Energy systems and services for zero emission buildings and neighborhoods

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Outline

• The Norwegian Research Centre on Zero Emission Buildings - ZEB
  – Facts and organization
  – Selected research activities
  – Energy supply systems and building services
  – Pilot project
  – Laboratories

• The new centre for environment-friendly energy research on buildings
Innovative Technologies and Processes for Buildings

– The Research Centre on Zero Emission Buildings
ZEB’s Main Objective

is to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings with zero greenhouse gas emissions related to their
* production,
* operation, and
* demolition.

The centre will encompass both residential, commercial, and public buildings.

www.zeb.no
ZEB Facts

• ZEB is a Centre for Environment-friendly Energy Research (FME), funded by the Research Council of Norway (RCN) and 25 partners.

• Host institution is NTNU with SINTEF Building and Infrastructure and SINTEF Energy Research as research partners.

• Centre started in November 2009,
• RCN funds the Centre for 8 years (5+3)
• 50% funding from industry.

• Total budget: ca. US $ 47 mill
• + Additional for research infrastructure
Expertise in the ZEB Centre

• ZEB includes experts within material science, building technology, energy technology, architecture, and social science.

• Strong industry involvement will put focus on finding cost-effective and competitive solutions.

• ZEB encompasses the whole value chain of market players within the Norwegian construction sector.

• ZEB cooperates with international well-known research institutions with relevant activities.

• The expected volume of formally trained research personnel is 15 PhD-students, 5 post-doctoral fellows and at least 50 MSc-students.
ZEB – A National Team

- Users (the reference group)
- Contractors
- Producers of materials and components for the building industry
- Consulting engineers, architects
- Property managers
- Public administration
- Trade organizations
- University and research institutions
- The Research Council
Other institutions cooperating with ZEB:

International partners:
- VTT (Finland)
- Chalmers (Sweden)
- Fraunhofer (Germany)
- TNO (The Netherlands)
- LBNL (USA)
- MIT (USA)
- University of Strathclyde (Scotland)
- Tsinghua University (China)
- Shanghai Jiao Tong University (China)

The reference group:
- Lavenergiprogrammet
- NBBL
- NVE
- Forbrukerrådet
- EcoBox
- Driftsforum
- Enova

In addition, we are actively involved in a number of IEA projects within the SHC and EBC programmes (Tasks 40, 41, 42,..., Annex 53, 58 ..), as well as in a number of EU and Nordic research projects.
Energy Use in Buildings in Norway

- Production of energy carriers: 7%
- Industrial processes: 25%
- Buildings (residential and non-residential): 31%
- Mobile energy use - All vehicles and means of transportation: 37%

83 TWh til bygninger, hvorav 80% er elektrisitet.

Source: Energibruk i Fastlands-Norge, NVE, 2011
Why Zero Emission Buildings?

• Norwegian Policy documents
  – Two White Papers from the Norwegian government in 2012 stress all new buildings should be nearly zero energy buildings before 2020. Stricter requirements will also apply to rehabilitation of existing buildings

• EU Regulation: The Energy Performance of Buildings Directive 2010/31/EU (EPBD)
  – Member States shall ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings
Why Zero Emission Buildings?

Global GHG abatement cost curve beyond business-as-usual – 2030

Low Hanging Fruit: Energy Efficiency Pays for Itself

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO$_2$e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: Global GHG Abatement Cost Curve v2.0

The challenge:

Renewable energy sources produced or transformed at the building site have to compensate for CO₂ emissions from operation of the building and for production, transport and demolition of all the building materials and components during the life cycle of the building.

Source: SINTEF Byggforsk
ZEB Research Activities

ZEB will focus its work in areas that interact and influence each other:

- **WP1** Advanced materials technologies
- **WP2** Climate-adapted low-energy envelope technologies
- **WP3** Energy supply systems and services
- **WP4** Use, operation, and implementation
- **WP5** Concepts, strategies and demonstration buildings
- **Laboratories**

Nano insulation material

VIP Leca Isoblokk

Membrane heat exchanger

ZEB Living Lab

ZEB Pilot buildings

ZEB Definition
Nano Insulation Materials (NIM)

