Part 3

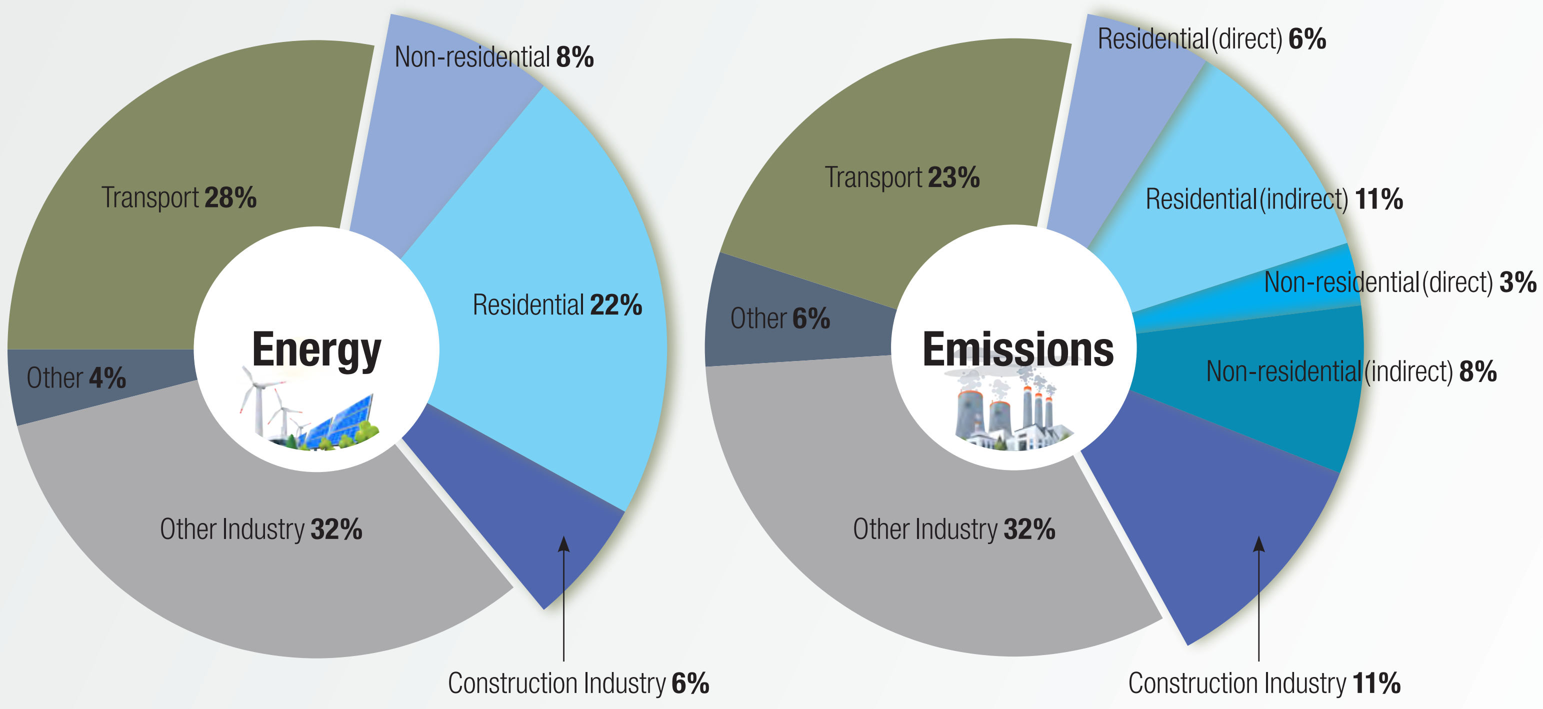
Fact Sheet

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.

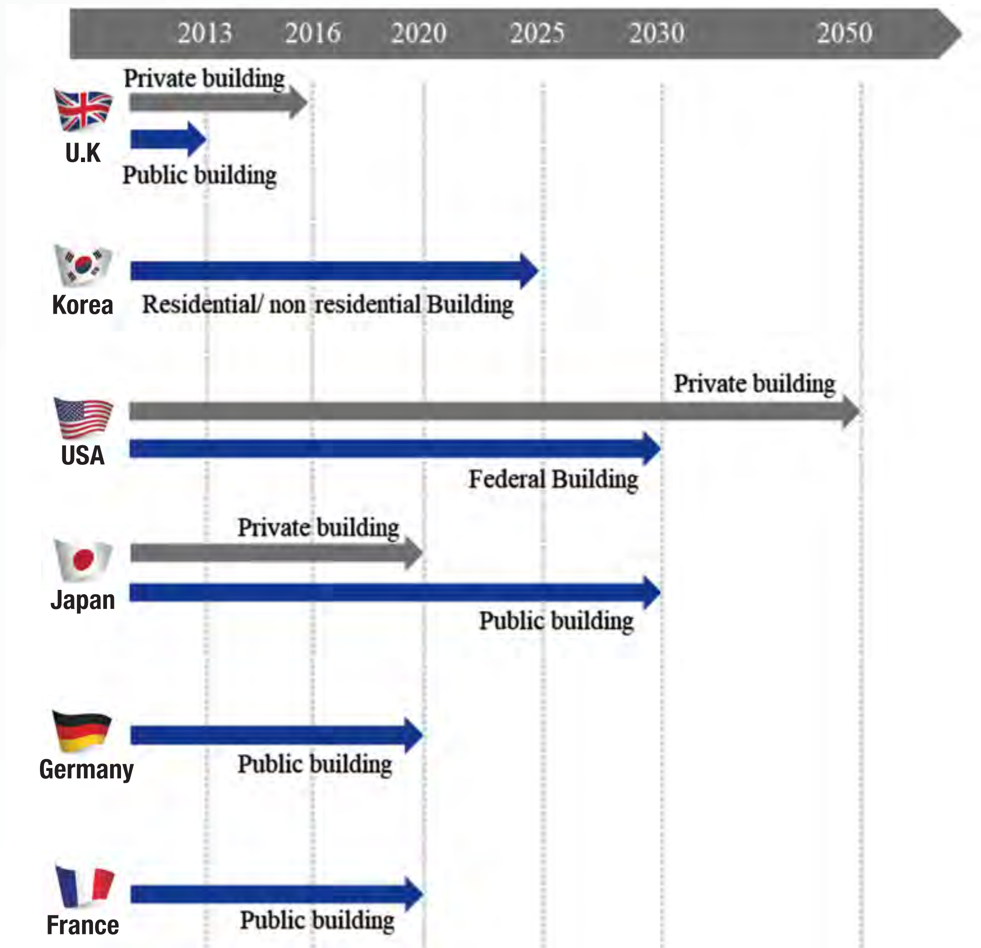
Global share of buildings and construction final energy and emissions, 2017



