1. INTRODUCTION

PROJECT SUMMARY
- Year of construction: 1980
- None past energy renovations

MAIN RENOVATION TOPICS
• High insulated facades
• Airtightness 0.6 h⁻¹
• High efficiency technical systems, ground coupled heat pump, COP = 15 for cooling, COP = 3.5 for heating, efficient heat recovery, and low SFP
• PV electricity production on site

Architect
Snøhetta Architects AS, Oslo

Consultants
Skanska Norway, Hydro, Zero, ZEB and Asplan Viak

Owner
Entra Eiendom AS

Brochure: Arne Førland-Larsen
Contact:
Arne.forlandlarsen@asplanviak.no

Powerhouse Kjørbo – Norway

IEA SHC Task 47
Renovation of Non-Residential Buildings towards Sustainable Standards
2. CONTEXT AND BACKGROUND

BACKGROUND

- The building situated in Sandvika, close to the Oslofjord from the northeast to the southeast side, with a highway with heavy traffic on the northwest.
- The renovation includes two blocks out of a total of 9 of the entire site. (Map next page)
- The refurbish buildings have an area of 5,180 m² (internal area without outer walls)
- The buildings are programmed for approximately 240 person, which makes an average area of 22 m² per person

OBJECTIVES OF THE RENOVATION

- Powerhouse is defined as a building that during its lifecycle produces more renewable energy than it consumes for the production of building materials, construction, operation and demolition of the building
- The building shall be built within commercial marketable conditions
- The energy production must be based on energy sources on site or nearby with access from the site
- Energy use for electrical appliances shall not be included in the energy balance account.
- BREEAM classification score: Outstanding
3. DECISION MAKING PROCESSES

The Powerhouse Alliance
The Powerhouse Alliance includes the companies: Snøhetta Architects, Skanska, Hydro, Entra Eiendom and the NGO Zero. The Powerhouse concept was first launched in 2011. The proposal for the first Powerhouse project, a new office building in Trondheim, was presented in 2012. The Powerhouse Kjørbo is the first renovation project of the Alliance.

Powerhouse, criteria of the energy goal
In order to fulfill the declared goal of the PowerHouse (given in a press release from the Alliance): The Powerhouse alliance will:
• challenge existing building conventions
• develop cutting-edge concepts
• promote new national and international standards for energy efficiency and energy positive buildings
• be technological path-breaking

The main definition of PowerHouse:
Powerhouse shall during its lifetime produce more energy than it uses for materials, production, operation, renovation and demolition

Timeline for the decision making process

- Idea was born
  2011

- First brief project description completed
  01.07.2012

- Detailed project description completed
  01.11.2012

- Tendering process started
  01.11.2012

- Signing of contract with main contractor
  18.03.2013

- Start renovation (demolishing)
  01.02.2013

- Renovation completed
  Q1.2014

- Evaluation among occupants
  TBD
### 4. BUILDING ENVELOPE

#### Roof construction:
- **U-value**: 0.08 W/m²K (average value)

#### Wall construction:
- **U-value**: 0.15 W/m²K (average value above and below ground)

#### Floor facing ground (basement) equivalent value in average:
- **U-value**: 0.16 W/m²K

#### Windows:
- **U-value**: < 0.8 W/m²K (average value)

#### Floor on ground
- **U-value**: 0.12 W/m²K

#### Floor in basement
- **U-value**: 0.16 W/m²K

#### Thermal bridge avoidance:
Focus on thermal bridges in:
- Mounting of windows
- Insulation thickness where concrete slabs meet the façade
- Wood facade construction with few thermal bridges, and 200 mm insulation in front of slabs

Overall demand to thermal bridges are:
- < 0.03 W/m²k

#### Window / to wall ratio: 40 / 60

#### Light transmitting factor for windows: 68%

#### Daylight factor:
- average on working areas 2.1

### Summary of U-values [W/m²K]

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof/attic</td>
<td>~0.2</td>
<td>0.08</td>
</tr>
<tr>
<td>Floor/slab</td>
<td>-</td>
<td>0.12 – 0.16</td>
</tr>
<tr>
<td>Walls</td>
<td>~0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Ceilings</td>
<td>~0.3</td>
<td>~0.3</td>
</tr>
<tr>
<td>Windows</td>
<td>~1.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