From theoretical concepts to development of new and innovative materials

\[ \lambda_{\text{gas}} = \frac{\lambda_{\text{gas},0}}{1 + 2\beta K_n} = \frac{\lambda_{\text{gas},0}}{1 + \frac{2\beta k_B T}{\pi d^2 p \delta}} \]

\[ K_n = \frac{\sigma_{\text{mean}}}{\delta} = \frac{k_B T}{\sqrt{2\pi d^2 p \delta}} \]

Without optimizing: So far we have reached 20 mW/(mK)

**Patent application**

- **Controlling:**
  - Sphere inner diameter
  - Sphere wall thickness

**ZEB**
The Research Centre on Zero Emission Buildings
A new glass material

- A new glass material has been made:
  - Reduced mass density (weight) by a factor 1.6
  - Reduced thermal conductivity by a factor 5.4
  - Increased solar transmittance

Various other glass and coating properties are being investigated

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ZEBO The Research Centre on Zero Emission Buildings
Development of Sandwich Elements with VIPs (Leca Isoblock)

- Development of thinner building components
- Prototype developed by ZEB partner Weber (patent has been applied for)
NorDan and Aventa Solar have developed a solar thermal collector that can be easily integrated in the facade
New Type of a Cross Flow Energy Exchanger using Membrane Technology

- Development of improved energy exchanger using membrane technology

- Recovery of moisture in addition to sensible heat will increase the overall energy efficiency of the exchanger.

- This will also reduce frosting problems in operation but it demand very careful design of the exchanger.
Modern Energy Supply

- Modern energy supply is centralized, where almost all production is industrial in large units, and then distributed to the markets due to:
  - Energy efficiency
  - Operation and maintenance
  - Reliability
  - Economy
Expectations for future energy supply for future buildings

- Efficient
- Flexible
- Decentralized
- Based on renewable sources
- Without green house gas emissions
  - Zero Emission Buildings - ZEB
Future Energy Supply

ZEB will focus on distributed and smaller units. Some of the benefits:

- Uses resources with less carbon footprint
- Uses local resources
- Less distribution and transport cost
- Less distribution loss

But small scale energy supplies also have some serious challenges:

- Lower energy efficiency
- Drawbacks locally with: noise, disturbance, traffic, area use, odors, dust and security
- Worse operation and maintenance, with more cost and effort
- More fluctuating energy sources
- Less reliability
- Higher investments
Technologies for Energy Supply

- Energy source
- Energy storage
- Supply system

Building

Users demand + financial budget
Technologies for Energy Supply

Supply system
- Combined Heat and Power (CHP/CCHP)
- District Heating
- Fuel Cell
- Heat Pump

Renewable energy source
- Biomass boiler
- Solar Thermal
- PV - Photovoltaic
- PVT - PV + Thermal
- Micro Wind Turbine

Energy storage
Simple decision support tool for selection of energy supply solutions in an early project design phase

- Study among partners and relevant players in the building industry in Norway focusing on obstacles for wider use of new technologies and solutions for energy supply discovered a great lack of necessary knowledge regarding practical application.

- A simple decision support tool focusing on selection of energy supply solutions in an early project design phase supported by a database on energy supply technologies which are good and robust for the near future under Norwegian conditions will enhance market penetration of new technologies and solutions.
Life Cycle Inventory for ventilation ductwork components
Analyses of End-Use in Energy Efficient Buildings

• Evaluation of new buildings with high energy ambitions
  – Bad interfaces
  – Lack of knowledge

• Unintended persistence of energy wasting behaviors (when refurbishing)
  – Deeply rooted values and attitudes
  – Negotiations within the household
The main concept of a zero emission building is that renewable energy sources produced or transformed at the building site have to compensate for CO2 emissions from operation of the building and for production, transport and demolition of all the building materials and components during the life cycle of the building.
Zero Emission Building Definition

Ref: B. Risholt et al.
Figure 6.6 Green house gas emissions divided on main material and technical inputs
Embodied and operational emissions

- Embodied emissions: 6.9 kg/m²/year (58%)
- Emission operation: 5.0 kg/m²/year (42%)
ZEB-Pilot Buildings

ZEB PILOT BUILDINGS:
4. Ådland, Bergen. 500-800 dwellings.
7. ZEB Living Lab, Trondheim.
Powerhouse Brattørkaia - Trondheim