36% of final energy use

39% of energy-process related emissions

Roadmap to move toward ZEB

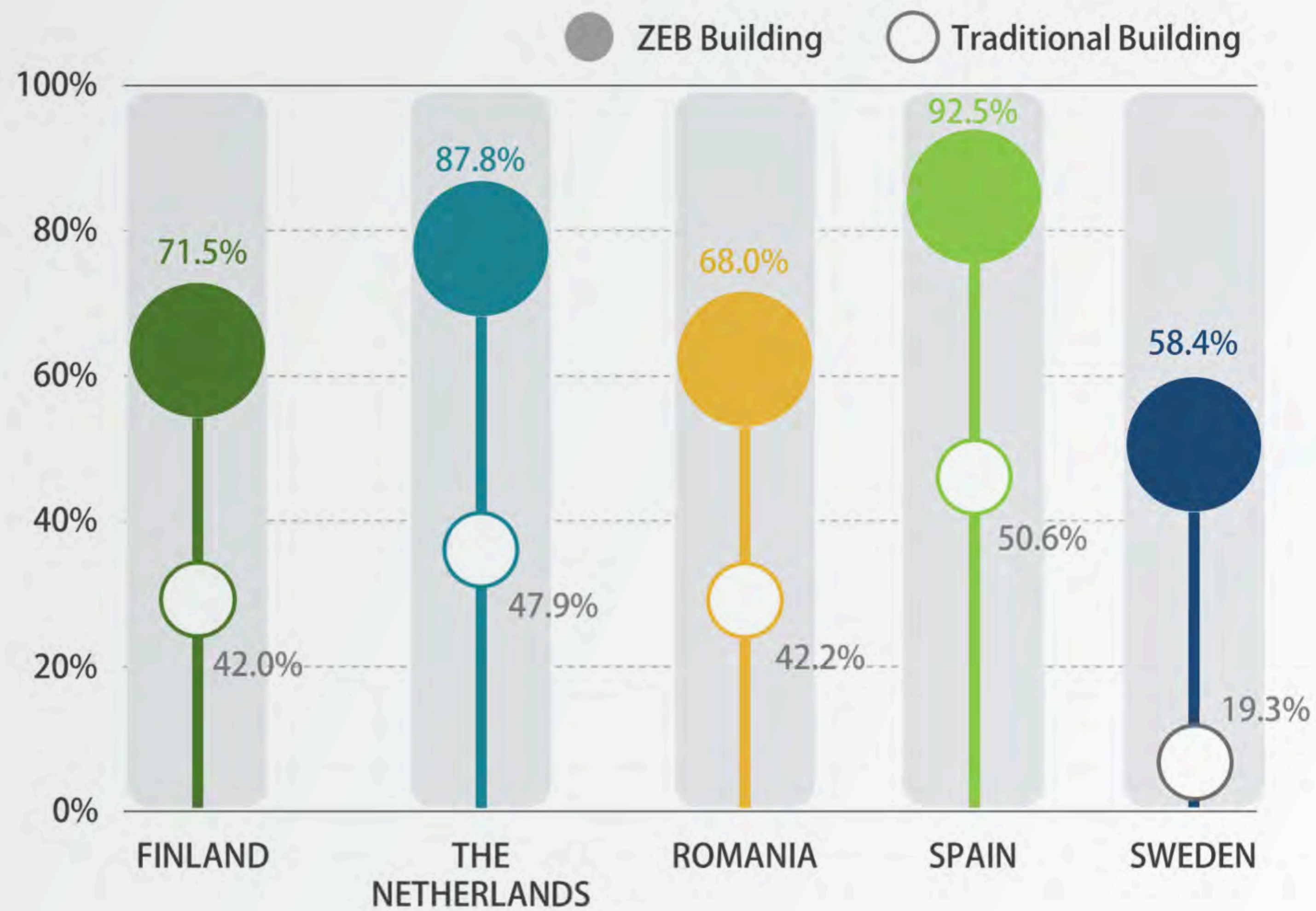


Source : Green Energy Technology Insight 2017 Vol.8, No.5

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

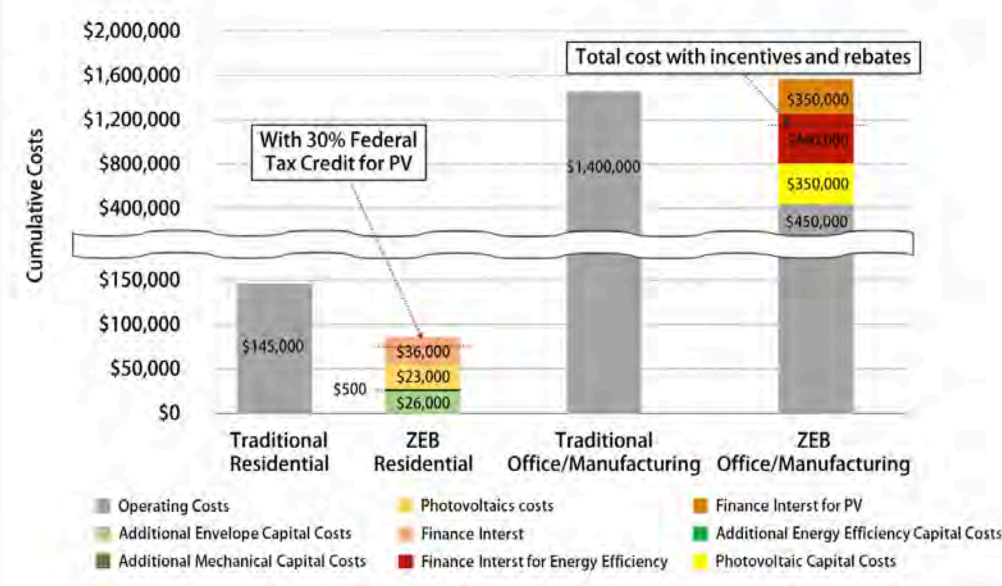


The **energy saving** potential with a ZEB was calculated to be between **60% - 90%**.

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)

Cost

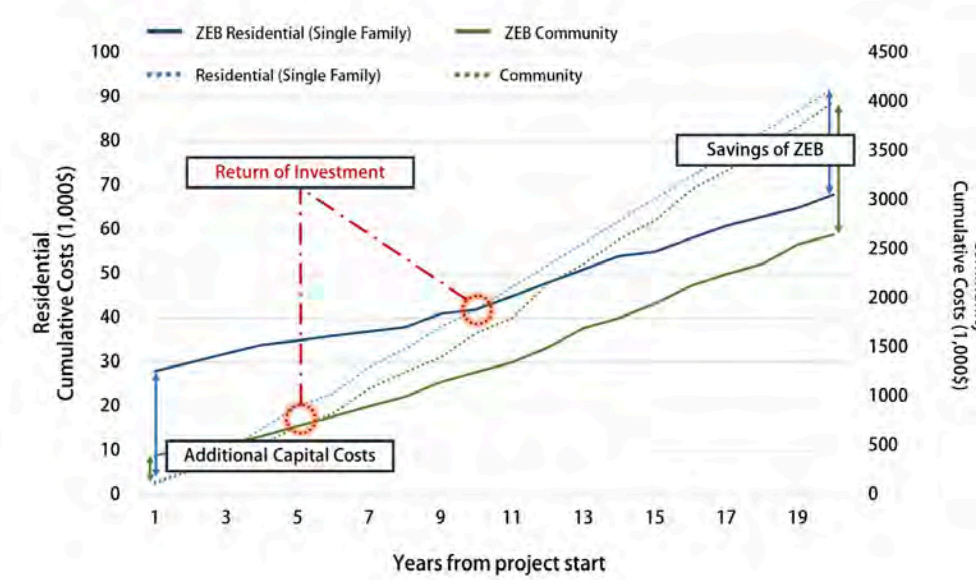


Residential (32,000 ~ 54,000ft²) can save **$1,500 ~ 2,300** per year

Commercial (13,000~27,000ft²) can save **$8,000 ~ 21,000** per year

Community (377,000ft²) can save over **$267,000** per year

Investment



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

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.

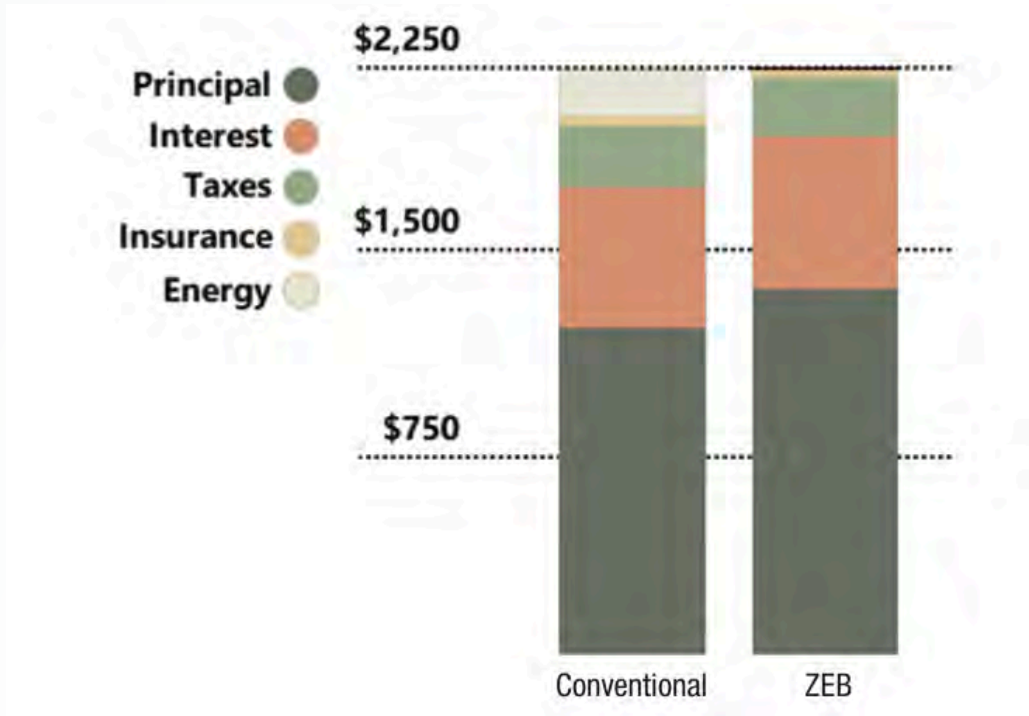
*PITI+E (Principal, Interest, Taxes, Insurance + Energy)

