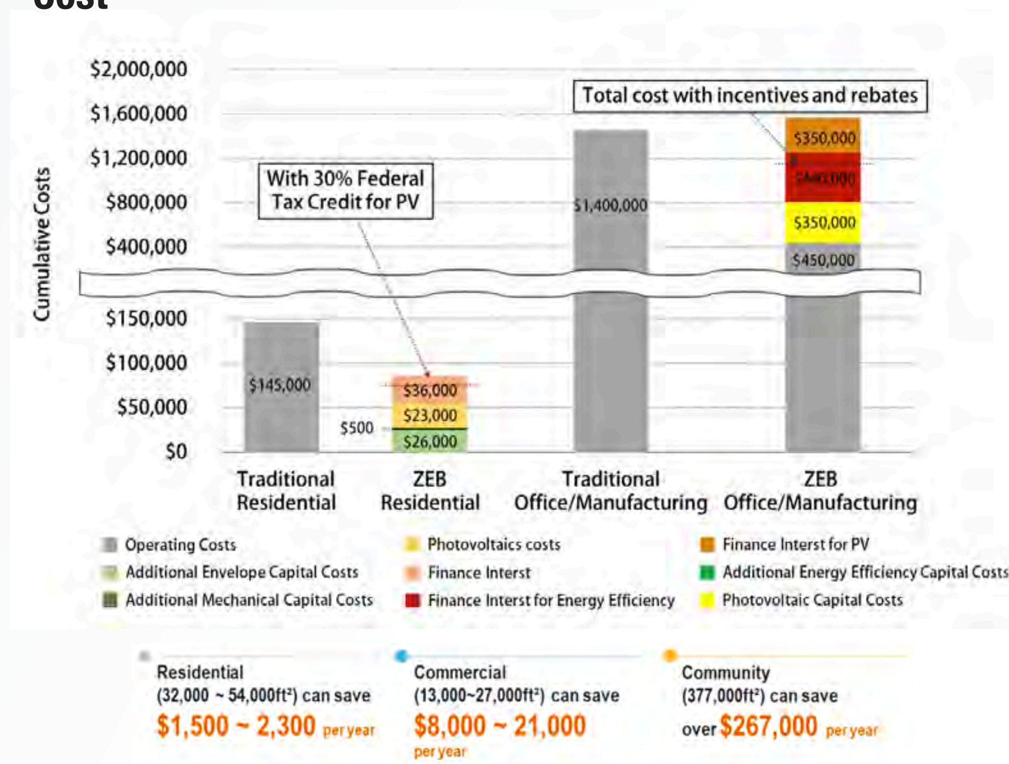
What is the benefit of ZEB?

Energy saving potential of ZEB

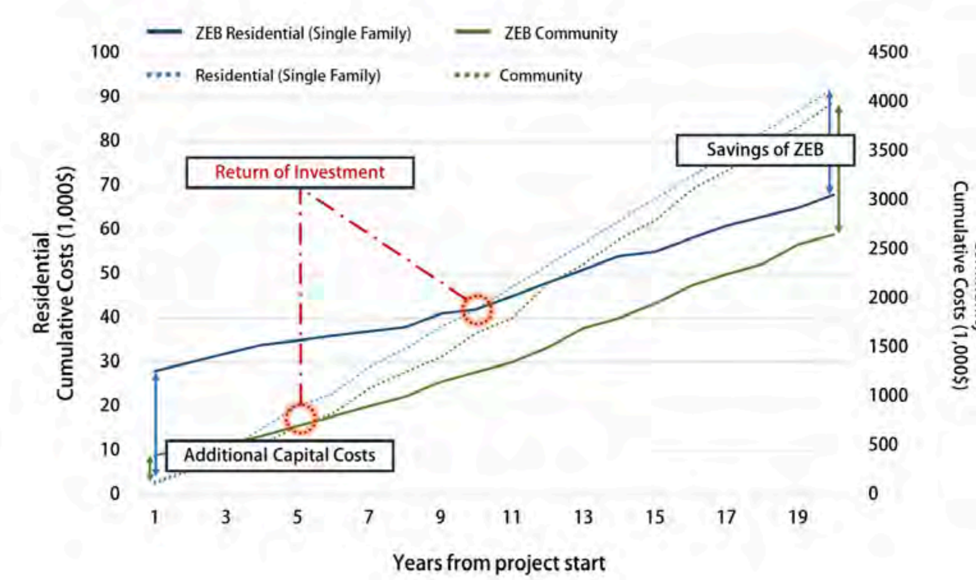


The **energy saving** potential with a ZEB was calculated to be between **60% - 90%**.

Cost



Investment



5 ~ 12 years of ROI (Return of Investment) when using ZEB

Sources : Holopainen et al. Feasibility studies of energy retrofits – case studies on Nearly Zero-Energy Building renovation, Energy Procedia, 2016

Sources : Making the Financial Case for Net Zero Buildings, AIA Northeast Sustainable Energy Association (2015)

Benefit of ZEB

Feasibility study and financial analysis for ZEB

The chart below shows a comparison of the monthly payments for a zero energy home with the monthly payments for a similar code built home using typical numbers for PITI+E. While the payments in this example are equal, the owners end up with a more comfortable building for the same cost per month. The energy savings from a zero energy home are actually added income that allows you to purchase a superior home.

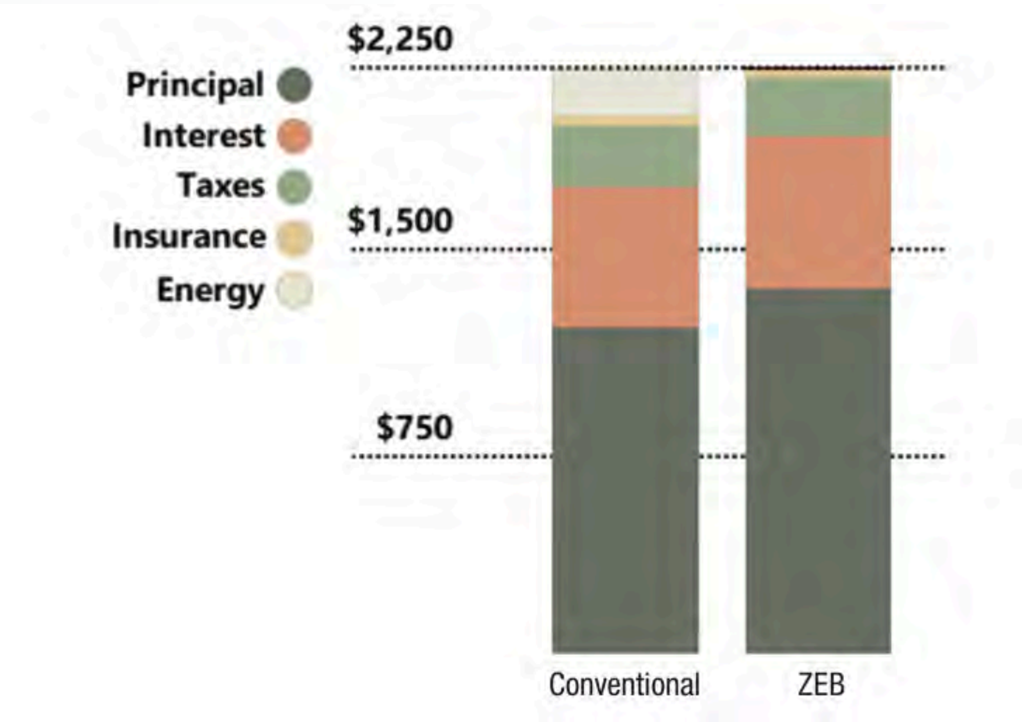
*PITI+E (Principal, Interest, Taxes, Insurance + Energy)

	Standard	ZEB	Energy savings
Windows	U=0.32	U=0.20	57% - 74% energy savings above conventional
Residential component	Basement Walls R-15 Basement slab none	Basement Walls R-20 R-20 slab edge Basement slab R-20	
	Rim insulation R21	Rim insulation R42	
	Walls R-25	Walls R-40	
	Attic R-49	Attic R-60	
Ventilation	25cfm, exhaust only	25cfm, heat recovery ducted	
HVAC	Propane 85% sealed combustion boiler	ASHP, annual heat COP 2.3	
Solar PV	None	7.7 kW system	

*The financial analysis assumes 4% fixed interest for 30 years for the residential buildings. The same financing terms are used for the PV.