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**External sun shading integrated in facade**
5. BUILDING SERVICES SYSTEM

OVERALL DESIGN STRATEGY
The overall design strategy based on:
• Optimizing the building envelope
• Optimizing technical system
• Utilization renewable energy

LIGHTING SYSTEM
New lighting system have planned LENI number ~9 kWh/m² year

HEATING SYSTEM
Before – Water based heating system
After – Air heating delivered from ventilation system combined with radiators in the wave wall in the center of the building

COOLING SYSTEM
Before:
• central cooling of inlet air for mechanical ventilation in combination with cooled beams.

After:
• Central air cooling – mechanical and displacement ventilation

HOT WATER PRODUCTION
• Heat pump and district heating

RENEWABLE ENERGY SYSTEMS
• Before: District heating
• After:
  • preliminary ground based heat pump
  • 310 kW PV system for electric generation to produce 230.000 kWh/year

Daylight strategy – average DF > 2,1

Ventilation and cooling Reduced duct length

Displacement ventilation

Exhaust air through staircase
6. ENERGY PERFORMANCES

ENERGY PERFORMANCE
Annual delivered before:
~ 240 kWh/m² (including data facilities.)

Annual delivered after:
~20,4 kWh/m² (without data and technical equipment)
~50 kWh/m² year (including data facilities)

RENEWABLE ENERGY USE
Annual delivered before:
Electricity ~ 125 kWh/m²
District heating ~ 75 kWh/m²
District cooling ~ 40 kWh/m²

Annual delivered after:
Electricity ~ 18,4 kWh/m²
District heating ~ 2 kWh/m²

PRIMAY ENERGY CONSUMPTION
Primary energy consumption is defined as delivered energy multiplied with primary energy factors, as primary factor for conversion of electrical consumption calculated for a 60 year life time /Source ZEB and Powerhouse project report – 2012/

<table>
<thead>
<tr>
<th>Energy budget - net energy/ space deliverable</th>
<th>Netto energy</th>
<th>Delivert energy</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity</td>
<td>District heating</td>
<td>Total</td>
</tr>
<tr>
<td>Space heating</td>
<td>15,4</td>
<td>0,9</td>
<td>5,5</td>
</tr>
<tr>
<td>Mechanical ventilation - heating</td>
<td>2,4</td>
<td>0,1</td>
<td>0,9</td>
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<tr>
<td>Hot Water</td>
<td>4,3</td>
<td>1</td>
<td>2,1</td>
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<tr>
<td>Energy fans for mechanical ventilation</td>
<td>2,1</td>
<td>0,8</td>
<td>2,1</td>
</tr>
<tr>
<td>Energy pumps for heating, ventilation, cooling</td>
<td>0,8</td>
<td>0,8</td>
<td>0,8</td>
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<tr>
<td>Lighting</td>
<td>7,7</td>
<td>7,7</td>
<td>7,7</td>
</tr>
<tr>
<td>Technical equipmnet, PC, copymachines etc.</td>
<td>12</td>
<td>12</td>
<td>12</td>
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<tr>
<td>Central data facilities - servers</td>
<td>16,9</td>
<td>16,9</td>
<td>16,9</td>
</tr>
<tr>
<td>Cooling, cooled beams in office areas</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cooling, central servers</td>
<td>16,9</td>
<td>1,1</td>
<td>1,1</td>
</tr>
<tr>
<td>Cooling, central mechanical ventilation</td>
<td>3,5</td>
<td>0,2</td>
<td>0,2</td>
</tr>
<tr>
<td>Sum energy demand</td>
<td>82</td>
<td>47,3</td>
<td>29,3</td>
</tr>
<tr>
<td>Sum exclusive central data facilities</td>
<td>65</td>
<td>30,4</td>
<td>32,4</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electricity</td>
<td>District heating</td>
<td>Total</td>
</tr>
<tr>
<td>PV - production, first 30 years</td>
<td>40,7</td>
<td>1,98</td>
<td>80,6</td>
<td>kWh/m²</td>
</tr>
<tr>
<td>PV - production, last 30 years</td>
<td>60,1</td>
<td>0,93</td>
<td>55,9</td>
<td>kWh/m²</td>
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<tr>
<td>PV - production, average 60 years</td>
<td></td>
<td>68,7</td>
<td></td>
<td>kWh/m²</td>
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<tr>
<td>Operational energy use</td>
<td>-20,4</td>
<td>1,46</td>
<td>-29,8</td>
<td>kWh/m²</td>
</tr>
<tr>
<td>Embodied energy</td>
<td></td>
<td>-22,1</td>
<td></td>
<td>kWh/m²</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>16,8</td>
<td></td>
<td>kWh/m²</td>
</tr>
</tbody>
</table>