	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



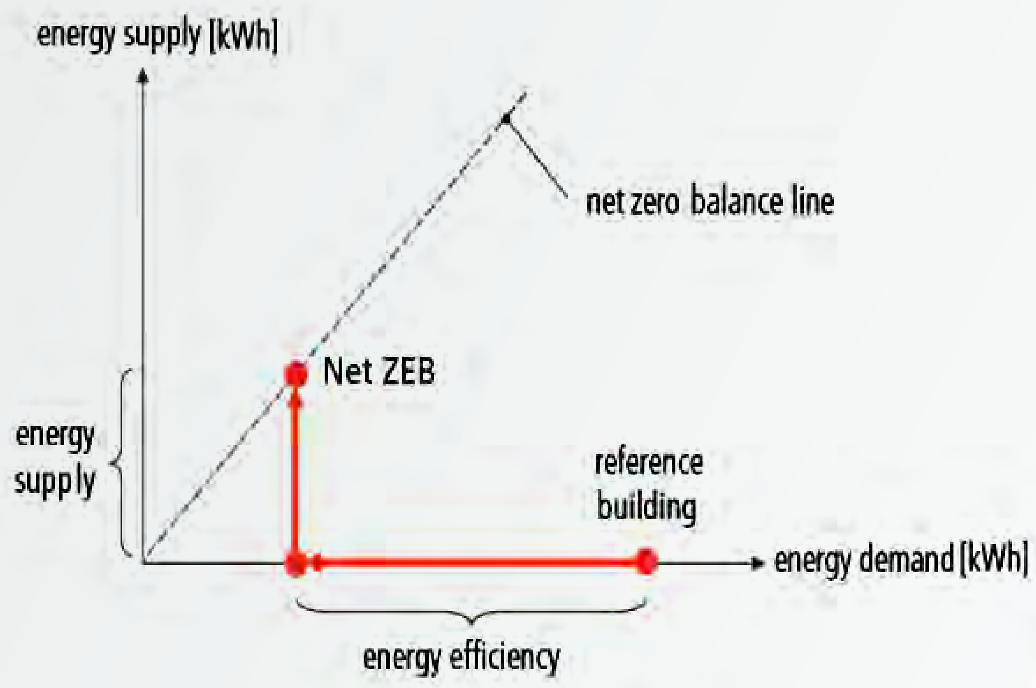
Definition of ZEB

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

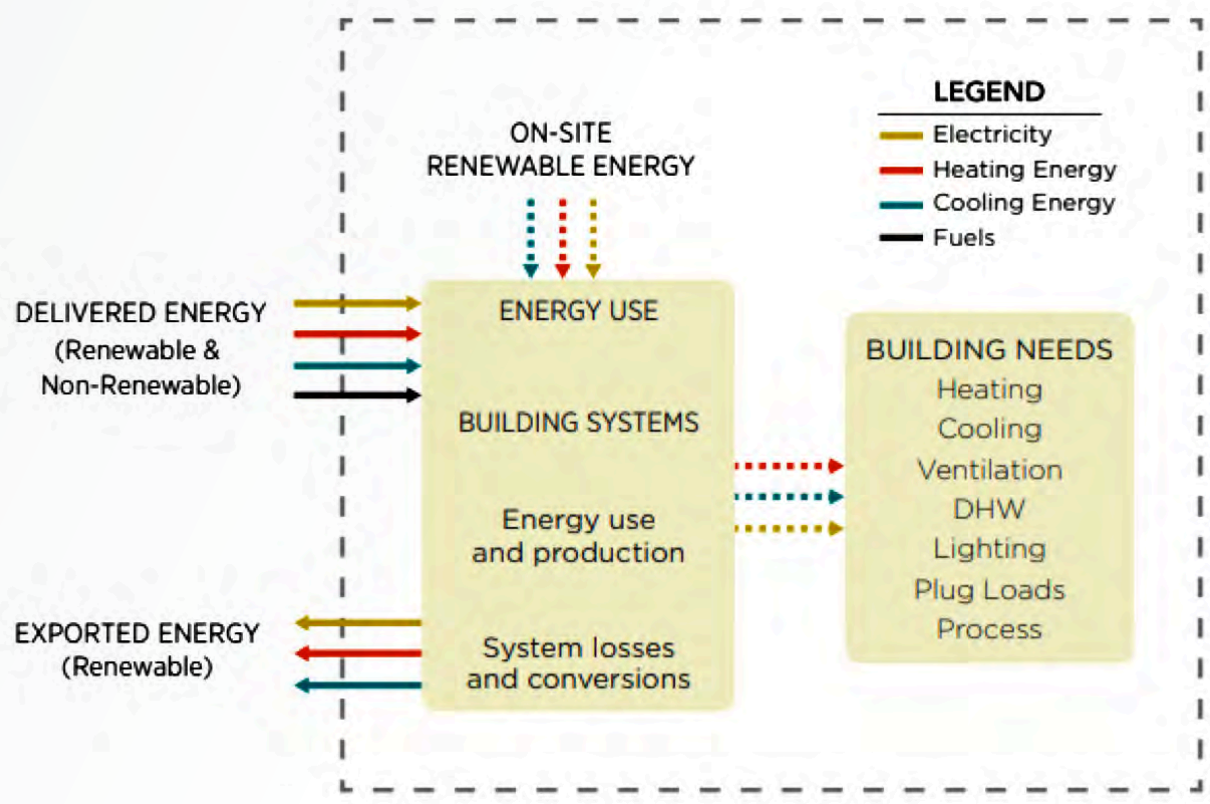
Zero Energy Building

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.

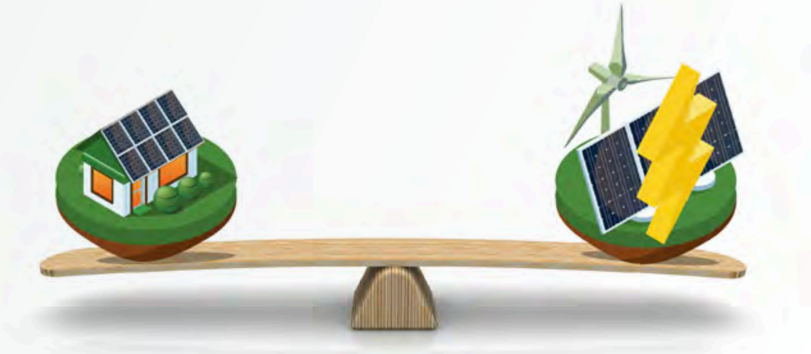
Renewable energy, however, plays a critical role in Nearly Zero Energy Buildings, Net Zero Energy Buildings and Net Plus Energy Buildings. It has been widely adopted as a primary energy source in these buildings to balance the energy use after demand and energy reduction. The difference between energy 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, 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