Source : Making the Financial Case for Net Zero Buildings, AIA Northeast Sustainable Energy Association (2015), https://zeroenergyproject.org/2019/06/03/financing-energy-saving-improvements-and-zero-energy-homes-for-all/

Monthly benefit (Single-family house) $200



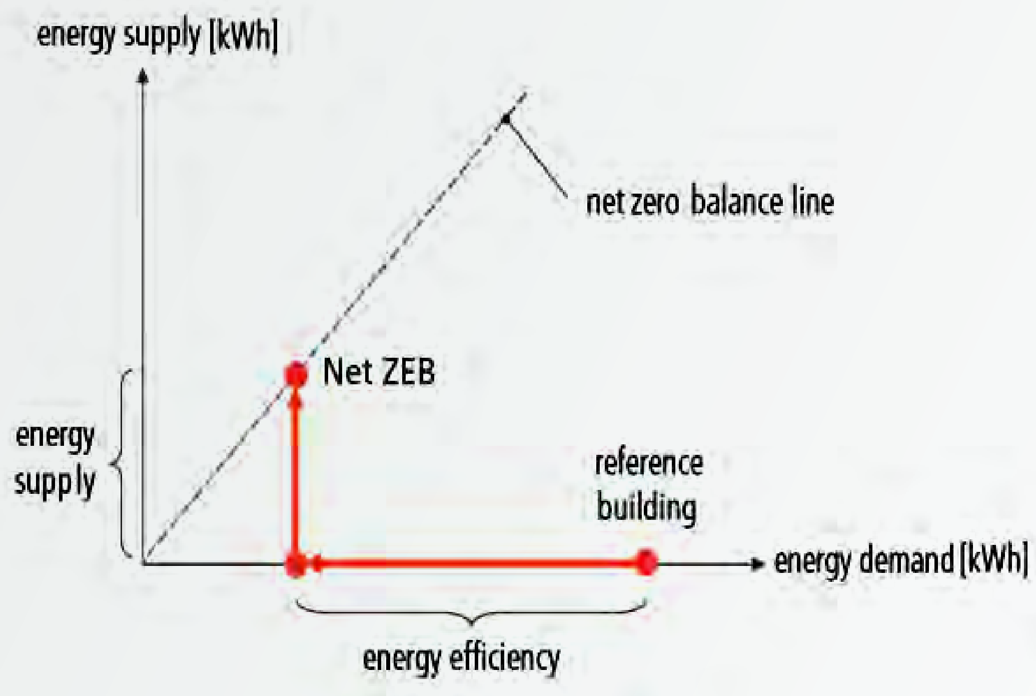
Definition of ZEB

A Common definition for Zero Energy Building

In addition to establishing a definition for ZEB, shown belo , it was clear that definitions were needed to accommodate the collection of buildings where renewable ene gy resources were shared. To meet this need, the team provided variations on the ZEB definition

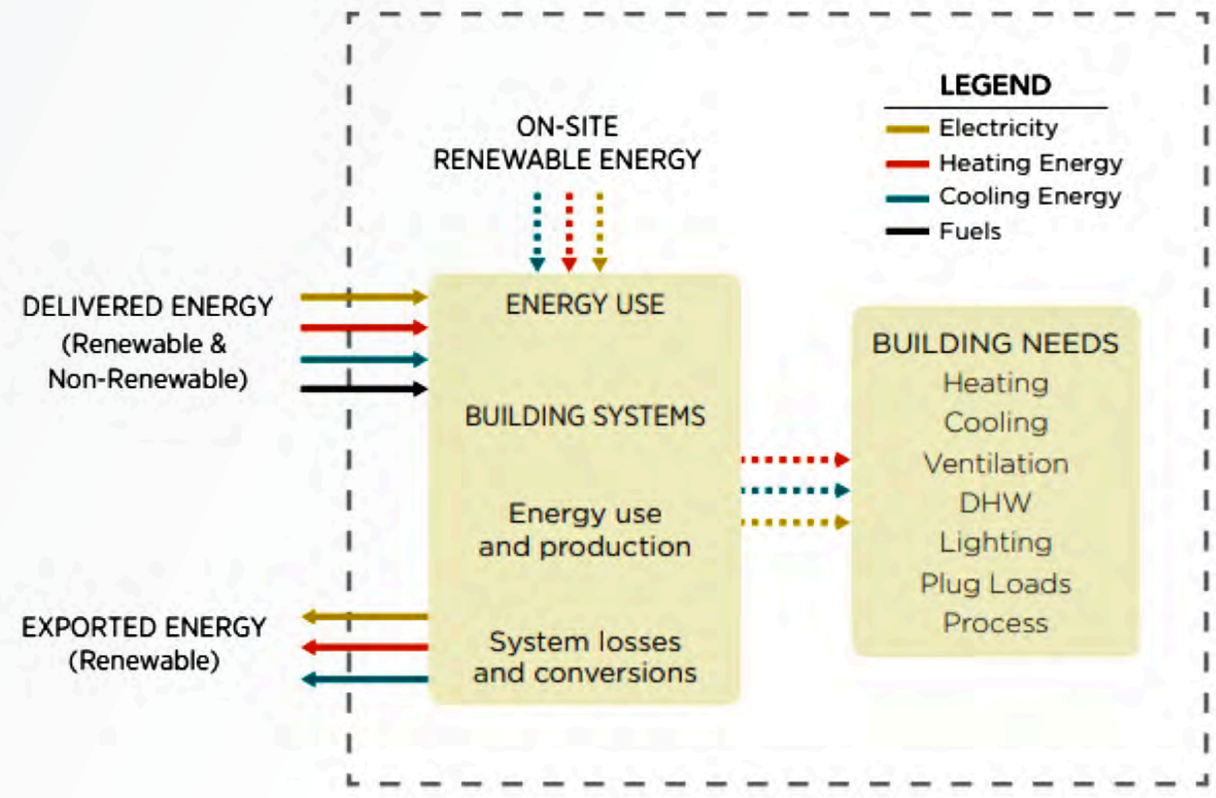
Zero Energy Building

An energy-efficient **building** where, on a **source energy** basis, the actual **annual delivered energy** is less than or equal to the on-site renewable **exported energy**.



Source : A Common Definition for Zero Energy Buildings, U.S. DOE, 2015

A Common Definition for Zero Energy Buildings, U.S. DOE, 2015



Note : 1. The dashed lines represent energy transfer within the boundary.
2. The solid lines represent energy transfer entering / leaving the boundary used for zero energy accounting.

Definition of ZEB

Definitions of nearly, net and plus energy buildings.

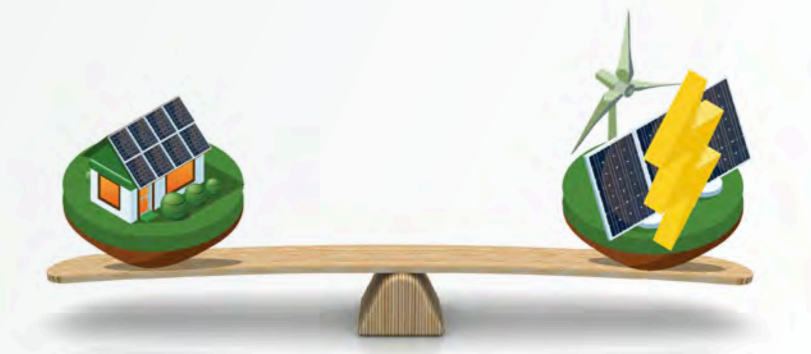
Renewable energy, however, plays a critical role in Nearly Zero Energy Buildings, Net Zero Energy Buildings and Net Plus Energy Buildings. It has been widely adopted as a primary energy source in these buildings to balance the energy use after demand and energy reduction. The difference between energy consumption and energy generation reflects the ZEB target. Renewable energy can either be produced on-site or transported to the site. On-site generation includes renewable energy systems installed on the building footprint or on the land beside the building, while off-site generation embraces investments in off-site renewable energy technologies or the purchase of green power.

According to the European Union Commission, a Nearly Zero Energy Building is defined as a building that has a very high ene gy performance as determined on the basis of the calculated or actual annual energy consumed. Furthermore, the nearly zero or very low amount of energy required for the building consumption should be covered to a significant extent by energy from renewable sources, produced on-site or nearby

Nearly Zero Energy Building (nZEB)

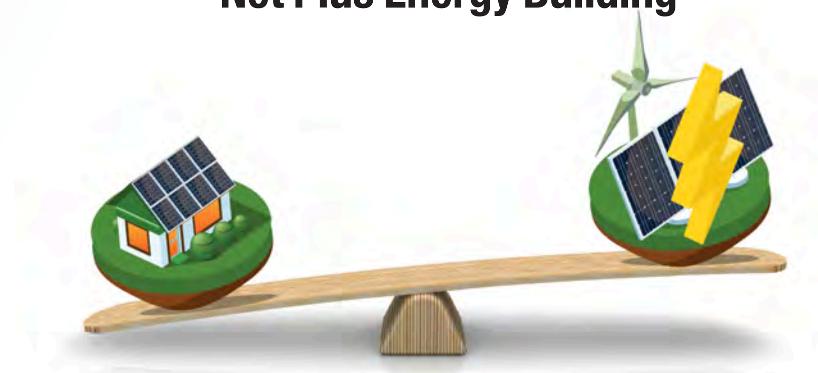
The nearly zero net energy required should be supplied from renewable energy sources, including those produced on-site or nearby.

Net Zero Energy Building (NZEB)



A building with greatly reduced energy needs from higher efficiency so that the energy required can be supplied with renewable technologies on site.

