Energy and Indoor climate measurements in Denmark's first Energy Neutral block of flats BOLIG+

KIM B. WITTCHEN

DANISH BUILDING RESEARCH INSTITUTE,
AALBORG UNIVERSITY

DANISH BUILDING RESEARCH INSTITUTE
AALBORG UNIVERSITY COPENHAGEN

BOLIG+ dogmas

1. Energy neutral on annual basis,
2. Intelligent and user friendly dwelling,
3. Flexible in use and over time,
4. Good and healthy indoor climate,
5. Adapted to local context,
6. Constructed at normal economic market conditions.

Energy neutral on annual basis

- Energy neutrality means that energy used (heating, domestic hot water plus electricity used for household and operating the building) is optimised to local conditions and the amount of energy from the grids balances that delivered to the grids.
- Energy delivered to the grids must have at least the same quality and usability as energy from the grids

- Better than the voluntary Danish low-energy class for residential buildings
  - BOLIG+ must comply with the low-energy class, without local production of electricity (PV or wind)

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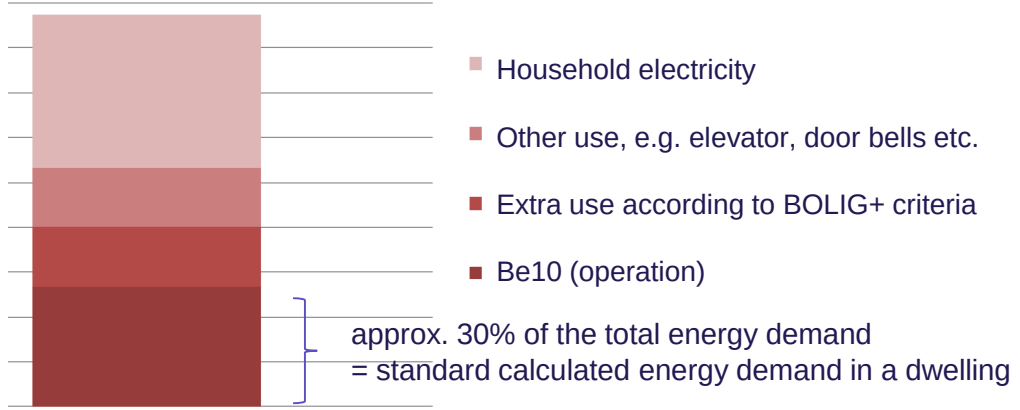
After the building crisis in Denmark

- Smaller scale, but with the same level of ambitions

- Søborg, Gladsaxe near Copenhagen
- 5 floors (4 habitated), 10 flats

BOLIG+ energy neutrallity



- RES contribution: 40 497 kWh (reference year) electricity from PV on roof and facade
  - Roof free of technical installations to keep as much area for PV as possible, i.e.
    - Lift replacing elevator => reduced electricity consumption due to better efficiency and lower speed
    - Inlets and exhausts for ventilations air through the facade
- Net energy use: 40.036 kWh/yr
- Primary energy: - 461 kWh/yr