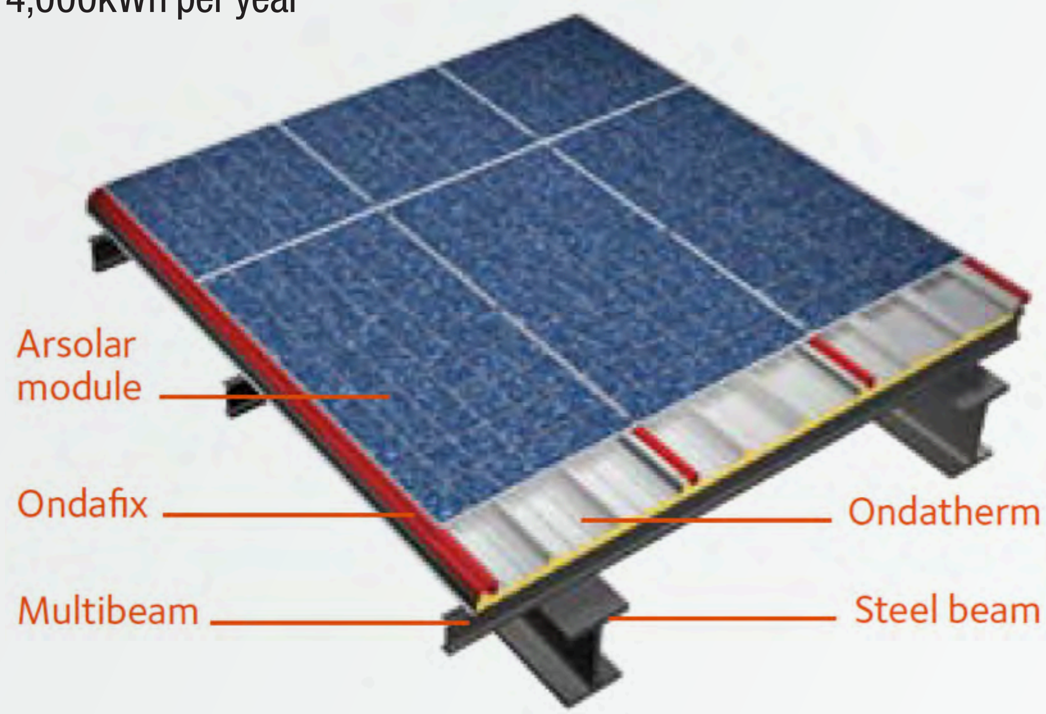
Roofing and Photovoltaic System

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

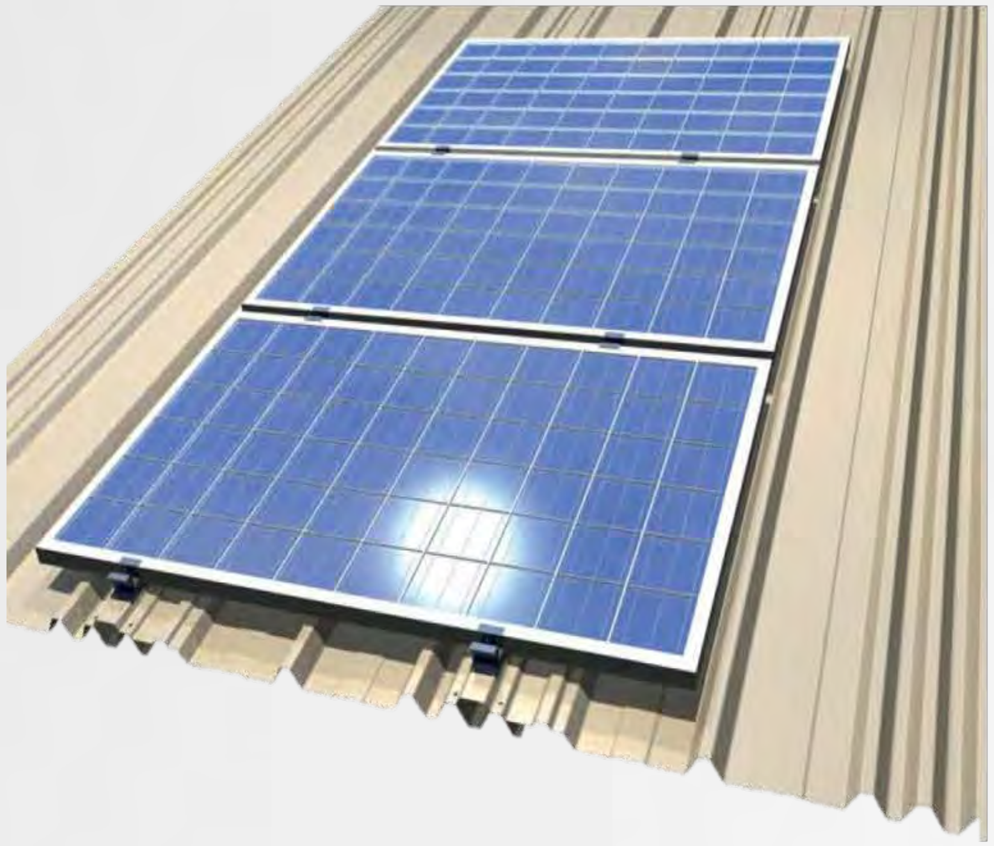
Type:	polycristalline silicium cells
Nominal Power:	135-142 Wp/m^2 (±5%)

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

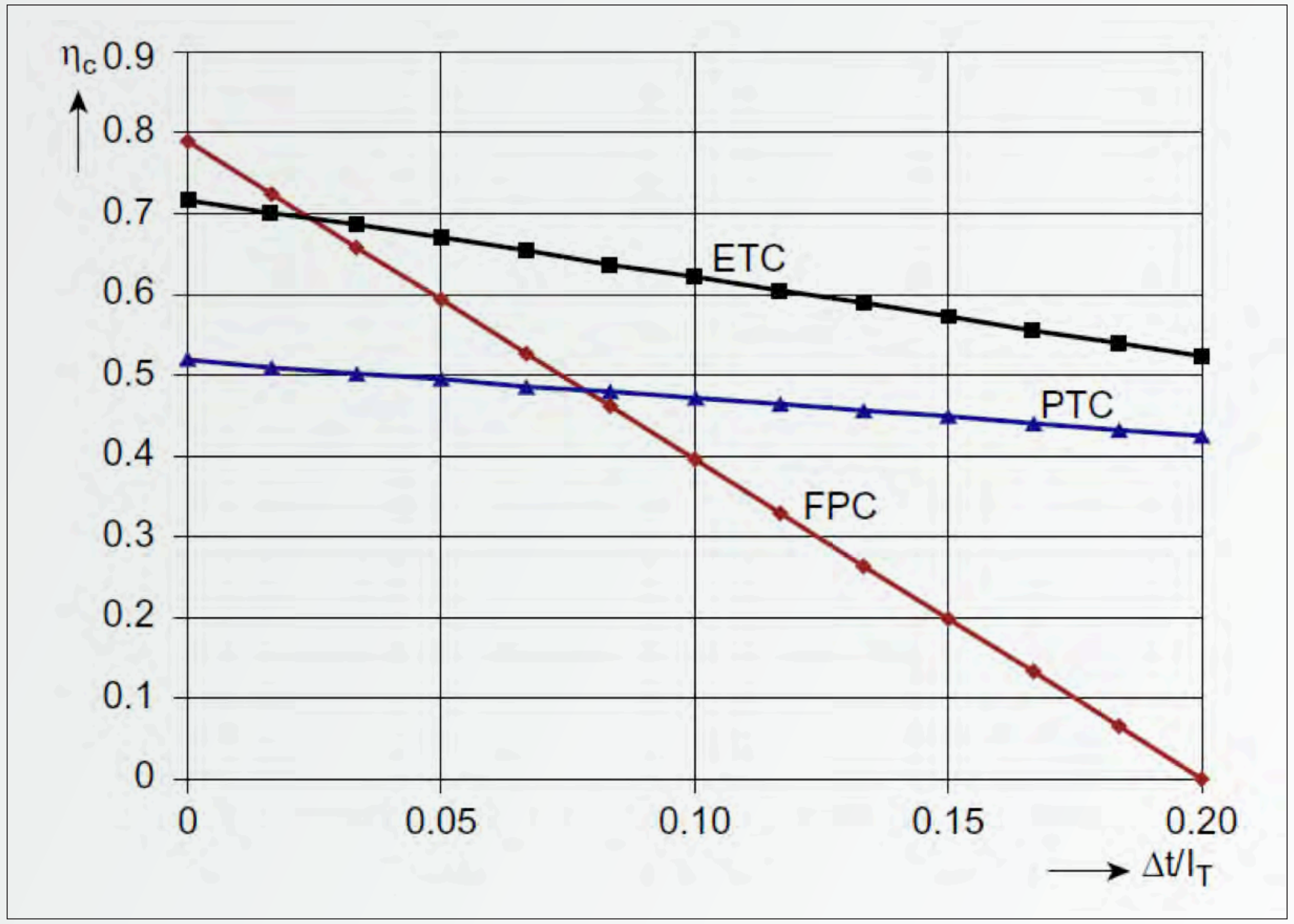
Source: ArcelorMittal Avis Technique 21/14-49_V2 Komet®,

