Passive houses: Principles and Projects

1. Background and definitions
2. Description of passive row houses in Lindås / Gothenburg
3. Results from measurements
4. Results from simulations
- Important parameters
5. Summary

Strategy for energy-efficient buildings

1. Minimize the energy use – minimize the energy losses

The most environmentally friendly energy is the one not used!

2. For the remaining energy demand:
Maximize renewable energy use

What is a Passive House?

It should be possible to heat the building using the supply air as heat distribution system (normal air change rates and no re-circulation of air).

By using the ventilation system to distribute the heat, costs are saved by not installing a traditional heating / distribution system (e.g. radiators). Money that instead could be used for added insulation, better windows etc.

However, air is a poor heat carrier, which imposes high demands to reduce the energy losses of the building!

Passive house concept

Energy conservation by
- Highly insulated and airtight building envelope - including windows
- Balanced mechanical ventilation (supply/exhaust) with efficient heat recovery (heat exchanger)

Passive houses have a low peak load demand and space heating demand
Peak load ~ 10 – 16 W/m²
The low peak load results in a low space heating demand; ca 10 – 25 kWh/m²a
+ reduce household electricity and domestic hot water heating!

> 5000 housing units built in Germany!
Austria, Switzerland, Belgium, The Netherlands, Norway, Denmark, USA…
Schools, office buildings etc, also built!

The Swedish Building Code BBR 2006

Climate zones

<table>
<thead>
<tr>
<th>Climate zone South (kWh/m²a)</th>
<th>Residential blds</th>
<th>Non-residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>South</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

For 1-2 family houses with electric resistance heating: max 95 kWh/m²a

Passive houses (residential)

Peak load demand for space heating

<table>
<thead>
<tr>
<th>Climate zone South</th>
<th>Climate zone North</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&lt;sub&gt;max&lt;/sub&gt;</td>
<td>10</td>
</tr>
<tr>
<td>P&lt;sub&gt;max&lt;/sub&gt; 200 m²</td>
<td>14</td>
</tr>
</tbody>
</table>

The most environmentally friendly energy is the one not used!
Building envelope demands
Maximum air leakage through the building envelope: 0.3 l/s·m² at +/- 50 Pa
Windows U-value ≤ 0.90 W/m²K
Measured by accredited test laboratory according to the standard SS-EN ISO 12567-1

Indoor environment
Noise from the ventilation system:
The Swedish class B or better in bedrooms.
Air supply temperature: maximum 52°C

Assumptions: Domestic hot water use per year
Edhw = Vdhw / 55 / Atemp (kWh/m²)
Vdhw: 12 m³/apt + 18 m³/person
1-2 family houses, terrace houses: 16 m³/person

Number of occupants in apartments estimated as:
1 room and kitchen: 1.0 person
2 rooms and kitchen: 1.5 person
3 rooms and kitchen: 2.0 person
4 rooms and kitchen: 3.0 person
5 rooms and kitchen: 3.5 person
Single family houses < 120 m² assume 3 persons
Single family houses > 120 m² assume 4 persons

Passive houses (residential)
Recommended energy demand
Total (bought) energy demand excluding household electricity

<table>
<thead>
<tr>
<th>Energy demand</th>
<th>Climate zone South</th>
<th>Climate zone North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fmax</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Fmax 200 m²</td>
<td>55</td>
<td>65</td>
</tr>
</tbody>
</table>

Terrace houses in Lindås

The goal was to show that it was possible to build passive houses in a Swedish climate!
Strategy: energy conservation
- Highly insulated building envelope
- Airtight construction, minimizing thermal bridges
- Mechanical ventilation (supply/exhaust) with heat recovery
No traditional heating system, savings used for better windows, added insulation etc.

Solar collectors for Domestic Hot Water:
Solar fraction approx. 40%
5 m² / living unit
DHW tank: 500 litres

U-values (W/m²K)
- Windows 0.85 (Triple + 1-2 LE)
- Walls 0.10 (43 cm insulation)
- Floor 0.11 (25 cm insulation)
- Roof 0.08 (48 cm insulation)

Envelope U_mean = 0.16 W/m²K

Mechanical Ventilation
- Heat exchanger η = 75-83%
- 35-35 W fans ca. 600 kWh/year
- Air tightness 50 Pa: 0.3 l/s/m² (leaking area)

Heating
- Electric heater, inlet air: 900 W (~ 8 W/m²)

The ventilation system
- Air change rate: 0.5 ach
- Heat exchanger:
  During summer, automatic bypass
  – Important for the comfort!
Measurements and evaluation