Net Plus Energy Building



An incredibly efficient energy performing building, which generates more renewable energy than its annual needs

Source : Defining Nearly Zero Energy Buildings in the UAE,2017

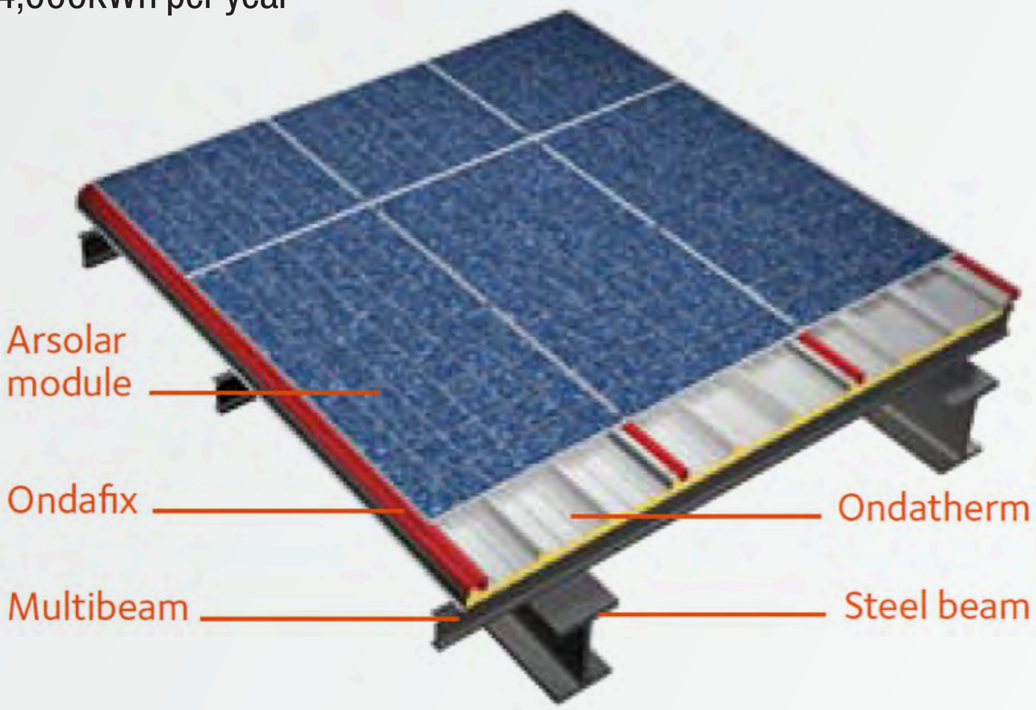
Roofing and Photovoltaic System

Arsolar Plus / Arval systems & solution

Steel contributes PV to perform as the efficient exterior building system. A novel steel BIPV produces 114~133kWh/m^2 per year. The BIPV solution in roofing can produce up to 14% higher ene gy than conventional BIPVs.
(Energy production of conventional BIPV: 100~130 kWh/m^2/year)

Arsolar® Plus Photovoltaic System

30~35 m^2 of roofing produce
4,000kWh per year



GENERAL PROPERTIES

SOLARTHERM Roof Panel

Thickness (t = mm):	40	80	100
U-value (W/m^2K):	0,56	0,29	0,24
Weight incl. modules (kgs/m^2):	27	29	30
Length (m):	18	18	18
Panel width (mm):	1000		

PV Module

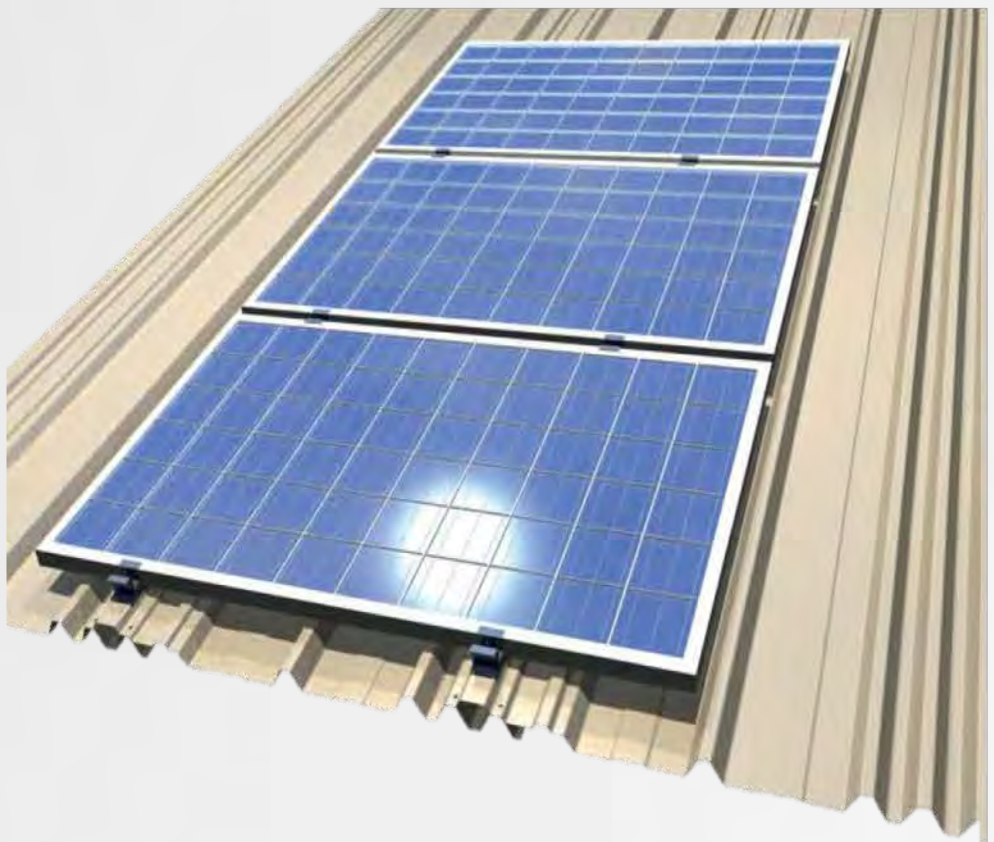
Type:	polycristalline silicium cells
Nominal Power:	135-142 Wp/m^2 (±5%)

Source :ArcelorMittal Arval System & Solutions, ArcelorMittal Steel solutions for solar installations and Steel Solutions for Green Building Catalogue
E.Biyik et al., A key review of building integrated photovoltaic (BIPV) systems, Engineering Science and Technology, an International Journal (2017)
Eiffert and Kiss, Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures, NREL, 2000

Building Attached Photovoltaic System

Roofing attached PV system

A steel application ensures both the roof and the mounting system function.
The energy production can reach 145 – 175 Wp/m² depending on the module type (mono/poly).



Recom Sillia modules

Modules Recom Sillia 60MXXX

P_{mpp}	295	300	305	310	315	320
U_{co}	39.1	39.2	39.4	39.6	39.9	41.1
U_{mpp}	31.9	32.0	32.2	32.4	32.9	33.4
I_{cc}	9.69	9.78	9.86	9.95	9.97	9.98
I_{mpp}	9.26	9.37	9.48	9.56	9.57	9.58
αT (P_{mpp}) [%/K]	-0.41					
αT (U_{co}) [%/K]	-0.31					
αT (I_{cc}) [%/K]	+0.04					
Reverse current Maximum (A)	15					

Modules Recom Sillia 60PXXX

P_{mpp}	265	270	275	280	285	290
U_{co}	38.0	38.2	38.4	38.7	38.9	39.2
U_{mpp}	30.8	31.1	31.3	31.5	31.7	32.0
I_{cc}	9.15	9.23	9.32	9.41	9.49	9.63
I_{mpp}	8.60	8.69	8.79	8.89	8.99	9.17
αT (P_{mpp}) [%/K]	-0.40					
αT (U_{co}) [%/K]	-0.30					
αT (I_{cc}) [%/K]	+0.04					
Reverse current Maximum (A)	15					

P_{mpp} : Power at maximum power point
U_{co} : Open circuit voltage.
U_{mpp} : Nominal voltage at the point of maximum power
I_{cc} : Short circuit current
I_{mpp} : Nominal current at the point of maximum power
αT (P_{mpp}) : Temperature coefficient for maximum power
αT (U_{co}) : Temperature coefficient for open circuit voltage.
αT (I_{cc}) : Temperature coefficient for short circuit intensity