Solar Heating System

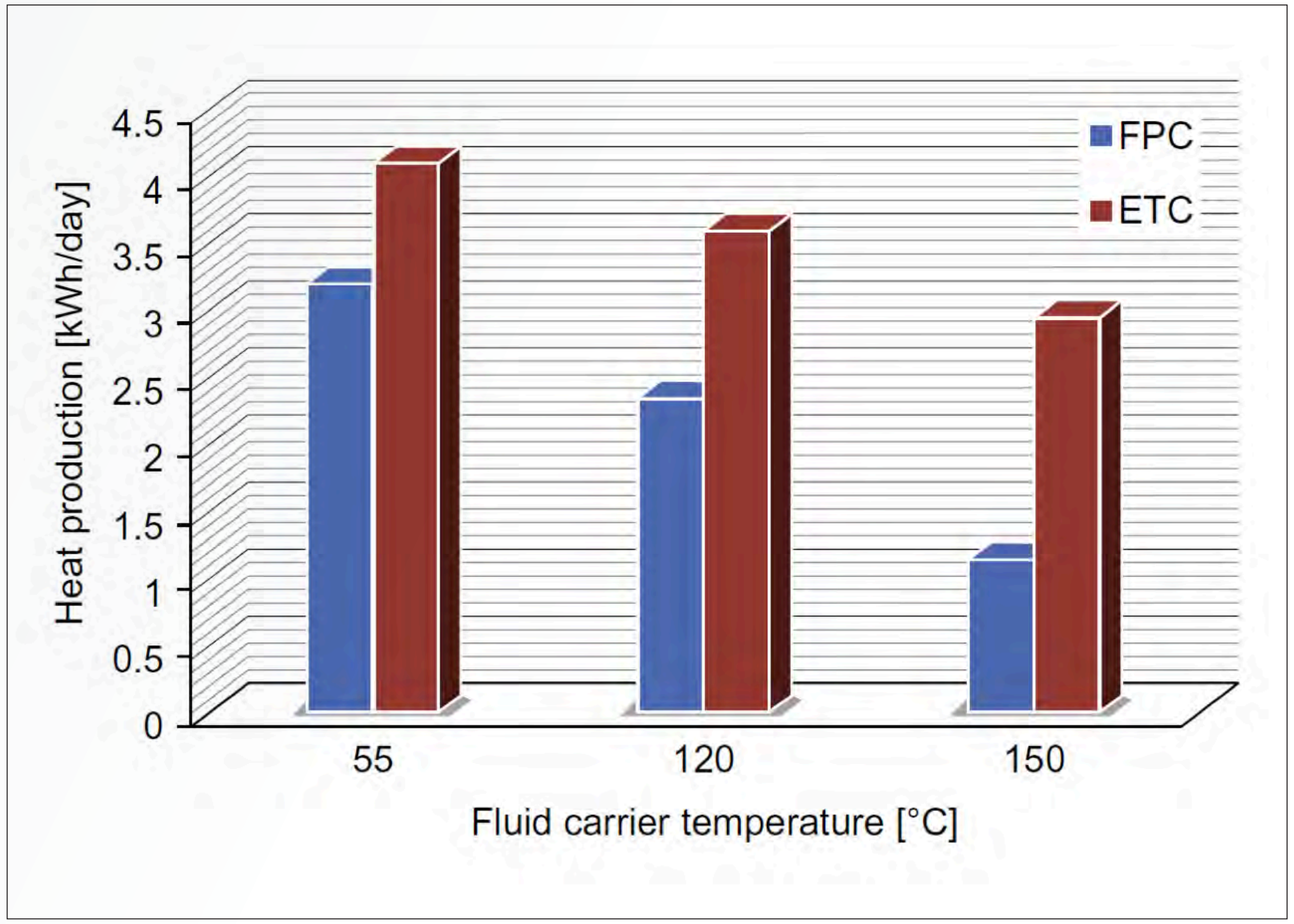
Efficiency of roof solar heat collector

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

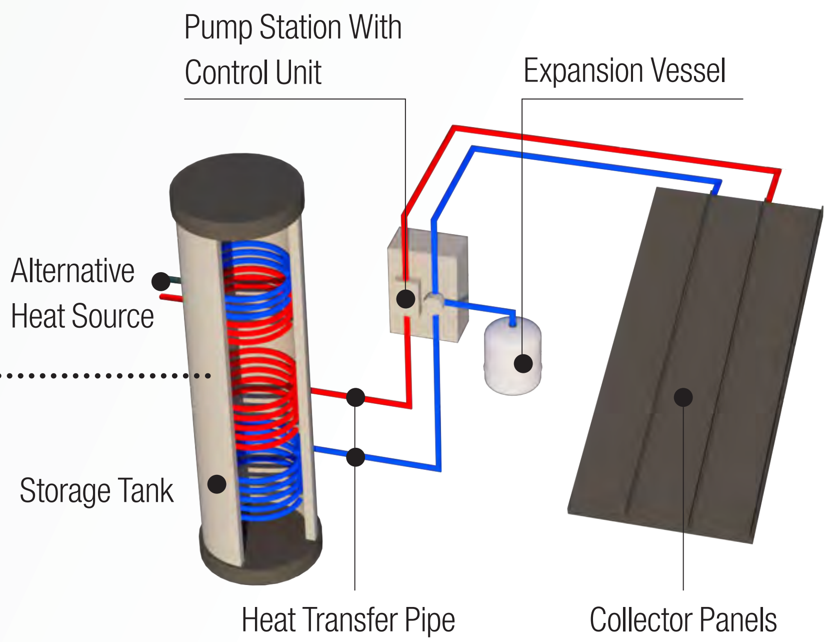
Solar Thermal Solution

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.