- Costs:
  - Normal costs for BR2015: 1 215 €/m² (Molio)
  - LE class: 1 595 €/m² (excl. site etc.)
  - Total LE class: 2 067 €/m² (incl. site etc.)
  - Extra BOLIG+ cost: 197 €/m² (incl. PV, heat recovery from waste water, Zensehome)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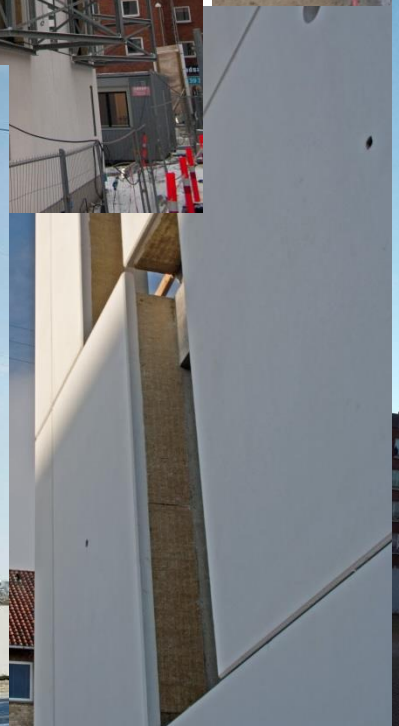
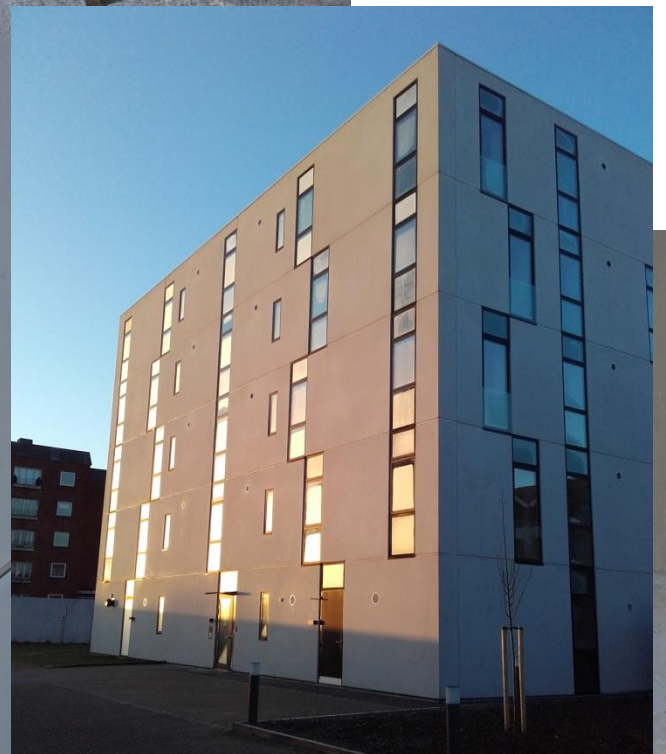
137 kvm.