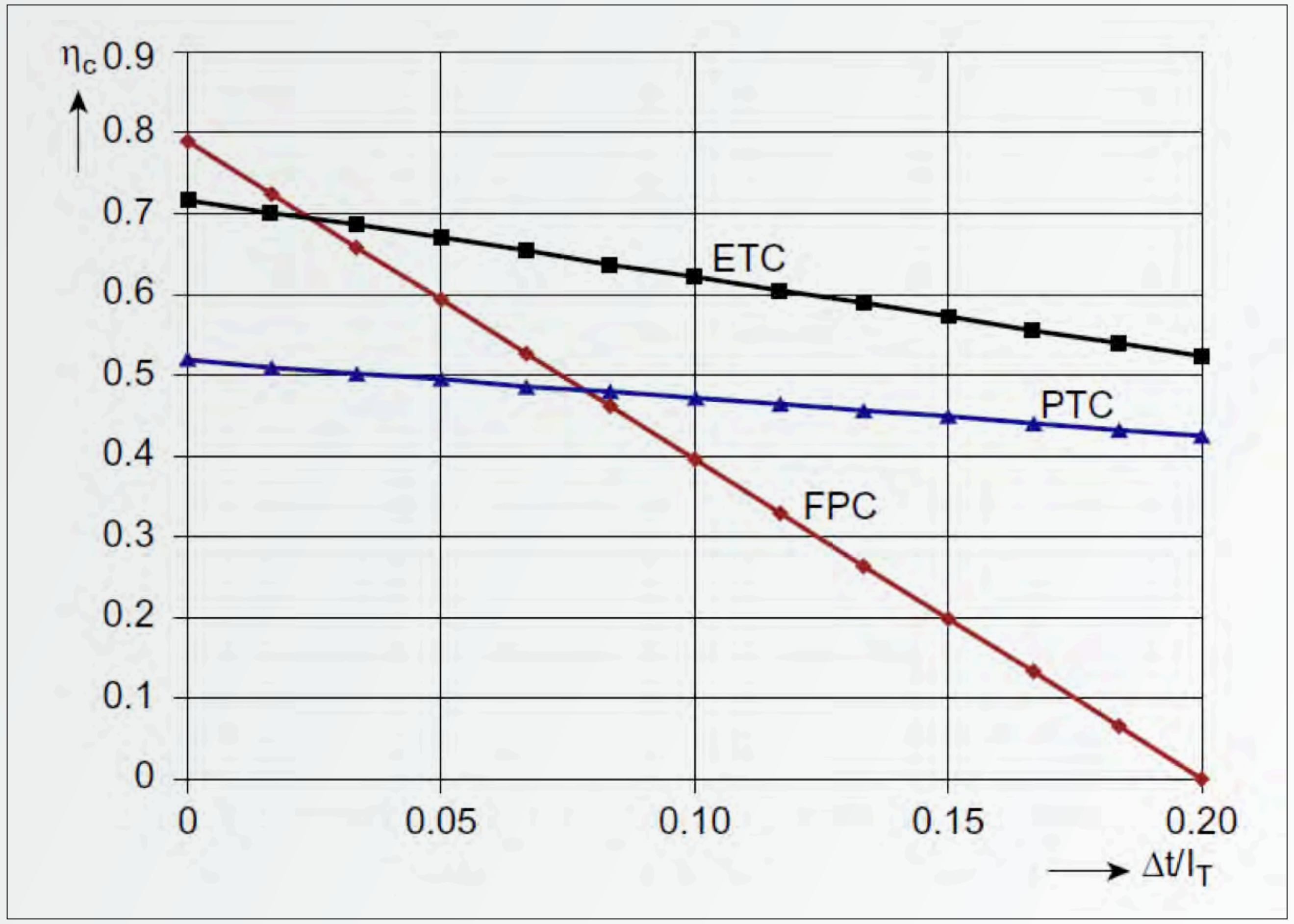
Source: ArcelorMittal Avis Technique 21/14-49_V2 Komet®,

Solar Heating System

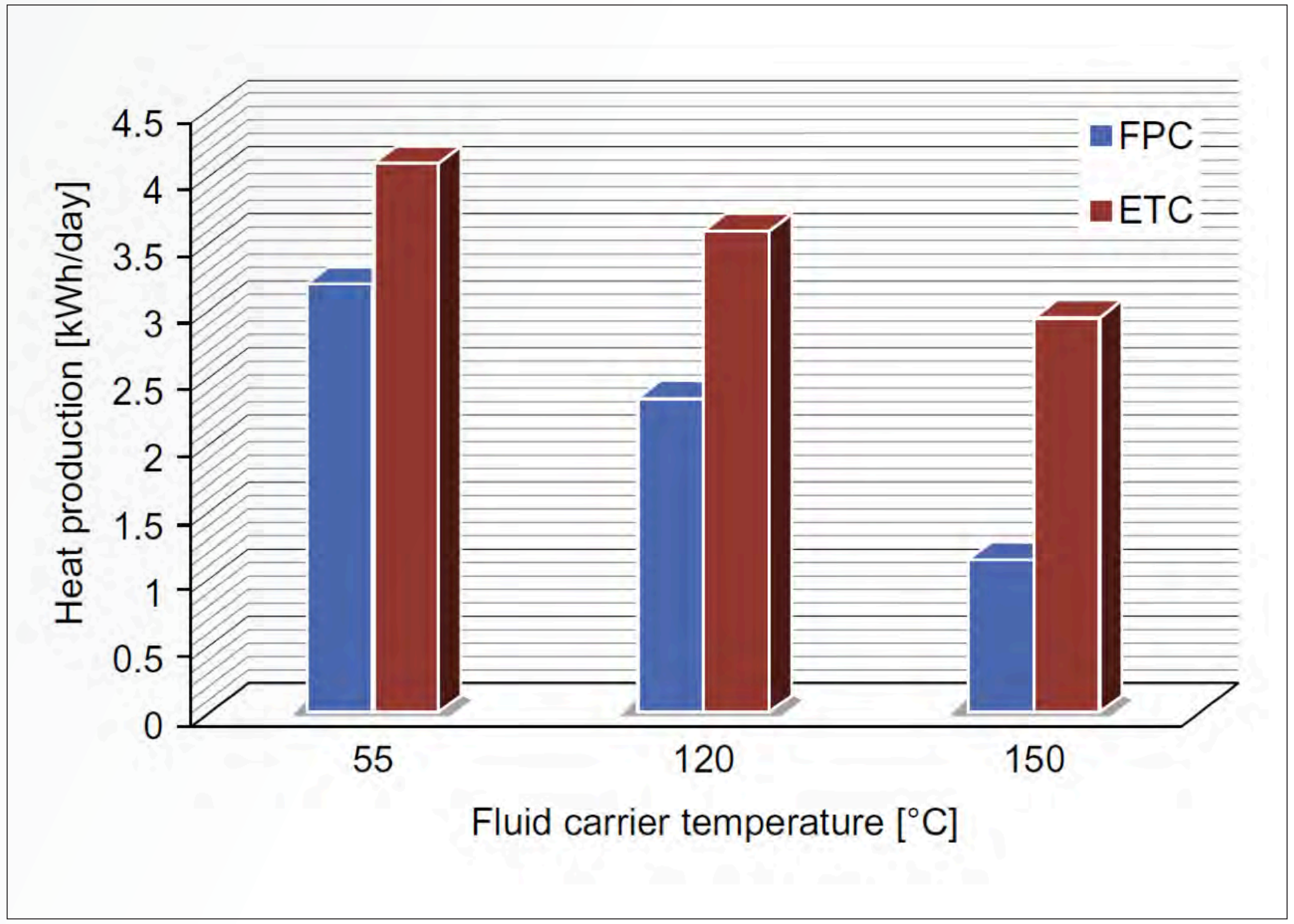
Efficiency of roof solar heat collector

Evacuated Tube Collector(ETC)s produce more heat daily than Flat Plate Collectors (FPC). However, at low heat-delivery temperatures, the difference is only about 25% while at high temperatures, the difference becomes quite large, at more than 60%. Since FPCs cost approximately 50% of ETCs, the heat generated by FPCs is always cheaper for the specific location considered. FPCs using steel panels can achieve 80% of thermal efficiency on a sunny da .

Boundary of Efficiency curves of the three typologies of considered solar collectors



Daily solar collector heat production for different temperature levels



Source : Solar Heating and Cooling Systems – Fundamentals, Experiments and Applications (Chapter 3 – Solar Collectors), Ioan Sarbu and Calin Sebarchievici

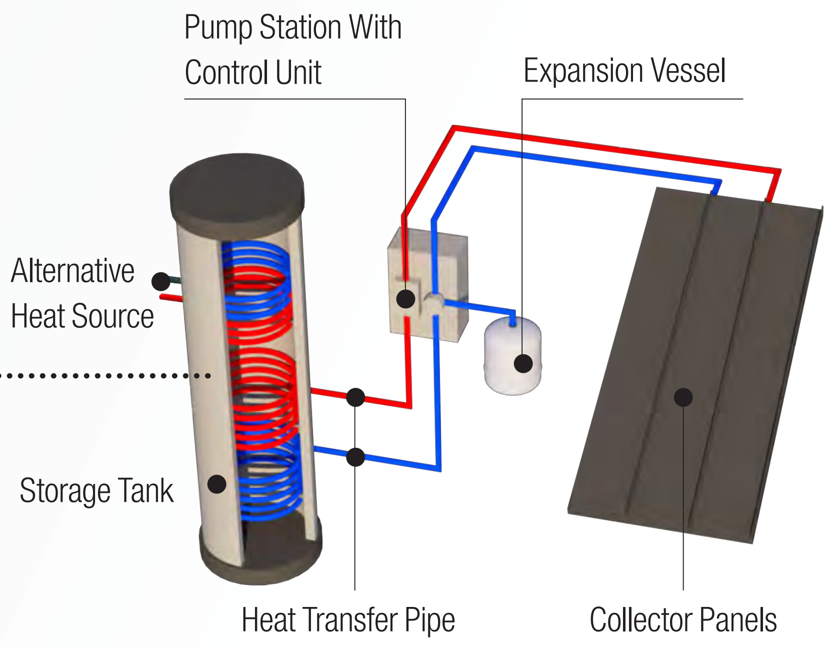
Solar Thermal Solution

Solar thermal system with DHW(Domestic Hot Water)