<table>
<thead>
<tr>
<th>Area</th>
<th>Electricity Production per Solar Cell Area [kWh/m² year]</th>
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<tbody>
<tr>
<td>Roof 26 degrees</td>
<td>191</td>
</tr>
<tr>
<td>Roof 20 degrees</td>
<td>185</td>
</tr>
<tr>
<td>Roof 18,9 degrees</td>
<td>184</td>
</tr>
<tr>
<td>Roof 17,3 degrees</td>
<td>182</td>
</tr>
<tr>
<td>Roof flat</td>
<td>136</td>
</tr>
<tr>
<td>Roof towards north</td>
<td>97</td>
</tr>
<tr>
<td>Western facade</td>
<td>95</td>
</tr>
<tr>
<td>Southern facade</td>
<td>155</td>
</tr>
</tbody>
</table>
Powerhouse Brattørkaia - Trondheim

2013 version

- Roof angle 20 degrees
- Heated area 13 114 m²
- Average yearly solar energy 607 212 kWh
- Average yearly energy balance during the life of the building divided by heated area: +3.0 kWh/m²-year
- Height C + 42.8
Upgrading of existing buildings
Pilot building in Sandvika – Powerhouse Kjørbo
POWERHOUSE #2

POWERHOUSE #2 CONCEPT:

1. VENTILATION: Innovative building integrated low pressure solution.
2. CONSTRUCTION: Optimised building envelope.
3. THERMAL PRODUCTION: High performance geothermal system for space heating, cooling and DHW production.
4. HEATING: Innovative simplified hydronic heating system.
5. COOLING: Optimised thermal mass, low internal loads and use of free cooling from the bore holes.
6. DAYLIGHT: Optimised facade solution and floor plan for good daylight condition.
7. PV-PRODUCTION: PV-production on roof and nearby parking facility.
8. MATERIAL CHOICES: Materials with low embodied energy chose where possible, extensive reuse of materials.
Establishment of Test Buildings at NTNU – ZEB Living Lab and Test Cell

ZEB Living Lab – A dwelling for user-technology studies

ZEB Test Cell for testing different technologies

The Research Centre on Zero Emission Buildings
ZEB Living Lab

- 100 m² living area
- Building Integrated Photovoltaics: 80 m²
- Solar panel in the facade
- Ground to water heat pump
- Heat recovery system
- A part of student work
ZEB Living Lab

The Research Centre on Zero Emission Buildings
ZEB Test Cell

- Collaboration with Lawrence Berkeley National Laboratory
- PhD and MSc student activities
New centre for environment-friendly energy research on buildings

Illustration: Snøhetta
The research centre on zero emission building communities

Vision

• To decarbonise the building stock in the context of smart cities
• The Centre will focus on the building communities dimension since this is the necessary link between individual energy efficient buildings and the smart city

Duration

• 2016-2023

Application deadline

• November 25, 2015.
The research activities to be carried out in the centre will depend on partner interest and input.
Work packages

1. Analysis and design for transformation to zero emission building communities
2. Building materials and technologies
3. Building and community energy system and services
4. Smart planning and design, demonstration projects and test facilities
## Potential partners, so far

<table>
<thead>
<tr>
<th>Category</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>Oslo, Bergen, Trondheim, Bodø</td>
</tr>
<tr>
<td>Property owners/developers</td>
<td>TOBB, ByBo, Statsbygg</td>
</tr>
<tr>
<td>Consultants and architects</td>
<td>Snøhetta, Multiconsult, Reinertsen, Asplan Viak, Civitas</td>
</tr>
<tr>
<td>Contractors</td>
<td>Caverion, Skanska, GK, Veidekke, NCC</td>
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<tr>
<td>Energy companies</td>
<td>BKK</td>
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<tr>
<td>Manufacturers of materials and products</td>
<td>Brødrene Dahl A/S, Isola AS, NorDan, Trox Auranor, Siemens</td>
</tr>
<tr>
<td>Public institutions</td>
<td>NVE, Husbanken</td>
</tr>
<tr>
<td>Trade organizations</td>
<td>Byggenæringens Landsforening</td>
</tr>
<tr>
<td>Research organizations</td>
<td>NTNU, SINTEF</td>
</tr>
</tbody>
</table>
Thank you for your attention

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