Influence of Energy-efficient Renovation on Energy Use & Thermal Comfort in Swedish Single-family Residential Buildings from the Million Program

Shimantika Bhattacharjee, Dr. Åke Blomsterberg, Tomas Ekström
Energy efficient and Environmental Building design
Lund University
BACKGROUND

40% of the total energy consumption

36% of the total EU's CO2 emission

Source: JRC Europe, 2015

’20 20 20’ target
BACKGROUND

SINGLE FAMILY RESIDENCES FROM THE MILLION PROGRAM

- Cold during winter
- Warm during summer

THERMAL COMFORT
What is the influence of energy-efficient renovation on thermal comfort in Swedish single-family houses built during the Million program?

• What are the factors contributing to energy use and what are the possible renovation measures?

• Which renovation measures have a major impact on the thermal comfort of the occupants?

• What are the changes in the thermal comfort of the occupants before and after adopting the proposed renovations aimed through efficient energy use?
CASE STUDY BUILDING 1

- Location: Outside Gothenburg
- Built period: 1968
- Floor area: 235m²
CASE STUDY BUILDING 2

- **Location:** Near Stockholm
- **Built period:** 1975
- **Floor area:** 150 m²
ACTIVITY DIAGRAM

SIMULATION PARAMETER
• THERMAL COMFORT

PARAMETRIC STUDY ANALYSIS
• IDA ICE

Before renovation
Operative temperature
Overheating hours

Shading analysis
- Shading type 1: External blind
- Shading type 2: Interior roller blind
- Shading type 3: Venetian blind with panes
- Shading type 4: Ext. Venetian blind with schedules

Efficient Shading System

PPD analysis

Results
OPERATIVE TEMPERATURE - BUILDING 1

Before renovation
• MAX. OPERATIVE TEMPERATURE 28 °C
• MIN. OPERATIVE TEMPERATURE 15.5 °C

After passivehouse renovation
• MAX. OPERATIVE TEMPERATURE 27 °C
• MIN. OPERATIVE TEMPERATURE 21 °C
<table>
<thead>
<tr>
<th>Glass type</th>
<th>Shading device</th>
<th>U-value without shading (W/m²·K)</th>
<th>U-value with shading (W/m²·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3mm low-emissive glass</td>
<td>Interior roller blind</td>
<td>1.53</td>
<td>1.27</td>
</tr>
<tr>
<td>Triple-glazed with low-e film</td>
<td>Exterior screen</td>
<td>1.12</td>
<td>1.08</td>
</tr>
<tr>
<td>Triple pane low</td>
<td>Exterior venetian</td>
<td>1.12</td>
<td>1.01</td>
</tr>
<tr>
<td>emissive glass</td>
<td>with schedules</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Overheating hours (25°C)

- Living room: 750 hours
- Bedroom 3: 500 hours
- Bedroom 1: 350 hours

### Overheating hours (>27°C)

- Living room: 300 hours
- Bedroom 3: 200 hours
- Bedroom 1: 100 hours
## OVERHEATING HOURS AFTER RENOVATION - BUILDING 2

<table>
<thead>
<tr>
<th>Glass type</th>
<th>Shading device</th>
<th>U-value without shading (W/m²·K)</th>
<th>U-value with shading (W/m²·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double high solar gain, low emissive</td>
<td>External blind</td>
<td>1,75</td>
<td>1,5</td>
</tr>
<tr>
<td>Triple pane clear glass</td>
<td>Interior roller blinds</td>
<td>1,86</td>
<td>1,57</td>
</tr>
<tr>
<td>Triple pane suspended, low-e-film</td>
<td>External venetian blind with schedules</td>
<td>1,12</td>
<td>1,016</td>
</tr>
<tr>
<td>Venetian blind</td>
<td>-</td>
<td>0,91</td>
<td>0,83</td>
</tr>
</tbody>
</table>

**between two panes**

### Overheating hours >\(25 \, ^{\circ}C\)

- **Living room**
- **Bed room 3**
- **Bed room 4**
- **Bed room 5**
- **Family room**

### Overheating hours >\(27 \, ^{\circ}C\)

- **Living room**
- **Bed room 3**
- **Bed room 4**
- **Bed room 5**
- **Family room**

**Legend:**
- Without shading
- Interior roller blind
- Venetian blinds between panes
- External venetian blinds
- External venetian blind with schedules
**Case study building 2**
Max op.temp January 21
Livingroom 22.3 °C
Familyroom 21.9 °C
Bedroom 5 21.8 °C

**Case study building 1**
Max op.temp January 21
• Livingroom 23.3°C
• Bedroom 1 22.4°C
• Bedroom 3 23°C
• Kitchen 23.2°C
PPD ANALYSIS IN THE EXISTING CASE STUDY BUILDING 2

<table>
<thead>
<tr>
<th>Thermal climate</th>
<th>Bronze</th>
<th>Silver</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPD (%)</td>
<td>\leq 20%</td>
<td>\leq 15%</td>
<td>\leq 10%</td>
</tr>
</tbody>
</table>

- Higher PPD (Predicted percentage of dissatisfied) levels during winter > 20
- Average PPD >10
Case study building 2
Max PPD
- Family room 10,5%
- Bedroom1 9,7%
- Bedroom 4 9,1%

Case study building 1
- Livingroom 10,2%
- Kitchen & family room 7,5 %
Scenerio after renovation

Building 1
• 5 – 9.5%

Building 2
• 7.5 – 9.7%
• Energy use according to **Swedish passivehouse standard** after renovation

• **Shading** implementation & **orientation**

• Satisfactory indoor thermal environment after renovation

• Comparative analysis between **simulated** and **scientific equations** for comfort temperature

• Attained **PPD** level below 10% after renovation
Thank you all for your attention