In non-residential buildings with a low DHW use, solar collectors may be integrated with space heating systems. The integration of solar panels with ground source heating (e.g. energy piles) increases the efficiency of the piles: by recha ging the ground with solar heating energy during the summer, when space heating is not needed, the medium and long term performance of the ground source heating system can be significantly improved. As the recharging of the ground is achieved with relatively low temperatures (if compared to DHW for instance), the annual efficiency of the solar heat system increases to 85%

Single and double compartment water tanks for DHW and space heating

Solar thermal system with DHW



Source : ZEMUSIC, WP6.4: Design Guide for Steel Intensive nearly-Zero Energy Buildings

Energy Pile System

Performance of energy pile system

In Japan, field experiments were conducted with 25 eight-mete -long steel energy piles. The steel energy pile [Type 1] could achieve maximum 140 W/m and average 80 W/m of heat exchange rate as it has relatively long diameter and high thermal conductivity. The heat exchange rate of ordinary ground heat exchanger is 40~45 W/m.

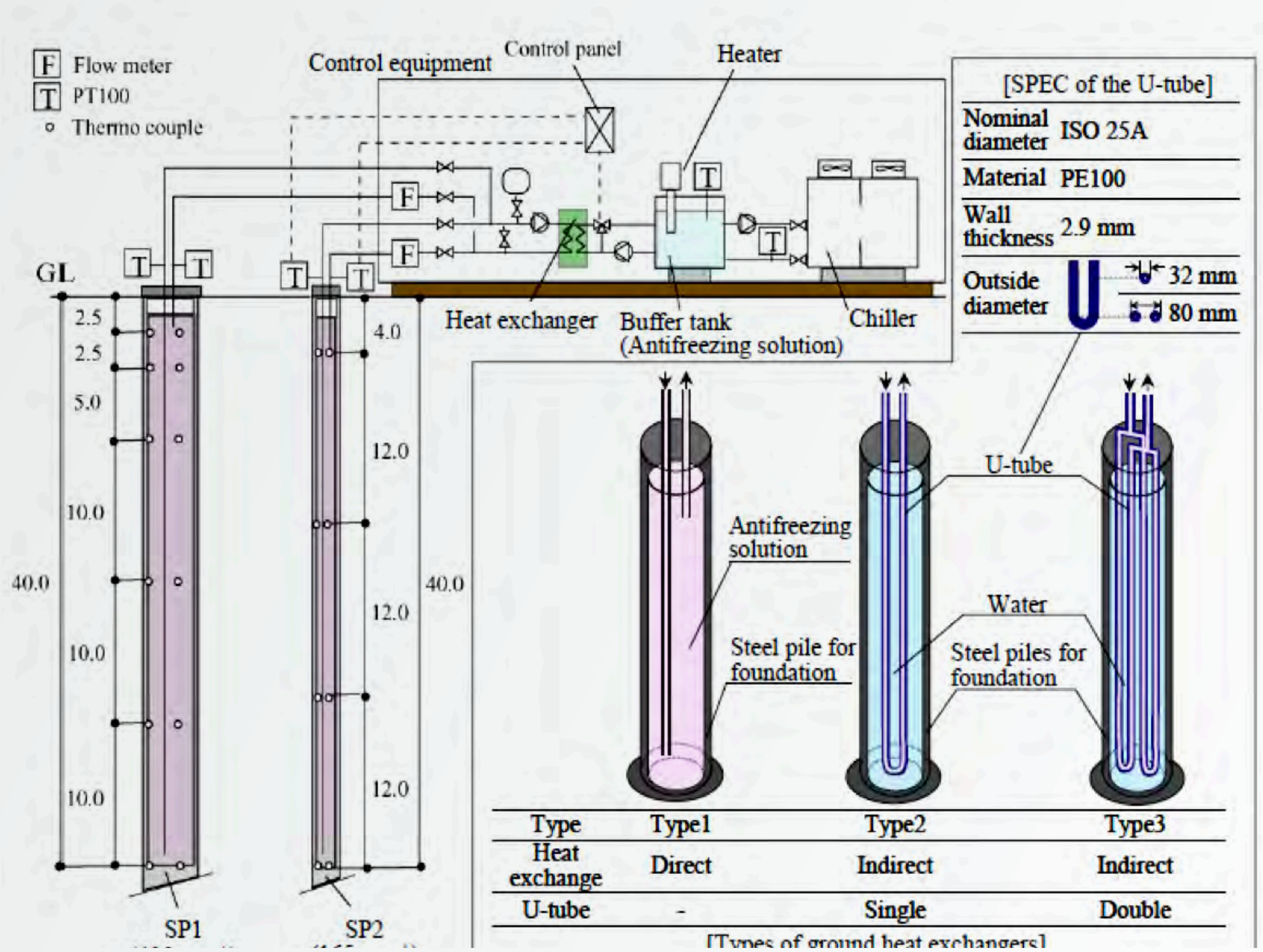


Table 1. Experimental conditions

Exp.No.	Steel pile	Type of the ground heat exchanger	m_f [l/min]	$T_{f\text{-}in}$ [ºC]	Period Start	Period End
Exp.1-1	SP1	Type 1	5	2	May 30th, 2003	Jan. 13rd, 2003
Exp.1-1L			10 to 30	-5	Aug. 31st, 2003	Oct. 16th, 2003
Exp.1-2		Type 2	10 to 30	2	Apr. 12nd, 2004	Jun. 13rd, 2004
Exp.1-2L			10 to 12	-5	Dec. 1st, 2003	Dec. 18th, 2003
Exp.1-3		Type 3	10 to 30	2	Jal. 29th, 2004	Sep. 30th, 2004
Exp.2-1	SP2	Type 1	10 to 30	2	Jan. 24th, 2004	Mar. 7th, 2004
Exp.2-1L			10 to 30	-5	Aug. 31st, 2003	Oct. 16th, 2003
Exp.2-2		Type 2	10 to 30	2	Apr. 12nd, 2004	Jun. 13rd, 2004
Exp.2-2L			6 to 10	-5	Dec. 1st, 2003	Dec. 18th, 2003
Exp.2-3		Type 3	10 to 30	2	Jal. 29th, 2004	Sep. 30th, 2004

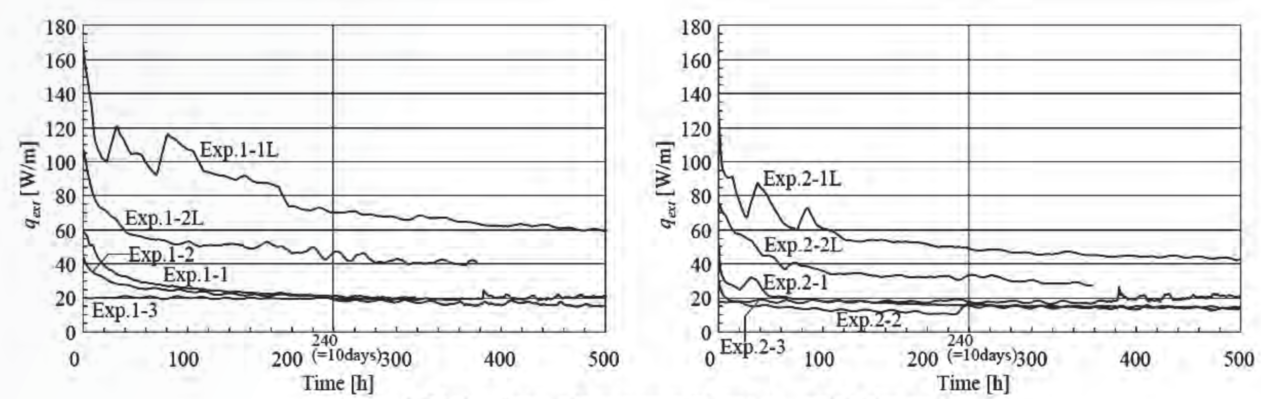


Fig. 4. Variations of extracted heat q_{ext} with time

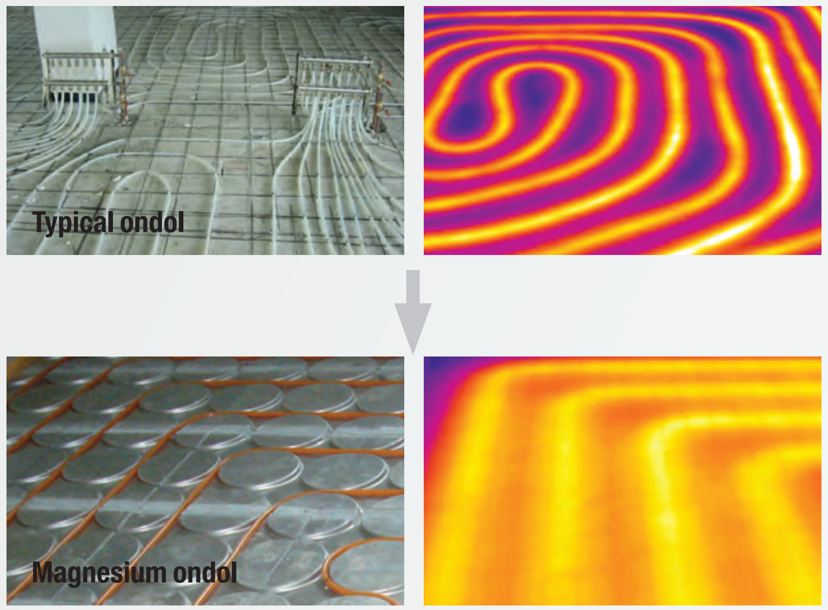
Source : K. Nagano et al., THERMAL CHARACTERISTICS OF STEEL FOUNDATION PILES AS GROUND HEAT EXCHANGERS

