VENTILATIVE COOLING

PER HEISELBERG
DEPARTMENT OF CIVIL ENGINEERING
Residential Buildings
WHY DO WE EXPERIENCE AN OVERHEATING PROBLEM IN HIGH PERFORMANCE BUILDINGS?

OVERHEATING IS AN INCREASING PROBLEM FOR LOW ENERGY RESIDENCES
• Is underestimated and are not given enough focus in the design process
• Compliance with energy use is documented – not indoor environment

TOO SIMPLIFIED DESIGN METHODS ARE USED
• Averaging heat loads in time and space
• Uncertain correlation between cooling need and overheating risk

NO (VERY FEW) AVAILABLE STANDARD SOLUTIONS – ESPECIALLY FOR RESIDENCES
• Users have no (very limited) experience in handling overheating
• “One-of-a-kind” solutions are often not ”adapted to practical use”
WHY DO WE EXPERIENCE AN OVERHEATING PROBLEM IN HIGH PERFORMANCE BUILDINGS?

IT IS NOT POSSIBLE TO REACH GOALS THROUGH MORE

• Envelope insulation, Building airtightness, Ventilation heat recovery,

WHICH ARE ROBUST TECHNOLOGIES WITHOUT USER INTERACTION

NEW MEASURES NEEDS TO BE INCLUDED

• Demand controlled ventilation
• Shading for solar energy control
• Shading for daylighting control
• Lighting control
• Window opening

ALL TECHNOLOGIES:

• Where performance is very sensitive to control
• Which involve different degree of user interaction
• Whose function and performance are difficult for users to understand
ENERGY RENOVATION
“ENERGIPARCEL”, TILST, DENMARK
## Energiparcel – Renovation Examples

<table>
<thead>
<tr>
<th>Feature</th>
<th>Mejlovænget 9 Seniorhuset</th>
<th>Langovænget 1 Familiehus - Passiv</th>
<th>Farovænget 4 Familiehus - Aktiv</th>
<th>Langovænget 8 Prototypehuset</th>
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<tbody>
<tr>
<td>Tætning og isolering af facader</td>
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<tr>
<td>Solceller</td>
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<td>Ovenlys</td>
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<tr>
<td>Isolering fundament</td>
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<tr>
<td>Isolering mod terræn, overalt</td>
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<td>Isolering mod terræn, delvist</td>
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<tr>
<td>Superlavenergi-vinduer, nordfacade</td>
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<td>Superlavenergi-vinduer, østfacade</td>
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<td>Superlavenergi-vinduer, vestfacade</td>
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<tr>
<td>Superlavenergi-vinduer, sydfacade</td>
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<td>Isolering vinduesfalse</td>
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<td>Automatisk styring, varmeanlæg</td>
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<td>Isolering rem</td>
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<tr>
<td>Isolering loft/tag</td>
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Source: Tine Steen Larsen, Jørgen Søndermark
ENERGIPARCEL – OVERHEATING 2010

<table>
<thead>
<tr>
<th>Temperatur Living Room</th>
<th>Mejløvænget 9</th>
<th>Langøvænget 1</th>
<th>Farøvænget 4</th>
<th>Langøvænget 8</th>
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<tbody>
<tr>
<td>&gt; 26 C (hours)</td>
<td>181</td>
<td>578</td>
<td>180</td>
<td>99</td>
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<tr>
<td>&gt; 27 C (hours)</td>
<td>54</td>
<td>370</td>
<td>60</td>
<td>28</td>
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</table>

Reference: Tine Steen Larsen, Aalborg University and Jørgen Søndermark, Realdania Byg
ENERGY RENOVATION AND OVERHEATING IN TYPICAL HOUSING IN CENTRAL/NORTH EUROPE

AUSTRIA
- 1960-1979
- Area 144 m²
- Ref. 2

DENMARK
- 1961-1972
- Area 118 m²
- Ref. 1

FRANCE
- 1982 – 1989
- Area 116 m²
- Ref. 1

UNITED KINGDOM
- Before 1978
- Area 80 m²
- Ref. 3

SELECTED RENOVATION MEASURES

- WINDOWS RETROFIT (REGULATIONS AND NZEB/PH STANDARD)
- + CEILING RETROFIT (REGULATIONS AND NZEB/PH STANDARD)
- ++ EXTERNAL WALL RETROFIT (REGULATIONS AND NZEB/PH STANDARD)
- +++ FLOOR RETROFIT (REGULATIONS AND NZEB/PH STANDARD)
- ++++ AIRTIGHTNESS IMPROVEMENT (REGULATIONS AND NZEB/PH STANDARD)
### THERMAL CHARACTERISTICS FOR REFERENCE CASES AND DIFFERENT RENOVATION LEVELS