CLARIFICATION: the energy calculations and given energy numbers will be according to the national standards which might vary between countries, i.e. numbers are not always comparable
ENVIRONMENTAL PERFORMANCE

Waste management
- More than 90% of waste from construction phase is recycled and/or reused

Ecological materials/ indoor AQ
- Building materials with lowest possible embodied energy
- Burned wood for façade cladding
- Labeling materials or materials with low polluting according to EN 15251
- All product categories listed in BREEAM have been tested against and documented to meet the relevant standards Volatile Organic Compound (VOC) emissions.
- The climate gas emissions from new materials in the building comprise 50% of the emissions in a new reference building. (Ref definition see /Klimagassutslipp.no/
- EPDs (Environmental Product Declarations according to ISO 14025/EN-NS15804) have been procured for at least 10 different building products used to a large extent

Certification / Labels
- BREEAM-NOR, planned for certification label outstanding

<table>
<thead>
<tr>
<th>Building table element</th>
<th>kWh/m² per year</th>
<th>kg CO₂-eq/m² per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 Superstructure</td>
<td>0,07</td>
<td>0,04</td>
</tr>
<tr>
<td>23 Outer walls</td>
<td>3,81</td>
<td>1,75</td>
</tr>
<tr>
<td>24 Inner walls</td>
<td>1,50</td>
<td>1,49</td>
</tr>
<tr>
<td>25 Structural deck</td>
<td>6,09</td>
<td>1,27</td>
</tr>
<tr>
<td>26 Outer roof</td>
<td>2,20</td>
<td>0,78</td>
</tr>
<tr>
<td>28 Stairs, balconies etc.</td>
<td>0,03</td>
<td>0,01</td>
</tr>
<tr>
<td>36 Ventilation and aircondition</td>
<td>1,99</td>
<td>0,30</td>
</tr>
<tr>
<td>43 Low voltage supply</td>
<td>0,23</td>
<td>0,11</td>
</tr>
<tr>
<td>49 Other electric power installations (PV)</td>
<td>9,57</td>
<td>1,78</td>
</tr>
<tr>
<td>62 Person and product transport</td>
<td>0,08</td>
<td>0,02</td>
</tr>
<tr>
<td>69 Other technical installations</td>
<td>0,33</td>
<td>0,07</td>
</tr>
<tr>
<td>Energy consumption in construction phase</td>
<td>1,21</td>
<td>0,06</td>
</tr>
<tr>
<td><strong>Total with reinforcing steel and concrete</strong></td>
<td><strong>27,2</strong></td>
<td><strong>5,7</strong></td>
</tr>
<tr>
<td><strong>Total without reinforcing steel and concrete</strong></td>
<td><strong>22,1</strong></td>
<td><strong>4,5</strong></td>
</tr>
</tbody>
</table>
8. MORE INFORMATIONS

RENOVATION COSTS
The building shall be renovated within commercial market conditions.

The specific cost of the project are not public for the time being. The tenant Asplan Viak has signed a 10 year renting contract. The rent is higher than for a similar office building with an average energy standard. However, when the reduced energy costs are included, the total cost for the tenant is at the same level as for a standard office building.

OTHER INTERESTING ASPECTS
Measured/delivered energy shall in net be counted to zero or be negative, and shall be calculated according to method/principles given in the Norwegian Standard 3031. Real operation conditions shall be used in the calculations, and technical equipment shall not be included.

The boundary of the plus energy building/Powerhouse is the site on which the building is located.

The energy goal must not be reached at the sacrifice of good architecture and indoor climate, or other central environmental qualities.

The Powerhouse boundary is similar to the Boundary II (On site generation from on-site renewable) as illustrated below.