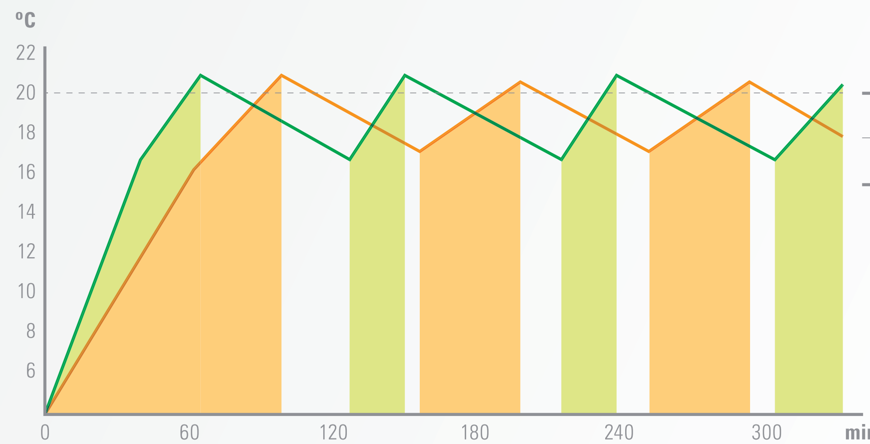
Radiant Floor Heating Solution

Magnesium radiation plate for floor heating (POSCO)

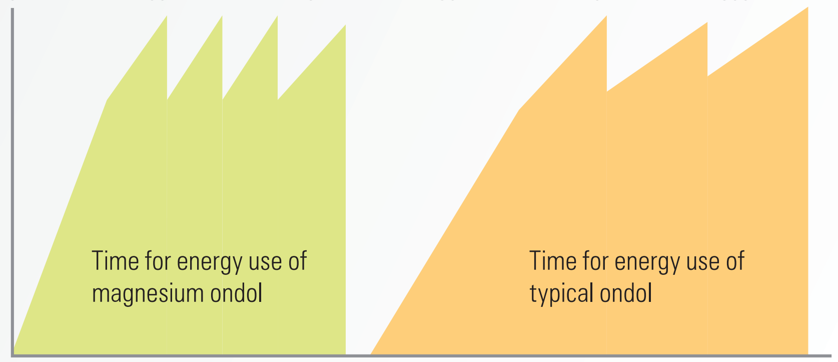
Magnesium radiant floor heating system not only improves heating performance, but also economics for construction and maintenance costs, and reduces floor noise. Radiant flo heating system can be constructed in a short time with a small number of people, contributing to labor cost reduction and shortening of construction time. In the long term, the magnesium radiant floor heating system shows a 37.5% cost reduction compared to the normal radiant floor heating system, and the time to reach the set temperature is 49.4% faste than the normal system.

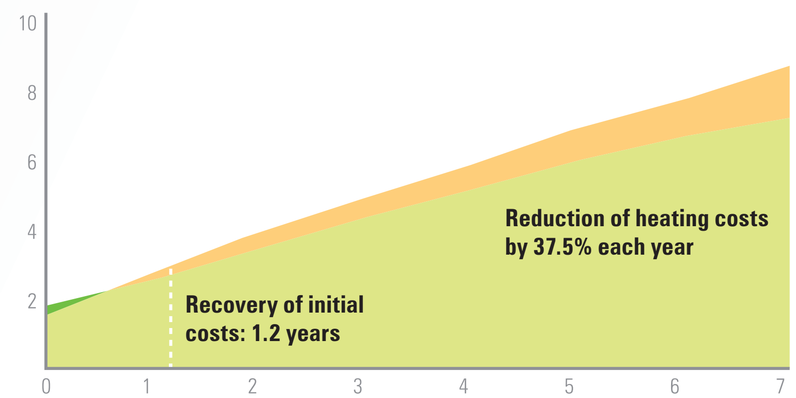
Characteristics of Magnesium Ondol panel





	Heating time	Heat retention time	Re-heating time
Typical ondol	86.54 min	79.68 min	28.15 min
Magnesium ondol	**57.93 min**	67.91 min	**18.84 min**





Source : Magnesium radiation plate, floor heating panel having the magnesium radiation pate and floor heating panel system having the floor heating pannel and POSCO, magnesium radiation pannel catalog

Reflective Panel System

Colorcoat® High Reflect

The optimum reflectivity for an internal line , maximizing daylight and reducing requirements for artificial lighting. Colorcoa ® High Reflect is a bespoke liner designed with maximum reflectivity to reduce ene gy requirements, associated operational costs and CO_2 emissions.

Test building with Colarcoat ®

- ≥ 85% reflectance, reducing the amount of energy required to achieve the same level of lighting
- Significantly reduces CO_2 emissions by 2-3% per year, helping to achieve compliance with tightening regulations.
- Can improve daylight factor by 10%
- Possible energy savings of up to 12% per annum.
- Galvanised substrate with Zinc metallic coating or equivalent for very good corrosion resistance.

Typical payback and savings

Lux	Energy savings (%)	CO_2 reduction (%)	Payback (years)
300	11	3*	9.8
500	12	3*	3.8
1000	12	3*	1.1

Based on 4000m2 building, daytime operation (Payback for 24 hour operation is ≤ 1.5 years).
*Based on SBEM Calculation under NCM conditions for Part L compliance.

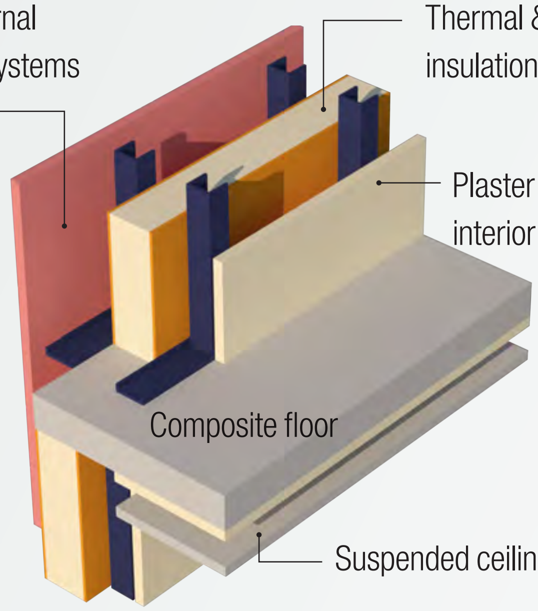
Source : TATA Steel, Colorcoat® High Reflect data sheet

Thermal Conductivity

Thermal efficient steel-based design

A high proportion of energy use is devoted to heat control, by artificially cooling the building: good steel-based design or use of appropriate steel products can achieve a major reduction in this energy consumption.

Thermal efficient steel system



Source : ArcelorMittal, Steel solutions for green building

- The combination of steel structure with effective external insulation drastically reduces a building's losses.
- Double skin systems and/or sandwich panels provide a thermally efficient envelope, matching latest energy standards.
- No thermal bridges due to approved design.
- Airtightness of steel cladding or roofing systems eliminate air leakage that contributes to energy waste.
- Intelligent use of the thermal mass effect of steel products or components enables energy savings.

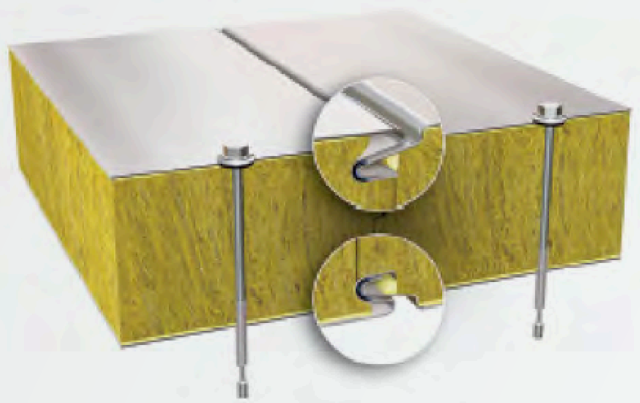
Source : ArcelorMittal, K'energy – your key to save energy

Thermal Conductivity

Steel with PU(Polyurethane) / PIR(Polyisocyanurate)

Sandwich panels are cost-effective prefabricated elements for use in e.g. façades, compartment structures, partition walls, ceilings and roofs. Typical applications include industrial and commercial buildings, sports facilities, warehouses and power plants. The panels can be used in food industry construction and demanding clean room applications. An optimal insulation core is selected based on customer needs, ensuring excellent thermal insulation properties even for thin panels.