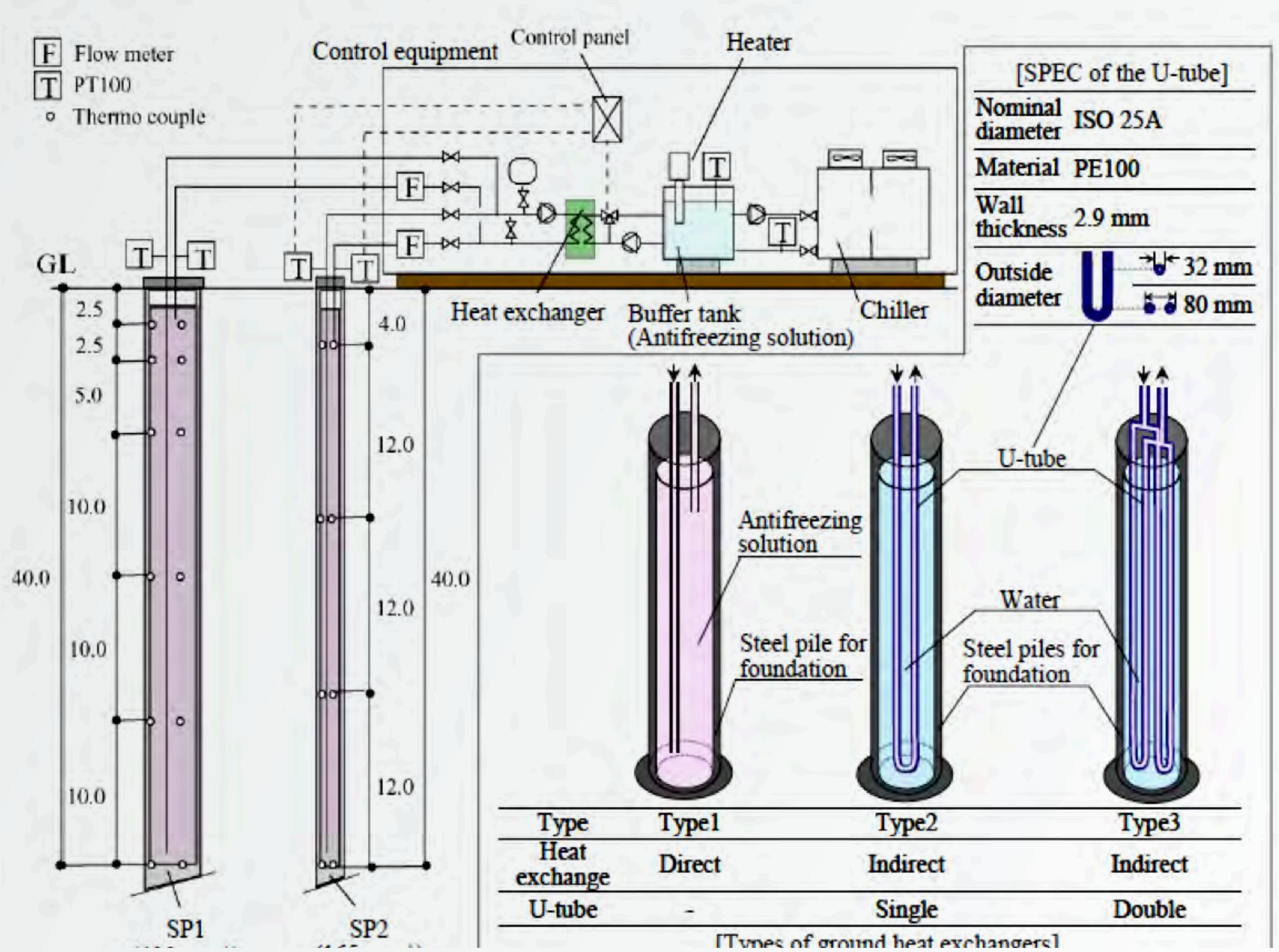


Table 1. Experimental conditions

Exp.No.	Steel pile	Type of the ground heat exchanger	m_f [l/min]	$T_{f\text{-}in}$ [°C]	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

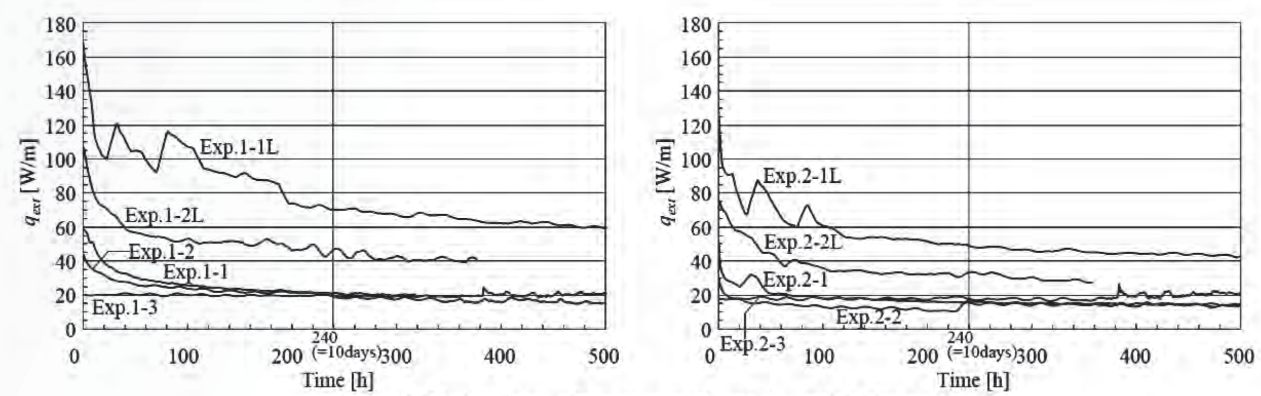


Fig. 4. Variations of extracted heat q_{ext} with time

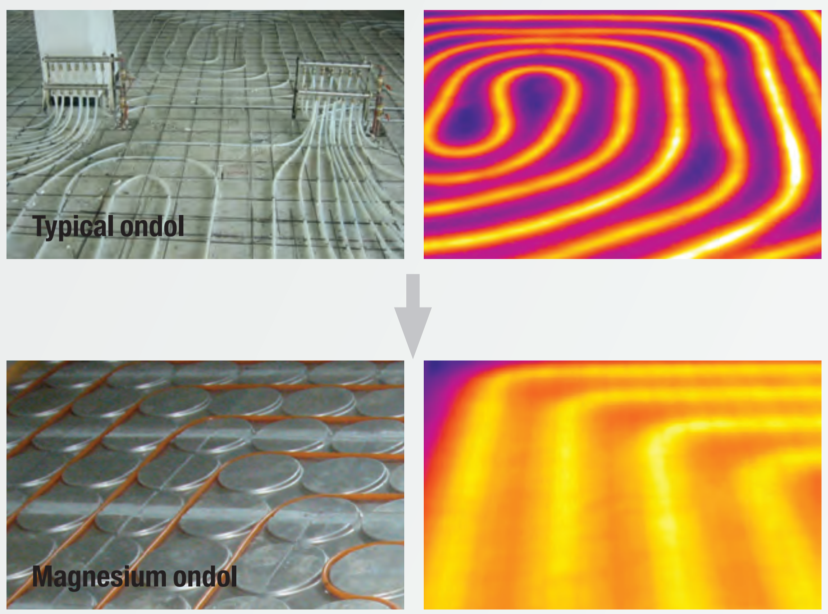
Source : K. Nagano et al., THERMAL CHARACTERISTICS OF STEEL FOUNDATION PILES AS GROUND HEAT EXCHANGERS

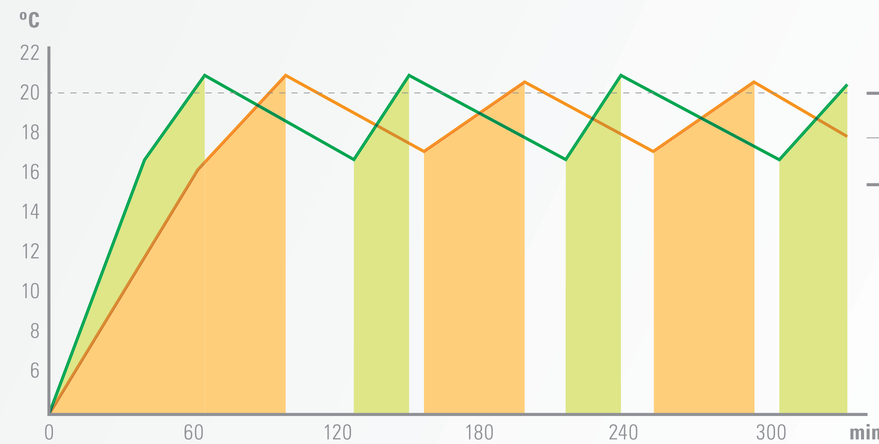
Radiant Floor Heating Solution

Magnesium radiation plate for floor heating (POSCO)

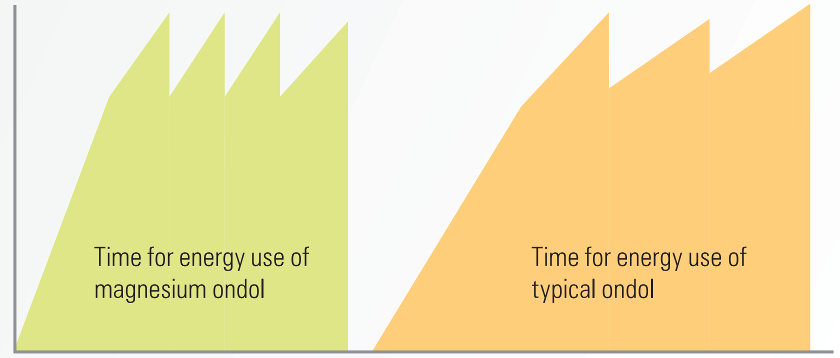
Magnesium radiant floor heating system not only improves heating performance, but also economics for construction and maintenance costs, and reduces floor noise. Radiant flo heating system can be constructed in a short time with a small number of people, contributing to labor cost reduction and shortening 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.

