ZEB Pilot house Larvik
(Multikomfort)

As-built

ZEB - KLIMAX

October 12, 2016
Åse Lekang Sørensen, SINTEF
My presentation

• Introduction
• Building design
• Technical installations and energy system
• Performance
• Material emissions
• The ZEB balance
• Economy
ZEB Pilot house Larvik (Multikomfort)

INTRODUCTION
The ZEB pilot house Larvik ("Multikomfort-house")

- Two-storey single-family residential building
- Demonstration and exhibition house
- Heated floor area: 201.5 m²
- Opening Autumn 2014

photo: Brødrene Dahl/Paal-André Schwital
Location

• Located near Larvik, by Brødrene Dahl warehouse

Pictures: Google maps
### The team

<table>
<thead>
<tr>
<th>Role</th>
<th>Teams and Supporting Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building owners</td>
<td>Brødrene Dahl AS and Optimera AS</td>
</tr>
<tr>
<td>Design team</td>
<td><strong>Brødrene Dahl</strong> (energy concept), <strong>Optimera</strong> (building construction), <strong>Snøhetta</strong> (architect), and the <strong>ZEB Research Centre</strong> (energy and GHG emissions)</td>
</tr>
<tr>
<td>Construction</td>
<td>Espen Staer AS</td>
</tr>
</tbody>
</table>
Design criteria: ZEB-OM + transport

Source: A Norwegian ZEB Definition Guideline
ZEB Pilot house Larvik (Multikomfort)

BUILDING DESIGN
The design phase

- Focus on combining high aesthetic quality with comfort and energy efficiency
- Minimizing emissions from construction materials

Example workshop: integrating spacial qualities and experiences
The building envelope

Reduce the need for heating
• Well insulated
• Airtight

Avoid the need for cooling
• Solar protection (bedroom windows)
• Windows placed shaded from the sun
Construction materials

- **Reused bricks** are used in a wall inside - **Thermal mass** effect
- Stacks of **natural stone** and **timber** in the exterior facade
- Foundation slab based on **timber** and **fibre plate** construction
- **Strip foundation** to minimize the amounts of concrete
- **Low carbon concrete** was used
- **Timber based bearings** in light weight frames of outer walls
- Exterior walls are **well insulated**: 350mm glass wool insulation

<table>
<thead>
<tr>
<th>U-values</th>
<th>Floor</th>
<th>Roof</th>
<th>Walls</th>
<th>Windows and doors</th>
</tr>
</thead>
<tbody>
<tr>
<td>W / m²K</td>
<td>0.080</td>
<td>0.084</td>
<td>0.111</td>
<td>0.75</td>
</tr>
</tbody>
</table>
VEGG I ATRIET VED STABLET I RAMMER

UTVENDIG KLEDNING TREPANEL, DOBBELTFALS MED SPOR, BESET.

TAK SOLCELLEPANELER OG SOLFANGERE

RESIRKULERT TEGL

LOKAL STEIN

UTVENDIG KLEDNING TREPANEL, TRYKKIMPREGNERT OG KOKT I LINOLJE

Illustration: Snøhetta
daylight distribution / solar shading

How to calculate DA?

- As an example, DIAL+ software is able to calculate DA on one year based in different points in a room.
- The average value for the room is used.

Main hypothesis for calculations

- Simplifications made on rooms geometry.
Re-used brick (old barn)
spacial connection indoor - outdoor
The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
ZEB Pilot house Larvik (Multikomfort)

TECHNICAL INSTALLATIONS AND ENERGY SYSTEM
Conclusion: material optimization / technical optimization

Illustration: Snøhetta
Overview of the energy system

- **Electricity:** Solar cells
  Battery bank

- **Heat:** Geothermal heat pump
  Solar thermal panels

  Ventilation system: High efficiency heat recovery
  Grey water heat recovery systems
## Energy budget: Energy demand