An Spa panel with a mineral wool insulation core and a PU panel with a polyurethane insulation core



Core thickness D mm	Modular width mm	Thickness of facings		Maximum Length m	Weight kg/m²	U value W/m²K	Reaction to fire	Sound insulation Rw dB
		External mm	Internal mm					
120	1100	0.5 or 0.6*	0.4* or 0.5	18.5	13.8	0.18	B-s1,d0	≥25
140					14.7	0.16		
160					15.5	0.14		
180					16.4	0.12		
200					17.3	0.11		

Source : Ruukki, Sandwich panels Environmental product declaration EN 15804 ISO 14025
Source : Ruukki , Energy-efficient sandwich panels

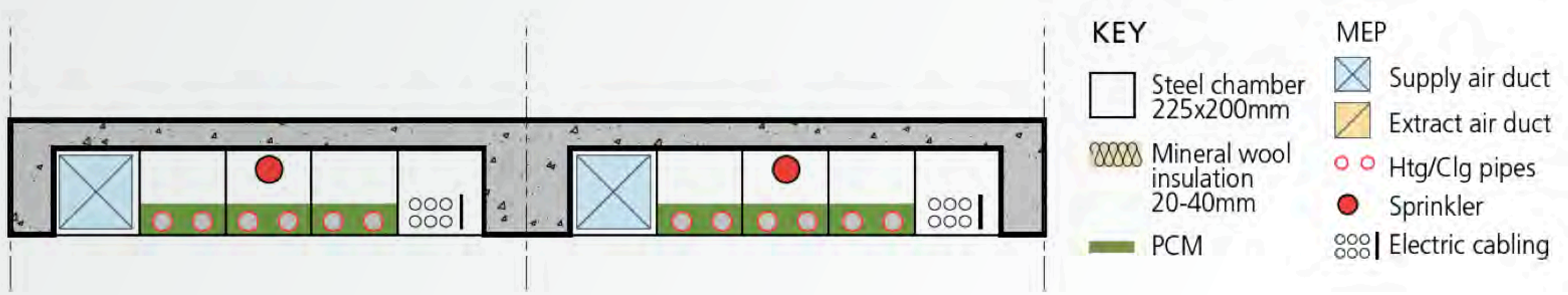
PCM Thermal Storage

Steel floor system with PCM layer

This system is based on the radiant ceiling. Since the solution with radiant cooling is not sufficient for the hotter climates, the radiant cooling system can be combined with an additional PCM layer where the pipes are embedded in the PCM in the middle of each half-module.

The PCM is able to absorb the heat when the temperature in the room increases. The cooling energy from the pipe passes not only into the steel sheet and it can also be used for a recharging of the PCM around the pipe. The PCM between the pipes leads to a reduction of the maximum temperature peaks. The system including PCM is still not able to keep the temperatures below 25 °C for warmer climates, but it reduces the cooling peaks and it could help in reducing the additional energy demand.

Steel floor system with MEP routing and heating/cooling pipes embedded into a PCM layer



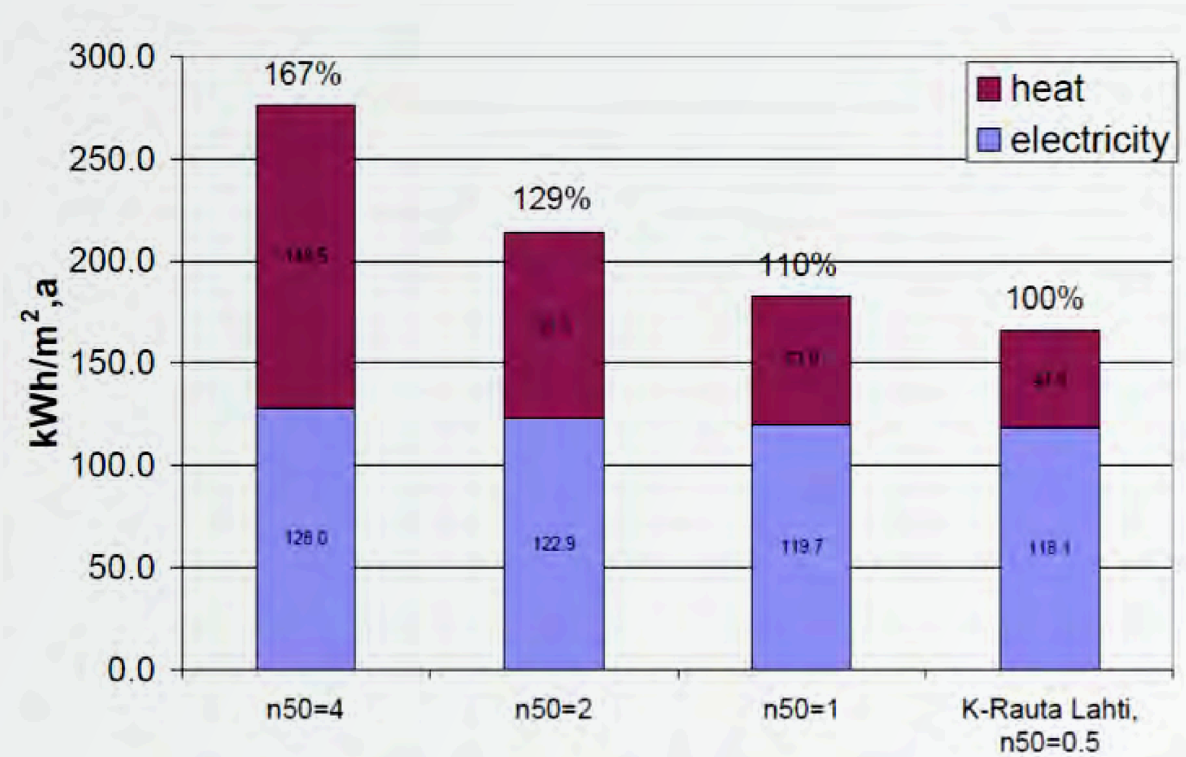
Source : Zemusic, Design Guide for Steel Intensive Nearly – Zero Energy Office Buildings, WP 6.4

Airtightness System

Airtightness system

According to the reference, the airtightness has very high influence on the heating ene gy demand in the cold climate. Heating energy demand of the building with airtightness of 0.5 [1/h, n50] is about half of that of the building with airtightness of 2.0 [1/h, n50]. Even though its influence depends on the local climate, the airtightness is very significant factor fo energy saving in buildings. There are many steel applications which have excellent airtightness.

Effect of airtightness on energy consumption of the single-storey store building



Comparison of heating and electricity demand between the standard building and best case in Finland

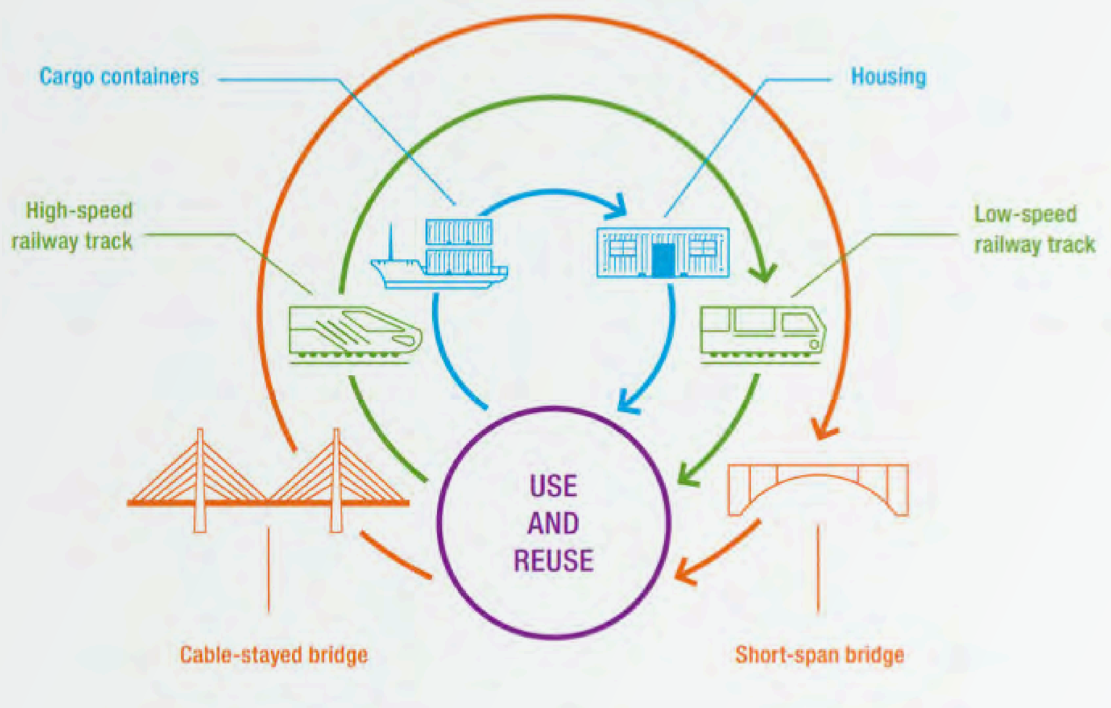
Source : Jyrki Kesti and Petteri Lautso, Improving life cycle efficiency in single-storey commercial buildings