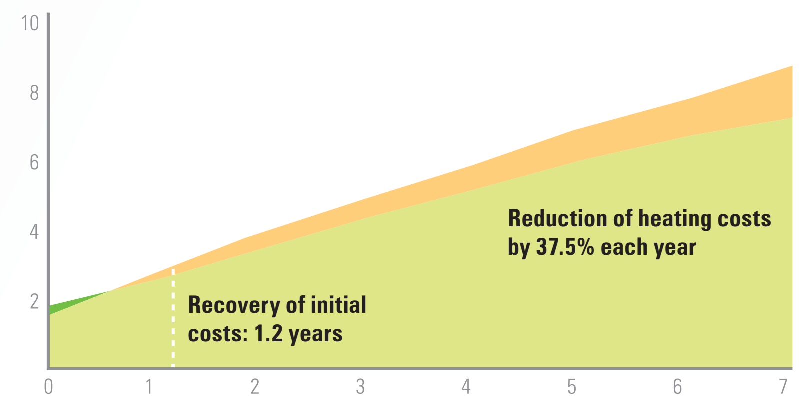
Characteristics of Magnesium Ondol panel





	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.

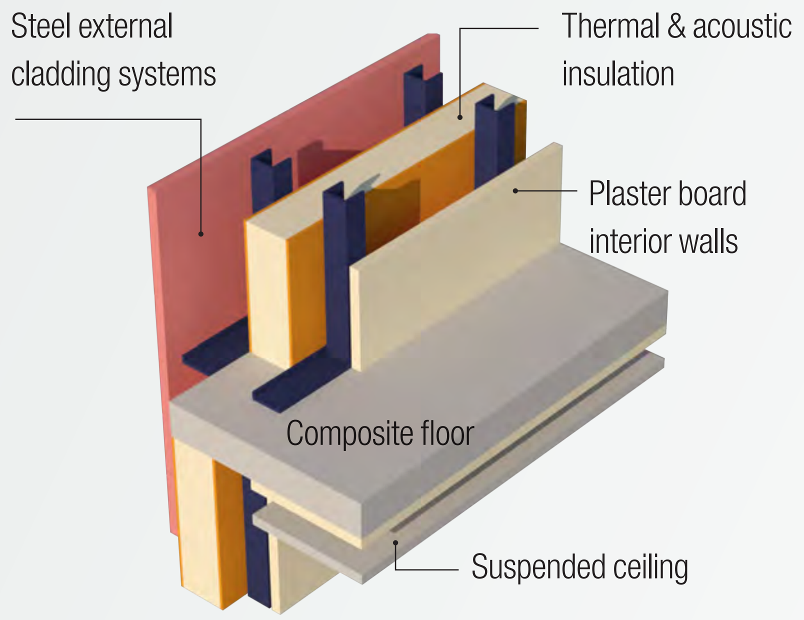
Source : TATA Steel, Colorcoat® High Reflect data sheet

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.

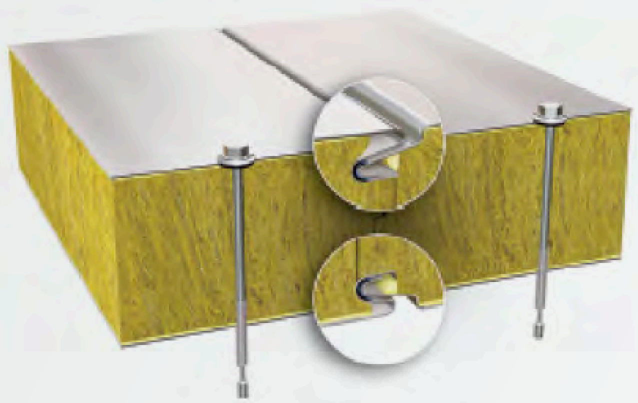
Source : ArcelorMittal, K'energy – your key to save energy

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

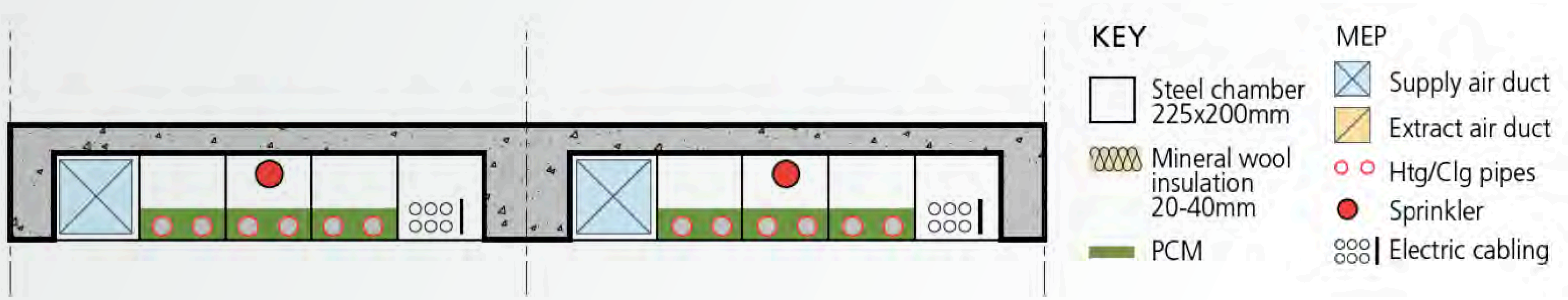
PCM Thermal Storage

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



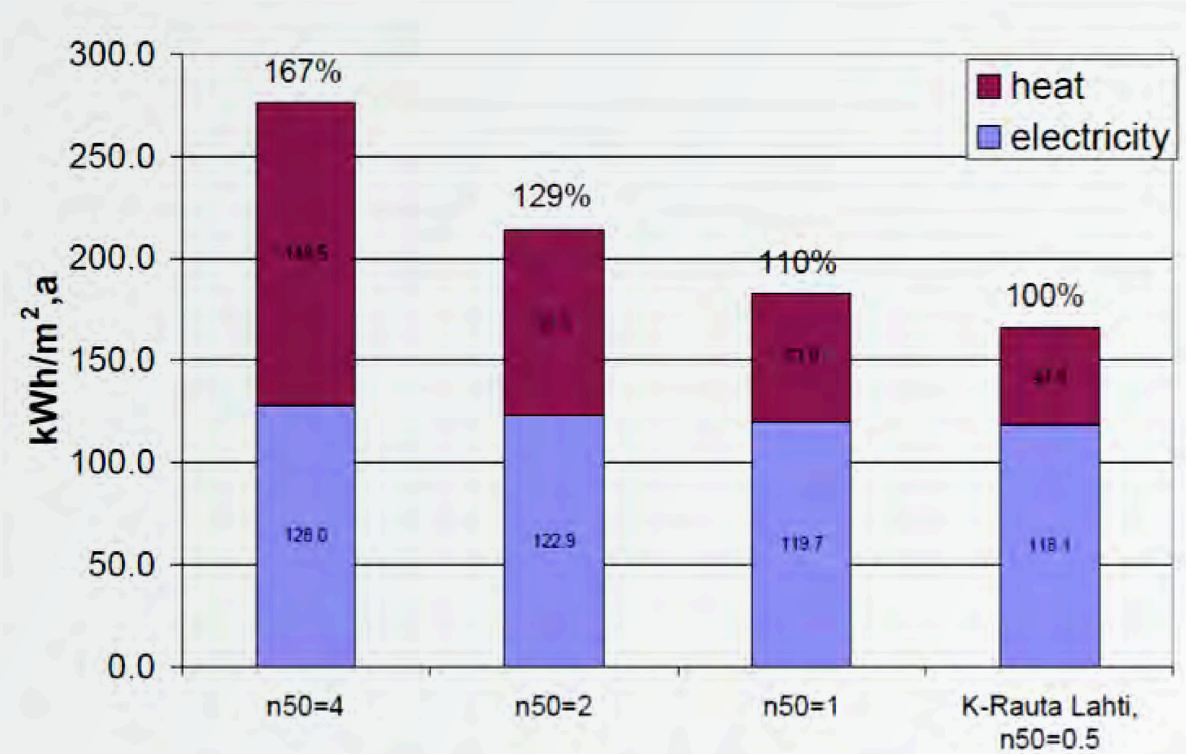
Source : Zemusic, Design Guide for Steel Intensive Nearly – Zero Energy Office Buildings, WP 6.4

