Energy efficiency of strategies to enable temperature zoning during winter in highly-insulated buildings

Case of detached house with balanced mechanical ventilation

Laurent Georges, Eirik Selvnes, Vegard Heide and Hans Martin Mathisen
Energy and Process Engineering Department, NTNU

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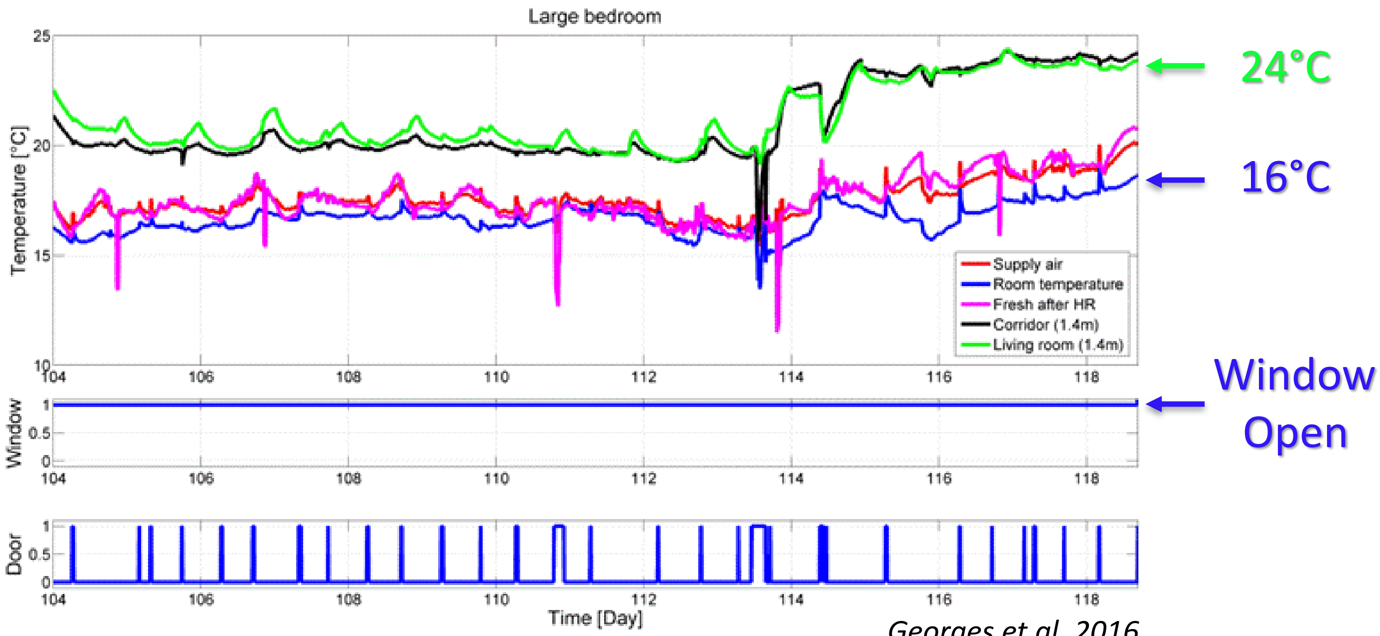
Temperature zoning: background

- Limited temperature zoning in super-insulated building envelopes
  - Highly-insulated external walls and high-performance windows
  - Centralized one-zone balanced mechanical ventilation with efficient heat recovery

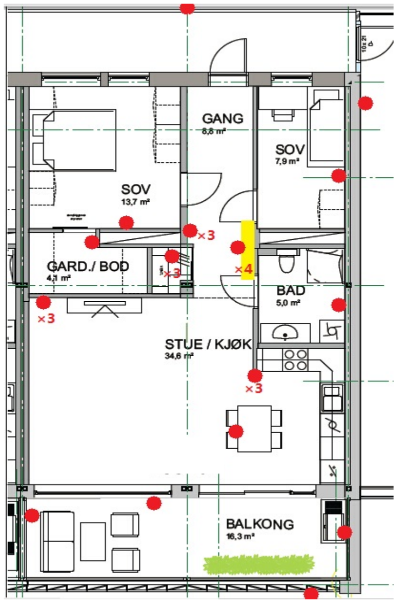
- Many Norwegians would apply temperature zoning
  - Based on questionnaires and field measurements in Passive Houses (ex. Berge 2016)
  - Many Norwegians want colder bedrooms (< 16°C)
  - ~50% occupants open bedroom windows several hours every day during winter time
  - The main motivation is temperature control not IAQ
  - Occupants do not choose the supply air temperature consistently to get colder bedrooms
  - Desired indoor temperature in living areas is often between 22 and 24°C

