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
# The team

<table>
<thead>
<tr>
<th>Building owners</th>
<th>Brødrene Dahl AS and Optimera AS</th>
</tr>
</thead>
<tbody>
<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

Picture: Snøhetta
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>
Utvendig kledning: trepanel, trykkimpregnert og kokt i linolje

Solavskjerming på vaiere over atriumet

Tak solcellepaneler og solfangere

Vegg i atriet ved stabel i rammer

Resirkulert tegl

Lokal stein

Illustrasjon: 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

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The construction process

Pictures: Brødrene Dahl/Paal-André Schwital
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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*(6,424)</td>
<td>15.9/31.8*(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>Total net energy demand</td>
<td>14,136/17,348*(17,348)</td>
<td>70.2/86.1*(86.1)</td>
</tr>
</tbody>
</table>

* Assumption: Recover 50% of the energy in the grey water in heat recovery system
<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>Total delivered energy</td>
<td>7,142</td>
<td>35.4</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><strong>Total</strong></td>
<td><strong>17 348</strong></td>
<td><strong>7 142</strong></td>
</tr>
</tbody>
</table>

| **Total** | **17 348** | **17 348** |
Solar cells and battery bank

- 22.75 kWp PV system, 150 m², 91 modules (Innotech Solar)
- Each module: 15.5% efficiency, peak power 250 Wp
- 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

<table>
<thead>
<tr>
<th>DesignBlack – Poly</th>
<th>STC*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pmax</strong></td>
<td>Wp</td>
</tr>
<tr>
<td>Vmpp</td>
<td>V</td>
</tr>
<tr>
<td>Impp</td>
<td>A</td>
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<td>Voc</td>
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<td>Isc</td>
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<td>IR****</td>
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<td>η</td>
<td>%</td>
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</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**
### Components of Solar Systems

**Flat Plate Solar Collectors:**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Article number</td>
<td>14.22.00</td>
<td>11.22.00</td>
<td>14.41.00</td>
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<tr>
<td>(14.21.00)</td>
<td></td>
<td>(11.21.00)</td>
<td>(14.40.00)</td>
</tr>
<tr>
<td>Solar Keymark certificate (PN-EN12975-1,2:2007)</td>
<td>011-751811 F</td>
<td>011-751801 F</td>
<td>011-751693 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>

Optima Twin Coil - EPTC - gir varme og varmtvann
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
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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
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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 CO₂ eq/m²/y
- Assumed less emissions replaced PV: -0.6 kg CO₂ eq/m²/y
- CO₂ emissions from batteries: +0.6 kg CO₂ eq/m²/y
- Estimated increase, rough calculations: +1.16 kg CO₂ eq/m²/y
- New total annual material emissions: 6.9 kg CO₂ eq/m²/y
The ZEB balance

Balance: ZEB-OM + 7,600 km

Electrical car

- 12 000 km, 2400 kWh
- 0,132 kg CO₂ eq/kWh

- 6.9 kg CO₂ eq/m²
- 201,5 m²

- 7142 kWh
- 0,132 kg CO₂ eq/kWh

ZEB-OM

- 2534

- 943

- 1390

- 317

Electricity production solar cells, 19 200 kWh

Electrical car, 12 000 km

(A1-3+B4) Emissions building materials and solar cells

(B6) Electricity demand, 7142 kWh
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ECONOMY
## Economy

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