Cold Days!
Lindås 28/12 2001 - 1/1 2002

Energy Use

Energy use compared to the new Swedish building code

Results from parametric studies – a sensitivity analysis
Design Questions

Special Focus:
Space heating demand and peak load
Thermal comfort

Key Parameters:
- Passive solar utilisation
- Window types and window area
- Airtightness / building envelope
- Occupancy – internal gains
- Thermal bridges
- Shading devices and ventilation - Summer comfort
- Ventilation system: heat exchanger efficiency, ground heat exchanger
- Household appliances

Sensitivity Analyses

- Simulation tool DEROB-LTH
  - Whole building energy balance program
  - Hourly simulations
  - Detailed calculations of solar distribution and useful solar gains

- Simulations based on
  - Geometric model of the building
  - Climate data from Göteborg 1988 (“normal” year)
  - Occupancy 2 adults + 2 children (base case)
  - Energy-efficient household appliances are assumed

PASSIVE SOLAR UTILISATION

Questions

- How large are the passive solar gains?
- Will the solar gains influence the space heating demand and peak load?

When
- Mid Unit heated to 20°C or 23°C
- Occupants; 2 adults + 2 children
Influence of passive solar gains on space heating demand

**DEROB-LTH**

Simulation with/without solar radiation in the climate file

**Influence on passive solar gains on heat loads**

**Passive Solar Utilisation**

**Conclusions**

- Yearly solar energy gains (Sep - May) ~ 800 kWh ~ 40-50%
- Solar gains are not important for the peak load
- The mid unit could be heated to approx 23°C using the installed maximum heating power (900 W)
- The end unit may have problems to keep 20°C during longer cold periods. Could have increased the heating power to ca 1200 W.

**Window Type**

**Questions**

- Do we have to use high performance windows? (with low U-values)
- If we use traditional clear glass windows, will they not give rise to larger solar gains and thus compensating the higher transmission losses?

Study on:

1. No windows at all!
2. Actual windows (Triple, Ar/Kr, 2 LE coatings)
3. Use air in the gaps instead of Argon and Krypton
4. Take away 1 LE-coating (=Triple, air, 1 LE)
5. Take away both LE-coatings (= triple glazed, clear)
6. Take away one pane (= double glazed, clear)
Window Type

Conclusions

- Important to use high performance windows
- The type of gas is not crucial
- Low emissivity coatings are essential
- The used windows are almost as good as a highly insulated wall – but give daylight as well!
- The glass area is less important for the space heating demand – some flexibility for the architect!

- But check the peak loads! And excessive temperatures!

Airtightness

Questions

- How important is an airtight building envelope?

Studies on the Mid Unit
Pressurization test at 50 Pa: 0.3 l/s,m² (0.5 ach)
approx infiltration rate 0.05 ach

Influence of airtightness

mid unit, Ti = 20°C

Airtightness

Conclusions

- The airtightness is very important for both the space heating demand and the peak load
- Special care has to be taken during the construction phase!

Occupancy

Questions

- Are the houses “heated” by occupants? (internal gains)
- Are the houses dependent on that the occupants are at home all the time, heating the house?

Studies on

- Mid Unit
- 4 occupants (2 adults + 2 children)
- 2 occupants (2 adults)
- No occupants (only heat gains from boiler, refrigerator, freezer, fans)
Occupancy

Conclusions

- In highly insulated buildings, internal gains from occupants and household electricity are important
  ~ 400 kWh / occupant (adult)
- The installed maximum power for heating should allow for variations in occupancy
- The extreme design cases are without occupants during winter and summer vacations
- The Mid Unit can easily keep 20°C. Only when the house is empty for a longer period, the temperature could decrease below 20°C
- Higher acceptance for high/low indoor temperature when no one is at home

Summary and Conclusions from parametric studies

- Important parameters for energy-efficient housing
  - Energy conservation with simple technique gives robust buildings
  - Highly insulated building envelope including windows
  - Air tight building envelope – construction phase important!
  - Mechanical ventilation with heat recovery > 80%
  - We are building for the users!
  - Passive solar gains are small for a passive house in Sweden. The short heating season limits the available gains
  - Bypass of ventilation heat exchanger during summer
  - Shading devices and window ventilation to minimize excessive temperatures
  - Cost-effective heating system for space heating and DHW
    - not easy since the demand is very small

Summary and Conclusions from monitoring and evaluation

- The row houses are performing as planned – but higher indoor temperatures (23°C during heating season) than expected give rise to somewhat higher space heating demand
- The contribution from the solar collection represents 37% instead of the anticipated 50%. The water tank was poorly insulated and larger than necessary
- The household electricity was higher than expected but not higher than for an average household. The appliances installed were not as energy-efficient as planned.
- The heating system is based purely on electricity. In order to reduce electricity use, other solutions would be welcome.
- A successful design and performance necessitates an interdisciplinary teamwork, including energy specialists already during an early design stage.
- The demonstration project in Lindås has proved to be a good way to increase the interest in Sweden to develop new energy-efficient buildings.
  - New projects are now built or are in planning/construction!

Development in Sweden

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