Temperature zoning: example

- Measurement during two weeks in a passive house apartment



Georges et al. 2016



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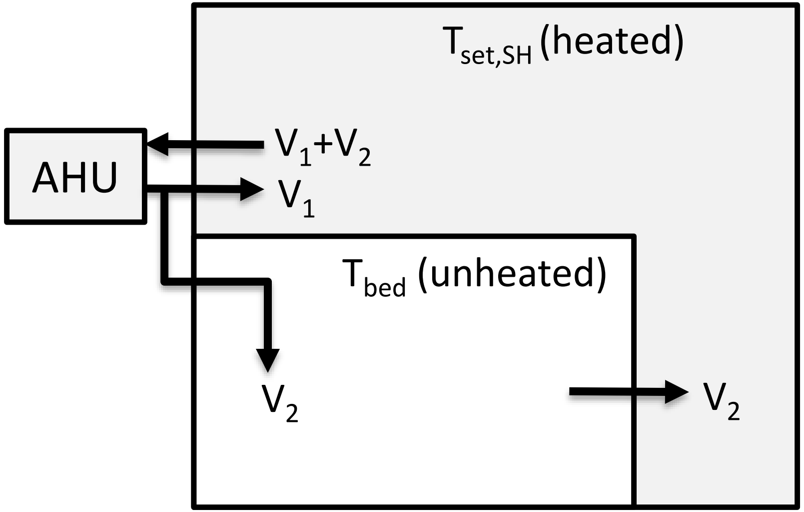
Temperature zoning: research question

- Research showed that
  - Based on calibrated multi-zone dynamic simulations (ex. Georges et al. 2016)
  - Extensive window opening leads to significant increase of space-heating needs (ΔE)
  - Control alone cannot decrease bedroom temperature without large ΔE
  - Something should be changed in the building concept, like the ventilation strategy

- Our research question is how to reduce ΔE from window opening?
  1. Relative importance of ventilation and heat conduction in partition walls?
  2. How alternative ventilation strategies would improve energy efficiency?

Framework of analysis

- Steady-state heat transfer from heated to unheated rooms



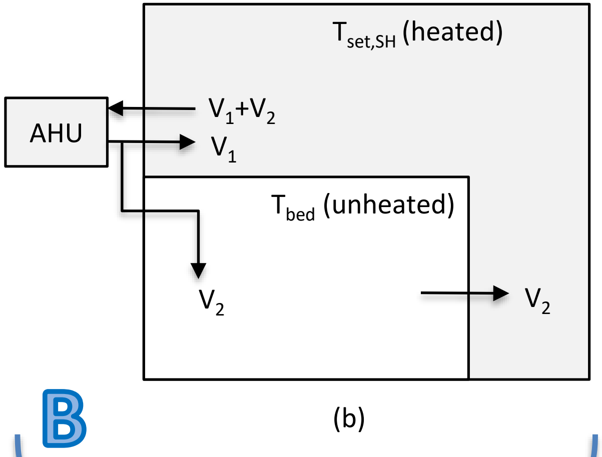
$$P = \underbrace{U_p (T_{set,SH} - T_{bed})}_{Heat\ conduction} + \underbrace{\dot{V}_2 C_p (T_{set,SH} - T_{bed})}_{Ventilation\ reheating}$$

- When open bedroom window, nothing changes except

$$\underbrace{T_{bed,open}}_{\substack{windows\\open}} < \underbrace{T_{bed,closed}}_{\substack{windows\\closed}} \Rightarrow \underbrace{P_{open}}_{\substack{windows\\open}} > \underbrace{P_{closed}}_{\substack{windows\\closed}}$$

Alternative ventilation strategies

- To reduce the ventilation contribution on ΔE



(b)