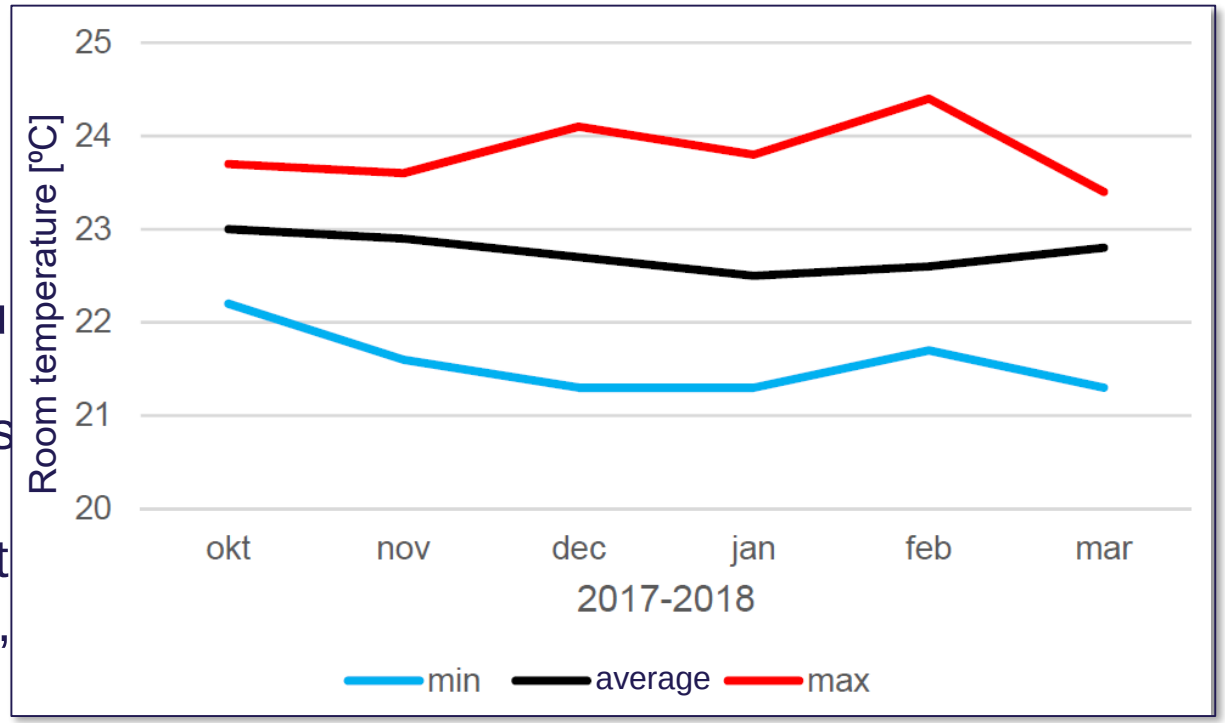
Energy saving measures - summary

- Compact and well insulated building
- Minimizing thermal bridges
- Airtight building (as PassivHause)
- Decentral ventilation system controlled by moisture and pir sensor. System is seasonal controlled i.e. ventilation is natural during summer except when needed due to e.g. bathing or cooking
- Users can control the indoor climate (summer comfort) by operating the windows
- Heat recovery from grey waste water
- ”Intelligent control” with optional ”all off” function in flats to minimise stand-by consumption
- Slow running lift
- Danfoss Living thermostat that, among others closes when opening windows
- Water guide signalling about excessive use of hot water during showers
- Water saving fixtures in kitchen and bath
- Zensehome to control, measure and display electricity consumption from any outlet
- Battery to optimise PV electricity use behind meter (for private economy reasons)

Measuring system

The measuring system do to the widest extend bu
supplemented by:

- Measurements of heat recovery from grey was
- Measurements of electricity use for ventilation
- Measurement of electricity for salmonella treat
- Measurements of indoor climate (temperature,
- Zensehome to control and measure electricity



- Indoor temperature are generally above the raised level used in the calculations (22 °C), with variations between individual flats
- CO_2 levels are reasonable, though with large individual variations between flats
- Moisture content was as expected in flats with mechanical ventilation during winter and indoor temperatures at a high level

District heating

- Delivered DH: 47 427 kWh = 46.4 kWh/m² per yr.
- DHW: 14 346 kWh = 14.0 kWh/m² per yr.

- DHW consumption 185 l/m² per yr. (common DHW meter).
  - Individual meters: 199 l/m² per yr.

- Space heating, flats: 24 720 kWh = 24.2 kWh/m² per yr. (Individual meters)

- Losses: 8 361 kWh = 8.2 kWh/m² per yr.
  - Delivered district heating minus DHW and space heating in the flats

- Recovered heat from grey waste water: 1 462 kWh = 1.4 kWh/m² per yr.

Production and consumption of electricity

- Electricity, buying: 21 166 kWh
- Electricity, selling: 18 530 kWh
- Produced electricity: 28 972 kWh
  - Should have produced 40.000 kWh
- Electricity to battery: 2 829 kWh or 9.8 % of production
- Electricity from battery 1 654 kWh (during start-up period) → battery efficiency = 58.5 %.

Flats consumption

- 26 681 kWh ≈ 2 670 kWh per flat per yr.
- Designed to 1 725 kWh → consumption is 55 % higher than expected
- In one flat, there was a significant increase in electricity consumption during October-December due to new owner moved in with an electric vehicle

Energy neutral ?

No and yes !

- If the flats have used the expected amount of electricity (1 725 kWh) and the PV system had produced as expected (40 000 kWh/yr) energy neutrality would have been fulfilled as:

Measured values	Use	Production
District heating	47.3	-
Electricity	32.2	29.8
Total, primary energy	**86.4**	**53.6**

BOLIG+ rules	Use	Production
District heating	47.3	-
Electricity	28.8	40.0
Total, primary energy	**80.4**	**72.4**

If PV production and electricity use had been as designed, energy neutrality would have been exceeded by 11% !
Higher indoor temperatures, less internal loads, along higher ventilation rate and floor heating in baths (not designed), less efficient heat recovery on grey waster water are among reasons and can easily explain the remaining discrepancy!

BOLIG+ questions?

- Academic Architect association
- Danish Engineering association
- Danish Electricity saving trust
- Tekniq (industry and installation employers' organisation)
- Danish Construction Association
- Innovation in the build environment
- Eco council Denmark
- Danish Technological Institute
- Danish Building Research Institute, Aalborg University
  kbw@sbi.aau.dk

- www.boligplus.org

- Realdania By og Byg (developer)

AKADEMISK ARKITEKTFORENING

TEKNIQ
INSTALLATØRERNES ORGANISATION

dansk byggeri

BYGGERIETS INNOVATION

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