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 energy use and 39% of energy-related carbon dioxide (CO₂) 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.

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


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)

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

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

Definition of ZEB

A Common definition for Zero Energy Building

In addition to establishing a definition for ZEB, shown below, it was clear that definitions were needed to accommodate the collection of buildings where renewable energy 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.


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.
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 energy 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 114~133 kWh/m² per year.
The BIPV solution in roofing can produce up to 14% higher energy than conventional BIPVs.
(Energy production of conventional BIPV: 100~130 kWh/m²/year)

Arsolar® Plus Photovoltaic System

30~35 m² of roofing produce
4,000 kWh per year

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)
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

<table>
<thead>
<tr>
<th>Modules Recom Sillia 60MXXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{m}</td>
</tr>
<tr>
<td>U_{m}</td>
</tr>
<tr>
<td>I_{m}</td>
</tr>
<tr>
<td>αT P_{m} [%/K]</td>
</tr>
<tr>
<td>αT U_{m} [%/K]</td>
</tr>
<tr>
<td>αT I_{m} [%/K]</td>
</tr>
<tr>
<td>Reverse current Maximum (A)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modules Recom Sillia 60PXXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{m}</td>
</tr>
<tr>
<td>U_{m}</td>
</tr>
<tr>
<td>U_{an}</td>
</tr>
<tr>
<td>I_{m}</td>
</tr>
<tr>
<td>I_{sc}</td>
</tr>
<tr>
<td>αT P_{m} [%/K]</td>
</tr>
<tr>
<td>αT U_{m} [%/K]</td>
</tr>
<tr>
<td>αT I_{m} [%/K]</td>
</tr>
<tr>
<td>Reverse current Maximum (A)</td>
</tr>
</tbody>
</table>

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

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 recharging 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%.

Performance of energy pile system

In Japan, field experiments were conducted with 25 eight-meter-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.

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 floor 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% faster than the normal system.

**Characteristics of Magnesium Ondol panel**

<table>
<thead>
<tr>
<th>Source</th>
<th>Magnesium radiation plate, floor heating panel having the magnesium radiation plate and floor heating panel system having the floor heating panel and POSCO, magnesium radiation panel catalog</th>
</tr>
</thead>
</table>

[Graph showing temperature changes over time and energy use]

**Heating time**

- **Typical ondol**: 86.54 min
- **Magnesium ondol**: 57.93 min

**Heat retention time**

- **Typical ondol**: 79.68 min
- **Magnesium ondol**: 67.91 min

**Re-heating time**

- **Typical ondol**: 29.15 min
- **Magnesium ondol**: 18.84 min

**Time for energy use of magnesium ondol**

- Recovery of initial costs: 1.2 years
- Reduction of heating costs by 37.5% each year
Reflective Panel System

Colorcoat® High Reflect

The optimum reflectivity for an internal line, maximizing daylight and reducing requirements for artificial lighting. Colorcoat® High Reflect is a bespoke liner designed with maximum reflectivity to reduce energy requirements, associated operational costs and CO₂ emissions.

Test building with Colorcoat®

- ≥ 85% reflectance, reducing the amount of energy required to achieve the same level of lighting
- Significantly reduces CO₂ 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

<table>
<thead>
<tr>
<th>Lux</th>
<th>Energy savings (%)</th>
<th>CO₂ reduction (%)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>11</td>
<td>3*</td>
<td>9.8</td>
</tr>
<tr>
<td>500</td>
<td>12</td>
<td>3*</td>
<td>3.8</td>
</tr>
<tr>
<td>1000</td>
<td>12</td>
<td>3*</td>
<td>1.1</td>
</tr>
</tbody>
</table>

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

- 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, Steel solutions for green building

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**

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

**Source:** Ruukki, Sandwich panels Environmental product declaration EN 15804 ISO 14025

**Source:** Ruukki, Energy-efficient sandwich panels
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

Airtightness System

Airtightness system

According to the reference, the airtightness has very high influence on the heating energy 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 for 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
1. Green Energy Technology Insight 2017 Vol.8, No.5
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