Airtightness System

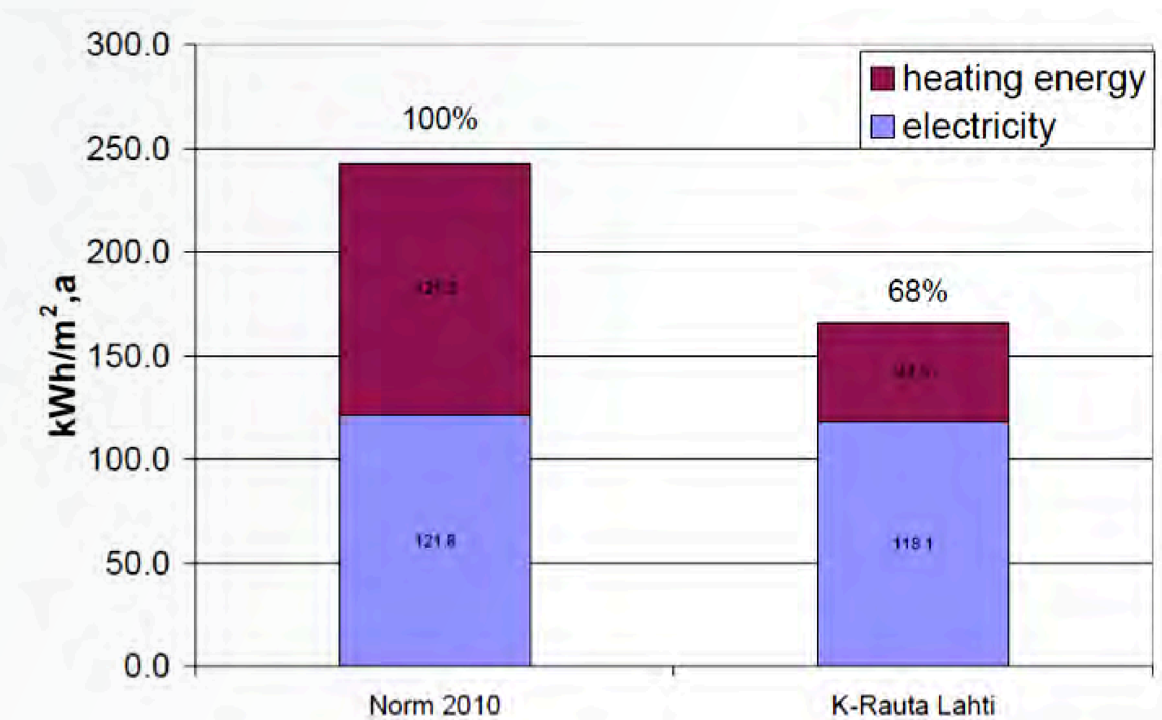
Airtightness system

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



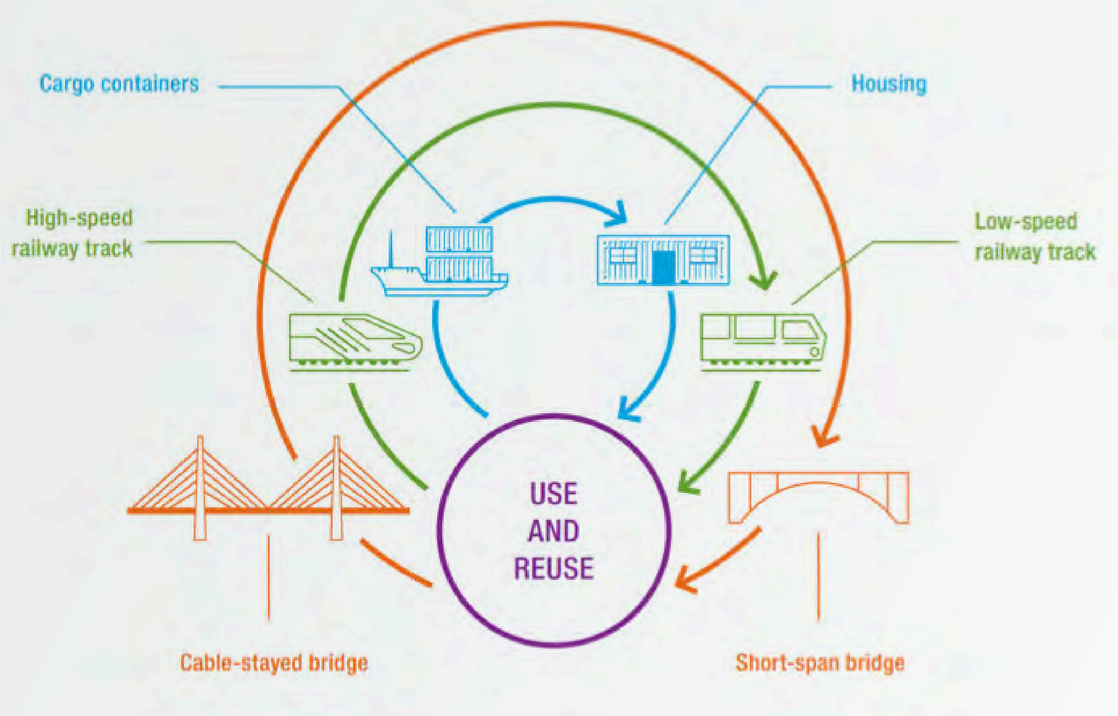
Source : Jyrki Kesti and Petteri Lautso, Improving life cycle efficiency in single-storey commercial buildings

Steel Structure Sustainability

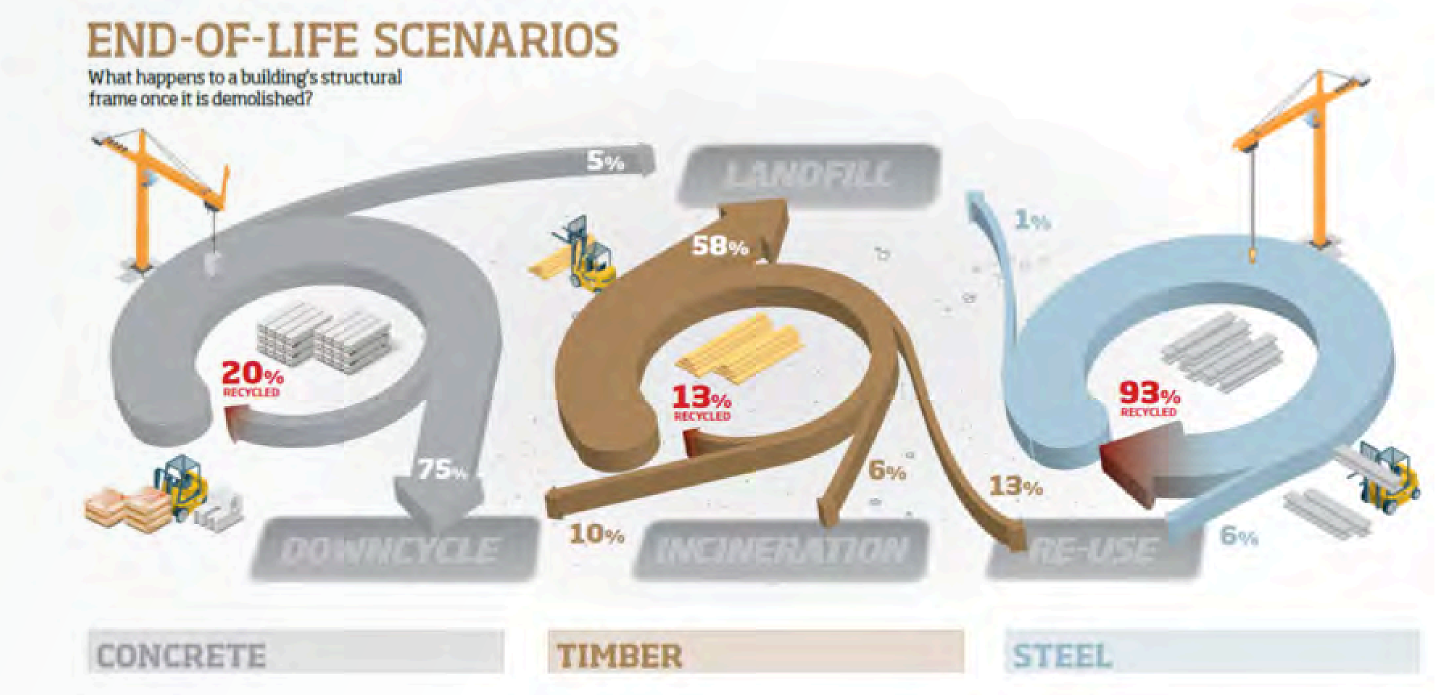
Reuse in steel structure

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