V_2 from bedrooms to heated zone if windows opened

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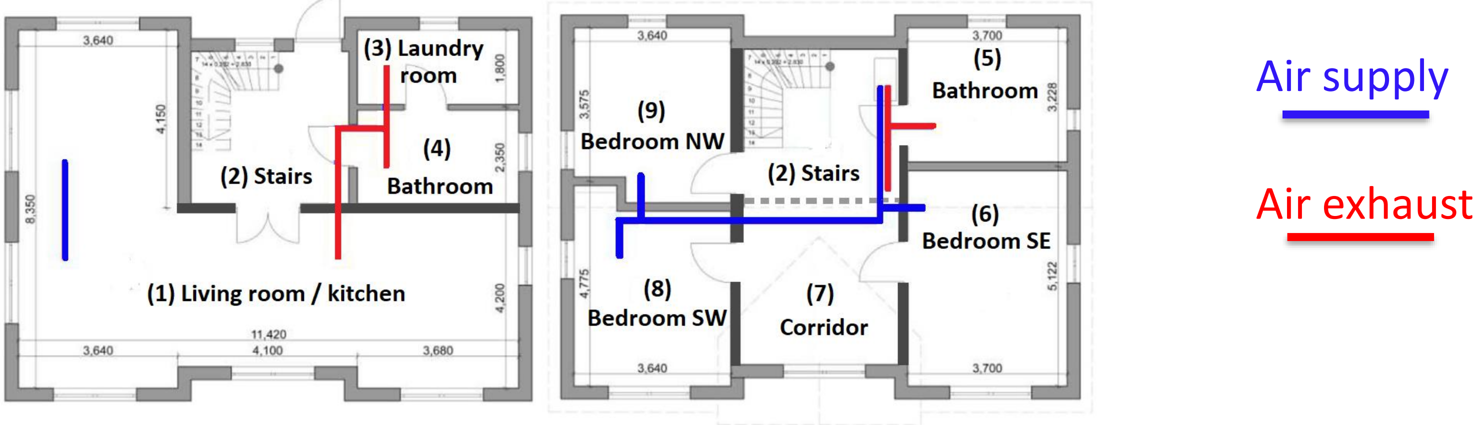
Case study

- Detached house
  - 173 m² located in Oslo (open flat terrain without obstacle)
  - Passive house (NS3700) with different construction models (lightweight to heavy)
  - Simulated in IDA-ICE with embedded ventilation network
  - CAV with airflow rates according to TEK17 adapted for each ventilation strategy



(a) First floor *Cascade ventilation* (b) Second floor

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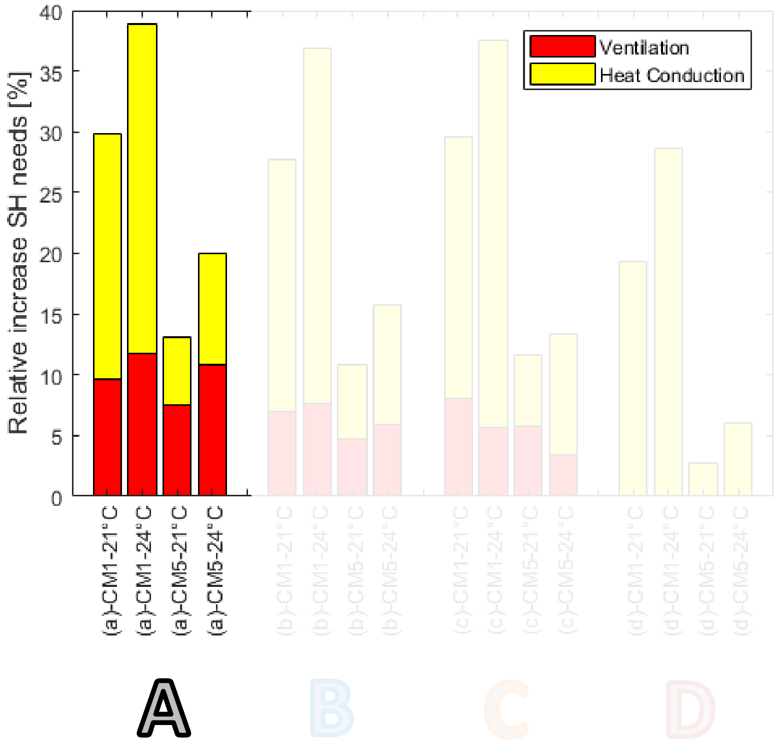
Case study

- Control strategies changing set-points for
  - Heated zones, AHU heating coil, bedrooms, window and door opening