Steel Structure Sustainability

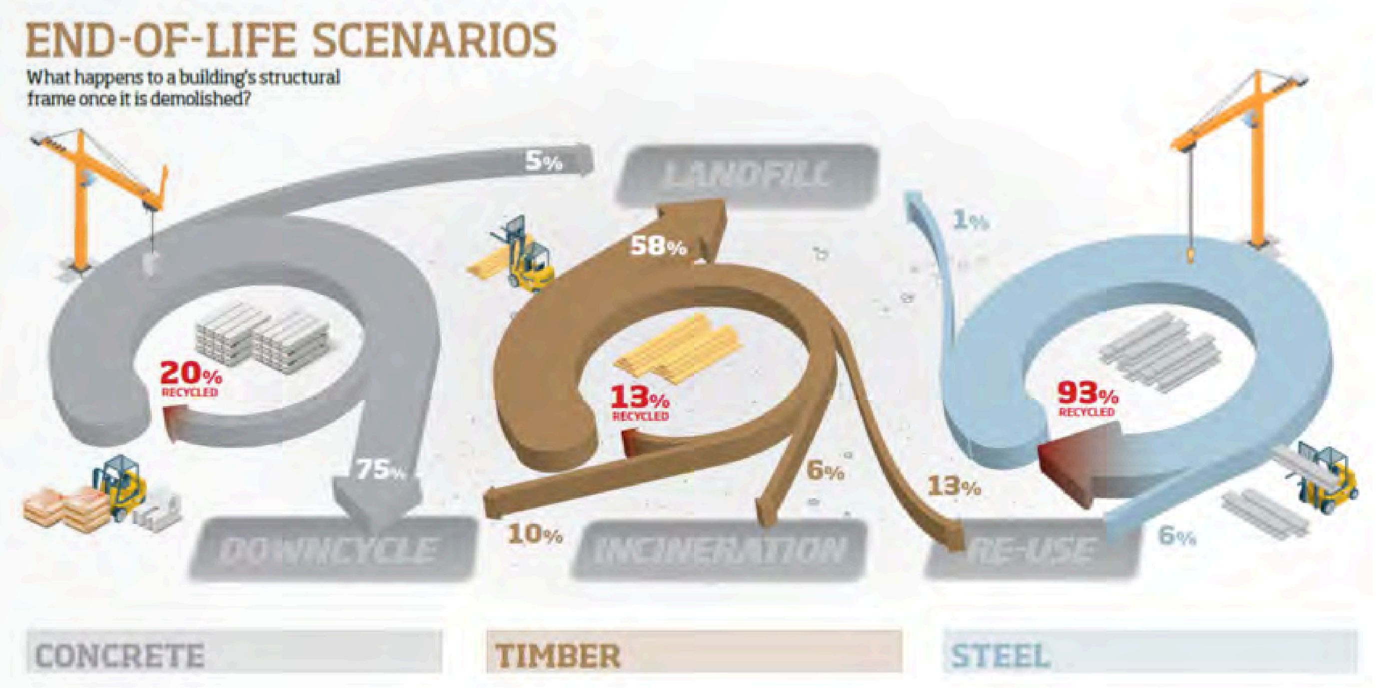
Reuse in steel structure

Steel can be recycled and reused with the same, or higher, standard and quality as the original material. Especially, in construction, most steel products are easily captured at the end of a building's life. Capture rates of steel products are generally above 90% and average 96%. Moreover, the capture rate for hot rolled structural sections is 99%.

Reuse in steel application



End-of-Life scenarios each material



Source : Worldsteel Association, Steel – the permanent material in the circular economy
Source : https://steelconstruction.info

Reference List

1. Green Energy Technology Insight 2017 Vol.8, No.5
2. Derived from IEA (2018a), World Energy Statistics and Balances 2018, www.iea.org/statistics and IEA
   Energy Technology Perspectives Buildings Model, www.iea.org/buildings.
   https://www.grandviewresearch.com/industry-analysis/net-zero-energy- buildings-nzebs-market
3. Holopainen et al. Feasibility studies of energy retrofits – case studies on Nearly Zero-Energy Building renovation, Energy Procedia, 2016
4. Making the Financial Case for Net Zero Buildings, AIA Northeast Sustainable Energy Association (2015)
   https://zeroenergyproject.org/2019/06/03/financing-energy-saving-improvements-and-zero-energy-homes-for-all/
5. A Common Definition for Zero Energy Buildings, U.S. DOE, 2015
6. Defining Nearly Zero Energy Buildings in the UAE,2017
7. ArceloMittal Arval System & Solutions Catalogue & ArceloMittal Steel solutions for solar installations Catalogue and Steel Solutions for Green Building Catalogue
8. E.Biyik et al., A key review of building integrated photovoltaic (BIPV) systems, Engineering Science and Technology, an International Journal, 2017
9. Eiffert and Kiss, Building-Integrated Photovoltaic Designs for Commercial and Institutional Sturctures, NREL, 2000
10. Solar Heating and Cooling Systems – Fundamentals, Experiments and Applications (Chapter 3 – Solar Collectors), Ioan Sarbu and Calin Sebarchievici
11. ZEMUSIC, WP6.4: Design Guide for Steel Intensive nearly-Zero Energy Buildings
12. K. Nagano et al., THERMAL CHARACTERISTICS OF STEEL FOUNDATION PILES AS GROUND HEAT EXCHANGERS
13. Magnesium radiation plate, floor heating panel having the magnesium radiation pate and floor heating panel system having the floor heating panel and POSCO, Magnesium radiation pannel catalog
14. TATA Steel, Colorcoat® High Reflect data sheet
15. ArcelorMittal, Steel solutions for green building
16. ArcelorMittal, K'energy – your key to save energy
17. ruukki, Sandwich panels Environmental product declaration EN 15804 ISO 14025
18. ruukki , Energy-efficient sandwich panels
19. Zemusic, Design Guide for Steel Intensive Nearly – Zero Energy Office Buildings, WP 6.4
20. Jyrki Kesti and Petteri Lautso, Improving life cycle efficiency in single-storey commercial buildings
21. Worldsteel Association, Steel – the permanent material in the circular economy
22. https://steelconstruction.info
23. Jyrki kesti, Life cycle cost-efficient near zero energy hall building for Nordic climat
24. Jyrki kesti, Near zero energy building with steel solutions – case study, 2016
25. POSCO, POSCO green building brochure, https://www.uponor.com/company/innovation/references/posco-green-building, 2013
26. 新日鉄住金エンジニアリング㈱, 北九州スマートコミュニティ創造事業における地中熱利用事例 新日鉄住金エンジニアリング北九州寮
27. Building Design + Construction, Nation's first zero energy retail store features metal roof,
    https://www.bdcnetwork.com/nations-first-zero-energy-retail-store-features-metal-roof-composite-panels, 2015
28. Bone Structure, Comparing energy need, https://bonestructure.ca/en/netzero/
29. Bone Structure, Bridge House by Dan Brunn Architecture,
    https://bonestructure.ca/en/articles/bridge-house-by-architect-dan-brunn-straddles-natural-stream-in-los-angeles/, 2020
30. Bone Structure, PROJECT 15-580, https://bonestructure.ca/en/portfolio/project-15-580/, 2016
31. Bone Structure, PROJECT 15-621, https://bonestructure.ca/en/portfolio/project-15-621/, 2016
32. Metal Sales, Case study Bullitt center, https://www.metalsales.us.com/?case_studies=bullitt-center, 2013
33. Metal Sales, CASE STUDY UC DAVIS WEST VILLAGE, https://www.metalsales.us.com/?case_studies=uc-davis-west-village, 2013
34. Jarek Kumitski and Jevgeni Fadejev, K-Rauta hall energy performance, 2013
35. Miika Nuuttila, HVAC system technical and economic utilization possibilities for renewable energy and condensation heat in shopping centres, 2013
36. TATA STEEL, Active Office/Active Classroom, Swansea,
    https://www.tatasteelconstruction.com/en_GB/tata-steel-case-studies/Educational/Active-Office-Active-Classroom-Swansea
37. Lichtenberg, J, Slimbouwen, Aeneas Boxtel, ISBN 90-75365-74-8, 2015
38. Lichtenberg, J, Slimbouwen, a strategy for efficient and sustainable building innovation, paper International Symposium "Construction in the 21st Century–Local and Global Challenge", ARTEC, Rome October 2006
39. Activehouse, House of Tomorrow Today (HoTT), https://www.activehouse.info/cases/house-of-tomorrow-today-hott/
40. https://www.slimbouwen.nl