<table>
<thead>
<tr>
<th>Energy budget</th>
<th>Energy demand (kWh/year)</th>
<th>Specific energy demand (kWh/m²/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room heating</td>
<td>4,799</td>
<td>23.8</td>
</tr>
<tr>
<td>Ventilation heating</td>
<td>418</td>
<td>2.1</td>
</tr>
<tr>
<td>Domestic hot water</td>
<td>3,212 (6,424)*</td>
<td>15.9 (31.8)*</td>
</tr>
<tr>
<td>Fans</td>
<td>765</td>
<td>3.8</td>
</tr>
<tr>
<td>Lighting</td>
<td>1,765</td>
<td>8.8</td>
</tr>
<tr>
<td>Technical equipment</td>
<td>3,177</td>
<td>15.8</td>
</tr>
<tr>
<td><strong>Total net energy demand</strong></td>
<td><strong>14,136 (17,348)</strong>*</td>
<td>*<em>70.2 (86.1)</em></td>
</tr>
</tbody>
</table>

* Assumption: Recover 50% of the energy in the grey water in heat recovery system
The Research Centre on Zero Emission Buildings
### Energy budget: Delivered energy

<table>
<thead>
<tr>
<th>Energy budget</th>
<th>Delivered energy (kWh/year)</th>
<th>Specific delivered energy (kWh/m²/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct electricity</td>
<td>5,707</td>
<td>28.3</td>
</tr>
<tr>
<td>Electricity heat pump (ground-source HP)</td>
<td>1,014</td>
<td>5.0</td>
</tr>
<tr>
<td>Electricity solar energy</td>
<td>144</td>
<td>0.7</td>
</tr>
<tr>
<td>Other energy sources (HP in ventilation)</td>
<td>276</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total delivered energy</strong></td>
<td><strong>7,142</strong></td>
<td><strong>35.4</strong></td>
</tr>
</tbody>
</table>
Total energy balance

<table>
<thead>
<tr>
<th>Energy balance (kWh/year)</th>
<th>Energy demand</th>
<th>Delivered energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electricity</td>
</tr>
<tr>
<td>Room heating and ventilation</td>
<td>5 217</td>
<td>1 025</td>
</tr>
<tr>
<td>Domestic hot water</td>
<td>6 424</td>
<td>409</td>
</tr>
<tr>
<td>Fans, lighting, technical equipment</td>
<td>5 707</td>
<td>5 707</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 142</td>
</tr>
<tr>
<td>Total</td>
<td>17 348</td>
<td></td>
</tr>
</tbody>
</table>
Solar cells and battery bank

- 22.75 kW<sub>p</sub> PV system, 150 m<sup>2</sup>, 91 modules (Innotech Solar)
- Each module: 15.5% efficiency, peak power 250 W<sub>p</sub>
- Calculated: 19,200 kWh per year
- Connected to the utility grid
- Battery bank with 24 batteries: 48V at 600Ah in total
Solar cells from Innotech solar

DesignBlack – Poly
STC*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Wp</th>
<th>240</th>
<th>250</th>
<th>260</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pmax</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vmpp</td>
<td>Y</td>
<td>30.2</td>
<td>31.0</td>
<td>31.2</td>
</tr>
<tr>
<td>Impp</td>
<td>A</td>
<td>8.11</td>
<td>8.22</td>
<td>8.49</td>
</tr>
<tr>
<td>Voc</td>
<td>Y</td>
<td>37.1</td>
<td>37.6</td>
<td>37.8</td>
</tr>
<tr>
<td>Isc</td>
<td>A</td>
<td>8.66</td>
<td>8.79</td>
<td>8.98</td>
</tr>
<tr>
<td>IR****</td>
<td>A</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>η</td>
<td>%</td>
<td>14.6</td>
<td>15.2</td>
<td>15.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15.2</td>
<td>15.8</td>
<td>16.4</td>
</tr>
</tbody>
</table>
Calculated electricity production

Electricity yield from the PV system (kWh)
Geothermal heat pump and Solar thermal panels

• Ground-source-to-water heat pump, 3 kW
  – Cover 80% of the heating load
• Solar thermal collector system, 16.8 m²
  – Cover 20% of the heating load
• Hot water is collected in a 400 liter tank
• Low temperature distribution system
HEWALEX

FLAT PLATE SOLAR COLLECTORS:

HEWALEX KS2000 TLP

HEWALEX KS2000 SLP

COMPONENTS OF SOLAR SYSTEMS

Optima Twin Coil - EPTC - gir varme og varmtvann

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Article number</td>
<td>14.22.00</td>
<td>11.22.00</td>
<td>11.22.00</td>
</tr>
<tr>
<td></td>
<td>(14.21.00)</td>
<td>(11.21.00)</td>
<td>(11.21.00)</td>
</tr>
<tr>
<td>Solar Keymark certificate (PN-EN12975-1,2:2007)</td>
<td>011-75181 F</td>
<td>011-75180 F</td>
<td>011-751695 F</td>
</tr>
<tr>
<td>Active (aperture) area, m²</td>
<td>1.818</td>
<td>1.817</td>
<td>1.827</td>
</tr>
<tr>
<td>Gross area (total), m²</td>
<td>2.095</td>
<td>2.094</td>
<td>2.091</td>
</tr>
</tbody>
</table>