Cases	Living areas $T_{set,SH}$	AHU $T_{set,AH}$	Bedrooms $T_{set,bed}$	Windows Schedule	Windows $T_{set,win}$	Door Schedule
1	21 or 24°C	$T_{set,SH}$-3	$T_{set,SH}$	Closed	-	Closed
2	21 or 24°C	$T_{set,SH}$-3	None	Closed	-	Closed
3	21 or 24°C	16°C	None	Closed	-	Closed
4	21 or 24°C	14°C	None	Closed	-	Closed
5	21 or 24°C	$T_{set,SH}$-3	None	Open (Night)	16°C	Closed
6	21 or 24°C	16°C	None	Open (Night)	16°C	Closed
7	21 or 24°C	14°C	None	Open (Night)	16°C	Closed
8	21 or 24°C	$T_{set,SH}$-3	None	Open (Night)	16°C	Open (Day)

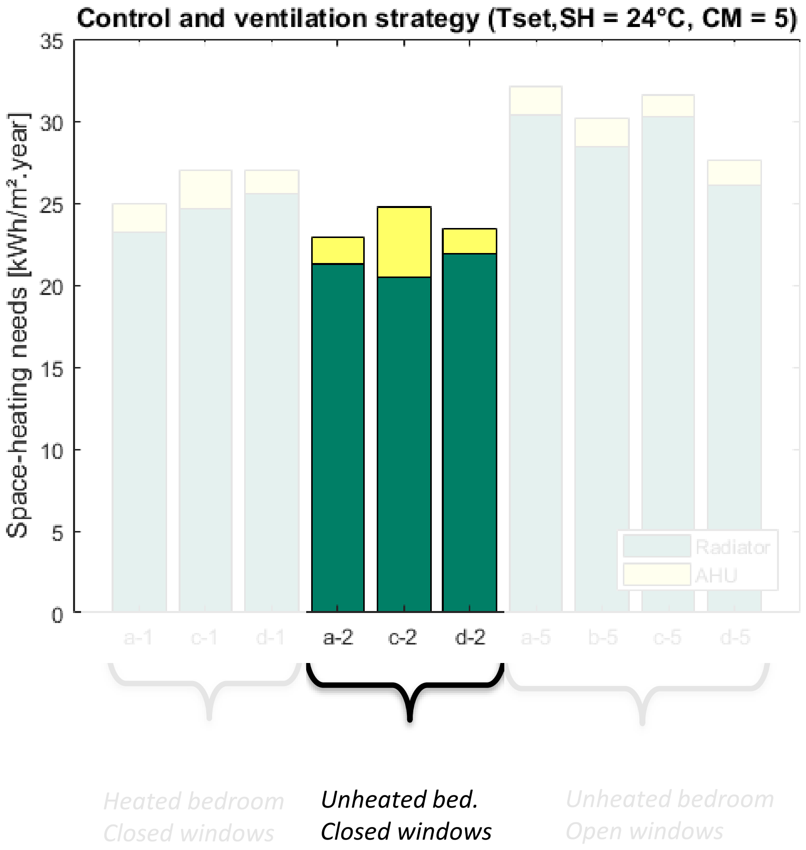
Steady-state analysis

- Setup
  - Outdoor temperature selected to give typical temperature zoning
  - Heavy-weight (CM1) and lightweight (CM5) construction
  - Two different set-point temperature in living areas (21 and 24°C)
  - Increase of space-heating needs analyzed
- Conclusions
  - Heat conduction dominant with heavy-weight
  - Heat conduction ≈ ventilation effect in light-weight construction
  - Moderate reduction of ventilation contribution for strategies (b) and (c)
  - No ventilation effect with strategy (d)
  - Heat conduction part left almost unchanged



Yearly dynamic simulation

- Setup
  - For lightweight (CM5) construction
  - For set-point temperature in living of 24°C
  - Different strategies for control (here 1-2-5)
- Conclusions closed bedroom windows
  - Slightly higher space-heating needs without cascade ventilation (increased airflow rates)
- Conclusions open bedroom windows
  - Always an increase of space-heating needs
  - Moderate reduction for (b) and (c)
  - Larger reduction for decentralized (d)



Conclusions

- Energy efficiency with window opening in bedrooms (or other heat sinks)

- Research question 1:
  - Heat conduction dominant in heavyweight buildings (non-insulated partition walls)
  - Effect heat conduction and ventilation reheating same order for lightweight buildings
  - Ventilation strategy cannot solve the problem alone

- Research question 2
  - Ventilation contribution can be moderately reduced by shutting down supply air in bedrooms of mechanical ventilation when bedroom windows opened (strategy b)
  - Ventilation contribution can be moderately reduced by balancing airflows in bedrooms (strategy c, here still with a one single supply air temperature)
  - Ventilation contribution can be significantly reduced by decentralized ventilation