<table>
<thead>
<tr>
<th>a/a</th>
<th>Reference period</th>
<th>Uwall (W/m²K)</th>
<th>Uceiling (W/m²K)</th>
<th>Ufloor (W/m²K)</th>
<th>Uwin/g (W/m²K)</th>
<th>n50 (ach)</th>
<th>Number of Storey</th>
<th>Source</th>
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<td><strong>Austria</strong></td>
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<tr>
<td>Base</td>
<td>After 1960</td>
<td>1.2</td>
<td>0.55</td>
<td>1.35</td>
<td>3.00/0.67</td>
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<td>Cost-Optimal report</td>
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<td>Renovation nZEB</td>
<td>0.27</td>
<td>0.15</td>
<td>0.3</td>
<td>1.20/0.6</td>
<td>1.5</td>
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<td><strong>Denmark</strong></td>
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<td>Base</td>
<td>1973-1978</td>
<td>0.45</td>
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<td>0.35</td>
<td>2.70/0.76</td>
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<td>TABULA</td>
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<td>Renovation /2015/2020</td>
<td>0.2</td>
<td>0.15</td>
<td>0.12</td>
<td>1.65/0.7-1.20/0.6</td>
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<tr>
<td><strong>France</strong></td>
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<tr>
<td>Base</td>
<td>1982-1989</td>
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<td>1.00</td>
<td>4.60/0.9</td>
<td>5.0</td>
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<td>Cost-Optimal report/TABULA</td>
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<td>Renovation nZEB</td>
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<td>0.43</td>
<td>1.50/0.7</td>
<td>1.4</td>
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<td>Cost-Optimal report/TABULA</td>
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<td><strong>UK</strong></td>
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<tr>
<td>Base</td>
<td>Before 1978</td>
<td>2.25</td>
<td>0.85</td>
<td>1.35</td>
<td>3.20/0.8</td>
<td>8.0</td>
<td>2 (semi detached)</td>
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<td>Renovation nZEB</td>
<td>0.30</td>
<td>0.18</td>
<td>0.20</td>
<td>1.60/0.7</td>
<td>4.0</td>
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<tr>
<td></td>
<td></td>
<td>0.15</td>
<td>0.15</td>
<td>0.80/0.5</td>
<td>0.6</td>
<td>2</td>
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<td>Cost-Optimal report</td>
</tr>
</tbody>
</table>
RENOVATION CASE - AUSTRIA

Overheating hours for different energy renovations in room level (26/28 °C)

- Living Room
- Room SW
- Room NE
- Building

Regulations

NZEB/PH
RENOVATION CASE - DENMARK

Overheating hours for different energy renovations in room level (26/28 °C)

- Living Room
- Room SW
- Room NE
- Building

Regulations → NZEB/PH
PERCENTAGE OF OVERHEATING HOURS FOR DIFFERENT VENTILATION FLOW RATES - DENMARK

PHASES
1. Reference
2. Regulation
3. NZEB/PH
PERCENTAGE OF OVERHEATING HOURS FOR DIFFERENT SHADING STRATEGIES - DENMARK

PHASES
1. Reference
2. Regulation
3. NZEB/PH
DENMARK
TUEN, BIRKERØD, DENMARK
- TEST OF CONTROL AND USER INTERACTION
OVERHEATING IS AN ISSUE THAT’S NEEDS TO BE ADDRESSED IN BOTH NEW HIGH PERFORMING RESIDENTIAL BUILDINGS AS WELL AS IN DEEP RENOVATIONS

SOLAR SHADING AND VENTILATIVE COOLING ARE SUSTAINABLE MEASURES THAT ARE ABLE REDUCE OVERHEATING RISK

“EXPECTED” PERFORMANCE WILL BE REDUCED IN PRACTICE DUE TO USER OVERRIDE

IMPROVED CONTROL STRATEGIES (PARTLY AUTOMATIC) AND USER GUIDANCE WILL REDUCE THE DISCREPANCY BETWEEN EXPECTATIONS AND PRACTICE
Office Buildings
COOLING IN OFFICES AND EDUCATIONAL BUILDINGS

WITH HIGH INSULATION AND AIR TIGHTNESS LEVELS ALWAYS A COOLING NEED DURING OCCUPIED HOURS EVEN IN THE WINTER SEASON

COOLING IS NOT A NEW TECHNOLOGY, BUT THE NEED FOR COOLING IS INCREASING AND MORE EFFICIENT SYSTEMS HAVE TO BE DEVELOPED TO FULFILL FUTURE ENERGY REQUIREMENTS

APPLICATION OF THE FREE COOLING POTENTIAL OF OUTDOOR AIR IS WIDELY USED IN MECHANICAL VENTILATION SYSTEMS, BUT HIGH AIR FLOW RATES ARE NEEDED IN WINTER BECAUSE OF DRAUGHT RISK LEADING TO RELATIVELY HIGH ENERGY USE FOR AIR TRANSPORT
WHAT IS DIFFUSE CEILING VENTILATION

THE SPACE ABOVE A SUSPENDED CEILING IS USED AS A PLENUM AND FRESH AIR IS SUPPLIED TO THE OCCUPIED ZONE THROUGH PERFORATED SUSPENDED CEILING.
# The Principle

<table>
<thead>
<tr>
<th>Rockfon / Troldtekt ceiling</th>
<th>![Diagram of Rockfon / Troldtekt ceiling]</th>
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<tbody>
<tr>
<td><strong>High local entrainment</strong></td>
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<thead>
<tr>
<th>Ecophon ceiling</th>
<th>![Diagram of Ecophon ceiling]</th>
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<td><strong>High local entrainment</strong></td>
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<thead>
<tr>
<th>Fully diffuse ceiling</th>
<th>![Diagram of Fully diffuse ceiling]</th>
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<tbody>
<tr>
<td><strong>Low local entrainment</strong></td>
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</table>
VENTILATIVE COOLING OFFICES IN COLD CLIMATE
SOLBJERGSKOLEN SOUTHWEST OF ÅRHUSS
SYSTEM PRINCIPLE
DRAUGHT RISK

Extreme winter condition: supply air temperature -8 °C, ACH =4

ISO 7730

DR <20%
CONCLUSION

Low draught risk in the occupied zone even, when supplying air at temperatures below 0°C.

Air distribution and draught risk dependent on heat load location, ceiling height, area and location of supply.

Very low vertical temperature gradient in the room with diffuse ceiling supply.

Low radiant temperature asymmetry and no clear radiation cooling potential of diffuse ceiling, due to low conductivity.

Very low pressure drop across diffuse ceiling (less than 5 Pa).
Thanks for your attention