ZEB
The Research Centre on Zero Emission Buildings

FORSKNINGS-SENTER FOR MILJØVennlig ENERGI
Radiators
Domestic hot water

- Heat from waste water
  - Solar heating
    - Ground source HP (Winter)
    - Exhaust air HP (Summer)
Grey water heat recovery systems
Ventilation system

- Balanced, mechanical ventilation system with constant air flows
- Exhaust air heat pump
- Heat exchanger (87% efficiency)
Water system

• Rain water is reused in toilets and for watering the garden
• Rain water from the roof is harvested, mechanically cleaned, and stored in a 6000 litre tank
ZEB Pilot house Larvik (Multikomfort)

PERFORMANCE
Measurements

• Air leakage number: 0.60 air changes per hour

• Energy metering:
  – Electrical consumption, electricity production, thermal energy production and consumption for heating and hot water
  – No-one living in the building
  – Few measurements available yet
Measurements solar collectors

Example sunny day:
60 kWh heat from solar collectors
ZEB Pilot house Larvik (Multikomfort)

THE ZEB BALANCE
Material emissions – from design phase (60 y)

Product phase: 3.6 kg CO₂ eq/m² per year + Material replacement 2.2 kg CO₂ eq/m² per year = 5.8 kg CO₂ eq/m²
## As-built estimations, material emissions

- **Rough design phase estimations** 5.8 kg CO\(_2\) eq/m\(^2\)/y
- **Assumed less emissions replaced PV** -0.6 kg CO\(_2\) eq/m\(^2\)/y
- **CO\(_2\) emissions from batteries** +0.6 kg CO\(_2\) eq/m\(^2\)/y
- **Estimated increase, rough calculations** +1.16 kg CO\(_2\) eq/m\(^2\)/y
- **New total annual material emissions** 6.9 kg CO\(_2\) eq/m\(^2\)/y
The ZEB balance

Balance: ZEB-OM + 7,600 km

Electrical car

- 12,000 km, 2,400 kWh
- 0.132 kg CO₂ eq/kWh

ZEB-OM

- 6.9 kg CO₂ eq/m²
- 201.5 m²
- 7,142 kWh
- 0.132 kg CO₂ eq/kWh

- Exported electricity: 2,534 kg CO₂ eq/year
- Electricity demand: 2,534 kg CO₂ eq/year
- Electricity production solar cells, 19,200 kWh
- Electrical car, 12,000 km
- (A1-3+B4) Emissions building materials and solar cells
- (B6) Electricity demand, 7,142 kWh

The Research Centre on Zero Emission Buildings
ZEB Pilot house Larvik (Multikomfort)

ECONOMY
## Economy

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment, inclusive tax</td>
<td>A future building similar to the pilot building</td>
<td>5.8 million NOK *</td>
</tr>
<tr>
<td>Delivered energy to building and el. car</td>
<td></td>
<td>7,142 kWh + 2,400 kWh</td>
</tr>
<tr>
<td>Annual energy cost, if 1 NOK/kWh</td>
<td></td>
<td>0 kr **</td>
</tr>
<tr>
<td>Income from plus-energy house, if 0.5 NOK/kWh</td>
<td></td>
<td>4,829 NOK (kWh: 19,200 -(7,142+2,400))</td>
</tr>
</tbody>
</table>

* Ambitious buildings and technology choices may qualify for support from Enova. Such support varies, and is not included in the cost efficiency calculation.

** Assume 100 % self-consumption or similar energy price for selling and buying electricity.
Summary ZEB Pilot house Larvik

• An interdisciplinary project team has been involved in the design and construction process
• A number of untraditional passive energy measures are demonstrated
• The demonstration house has gained a lot of attention

• Calculated ZEB balance: ZEB-OM ambition + 7,600 km el car

• Approach is sensitive to material emission accounting and electricity emission factors for import and export of electricity
Takk for meg!